APPENDIX NOT INCLUDED

FINAL INTERIM FEASIBILITY STUDY REPORT

SAN JACINTO RIVER WASTE PITS SUPERFUND SITE

September 2016

9871983

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LIST OF ACRONYMS AND ABBREVIATIONS

1V:3H	1 vertical to 3 horizontal
2H:1V	2 horizontal to 1 vertical
3H:1V	3 horizontal to 1 vertical
5H:1V	5 horizontal to 1 vertical
AOC	Administrative Settlement Agreement and Order on Consent for Removal Action: CERCLA Docket No. 06-12-10
ARAR	Applicable or Relevant and Appropriate Requirements
BAT	Best Available Technology Economically Achievable
BCT	Best Conventional Pollution Control Technology
BERA	Baseline Ecological Risk Assessment
BHHRA	Baseline Human Health Risk Assessment
BMP	Best Management Practice
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
Cfs	cubic feet per second
CMP	Coastal Management Plan
cm/year	centimeters per year
CNRA	Coastal Natural Resource Area
COC	chemical of concern
COPC	chemical of potential concern
CSM	Conceptual Site Model
CWA	Clean Water Act
CY	cubic yard
EAM	Exposure Assessment Memorandum
ESA	Endangered Species Act
FEMA	Federal Emergency Management Agency
FS	Feasibility Study
FS Report	Feasibility Study for the San Jacinto River Waste Pits Superfund Site
GLO	Texas General Land Office
GRA	General Response Action

HSC	Houston Ship Channel
I-10	Interstate Highway 10
ICs	Institutional Controls
IP	International Paper Company
MCL	Maximum Contaminant Level
MIMC	McGinnes Industrial Maintenance Corporation
mm/year	millimeters per year
MNR	Monitored Natural Recovery
MOU	Memorandum of Understanding
MSL	mean sea level
NAVD88	North American Vertical Datum of 1988
NCP	National Contingency Plan
ng/kg	nanograms per kilogram
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
NOx	nitrogen oxides
NFIP	National Flood Insurance Program
NPDES	National Pollutant Discharge Elimination System
NPL	National Priorities List
NRHP	National Register of Historic Places
NRRB	National Remedy Review Board
NSR	net sedimentation rate
OMM	Operations, Monitoring, and Maintenance
OSHA	Occupational Safety and Health Administration
PCB	polychlorinated biphenyl
PRG	protective concentration level
PM	particulate matter
$PM_{2.5}$	fine particle particulate matter
POTW	publically owned treatment works
PPE	personal protective equipment
PRG	Preliminary Remedial Goals
Proposed Plan	proposed remedial action plan for the SJRWP Site
PSCR	Preliminary Site Characterization Report

RACR	Removal Action Completion Report
RAL	remedial action level
RAM	Remedial Alternatives Memorandum
RAO	Remedial Action Objective
RCRA	Resource Conservation and Recovery Act
RI	Remedial Investigation
RME	Reasonable Maximum Exposure
ROD	Record of Decision
ROW	right-of-way
S/S	solidification and stabilization
Site	San Jacinto River Waste Pits Superfund Site
SJRF	San Jacinto River Fleet
SJRWP	San Jacinto River Waste Pits
SMA	sediment management area
SPME	solid phase micro extraction
SWAC	surface-weighted average concentration
SWPPP	Storm Water Pollution Prevention Plan
TBC	to-be-considered
TCCC	Texas Coastal Coordination Council
TCDD	2,3,7,8-tetrachlorodibenzo-p-dioxin
TCDF	2,3,7,8-tetrachlorodibenzofuran
TCEQ	Texas Commission on Environmental Quality
TCMP	Texas Coastal Management Plan
TCRA	time critical removal action
TEQ	toxic equivalents
$TEQ_{DF.M}$	TEQ concentration calculated for dioxin and furan congeners using toxicity equivalency factors for mammals
TES	threatened and endangered species
TMDL	total maximum daily load
TMV	toxicity, mobility or volume
TPDES	Texas Pollutant Discharge Elimination System
TSHA	Texas State Historical Association
TxDOT	Texas Department of Transportation

T&E	threatened and endangered
UAO	Unilateral Administrative Order for Remedial Investigation/Feasibility Study: CERCLA Docket No. 06-03-10
UECA	Uniform Environmental Covenants Act
USACE	U.S. Army Corps of Engineers
U.S.C.	U.S. Code
USDL	U.S. Department of Labor
USEPA	U.S. Environmental Protection Agency
USFWS	U.S. Fish and Wildlife Services

EXECUTIVE SUMMARY

This report presents the Feasibility Study (FS) for the San Jacinto River Waste Pits (SJRWP) Superfund Site (Site) in Harris County Texas, and was prepared to evaluate remedial alternatives based on Site conditions described in the Remedial Investigation (RI) Report (Integral and Anchor QEA 2013). The RI Report was prepared on behalf of McGinnes Industrial Maintenance Corporation (MIMC) and International Paper Company (IP) and in response to a Unilateral Administrative Order (UAO) issued by the U.S. Environmental Protection Agency (USEPA), Docket No. 06-03-10.

This FS Report presents remedial alternatives for two areas within the study area perimeter designated by USEPA for purposes of the RI/FS investigation (USEPA's Preliminary Site Perimeter).

One area is located north of Interstate Highway (I-10) where impoundments used for the disposal of paper mill waste (Northern Impoundments) are located. A time critical removal action (TCRA) has been implemented to construct a temporary armored cap to isolate and contain waste in those impoundments. The FS Report presents eight remedial alternatives for the Northern Impoundments (Alternatives 1N, 2N, 3N, 3aN, 4N, 5N, 5aN, and 6N). The alternatives range from continued maintenance of the existing temporary armored cap (Alternative 1N) to full removal of waste and impacted materials (Alternative 6N).

The second area is located on the peninsula south of I-10 to the west of Market Street, where various marine and shipping companies have operations; certain portions of the area of investigation south of I-10 may have been used for disposal of paper mill waste (as well as other wastes) in the 1960s. The remedial alternatives for this area (Alternatives 1S to 4S) address three distinct locations in which subsurface soils contain dioxins at levels above the Preliminary Remediation Goal (PRG) for a hypothetical future construction worker.

The Site and Site History

The SJRWP Site was added to the National Priorities List (NPL) under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) in 2008. USEPA's Preliminary Site Perimeter encompasses several impoundments and surrounding in-water and upland areas. The impoundments are located on the western side of the San Jacinto River, in Harris County, Texas, north and south of I-10 where I-10 crosses the San Jacinto River. The impoundments were built in the mid-1960s for disposal of paper mill wastes that were barged from the Champion Paper Inc. paper mill in Pasadena, Texas.

Large scale groundwater extraction by others resulting in regional subsidence of land in the vicinity of the SJRWP Site resulted in increased exposure of the contents of the Northern Impoundments to surface waters. The Northern Impoundments were the subject of a TCRA, discussed below, that since its completion in 2011 has temporarily capped and isolated waste material.

The area of investigation south of I-10 is an upland area, and the site of a former impoundment. The impoundment south of I-10 is not currently in contact with surface water. Since the 1960s, a variety of industrial and other activities have taken place on the upland area south of I-10. Most of the peninsula is currently in industrial or commercial use by marine services companies, with some parcels currently unused.

Stabilization and Isolation of the Northern Impoundments

MIMC and IP implemented a temporary cap to stabilize and isolate materials within the Northern Impoundments. The temporary cap was completed in 2011 pursuant to the terms of an Administrative Settlement Agreement and Order on Consent for Removal Action: CERCLA Docket No. 06-12-10 (AOC; USEPA 2010a). It included construction of a temporary armored cap that was designed in accordance with U.S. Army Corps of Engineers (USACE) and USEPA guidelines and capping guidance (USACE 1998; USEPA 2005) (temporary armored cap). The temporary cap also included installation of fencing around the Site, establishment of access controls, and the posting of warning signs.

The temporary armored cap includes layers of armor stone, geotextile and geomembrane and is constructed over an area of approximately 15.7 acres. It was designed and constructed at a cost of more than $9 million. The temporary armored cap was designed to withstand a 100-year storm event with an additional factor of safety to ensure its protectiveness. The storm event defines the depth of water and the currents that the cap armor layer must resist. Although a 100-year event was specified for the temporary cap design, events up to the 500-year storm were evaluated for the FS in order to assess the potential risk of an even larger storm.

Since being completed in July 2011, the temporary armored cap has generally isolated and contained impacted material. However, in July 2012, disruption of a localized area of the armor rock layer of the temporary armored cap occurred, and the geotextile was exposed. This occurred following wet weather in July 2012 and was addressed in accordance with the approved OMM Plan and USACE and USEPA guidance. The affected areas totaled about 200 square feet, or 0.03 percent of the overall area of the temporary armored cap.

The temporary armored cap's design and construction were the subject of a post-construction evaluation by MIMC and IP and a separate assessment by USEPA and USACE (USACE 2013).

Based on this review, the USACE recommending enhancements (e.g., placing additional armor rock and constructing flatter slopes) to further ensure the protectiveness of the temporary armored cap. In January 2014, the Respondents implemented all of the USACE recommendations (Anchor QEA 2014).

Despite implementation of the USACE's recommendations, in December 2015 another area (approximately 22 feet by 25 feet) on the northwest part of the cap was discovered to be deficient in armor rock material. The discovery of the uncapped area did not occur as a result of routine maintenance activities, which had not revealed the lack of armor rock, but was discovered by the USEPA Dive Team in the performance of other tasks at the Site. This deficiency resulted in exposing the underlying paper mill waste material to the San Jacinto River. Sampling of the exposed waste material found that it contained dioxin over 43,000 ng/kg TEQ dioxin. While sampling from the nearby undisturbed areas of the cap did not show elevated levels of waste materials containing dioxins, for an unknown period the paper mill material was in direct contact with surface water. Repairs of this area were completed in January 2016 by installing a geotextile fabric over the area and covering it with armor stone. Additional areas of missing rock were discovered in February and March 2016.

The temporary armored cap, and associated fencing, access controls and signs have been routinely inspected and maintained pursuant to a USEPA-approved Operations, Monitoring, and Maintenance (OMM) Plan. The OMM Plan originally was developed to address conditions that USACE and USEPA cap design guidance expressly presumes could occur post-construction (such as movement of rock cover in localized areas of the cap). However, the OMM Plan had to be modified because the original program of routine inspections failed to identify the cap deficiencies described above. The OMM Plan now requires not only periodic inspections, topographic survey data, bathymetric survey data, manual probing and monitoring following key storm events, but also, more frequent inspections and video surveillance to identify the need for possible cap maintenance and procedures to implement appropriate repair activities (USEPA 2005; USACE 1998).

Remedial Action Objectives and Protective Concentration Levels

Remedial Action Objectives (RAOs) for the Site and Preliminary Remediation Goals (PRGs) for waste material, soil and sediment are risk-based criteria that were developed as part of the RI/FS process. The PRGs are consistent with reasonably anticipated future uses and applicable to the areas north and south of I-10 for which remedial alternatives were developed. The risk-based PRG for dioxin/furan in sediment is 30 ng/kg TEQ (hypothetical recreational fisher, non-cancer Hazard Index (HI) = 1) (EPA, Khoury, Human Health Risk Evaluation and Recommended Sediment Cleanup Level, August 29, 2016). The risk-based PRG for dioxin/furan in waste

material is 200 ng/kg TEQ (hypothetical recreational visitor, non-cancer HI = 1) (Anchor QEA, Relative Bioavailability Adjustment Memo, 01/16/2015). Finally, the risk-based PRG for dioxin/furan in soil is 240 ng/kg TEQ (hypothetical construction worker, non-cancer HI = 1) (Anchor QEA, Relative Bioavailability Adjustment, January 16, 2015).

Principal Threat Waste

The NCP establishes an expectation that EPA will use treatment to address the principal threats posed by a site wherever practicable (NCP § 300.430(a)(1)(iii)(A)). In general, Principal Threat Wastes are those source materials considered to be highly toxic or highly mobile which generally cannot be contained in a reliable manner or would present a significant risk to human health or the environment should exposure occur. The "principal threat" concept is applied to the characterization of "source materials" at a Superfund site. At the Site, the northern waste pits contain dioxin/furan over 43,000 ng/kg TEQ, and the Southern Impoundment soils contains dioxin/furan over 50,000 ng/kg TEQ. The northern waste pits maximum dioxin/furan concentration is 215 times higher than the non-cancer hazard based waste material PRG, and the Southern Impoundment maximum dioxin/furan concentration is 208 times higher than its non-cancer hazard based PRG. The non-cancer hazard index for exposure to waste material (recreational visitor scenario) at the Site is 66, which is more than an order of magnitude greater that the acceptable hazard index of 1. Dioxin/furans are highly persistent chemicals and will not breakdown for hundreds of years. While there is considerable uncertainty regarding biodegradation of dioxins/furans, the EPA estimates that, for dioxins that are not exposed to sunlight, the dioxin half-life ranges from 25 to 100 years (https://clu-in.org/contaminantfocus/default.focus/sec/dioxins/cat/Chemistry_and_Behavior/).

The Site is located in the San Jacinto River, which has experienced a number of severe storms and floods in the past. For example, the 1994 flood exceeded the 100-year return period storm, resulted in severe riverbed scour while cutting new channels outside of the river bed, destroyed or damaged thousands of homes, and undermining and rupturing pipelines both inside and outside of the river channel. The 1994 storm crested at 27.09 feet at the Sheldon, Texas gauge located about five miles upstream of the Site. Previous storm resulted in even higher crests of 31.5 feet in 1940 and 32.90 feet in 1929.

Because of the high levels of dioxin/furan, which are over two orders of magnitude higher than the acceptable concentration, and its' highly toxic and persistent nature, there is a significant risk to human health or the environment should exposure occur. With the regular occurrence of severe storms and flooding in the area, there is high level of uncertainty that the waste material can be reliably contained over the long term (Appendix A). Therefore, the dioxin/furan waste at the San Jacinto River Waste Pits Superfund Site is considered a Principal threat waste based on high toxicity or potential mobility.

Remedial Alternatives for Area North of I-10

Remedial technologies presented in this FS Report were subjected to an initial screening process before being developed and included in the final set of remedial alternatives that are discussed in this FS Report. The initial screening process was performed by MIMC and IP pursuant to the UAO for the RI/FS; the EPA subsequently decided to revise and complete the Feasibility Study Report itself. The EPA also entered into an agreement with the USACE to provide additional information and modelling analysis of remedial alternatives for the Site (see Appendix A discussing the USACE's Evaluation of the San Jacinto Waste Pits Feasibility Study Remediation Alternatives, or "Alternatives Evaluation report").

For the area north of I-10, the remedial alternatives focus on containment, treatment, removal, and/or a combination of containment, treatment and removal, together with Institutional Controls (ICs) to achieve a range of post-remedy surface-weighted average concentrations (SWACs). All alternatives recognize the existence of the temporary armored cap.

The alternatives developed and presented in this FS Report for the area north of I-10 include:

- **Alternative 1N – Temporary Armored Cap and Ongoing OMM (No Further Action),**

  Estimated Operation & Maintenance Cost (e.g., inspection, maintenance): $0.4 million
  Estimated Total Present Worth Cost: $0.4 million
  Estimated Construction Time: Construction complete

  Assumes the temporary armored cap would remain in place, together with fencing, warning signs and access restrictions established as part of the temporary cap, and would be subject to ongoing OMM.

- **Alternative 2N – Armored Cap, ICs, Ground Water Monitoring, and Monitored Natural Recovery (MNR)**

  Estimated Operation & Maintenance Cost: $2.0 million
  Estimated Total Present Worth Cost: $2.0 million
  Estimated Construction Time: Construction complete

  Includes the actions described under Alternative 1N and institutional controls in the form of deed restrictions and notices would be implemented to place restrictions on

dredging and anchoring to protect the integrity of the armored cap and to limit potential disturbance and resuspension of buried sediment near the upland sand separation area. MNR would be used to achieve the PRG for sediment (30 ng/kg) in the sand separation area and the Texas Surface Water Quality Standard in the San Jacinto River. Ground water monitoring would be implemented to ensure that there are no long-term unacceptable impacts to ground or surface water resulting from the waste left in place. Monitoring may also involve collecting and analyzing sediment, tissue, and surface water and evaluating the data.

- **Alternative 3N – Upgraded Cap, ICs, Ground Water Monitoring, and MNR,**

  Estimated Capital Cost: $1.77 million
  Estimated In-Direct and Operation & Maintenance Cost: $2.38 million
  Estimated Total Present Worth Cost: $4.1 million
  Estimated Construction Time: 2 months

  Includes the actions described under Alternative 2N plus additional enhancements to the temporary armored cap. Institutional controls in the form of deed restrictions and notices would be implemented to place restrictions on dredging and anchoring to protect the integrity of the armored cap and to limit potential disturbance and resuspension of buried sediment near the upland sand separation area. MNR would be used to achieve the PRG for sediment (30 ng/kg) in the sand separation area and the Texas Surface Water Quality Standard in the San Jacinto River. This alternative will increase the long-term stability of the temporary armored cap consistent with isolation of impacted materials. The Upgraded Cap will use rock sized for the "No Displacement" design scenario, which is more conservative than the "Minor Displacement" scenario used in the temporary armored cap's design. This remedial alternative also includes additional measures to protect the Upgraded Cap from potential vessel traffic (e.g., rock berm). An off-site staging area may be required for management of rock armor materials, similar to that which was utilized during the temporary cap construction. However, the exact location and configuration of the staging area are beyond the scope of this FS and may not be fully reflected in the FS estimated durations or costs.

- **Alternative 3aN - Enhanced Cap, Protective Pilings, ICs, Ground Water Monitoring, and MNR,**

Estimated Capital Cost: $19.7 million
Estimated In-Direct and Operation & Maintenance Cost: $5.1 million
Estimated Total Present Worth Cost: $24.8 million
Estimated Construction Time: 15 months

Includes enhancements to Alternative 3N suggested by the USACE in an attempt to address the 80% erosion of the Upgraded Cap (Alternative 3N) (see Appendix A), which included substantial erosion of the underlying paper mill waste material. This alternative, 3aN, includes the actions described under Alternative 3N plus additional enhancements to the temporary armored cap recommended by the USACE to create a cap with increased long-term stability. Institutional controls in the form of deed restrictions and notices would be implemented to place restrictions on dredging and anchoring to protect the integrity of the armored cap and to limit potential disturbance and resuspension of buried sediment near the upland sand separation area. MNR would be used to achieve the PRG for sediment (30 ng/kg) in the sand separation area and the Texas Surface Water Quality Standard in the San Jacinto River.

The additional cap enhancements added for this alternative include pre-stressed concrete or concrete filled steel pipe pilings placed 30 feet apart around the perimeter of the cap to protect from barge strikes. The spacing is designed to catch a typical barge, which is 35 feet wide. An additional armor stone cap with a thickness of at least 24 inches would be placed over the armor cap for Alternative 3N. The armor stone would have a median diameter of 15 inches. This additional armor stone would cover 13.4 acres of the 17.1 acre armored cap. Also, a course gravel filter layer would be placed on 1.5 acres of the Northwest Area where there is currently no geotextile under the armor cap. The actual scope and design of the cap enhancements, and additional area needed to construct the required slopes, would be determined in the Remedial Design. This additional weight of rock on top of the waste pits may cause cap settling and/or pushing the waste material out the sides of the cap; the Remedial Design will consider the significance of and design issues related to this.

- **Alternative 4N – Partial Solidification/Stabilization, Upgraded Cap, ICs and MNR,**

Estimated Capital Cost: $11.13 million
Estimated In-Direct and Operation & Maintenance Cost: $3.74 million
Estimated Total Present Worth Cost: $14.8 million
Estimated Construction Time: 17 months

Provides for solidification and stabilization (S/S) of the most highly contaminated material. A dioxin/furan value that exceeds 13,000 ng/kg $TEQ_{DF,M}$ within the USEPA's

Preliminary Site Perimeter was used to define the most highly contaminated material. This alternative also includes the actions described under Alternative 3N; however, about 23 percent of the temporary armored cap (2.6 acres above the water surface and 1.0 acre in submerged areas) would be removed to provide for S/S of the most highly contaminated material. Institutional controls in the form of deed restrictions and notices would be implemented to place restrictions on dredging and anchoring to protect the integrity of the armored cap and to limit potential disturbance and resuspension of buried sediment near the upland sand separation area. MNR would be used to achieve the PRG for sediment (30 ng/kg) in the sand separation area and the Texas Surface Water Quality Standard in the San Jacinto River.

About 52,000 cubic yards (CY) of materials with $TEQ_{DF,M}$ that exceeds a concentration of 13,000 nanograms per kilogram (ng/kg), would undergo S/S. After the S/S is completed, the Upgraded Cap would be re-constructed and the same ICs and MNR as in Alternatives 2N and 3N would be implemented. Ground water monitoring would be implemented to ensure that there are no long-term unacceptable impacts to ground or surface water resulting from the waste left in place. An off-site staging area may be required for management of rock armor materials, stabilization reagents and associated treatment equipment. However, the exact location and configuration of the staging area are beyond the scope of this FS and may not be fully reflected in the FS estimated durations or costs.

- **Alternative 5N – Partial Removal, Upgraded Cap, ICs, Ground Water Monitoring, and MNR,**

  Estimated Capital Cost: $24.86 million
  Estimated In-Direct and Operation & Maintenance Cost: $4.94 million
  Estimated Total Present Worth Cost: $29.8 million
  Estimated Construction Time: 13 months

  Provides for removal of the most highly contaminated material. A dioxin/furan value that exceeds 13,000 ng/kg $TEQ_{DF,M}$ within the USEPA's Preliminary Site Perimeter was used to define the most highly contaminated material. The temporary armored cap would be partially removed and the same 52,000 CY of material that would undergo S/S under Alternative 4N would instead be excavated for off-site disposal. After the removal was completed, the Upgraded Cap would be re-constructed and the same ICs and MNR that are part of Alternatives 2N to 4N would be implemented. These institutional controls in the form of deed restrictions and notices would be implemented to place restrictions on dredging and anchoring to protect the integrity

of the armored cap and to limit potential disturbance and resuspension of buried sediment near the upland sand separation area. MNR would be used to achieve the PRG for sediment (30 ng/kg) in the sand separation area and the Texas Surface Water Quality Standard in the San Jacinto River.

Ground water monitoring would be implemented to ensure that there are no long-term unacceptable impacts to ground or surface water resulting from the waste left in place. An off-site materials management facility will be required for material staging, stabilization and processing for bulk transportation to an off-site landfill. The exact location, configuration, siting and operational impacts, as well as potential delivery restrictions by the receiving facility (e.g., tons per day) are beyond the scope of this FS and may not be fully reflected in the FS estimated durations or costs.

- **Alternative 5aN - Partial Removal of Materials Exceeding the PRG, Upgraded Cap, ICs, Ground Water Monitoring, and MNR,**

  Estimated Capital Cost: $60.38 million
  Estimated In-Direct and Operation & Maintenance Cost: $9.21 million
  Estimated Total Present Worth Cost: $69.6 million
  Estimated Construction Time: 19 months

  All material beneath the temporary armored cap in any location where the water depth is 10-feet or less and which has a $TEQ_{DF,M}$ at or above the PRG for the waste material for a hypothetical recreational visitor of 200 ng/kg[1] – about 137,600 CY – would be excavated for off-site disposal. Institutional controls in the form of deed restrictions and notices would be implemented to place restrictions on dredging and anchoring to protect the integrity of the armored cap and to limit potential disturbance and resuspension of buried sediment near the upland sand separation area. MNR would be used to achieve the PRG for sediment (30 ng/kg) in the sand separation area and the Texas Surface Water Quality Standard in the San Jacinto River.

  To implement this alternative, about 11.3 acres (72 percent) of the temporary armored cap would be removed to allow for this material to be removed. After excavation of the material, the remaining areas of the temporary armored cap would be upgraded to create an Upgraded Cap.

[1] In defining this alternative, USEPA included an additional requirement that all material exceeding 13,000 ng/kg $TEQ_{DF,M}$, regardless of water depth, would be removed. All locations that exceed 13,000 ng/kg $TEQ_{DF,M}$ are in areas with 10-feet of water or less. Thus, the horizontal boundary defining this alternative (the 10-foot water depth) includes all locations exceeding 13,000 ng/kg $TEQ_{DF,M}$.

Ground water monitoring would be implemented to ensure that there are no long-term unacceptable impacts to ground or surface water resulting from the waste left in place. An off-site materials management facility will be required for material staging, stabilization and processing for bulk transportation to an off-site landfill. The exact location, configuration, siting and operational impacts, as well as potential delivery restrictions by the receiving facility (e.g., tons per day) are beyond the scope of this FS and may not be fully reflected in the FS estimated durations or costs.

- **Alternative 6N – Removal of Waste Materials Exceeding the PRG, MNR, and ICs,**

  Estimated Capital Cost: $77.14 million
  Estimated In-Direct and Operation & Maintenance Cost: $9.83 million
  Estimated Total Present Worth Cost: $87 million
  Estimated Construction Time: 19 months

  This is the same alternative as 6N* evaluated by the USACE (Appendix A). All waste material above the waste material PRG of 200 ng/kg located beneath the temporary armored cap would be removed. Institutional controls in the form of deed restrictions and notices would be implemented to place restrictions on dredging and anchoring to protect the integrity of the armored cap and to limit potential disturbance and resuspension of buried sediment near the upland sand separation area. MNR would be used to achieve the PRG for sediment (30 ng/kg) in the sand separation area and the Texas Surface Water Quality Standard in the San Jacinto River.

  This alternative would involve removal of most of the existing temporary armored cap and the removal of approximately 152,000 CY of waste material. The full removal alternative will utilize Best Management Practices (BMPs) to reduce the re-suspension of sediment. The removal will be completed in stages or sections as appropriate to limit the exposure of the uncovered sections of the waste pits to potential storms. Raised berms, sheet piles, and silt curtains in addition to dewatering and removal in the dry to the extent practicable will be used to reduce the re-suspension and spreading to the removed material. The berms would be armored on the external/river side with armor material removed from the areas that have geotextile present. The design approach for removal and design of BMPs will be determined in the Remedial Design. Residual concentrations of contaminants following excavation and removal will be covered by at least two layers of clean fill to limit intermixing of residual material with the clean fill. An off-site materials management facility will be required for material staging, stabilization and processing

for bulk transportation to an off-site landfill. The exact location, configuration, siting and operational impacts, including severe weather, as well as potential delivery restrictions by the receiving facility (e.g., tons per day) are beyond the scope of this FS and may not be fully reflected in the FS estimated durations or costs.

Comparative Evaluation of Alternatives for Area North of I-10

The waste material is highly toxic and may be highly mobile in a severe storm and therefore is considered a Principal Threat Waste. The EPA considers material at the Site with more than 300 ng/kg dioxin to be Principal Threat Waste. This concentration was calculated by multiplying the risk-based sediment PRG of 30 ng/kg (Hazard Index = 1) by a factor of 10 (an order of magnitude). While no threshold level of toxicity or risk has been established to equate to a principal threat, the EPA generally considers source materials with a potential risk that is equal to or greater than an order of magnitude higher than a protective level should be considered a Principal Threat Waste.

In evaluating the Remedial Alternatives, the EPA has considered the location of the Principal Threat Waste materials, either partially submerged within the San Jacinto River (northern impoundments) or on a small peninsula on the San Jacinto River (southern impoundment). The Site is in a river environment that is subject to dramatic change, creating concerns about the protectiveness of leaving Principal Threat Waste in and adjacent to the River, even if contained with an armored cap. The area has a high threat of repeated storm surges and flooding from hurricanes and tropical storms, which, if the material was left in place, could result in a release of hazardous substances. The history of repeated temporary armor cap maintenance to replace missing or eroded armor stone, with flooding that has been less severe than the design 100-year flood, also creates concerns about the long-term permanence of an armored cap.

The two CERCLA Threshold Criteria are that a remedy must 1) provide for overall protection of human health and the environment; and 2) comply with the Applicable or Relevant and Appropriate Requirements (ARARs) identified for the Site. The containment alternatives (2N through 5aN) will only remain protective if they are properly maintained for the length of time (hundreds of years) that the impounded waste retains its toxicity, and assumes that their integrity is not compromised by extreme weather events, barge strikes and/or changes in the river channel which could result in a future release. Alternative 6N best realizes the Threshold Criteria of overall protectiveness because the waste material would be removed and therefore not subject to a potential future release of a significant amount of Principal Threat Waste into the San Jacinto River, although there will be some short term releases of dioxin (estimated by the USACE as between 0.2% and 0.34% of the waste material with Best Management Practices or BMPs) as a result of implementing the full removal alternative.

Alternatives 1N and 2N rely on continued containment of materials exceeding the PRGs within the existing temporary armored cap. These two alternatives each include a requirement, based on the approved OMM Plan, to monitor and maintain the temporary armored cap in accordance with USACE and USEPA guidance to ensure the long-term effectiveness of the cap system.

Alternative 3N includes the features of Alternatives 1N and 2N, together with construction of an Upgraded Cap that exceeds USACE and USEPA design guidance by placing additional armor rock and constructing flatter slopes. In addition, the Upgraded Cap uses larger rock sized for the "No Displacement" design scenario, which more conservative than the "Minor Displacement" scenario used in the temporary armored cap's design. In addition, Alternative 3N includes the construction of a protective perimeter barrier or other measures around the perimeter of the Upgraded Cap to address concerns regarding potential damage from vessel traffic.

The USACE performed evaluations to address the permanence of the existing repaired temporary cap with the proposed modifications outlined in the capping Alternative 3N. Since its completion in July 2011, the armored cap has generally isolated the waste, but has required many repairs and extensive maintenance. The expected long-term releases from capping are very small in the absence of cap erosion or a major disturbance by a barge strike. However, the USACE found that a severe storm could erode a sizable portion of the upgraded Alternative 3N cap. The most severe event simulated was the hypothetical synoptic occurrence of Hurricane Ike (Category 2 hurricane) and the October 1994 flood, with a peak discharge of approximately 390,000 cubic feet per second occurring at the time of the peak storm surge height at the Site. This storm flow is about 8% higher than the river flow during the 1994 storm. Approximately 80 percent (12.5 acres) of the 15.7 acre upgraded Alternative 3N cap incurred severe erosion during the simulated extreme storm. The maximum scour depth in any grid cell within the cap boundary during this potential extreme event was 2.4 feet resulting in erosion and release of the paper mill waste material containing dioxin.

Some localized disturbances of the cap may occur from bearing capacity failures of the soft sediment, gas entrapment by the geomembrane or geotextiles, or barge strikes, requiring maintenance or repair. The USACE believes that the expected releases from these localized disturbances would be very small, much smaller more than releases from removal of the contaminated sediment as predicted for Alternative 6N with enhanced resuspension BMPs, even if these disturbances are not quickly repaired.

The USACE estimated that these issues related to cap permanence might be addressed by additional modifications to Alternative 3N (modifications included in Alternative 3aN), including upgrading the blended filter in the Northwestern Area to control sediment migration into the cap, upgrading the armor stone size with a median size of 15 inches,

thickening of the armor cap by an additional 2-feet across most of the waste pits, and installing pilings to protect the cap from barge strikes. However, the USACE report did not consider changing river conditions in its evaluation of the long term permanence of a cap; new channels eroding during flooding as well as changes in channel cross section due to bank erosion, shoreline breaches, etc. during a high flow event caused by a major flood or hurricane is beyond the ability of existing sediment transport models to simulate. In addition, the uncertainty associated with estimates of the effects of some of the potential failure mechanisms, e.g., propwash, stream instability, is very high (USACE 2016b). Finally, even more severe hurricanes (exceeding Category 2) are possible during the hundreds of years that the dioxin waste will remain hazardous. Therefore, there is a high degree of uncertainty regarding the long term permanence of the cap, even with the improvements suggested by the USACE.

Alternatives 1N, 2N, 3N, and 3aN are containment alternatives that provide substantial long-term protectiveness under normal conditions while avoiding environmental impacts applicable to Alternatives 4N, 5N, 5aN and 6N, all of which require disruption of the existing temporary armored cap to conduct stabilization or removal/disposal of impacted materials. However, Alternatives 1N, 2N, 3N, and 3aN do not provide any further treatment or removal of the dioxin/furan Principal Threat Waste. Alternatives 3N and 3aN provide additional long-term protectiveness compared to Alternatives 1N and 2N due to the additional cap enhancements and measures to minimize potential damage to the Upgraded Cap from vessel traffic. Alternative 6N provides the greatest long-term protectiveness and effectiveness because the waste material, except for the residuals, would be permanently removed from the San Jacinto River and there would be no potential for a future release from the Site, and neither would there be any concerns regarding the long term viability and effectiveness of a maintenance program that would have to endure for an extremely long time, or hundreds of years. Alternative 6N also provides for removal of the dioxin/furan Principal Threat Waste, which will be treated for water removal as necessary for transportation and off-site disposal.

In situ capping, as discussed in USEPA and USACE guidance (USEPA 2005; USACE 1998) and in Table 4-1a, is a demonstrated technology that has been selected by USEPA for sediment remediation sites across the United States. However, the Site's location within the San Jacinto River creates an uncertainty regarding the ability of an engineered cap to reliably contain the dioxin waste over the hundreds of years that the dioxin will remain hazardous. The uncertainty comes from the severe storms and floods that have occurred in the area, and the potential for barge strikes to compromise the cap. The potential for barge strikes is heighted because of the increased barge traffic after the completion of the temporary armored cap. In summary, the armored cap is predicted by the USACE to have long-term reliability from scour related processes except under very severe hydrologic and

hydrodynamic events. However, the USACE also recognized that the uncertainty associated with estimates of the effects of some of the potential failure mechanisms, e.g., propwash, stream instability, is very high (Appendix A), and that potential changes in the river channel cannot be simulated due to modelling limitations.

Alternatives 4N, 5N, 5aN, and 6N include disruption of the existing temporary armored cap in order to conduct treatment or removal of materials beneath the cap. These alternatives employ design, engineering and operational controls to mitigate the resuspension of impacted waste materials that occurs when using these remedial technologies. Removal technologies have been used at sediment sites listed on Table 4-1b. Alternatives 4N and 5N would stabilize (4N) or remove (5N) materials with $TEQ_{DF,M}$ greater than the level set by USEPA of 13,000 ng/kg. Alternatives 5aN and 6N would remove some (5aN) or all (6N) waste materials that exceed the PRG of 200 ng/kg for a hypothetical recreational visitor. Alternative 4N would stabilize 52,000 CY of the waste material from beneath the temporary armored cap, while Alternative 5N, 5aN, and 6N would remove and dispose of off-site volumes of material ranging from 52,000 CY(Alternative 5N), to 137,600 CY (Alternative 5aN) to 152,000 CY (Alternative 6N). Alternatives 5N, 5aN, and 6N may reduce the amount of long-term OMM associated with the capping and treatment-based alternatives (1N thorough 4N), while 6N would eliminate most OMM except for actions to implement and maintain the MNR and the ICs.

Alternative 3N has an estimated construction duration of 2 months and may require an off-site staging area for armored rock, while Alternative 3aN has an estimated duration of 15 months. Alternatives 4N, 5N, 5aN, and 6N have estimated construction durations ranging from 13 to 19 months. Each of these alternatives would require the establishment, and potential permitting of an off-site facility for sediment and material handling. For Alternatives 5N, 5aN, and 6N, this facility would be utilized for processing and managing removed sediments. The availability and location of an off-site facility could impact the implementability, duration, and costs of these alternatives and are beyond the scope of the FS.

Implementation of Alternatives 4N, 5N, 5aN, or 6N would require removing part of the temporary armored cap and either excavation, dredging, or stabilizing the underlying waste deposits. Stabilization under Alternative 4A is consistent with USEPA's preference for treatment. However, experience at sediment sites indicates that resuspension and release of waste material residuals and dioxins/furans into the water column will likely occur, although to a significantly reduced extent with robust BMPs. Such releases may result in increased fish tissue concentrations of contaminants for several years following completion of dredging (Patmont et al. 2013).

The selection of management practices used in removal operations has a significant impact on the levels of potential waste material releases that the USACE estimates may occur during implementation of a removal alternative. The initial drafts of the FS prepared by MIMC and IP did not use robust BMPs, and therefore overestimated likely releases from removal alternatives in comparison with the Alternative 6N described in this FS. Depending on the selection of BMPs, flooding and high flow conditions during removal operations could significantly increase the erosion of waste material residuals. Releases from flood flows over the containment structure regardless of the removal alternative will be dependent on the height of the containment structure and the flood stage. A sheet pile wall built in and supported by an armored waste pit berm and along the southern shoreline to an elevation of about +10 ft would protect the waste pit excavation from releases from more common floods (e.g., the 25-yr or 50-yr flood stage, Appendix A). Excavation would be performed in the dry to the extent practicable. Removals may be performed in small sections at a time such that the armor stone and geotextile within the small section would be removed, and then the sediment removed and a thin layer of sacrificial fill placed before advancing to the next section and repeating the process. Under these removal operations, it would also be advisable to limit or restrict removal activities to a period when there is a lower probability of tropical storms and flooding conditions. The actual design of protective sheet piles and berms will be determined during the Remedial Design.

BMPs would be successful in mitigating potential resuspension and release. For alternatives 4N, 5N, 5aN, and 6N, a flood may occur during construction. Therefore, these alternatives will include design and construction methodologies to mitigate and reduce the impact of storms during construction.

For short-term effectiveness, Alternatives 1N and 2N are most favorable, followed by Alternative 3N. Short-term effectiveness ranks high for Alternatives 1N and 2N because these alternatives do not entail active construction. Alternative 3N ranks lower, followed by Alternative 3aN, than Alternatives 1N and 2N for short-term effectiveness because it includes active construction considerations such as increased truck traffic, worker safety, water quality, and construction equipment emissions of particulate matter (PM), greenhouse gases, and ozone. However, there are other sources of air emissions and traffic in the region, including the industrial activities that occur adjacent to the Site and the presence of I-10.

Alternatives 4N, 5N, 5aN, and 6N also involve potential water quality impacts, worker safety risks, and air emission impacts that are estimated to be more than 8 to 20 times greater[1] than for Alternative 3N. Traffic and community impacts for Alternatives 4N, 5N, 5aN, and 6N

(measured as truck trips) are estimated to range from 6 to nearly 70 times greater than for Alternative 3N and may not fully account for truck trips associated with operation of an offsite materials management facility. While the removal alternatives are less favorable for short-term effectiveness, Alternatives 4N, 5N, 5aN, and 6N all provide either treatment or removal of Principal Threat Waste, at least for a portion of the waste material. Alternative 4N includes treatment (solidification/ stabilization) for about 25% of the volume of the most highly contaminated portion of the waste. Alternative 5N and 5aN both include partial removal of the most highly contaminated waste, with Alternative 5N accounting for 25% of the volume, and Alternative 5aN accounting for about 2/3 of the waste volume. Alternative 6N includes full removal of the Principal Threat Waste above the cleanup level.

The USACE found that fish tissue contaminant concentrations are directly related to the releases to the water column, but are also related to the entirety of their food sources which are largely impacted by the water column concentrations and releases. Consequently, depending on the BMPs employed and the feeding range of the fish species, fish tissue contaminant concentrations may be dozens of times higher (for Alternative 6N) than existing tissue concentrations for several years before returning to near existing values (Appendix A). The release amount referenced in the Corps' Report, 2 grams of dioxin, or 0.34% of the amount removed, is based on using silt curtains in the Northwestern Area. However, using robust BMPs, including sheet piles in the Northwestern Area, would reduce the release by 40% and therefore reduce the estimated fish tissue increases by 40% as well (Appendix A, Table 12-19).

Construction of any of the proposed Alternatives is not expected to cause any flooding in the vicinity of the Site, and therefore should not require the implementation of any flood control measures during the construction of any of the Alternatives under consideration for the Site.

Comparative Cost Effectiveness of the Alternatives for the Area North of I-10

Costs for the remedial action alternatives range from $0.4 to $87 million. Alternatives 1N and 2N have similar costs, primarily related to long-term OMM of the temporary armored cap. Alternative 3N has a higher cost than Alternatives 1N and 2N as it also includes construction of the Upgraded Cap and a protective barrier to ensure the long-term integrity of the Upgraded Cap. Alternative 3aN has a higher cost than Alternatives 3N as it also includes construction of the Enhanced Cap and an additional protective barrier (pilings) to ensure the long-term integrity of the cap.

Costs for Alternatives 4N, 5N, 5aN, and 6N are higher than for Alternatives 1N, 2N, 3N, and 3aN. This reflects the challenges of establishing and operating an off-site staging and processing area, removal of the temporary armored cap, in situ treatment or excavation and

associated engineering controls, the quantity of materials being addressed, the duration of work, and the high cost of transportation and disposal of impacted sediments.

Alternatives 1N, 2N, 3N, and 3aN provide an equal reduction in the dioxins and furans in sediments in the river within USEPA's Preliminary Site Perimeter. For Alternatives 4N, 5N, 5aN, and 6N, the dioxins and furans in sediments in the river are predicted to increase the short-term releases from sediment re-suspension construction-related impacts (e.g., cap removal, disturbance of material below waterline, etc.). Alternatives 5N and 5aN would remove some while 6N would remove all impacted materials with higher dioxin/furan concentrations, but possible impacts from re-suspension during construction could potentially reduce the short-term protectiveness of the remedy. These alternatives are also incrementally and substantially more expensive because of their complexity and duration.

The USACE estimates (Appendix A) that the full removal alternative 6N with BMPs (Alternative 6N* in the USACE Corps Alternatives Evaluation report) including sheet piles in deeper water areas could result in a short-term release to the river of about 0.2% of the contaminant mass due to re-suspension during removal. For the enhanced capping Alternative 3N, no significant short-term release is expected and the cap is expected to be generally resistant to erosion except for very extreme floods, which could erode a sizable portion of the cap. A hypothetical occurrence of both Hurricane Ike and the October 1994 flood with a peak discharge of approximately 390,000 cubic feet per second was modelled. This storm flow is about is about 8% higher than the river flow during the 1994 storm. Approximately 80 percent (12.5 acres) of the 15.7 acre upgraded Alternative 3N cap incurred severe erosion with a release of underlying waste material during the simulated potential extreme storm.

The cost of Alternative 6N ($87 million) is about 21 times more that the cost of the upgraded capping Alternative 3N ($4.1 million), but is about 3.5 times more than the cost of enhanced capping Alternative 3aN ($24.8 million). However, the potential future dioxin release for the temporary cap with the upgrades described for the Upgraded Cap (Alternative 3N) during a future severe storm results in a release of approximately 29% of the dioxin in the waste pits. This modelled future storm erodes much of the cap with a potential release that is over 140 times higher than the short-term release for Alternative 6N using BMPs with sheet piles around all areas (0.2% release). If sheet piles cannot be used in deeper water due to technical reasons, the short–term release would still be much less (0.34%) than the severe storm release (USACE 2016b). The additional cost for Alternative 6N insures that that a future extreme storm will never result in a catastrophic cap failure and release of dioxin to the San Jacinto River.

Remedial Alternatives for Area South of I-10

The area south of I-10 is part of a peninsula on which industrial activity has occurred since at least the early 1960s. In contrast with the area to the north of I-10, the peninsula south of I-10 contains active operations of several shipping and marine industrial services businesses, with the area serving as a transport hub and as a location for barge or ship maintenance, cleaning and painting. Changes in the distribution of materials, locations of soil disturbance and staining, development of buildings or other structures, and evolution of roads and tracks throughout the southern peninsula area, indicate that the peninsula south of I-10 has been a busy industrial community in the decades after disposal of paper mill wastes in the mid-1960s took place.

Three dioxin and furan source types have been identified in soils of the area of investigation south of I-10, only one of which has a fingerprint that is similar to the paper mill wastes contained in the North Impoundments. Another source is from general urban background, such as fuel combustion and other common municipal activities, or specific local sources. A third source type has a fingerprint that is distinct from the other two sources, and affects only soils in the area of investigation on the peninsula south of I-10. The nature and origin of this dioxin and furan source are unknown.

There are no risks to ecological receptors from dioxins and furans in the area of investigation south of I-10. The only risks associated with the disposal of dioxins and furans associated with paper mill wastes in the area of investigation south of I-10 was for a hypothetical future construction worker who might come into contact with the dioxins and furans within the upper 10 feet of soil. The PRG for $TEQ_{DF,M}$ protective of a hypothetical future construction worker for $TEQ_{DF,M}$ was calculated to be 240 ng/kg in soil, and is applicable to the average concentration in a soil column of 10 feet.

Remedial alternatives were developed for the locations in the area south of I-10 where the average $TEQ_{DF,M}$ concentration in the upper 10-feet of soil below grade exceeds the PRG in soil for the hypothetical future construction worker. $TEQ_{DF,M}$ concentrations in the upper 10-feet of soil exceed the PRG with the highest $TEQ_{DF,M}$ concentrations occurring at 5-feet below the ground surface or deeper. Remedial alternatives developed for the area south of I-10 include:

- Alternative 1S – No Further Action
- Alternative 2S – ICs
- Alternative 3S – Enhanced ICs
- Alternative 4S – Removal and Off-site Disposal

The costs for these alternatives are $143,000 (Alternative 1S – No Further Action), $1,024,000 (Alternative 2S – ICs), $1,409,000 (Alternative 3S – Enhanced ICs) and $9.9 million (Alternative 4S – Removal and Off-site Disposal).

Other than Alternative 1S, the remedial alternatives for the area south of I-10 meet both of the CERCLA threshold criteria as established in the NCP: protectiveness and compliance with ARARs. The potentially affected receptor (hypothetical future construction worker) would be protected from exposure to soil with elevated $TEQ_{DF,M}$ concentrations by warnings and restrictions (Alternatives 2S and 3S) or removal of impacted soil (Alternative 4S).

Alternative 4S offers the benefit of permanent removal of impacted soil from the 0- to 10-foot interval. The risk management achieved by ICs is somewhat lower, although with the addition of the physical markers that are part of Alternative 3S the risk management is improved. Alternatives 2S and 3S would not require exposing impacted soil or transporting material off-site and would be simpler to implement. However, the toxic and persistent dioxin waste material would remain susceptible to future flooding in the San Jacinto River. Excavation of impacted soil (Alternative 4S) would introduce short-term risks of exposure on-site and potentially off-site in the event of a release in route to the disposal facility. The cost of Alternative 4S (removal), $9.9 million, is about 7 times the cost of Alternative 3S (enhanced ICs). The additional cost for Alternative 4S insures that that a future extreme storm will never result in a catastrophic erosion of the waste material and release of dioxin to the San Jacinto River. Alternative 4S is the only alternative that provides for treatment or removal of the Principal Threat Waste material.

In summary, Alternative 4S offers an increase in long-term effectiveness by removing the impacted soil; however, there is an increased short-term risk of exposure and potential traffic accidents. Alternatives 2S and 3S mitigate potential risks associated with exposure to soil in the area south of I-10 with reduced short-term exposure risks and at costs commensurate with the potential risk associated with the impacted soil at depth, although with a reduced long term protectiveness.

1 INTRODUCTION

This Feasibility Study (FS) Report was prepared for the San Jacinto River Waste Pits (SJRWP) Superfund Site (Site) (Figures 1-1 and 1-2). The location of U.S. Environmental Protection Agency's (USEPA's) Preliminary Site Perimeter is shown in Figure 1-2. This FS Report builds upon the final Remedial Alternatives Memorandum (RAM), which presented the initial screening of remedial technologies and the development of preliminary remedial alternatives. Additional information on remedial technologies was developed by the U.S. Army Corps of Engineers (USACE) in a report prepared for the EPA: the Evaluation of the San Jacinto Waste Pits Feasibility Study Remediation Alternatives (the Alternatives Evaluation report). This FS Report evaluates remedial alternatives for the SJRWP Site based on the Remedial Action Objectives (RAOs) provided in the RAM and Remedial Investigation (RI) Report (Integral and Anchor QEA 2013), and based on results of the Baseline Human Health Risk Assessment (BHHRA) (Integral 2013b) and Baseline Ecological Risk Assessment (BERA) (Integral 2013a). The Final BERA and BHHRA were submitted to USEPA on May 6, 2013 and May 22, 2013, respectively. The EPA subsequently modified the PRGs for waste material in the northern waste pits, and for soil and waste material in the southern impoundment, based on a memorandum regarding a Relative Bioavailability Adjustment (Anchor QEA, January 16, 2015); and modified the PRG for sediment in a memorandum regarding the Human Health Risk Evaluation and Recommended Sediment Cleanup Level (EPA, August 29, 2016).

1.1 Purpose and Organization of the Report

The FS Report evaluates remedial alternatives for the Site, and is consistent with specific guidance (USEPA 1988). The identification and screening of remedial technologies, which the guidance includes as an element of the FS Report (Table 6-5, USEPA 1988), is discussed in the RAM (Anchor QEA 2012b), as was required by the UAO.

The remainder of Section 1 provides a summary of the regulatory background with respect to the Site. Section 2 provides a summary of Site information as presented in previous documents prepared and submitted in support of the RI/FS process, including a summary of the Site setting and history, the nature and extent of contamination, chemical fate and transport, results of the BERA and BHHRA, and the Conceptual Site Models (CSMs) for the SJRWP Site. The other sections of the FS Report address the following:

- Section 3 identifies the Preliminary Remediation Goals (PRGs) described in the RI Report and identified by USEPA and describes the basis for the remedial action
- Section 4 describes the development of each remedial alternative
- Section 5 provides a detailed and comparative analysis of each remedial alternative

- Section 6 provides the comparative analysis of the remedial alternatives
- Section 7 provides the references

1.2 Regulatory Background

On March 19, 2008, the USEPA listed the SJRWP Site on the National Priorities List (NPL) under Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), also known as Superfund, due to presence of dioxins and furans (Texas Commission on Environmental Quality [TCEQ] and USEPA 2006, 2008) in soils and sediments at the SJRWP Site. On November 20, 2009, USEPA issued a UAO to IP and MIMC (USEPA 2009a). The 2009 UAO directs IP and MIMC to conduct an RI/FS for the SJRWP Site.

The RI Report was conditionally approved by USEPA on April 4, 2013, and the Final RI Report was submitted to USEPA on May 17, 2013. The FS Report will ultimately lead to a proposed remedial action plan for the SJRWP Site (Proposed Plan). The Proposed Plan will be the subject of public comment, and once the EPA Record of Decision (ROD) is finalized, the comments and a Responsiveness Summary and will be incorporated into the ROD for the Site.

The UAO describes a basic history of the SJRWP Site, but only for the impoundments located on the north side of Interstate Highway 10 (I-10), referred to as the Northern Impoundments. USEPA subsequently required investigation of soil and groundwater in an area to the south of I-10, or "Soil Investigation Area 4" citing historical documents indicating possible waste disposal activities in that area (Figure 1-2). The area of investigation south of I-10 ultimately also included areas adjacent to Soil Investigation Area 4, at locations to the south and west of it, where USEPA required additional soil and groundwater samples.

A time critical removal action (TCRA) was completed in July 2011 in the Northern Impoundments, pursuant to an Administrative Settlement Agreement and Order on Consent for Removal Action: CERCLA Docket No. 06-12-10 (AOC) (USEPA 2010a). The temporary cap generally stabilized and isolated pulp waste and sediments within the original 1966 perimeter berm of the Northern Impoundments, but has required many repairs and extensive maintenance. More information about the temporary cap is provided in Section 2.5.3.

The Respondents to the RI/FS UAO, MIMC and IP, prepared the first draft of this Feasibility Study report under EPA oversight. Following review and comment by the EPA and other Site stakeholders on the draft, a revised draft Feasibility Study was submitted to the EPA in March 2014. Following review of the Respondents' second draft, the EPA decided that it would revise and complete the Feasibility Study report. The EPA requested the assistance of

the United States Army USACE to provide additional information for the revised Feasibility Study.

The United States Army USACE 2016 report, the Evaluation of the San Jacinto Waste Pits Feasibility Study Remediation Alternatives (the Alternatives Evaluation Report), was prepared for EPA in order to evaluate and supplement the Feasibility Study work performed by the Respondents. As stated in the Alternatives Evaluation report, the technical assistance provided by the Corps was to assess the remediation alternatives presented in the draft Feasibility Study prepared by the Respondents; identify any other remedial action alternatives, technologies or best management practices (BMPs) that might be appropriate for the Site; evaluate the numerical models used by the Respondents for the Site; and assess the hydraulic conditions in and around the San Jacinto River. To perform these tasks, the USACE used surface water hydrologic, hydrodynamic and sediment transport models appropriate for the Site, including the Corps' LTFATE modeling system. The Corps organized the work into nineteen tasks as identified in the Corps Report.

The Corps Report evaluated the remedial alternatives presented in the draft Feasibility Study report prepared by the Respondents. In addition, the Corps Report identified additional alternatives, including an enhanced version of Alternative 3N, referred to in this Feasibility Study as Alternative 3aN, and Alternative 6N*, a full removal alternative with more robust BMPs than the original Alternative 6N proposed by the Respondents. In this Feasibility Study, EPA has changed the name of the Corps' Alternative 6N* to Alternative 6N, and removed from consideration the Respondents' original full removal alternative as it would result in much higher expected releases.

The Alternatives Evaluation Report provided new information for this Feasibility Study regarding how the TCRA cap would withstand an extreme storm in the area, based on the Corps' modeling. According to the report, the most severe event simulated was the hypothetical synoptic occurrence of Hurricane Ike and the San Jacinto River flooding that occurred in October 1994, with a peak discharge of approximately 390,000 cubic feet per second occurring at the time of the peak storm surge height at the Site. The results during the peak of the storm surge showed that the sections using Armor A (3-inches diameter) were completely eroded, while the sections using Armor D (10-inches diameter) were eroded more than 12 inches in about 33 percent of those sections. The sections using Armor B and C (6-inches diameter) incurred a net erosion of more than 9 inches in about 75 percent of those areas. Overall about 80% of the cap experienced significant erosion with scour reaching approximately 2.4-feet through the cap and into the waste material. The scenario defined above may cause significant erosion of the paper mill waste.

The Corps also states its belief that releases from catastrophic events can potentially be addressed by additional cap improvements, including upgrading the blended filter in the Northwestern Area to control sediment migration into the cap, upgrading the armor stone size to a diameter of 15 inches and adding 2 feet of additional armor stone over the existing cap across the waste pits to minimize the potential for disturbance during very severe hydrologic and hydrodynamic events. These improvements have been incorporated into new Alternative 3aN in this Feasibility Study. However, the Corps did not model the impact of the most severe storm/flooding event simulated with the improvements added to Alternative 3aN. More importantly, future flooding may be even more intense. According to the U.S. National Climate Assessment, flooding along rivers and other areas following heavy downpour and prolonged rains is exceeding the limits of flood protection infrastructure designed for historical conditions.

The Corps Report's evaluation of the containment alternatives is contingent on the continued integrity of the armored cap and is limited by uncertainties in modeling. The USACE acknowledges that the uncertainty inherent in any quantitative analysis technique used to estimate the long-term (500 years or more) reliability of the cap is very high, and the uncertainty associated with estimates of the effects of some of the potential failure mechanisms such as propwash and stream instability, is also very high.

The Corps Alternatives Evaluation report did not evaluate changing river conditions or stream instability on the containment alternatives. New channels eroding during flooding as well as changes in channel cross section due to bank erosion, shoreline breaches, etc. during a high flow event caused by a major flood or hurricane is beyond the ability of existing sediment transport models to simulate. While changing river conditions may be beyond the ability of current models to simulate, the October 1994 flood provides an example of how flooding can cause major erosion and create water channels outside of the San Jacinto River bed. The largest new channel was cut through the Banana Bend oxbow just west of the Rio Villa Park subdivision, about 2 ½ miles northwest of the Site. This new channel was approximately 510 feet wide and 15 feet deep. A second major channel cut through Banana Bend just north of the channel through the oxbow. Both of these new channels were cut through areas where sand mining had been done before, as is the case in the vicinity of the Site.

The Alternative Evaluation report also provided valuable information on BMPs that can be implemented to improve the performance of the full removal alternative; these BMPs have been incorporated in the new Alternative 6N in this Feasibility Study. However, the 2016 USACE report's evaluation of containment as compared to excavation and removal often focuses on risks which will be reduced and/or eliminated through use of the BMPs it has

identified. Several of the USACE's comparisons between containment and removal alternatives use the earlier version of Alternative 6N for the comparison, without BMPs, and therefore higher expected releases of hazardous substances during implementation. The expected releases from the Respondents' original version of Alternative 6N, not using BMPs, were estimated at 3.3% of the total waste to be removed during removal operations; the expected releases from the new Alternative 6N (Alternative 6N* in the Alternatives Evaluation report) are between 0.2% and 0.34% of the waste, depending on whether sheet pile walls can be effectively used in the Northwest Cell.

The USACE Alternatives Evaluation report also indicates that there are no documented cases of any armored cap or armored confined disposal facility breaches. However, there have been many occurrences of breaches and slope failures of armored dikes, jetties, and breakwaters, with some of those structures confining dredged material. In addition, the EPA has estimated that the dioxin contaminated paper mill waste in the impoundments will remain hazardous for hundreds of years; none of the examples cited by the USACE have been in place over 100 years, and many are not in aquatic environments as dynamic as the Site's location in the San Jacinto River.

2 SETTING

This section provides a summary of information gathered concerning physical, chemical, and biological conditions within the USEPA's Preliminary Site Perimeter. This information is intended to provide the reader with an understanding of the SJRWP Site and the human actions, natural processes, and physical properties that may influence the nature and extent of chemicals of concern (COCs) within the USEPA's Preliminary Site Perimeter, and that may influence evaluation of remedial alternatives presented in Sections 4 through 6 of this report. A more comprehensive physical and biological description, as well as more detailed history of the area within the USEPA's Preliminary Site Perimeter, its environmental setting, and land uses are provided in the RI Report (Integral and Anchor QEA 2013).

2.1 Location and History

USEPA's Preliminary Site Perimeter includes several waste impoundments within the estuarine section of the San Jacinto River (SJR), as well as surrounding in-water and floodplains in the upland areas. The impoundments are located on the western side of the San Jacinto River, north and south of I-10 (Figure 1-1). The area within the USEPA's Preliminary Site Perimeter is generally flat with very little noticeable topographic relief across most of the area.

The SJR is a coastal plain estuary. The San Jacinto River Waste Pits are located in a FEMA designated floodway zone, which is essentially the 100-year floodplain for the SJR. The base flood elevation, which is the water surface elevation resulting from a 100-year flood, has been determined by FEMA to be 19 feet (5.8 m) for the waste pits. The low lying Waste Pits are also subject to flooding from storm surges generated by both tropical storms (i.e., hurricanes) and extra-tropical storms. Storm surges generated in the Gulf of Mexico propagate into Galveston Bay and into the Lower SJR

The impoundments were built in the mid-1960s for disposal of paper mill wastes barged from the Champion Paper Inc. paper mill in Pasadena, Texas. These wastes are the source of dioxins and furans present in the impoundments within the USEPA's Preliminary Site Perimeter and have been targeted for remediation. Other sources of dioxins and furans within USEPA's Preliminary Site Perimeter, such as atmospheric inputs, industrial effluents, publicly owned treatment works, and storm water runoff, are discussed in Section 2.5.4; however, the dioxins and furans from the paper mill waste material are distinct from the dioxins and furans from other sources, as demonstrated by the waste "fingerprinting" performed by the EPA. Over time, a variety of actions occurring within and in the vicinity of the USEPA's Preliminary Site Perimeter resulted in actual or potential disturbances to the

impoundments, and introduced other sources of dioxins and furans, as well as other COCs into the soils and sediments within the USEPA's Preliminary Site Perimeter.

Large scale groundwater extraction by others, resulting in regional subsidence of land in the vicinity of the SJRWP Site, resulted in increased exposure of the contents of the Northern Impoundments to surface waters. Dredging and sand mining by others within the river and marsh to the west and northwest of the waste pits through the 1990s and early 2000s may have contributed to the exposure. Historical documents indicate that dredging actions also occurred in the river in the vicinity of the upland sand separation area located to the west of the Northern Impoundments (sand separation area) (Figure 1-2). In addition, barge maintenance and cleaning activities conducted on and adjacent to the sand separation area in the mid-1990s by Southwest Shipyards included generation and storage of unspecified hazardous materials and wastes, including residual spent blast sand, paint chips, and rust chips swept from vessels prior to painting, paint drip, and overspray (GW Services 1997).

The peninsula south of I-10 and the area of investigation south of I-10 were characterized by intense industrial activity in the 1980s based on review of historical aerial images (Integral and Anchor QEA 2013). Southwest Shipyards' activities also have impacted areas south of I-10, including the western shoreline of the peninsula south of I-10 (GW Services 1997). Most of the upland area south of I-10 is currently in industrial or commercial use by marine services companies, with some parcels currently unused.

A more detailed discussion of the SJRWP Site history is provided in Sections 5.1 and 6.1 of the RI Report (Integral and Anchor QEA 2013).

2.2 Land Use

The land use types in the area surrounding the USEPA's Preliminary Site Perimeter are shown in Figure 2-1. The land parcels closest to the USEPA's Preliminary Site Perimeter are predominantly commercial/industrial, followed by residential areas. Moving farther from the USEPA's Preliminary Site Perimeter, the amount of residential land use increases. Upstream of the USEPA's Preliminary Site Perimeter, land uses include industrial and municipal activities that may result in releases of dioxins and furans or other COPCs into the San Jacinto River, although these dioxins are distinct from the dioxins in the paper mill waste in the impoundments as discussed in Section 2.5 below.

2.2.1 Recreational and Navigational Use

The RI Report presents information regarding recreational and navigational use of the river and the area within the USEPA's Preliminary Site Perimeter. An advisory regarding the

consumption of fish and blue crab exists on the San Jacinto River, including the area within the USEPA's Preliminary Site Perimeter. Sections 3.3.1 and 3.7.3 of the RI Report (Integral and Anchor QEA 2013) discuss surface water use and fishing advisories. Although fishing was reported to have occurred prior to implementation of the temporary cap, there have been no systematic studies of the amount and frequency of fishing that may have occurred within the USEPA's Preliminary Site Perimeter prior to the implementation of the temporary cap. However, the Texas Department of State and Health Services (DSHS) could not identify subsistence fishers in the area of the Site. The completion of the temporary cap resulted in reduced public access to the Northern Impoundment area. Perimeter fencing was installed and warning buoys and signs were placed around the Site. In addition, access to the temporary cap via boat is currently constrained to the north, west, south, and southeast by industrial use and navigational hazards (i.e., submerged sand bars and shallow water). However, affidavits from local fisherman indicate fishing in the vicinity of the Site with sale to local businesses.

The commercial and industrial navigational use of the waterway is generally restricted by shallow depths outside the prescribed channel, as well as other "foul areas" where unidentified hazards are likely to exist. There is no Federally authorized navigation channel in the portions of the river within the USEPA's Preliminary Site Perimeter, and vessel heights are limited in the vicinity of the Site due to clearance limits under the I-10 Bridge. Barge fleeting and mooring occurs in many areas within the USEPA's Preliminary Site Perimeter, including the San Jacinto River Fleet (SJRF) operations near the former sand separation area (Figure 1-2).

2.3 Biological Habitat

The USEPA's Preliminary Site Perimeter is located within a low gradient, tidal estuary near the confluence of the San Jacinto River and the Houston Ship Channel (HSC). The surrounding area includes Lynchburg Reservoir to the southeast and the Lost Lake sediment management area (SMA) west of Lynchburg Reservoir (Figure 2-2). The I-10 freeway reduces the connectivity of habitats in the natural areas to the north and south of the highway, and industrial land use has diminished the habitat value of the uplands and aquatic areas within the USEPA's Preliminary Site Perimeter.

Some upland natural habitat adjacent to the river within the USEPA's Preliminary Site Perimeter remains, consisting primarily of clay and sand that support a variety of forest community types including composites such as loblolly pine-sweetgum, loblolly pine-shortleaf pine, water oak-elm, pecan-elm, and willow oak-blackgum (TSHA 2009). It is reasonable to expect a suite of generalist terrestrial species that are not highly specialized in their habitat

requirements and are adapted to moderate levels of disturbance (Integral 2013a). Such species could include reptiles and amphibians (e.g., snakes, turtles), birds (e.g., starlings, pigeons), and mammals common to semi-urban environments (e.g., rodents, raccoons, and coyotes).

Wildlife habitats within the northern portion of USEPA's Preliminary Site Perimeter include shallow and deep estuarine waters, and shoreline areas occupied by estuarine vegetation. A sandy intertidal zone is present along the shoreline throughout much of the USEPA's Preliminary Site Perimeter (Figure 2-2). The tidal portions of the river and upper Galveston Bay provide rearing, spawning, and adult habitat for a variety of marine and estuarine fish and invertebrate species. Species known to occur in the vicinity of the USEPA's Preliminary Site Perimeter include: clams and oysters, blue crab (*Callinectes sapidus*), black drum (*Pagonius cromis*), southern flounder (*Paralichthys lethostigma*), hardhead (*Ariopsis afelis*) and blue catfish (*Ictalurus furcatus*), spotted sea trout (*Cynoscion nebulosis*), and grass shrimp (*Paleomonetes pugio*) (Gardiner et al. 2008; Usenko et al. 2009). An estimated 34-acres of estuarine and marine wetlands are found within the USEPA's Preliminary Site Perimeter (Integral and Anchor QEA 2013).

On the peninsula to the south of I-10, most of the upland is zoned for commercial or industrial use. Minimal habitat is present in the upland terrestrial area within the USEPA's Preliminary Site Perimeter. Demolition of former industrial facilities and current operations in support of barge fleeting and other industrial activities have created a denuded upland with a covering of crushed concrete and sand. The sandy shoreline of this area has scattered riprap, other metal debris, and piles of concrete fragments. The upland vegetation present on the peninsula south of I-10 is primarily low-lying grasses, with a few shrubs and trees adjacent to the shoreline.

A more detailed description of the local ecological system can be found in Section 3.8 of the RI Report (Integral and Anchor QEA 2013) and in Section 3.4 of the BERA (Integral 2013a).

2.4 Physical Description

2.4.1 Waterway Hydrodynamics

The Site is located in the estuarine portion of the lower San Jacinto River where the river begins to transition from a river system to a delta. River conditions have significantly changed with respect to the location of the waste impoundments (Figures 2-4.1 through 2-4.4). These photos clearly show that the river channel has changed over time. These river changes will continue and could cause a catastrophic release of the highly toxic waste materials from the impoundments, if the waste materials remain in place.

The San Jacinto River within the USEPA's Preliminary Site Perimeter is a well-mixed estuarine system. Flow rates and freshwater inputs in the river in the vicinity of the USEPA's Preliminary Site Perimeter are partially controlled by the Lake Houston dam, upstream of the USEPA's Preliminary Site Perimeter. Salinity ranges from 2 to 20 parts per thousand, but may approach 0 parts per thousand during flood conditions (Integral and Anchor QEA 2013). During low-flow conditions when current velocities were dominated by tidal effects, maximum velocities were measured to be about 1 foot per second, with typical velocities of 0.5 feet per second or less during most of the tidal cycle (Integral and Anchor QEA 2013).

Water depths within the USEPA's Preliminary Site Perimeter range from relatively shallow in intertidal areas (3 feet or less) to relatively deep in the main channel of the river (about 30 feet). Flow rates in the San Jacinto River in the vicinity of the Site are partially controlled by the Lake Houston dam, which is located about 16 river miles upstream of the northern impoundments. The average flow in the river is 2,200 cubic feet per second. Floods in the river occur primarily during tropical storms (e.g., hurricanes) or intense thunder storms. Extreme flood events have flow rates of 200,000 cubic feet per second or greater. Floods can cause water surface elevations to increase by 10 to 20 feet or more (relative to average flow conditions).

Tropical weather systems in the region can have tremendous impacts on regional precipitation and hydrology along the Gulf Coast. Heavy precipitation events produce wide variations in the volume of discharge into and out of the San Jacinto River and may significantly affect variations in flow velocities, sediment transport, suspended sediment loads, and water levels. Floods in the river occur primarily during tropical storms, hurricanes, or intense thunder storms. Extreme flood events with flow rates of 200,000 cubic feet per second or greater and water surface elevations increased by 10 feet or more (relative to average flow conditions) could force the river out of its main channel.

Hurricane season runs from June 1 to November 30. Between 1851 and 2004, 25 hurricanes have made landfall along the north Texas Gulf Coast, seven of which were major (Category 3 to 5) storms. Tropical Storm Allison, which hit the Texas Gulf Coast in June 2001, resulted in 5-day and 24-hour rainfall totals of 20 and 13 inches, respectively, in the Houston area, resulting in significant flooding. More recently, Hurricane Rita made landfall in September 2005 between Sabine Pass, Texas and Johnsons Bayou, Louisiana, as a Category 3 storm with winds at 115 miles per hour and it continued on through parts of southeast Texas. The storm surge caused extensive damage along the Louisiana and extreme southeastern Texas coasts. In September 2008, the eye of Hurricane Ike made landfall at the east end of Galveston Island and travelled north up

Galveston Bay, along the east side of Houston. Ike made its landfall as a strong Category 2 hurricane, with Category 5 equivalent storm surge, and hurricane-force winds that extended 120 miles from the storm's center.

In October 1994, heavy rainfall occurred in southeast Texas resulting in the San Jacinto River Basin receiving 15 to 20 inches of rain during a week-long period. One of the largest measurements of stream flow ever obtained in Texas, 356,000 cubic feet per second (cfs), was made on the San Jacinto River near Sheldon on 19 October 1994 at a stage of 27 feet. During the measurement, velocities of water that exceeded 15 feet per second (about 10 miles per hour) were observed. Another storm occurring in 1940 had a river stage height of 31.5 feet at the same Sheldon location. The 100-year flood, which is defined as the peak stream flow having a one percent chance of being equaled or exceeded in any given year, was exceeded at 18 of 43 stations monitoring the area. For those stations where the 100-year-flood was exceeded, the flood was from 1.1 to 2.9 times the 100 year-flood.

The 1994 flooding caused major soil erosion and created water channels outside of the San Jacinto River bed. This flooding caused eight pipelines to rupture and 29 others were undermined at river crossings and in new channels created in the flood plain outside of the San Jacinto River boundaries. The largest new channel was cut through the Banana Bend oxbow just west of the Rio Villa Park subdivision, about 2½ miles northwest of the Site. This new channel was approximately 510-feet wide and 15-feet deep. A second major channel cut through Banana Bend just north of the channel through the oxbow. Both of these new channels were cut through areas where sand mining had been done before, as is the case in the vicinity of the Site. Sonar tests in a 130-foot section south of the I-10 Bridge located adjacent to the Site found about 10 to 12-feet of erosion from the bottom of the river bed (National Transportation Safety Board; Pipeline Special Investigation Report, PB96-917004, 1996).

The San Jacinto River is a very dynamic system, subject to changes in size and flow paths as experienced during the 1994 storm. A series of aerial photographs illustrate this variability. An aerial photograph taken in 1956 (Figure 2-4.1), before the waste pits were established, shows I-10 crossing the river and extensive islands and land to the north. The next photograph, from 1966 (Figure 2-4.2), shows the northern pits located just west of the I-10 Bridge (the pits were built and in operation in the mid–1960s); significant changes to the north can be seen compared to the 1956 photograph. Land erosion and subsidence is evident in the next photograph from 1973 (Figure 2-4.3); the river had carved a new passage to the west of the site since the 1966 photograph. Photographs in the 1990's and later (Figure 2-4.4) show continued loss of land.

The USACE performed an evaluation of the San Jacinto River and the armor cap using hydrodynamic and sediment transport models. In order to evaluate long term

protectiveness, these models must predict the river conditions for a very long time because dioxin is extremely persistent in the environment and will remain toxic for hundreds of years. The uncertainty inherent in any quantitative analysis technique used to estimate the long-term performance of the river and cap is very high. Further, changes in the river channel due to bank erosion, shoreline breaches, etc. during a high flow event caused by a major flood or hurricane is beyond the ability of any existing sediment transport model to simulate. The changes that the river has experienced over the last 50 years as described above will likely continue in the future; and these changes are specifically what the current models cannot simulate. Therefore, the model predictions should be considered as having a very limited long term reliability.

Future flooding may be even more intense. According to the U.S. National Climate Assessment, flooding along rivers and other areas following heavy downpours and prolonged rains is exceeding the limits of flood protection infrastructure designed for historical conditions. Sea level rise, storm surge, and heavy downpours in combination with the pattern of continued development in coastal areas are increasing damage to U.S. infrastructure and are also increasing risks to ports and other installations. Because the intensity of future storms and flooding may increase, estimates regarding the ability of a cap (even a cap with increased armoring) to contain the dioxin waste material is highly uncertain.

2.4.2 Riverbed Characteristics and Sediment Transport

A detailed evaluation and analysis of the riverbed and sediment transport processes within the USEPA's Preliminary Site Perimeter was presented in the RI Report, as well as in the Chemical Fate and Transport Modeling Report (Anchor QEA 2012c).

The nature of the sediment bed affects sediment transport processes, as well as chemical distributions. As described in the RI Report, the sediment bed within the USEPA's Preliminary Site Perimeter is composed of approximately 80 percent cohesive (i.e., muddy) and 20 percent non-cohesive (i.e., sandy) sediments (Integral and Anchor QEA 2013). Erosion rate data of cohesive sediment collected in the San Jacinto River indicate that the erodibility of bed sediment decreases with increasing depth in bed (Anchor QEA 2012c). The primary source of sediment to the San Jacinto River and within the USEPA's Preliminary Site Perimeter is suspended sediment in surface waters discharged from the Lake Houston Dam. The average annual sediment load at the dam is approximately 381,000 metric tons (Anchor QEA 2012c).

Sediment stability within the USEPA's Preliminary Site Perimeter may be affected by human activities and natural processes as discussed in the RI Report (Integral and Anchor QEA 2013):

- Near-bed velocities generated by episodes of propeller wash are expected to be higher than those due to tidal and riverine currents in areas of the river that are subjected to vessel operations (e.g., at the SJRF operations area and within the navigation channel). Bed-shear stress due to vessel operations is expected to be higher than bed-shear stress due to natural forces and may have the potential to disturb sediments in these vessel operation areas. Near and above the temporary armored cap where vessel access is constrained (Section 2.2.1), natural forces are expected to provide the dominant bed-shear stress.

- The rate of subsidence has decreased during the last 35 to 40 years, due to controls on groundwater usage within Harris County, but continues as does sea level rise. The combined effect of sea level rise and subsidence is reflected in the 1.97 foot increase in relative sea level rise recorded over the past 100 years in Galveston Bay (Brody et al. 2014). The impact of continued subsidence on the integrity and reliability of the existing cap to prevent any release of contaminated material would be dependent on the long-term rate of subsidence. The latter is not well known and cannot be predicted with any reliability. In general, subsidence and the slow rise in sea level would both result in slightly deeper water depths over the Eastern Cell and Northwestern Area of the cap, but the USACE does not believe that these effects would be substantial enough to affect the tidal, river and wind induced circulation in the SJR estuary. As such, it is not believed that the reliability of the cap would be lessened (Appendix A).

- Sea level rise is projected to continue at a rate of approximately 2 to 3 millimeters per year (mm/year) during the next century, with a total increase in sea level of about 0.5 to 2 feet by the year 2100 (Anchor QEA 2012c).

The stability of the sediment bed is an important factor for considering natural recovery processes and in evaluating remedial alternatives for deeply buried deposits of sediment that might exceed the identified PRGs (discussed in Section 3.1) for the areas within the USEPA's Preliminary Site Perimeter. The net sedimentation rate at the site is 1.3 cm/year ± 0.8 cm/year (Appendix A). Sedimentation rates may change with time if land use restrictions, discharge limitations, or other regulatory developments related to storm water discharge are implemented within the San Jacinto River basin; however, sediment loads from sources located downstream of Lake Houston dam are minimal compared to the load at the dam (Anchor QEA 2012c). Thus, any potential decreases in loads downstream of the dam in the

future will have negligible effect on long-term sedimentation within the USEPA's Preliminary Site Perimeter.

2.5 Nature and Extent of COCs

The RI Report (Integral and Anchor QEA 2013) contains a discussion of the nature and extent of COCs north of I-10 (RI Report Section 5.2) and the area of investigation south of I-10 (RI Report Section 6.2). Site conditions have been assessed by EPA based on RI sampling and prior sampling of the Site and the San Jacinto River in the Site area by the University of Houston and the State of Texas. Based on sediment data and the results of the BERA and BHHRA, dioxins and furans were identified as the indicator chemical group for the purposes of the RI/FS (see Appendix C of the RI/FS Work Plan; COPC Technical Memorandum [Integral 2011], and the RAM [Anchor QEA 2012b]). This section discusses the nature and extent of COCs focusing specifically on this chemical group.

The maximum background surface sediment dioxin and furan concentration is approximately 7.2 ng.kg. The average surface sediment dioxin and furan concentration within the Preliminary Site Perimeter, excluding the waste material in the impoundments but including the sand separation area, is 12.5 ng/kg, although levels as high as 198 ng/kg were found. About 190 acres in this area exceed the sediment background (Figure 2-7). Even though the average sediment concentration is 12.5 ng/kg, there are about 43 acres that exceed the sediment PRG of 30 ng/kg (Figure 2-8), discussed in Section 3.1 below.

The dioxins located in the upstream background sediment are distinct from the dioxins in the paper mill waste in the impoundments. There are other sources of dioxin to the San Jacinto River upstream from the Site, and these sources are characterized by different "fingerprint" than the dioxin in the waste pits. The dioxin in sediment upstream of the Site contains a relatively large amount of hepta-chlorinated dioxin (with 6 chlorine atoms per dioxin molecule) and very little tetra-chlorinated dioxin (has 4 chlorine atoms per dioxin molecule) (Figure 2-12). Conversely, the waste pit dioxin contains a relatively large amount of tetra-chlorinated dioxin and very little hepta-chlorinated dioxin (Figure 2-13).

2.5.1 North of I-10

Under baseline conditions, the highest 2,3,7,8-tetrachlorinated dibenzo-*p*-dioxin toxic equivalents (TEQ) concentrations calculated for mammalian receptors using dioxins and furans only ($TEQ_{DF,M}$) in sediment were found in the area of the Northern Impoundments, which corresponds to the area capped by the temporary cap. Outside of the temporary cap, $TEQ_{DF,M}$ concentrations in sediment and soils are significantly lower. Figure 2-3 presents the $TEQ_{DF,M}$ concentrations in surface sediment. As presented, concentrations for each sample

are color-coded based on powers of 10 to facilitate identifying areas of similar concentration. Figure 2-4 presents $TEQ_{DF,M}$ concentrations in samples collected from sediment cores. The $TEQ_{DF,M}$ concentrations in sediment are discussed in the context of the PRGs in Section 3.1.

The RI Report also examined concentrations of polychlorinated biphenyls (PCBs) and mercury in the Site soils/sediments. The source evaluation of the area north of I-10 and surrounding aquatic environments presented in Section 5.4 of the RI Report concluded that the PCB concentrations in sediments within the USEPA's Preliminary Site Perimeter, but outside the Northern Impoundments are not highly elevated relative to areas outside of the USEPA's Preliminary Site Perimeter and contribute very little dioxin-like toxicity to the sediment. In addition, because mercury concentrations in the soils on the sand separation area (as shown in Figure 1-2), are higher than they are in the wastes within the Northern Impoundments, the wastes within the Northern Impoundments may not the primary source of mercury in the aquatic environment under investigation.

2.5.2 Area of Investigation South of I-10

Some of the wastes deposited within Soil Investigation Area 4 may have originated from the Champion Paper Inc. paper mill (TDH 1966). As noted in the RI Report, the BHHRA for the area of investigation on the peninsula south of I-10 found no health risks in surface soil to hypothetical trespassers and hypothetical commercial workers above the thresholds considered acceptable by USEPA. For hypothetical future construction workers, exposure scenarios for certain core locations (each assumed to be representative of a potential building site, and assuming excavation or other activities that would disturb the soil) resulted in noncancer and dioxin cancer hazard indices greater than 1. Dioxins and furans, as $TEQ_{DF,M}$ were identified as COCs for the hypothetical future construction worker, based on hypothetical future exposures to the upper 10-feet of soil. At the request of USEPA, risk to a hypothetical future construction worker who could be exposed to the upper 5 feet of soil only was also evaluated, as described in Section 3.1. A description of the risk evaluation assumptions, uncertainties, and data evaluation is provided in the BHHRA (Integral 2013b).

The BERA for the area of investigation south of I-10 identified low risks to terrestrial bird populations from lead and zinc. Lead and zinc were therefore identified as COCs. Soil PRGs were not developed for these metals because of uncertainties associated with the exposure modeling that likely overestimated exposures, and because these two metals are not associated with paper mill waste, but are likely present due to other industrial activities within the area of investigation on the peninsula south of I-10.

Figure 2-5 presents $TEQ_{DF,M}$ concentrations in surface and subsurface soil in the area south of I-10. The data are discussed relative to the PRG for soil for a hypothetical future construction worker and a hypothetical future commercial worker in Section 3.1. The exposure scenario for the hypothetical future construction worker receptor assumes exposure to a depth-weighted average of $TEQ_{DF,M}$ concentrations throughout a 10-foot soil depth, but the most elevated $TEQ_{DF,M}$ concentrations are found in samples taken at locations several feet below grade. As discussed in the BHHRA and the RI Report, several feet of relatively clean soil isolates the soil with the highest $TEQ_{DF,M}$ concentrations from potential receptors at the surface.

2.5.3 Tissue

Tissue samples were collected from three Site fish collection areas (FCA) (Figure 2-9) in 2010 prior to construction of the temporary cap:

- FCA1 - Downstream of I-10, referred to below as "downstream";
- FCA2 - In the area surrounding the impoundments north of I-10 and the upland sand separation area, referred to as "adjacent to the northern impoundments"; and
- FCA3 - Immediately upstream of the northern impoundments and upland separation area, referred to as "upstream."

Tissue samples were also collected at background locations. Cedar Bayou, a small tributary to the San Jacinto estuary near Morgan's Point, and the lower San Jacinto River estuary, near the mouth of Cedar Bayou and downstream of the Fred Hartman Bridge, served as the background areas for catfish and crabs. Killifish were collected from the upstream background area sampled for sediments (Figure 2-6).

Data for blue crab, hardhead catfish, and Gulf killifish are summarized in Figure 2-10. The maximum detected values and highest mean values of dioxin and dioxin-like polychlorinated bi-phenyl generally were collected from the fish collection area adjacent to the northern impoundments. Compared to background results, the tissue results within the Preliminary Site Area before construction of the temporary cap averaged from about 4.5 times (for hardhead and crab) to 20 times (for killifish) higher than the background levels.

2.5.4 Sediment Background

The sediment background samples include surface sediments (0 to 6 inches) collected in 2010 and 2011 from 29 stations upstream and outside of USEPA's Preliminary Site Perimeter, both within the subtidal zone and in the intertidal zone. All of the upstream sediment sampling

locations are shown in Figure 2-6. Background surface sediment $TEQ_{DF,M}$ concentrations range from 0.108 to 6.54 ng/kg, with a mean of 1.17 ng/kg. Aroclors were not detected in background surface sediment. The Reference Envelope Value (statistical background level) for background surface sediment is 7.2 ng/kg dioxin. This background sediment level is less than the dioxin sediment PRG of 30 ng/kg (discussed below), and also less than the dioxin surface-area weighted average sediment concentration (SWAC) of 12.5 ng/kg in the San Jacinto River outside of the temporary cap. Because the background dioxin sediment level is less than the current Site dioxin level, re-contamination of the Site by dioxin from other sources following remediation is not expected.

2.5.5 Prior Actions at the SJRWP Site

As discussed in Section 1.2, a TCRA was implemented, pursuant to an AOC, to stabilize and isolate paper mill waste and sediments within the original 1966 perimeter berm of the Northern Impoundments (Anchor QEA 2011; USEPA 2012c). As presented in the Action Memorandum (USEPA 2010a, Appendix A) for the TCRA, the following removal action objectives for the TCRA were identified:

- Stabilize waste pits to withstand forces sustained by the river.
  - The barrier design and construction must be structurally sufficient to withstand forces sustained by the river including any future erosion and be structurally sound for a number of years until a final remedy is designed and implemented (USEPA 2010a).
  - Technologies used to withstand forces sustained by the river must be structurally sufficient to withstand a storm event with a return period of 100-years until the nature and extent of contamination for the Site is determined and a final remedy is implemented.
- Prevent direct human contact with the waste materials (USEPA 2010a, Appendix A, IV.A.1; Page 9; first paragraph).
- Prevent benthic contact with the waste materials (USEPA 2010a, Appendix A, III.B).
- Ensure that the "actions are consistent with any long-term remediation strategies that may be developed for the Site" (USEPA 2010a, Appendix A, V.A.2).

The TCRA included construction of a temporary armored isolation cap (temporary armored cap), completed in July 2011, that was designed in accordance with USACE and USEPA guidelines. During the design of the temporary cap, the area within the original 1966 perimeter of the

Northern Impoundments was divided into three distinct areas: 1) the Eastern Cell; 2) the Western Cell; and 3) the Northwestern Area (Figure 2-11). In general, the temporary cap design included an armor rock cap placed atop a geotextile bedding layer in all but the Northwestern Area, where an aggregate cap was constructed. Additionally, the Western Cell received treatment through stabilization and solidification (S/S) of approximately 6,000 cubic yards of waste material in the upper 3 feet over a 1.2 acre area. The treatment consisted of mixing in Portland cement at a ratio of 8%. A geomembrane cover layer was then installed prior to armor rock installation. The temporary armored cap is discussed further in Section 4 relative to the remedial alternatives, and shown in the figures from that Section. In addition to capping the Northern Impoundments, the temporary cap upland perimeter was fenced and signage was installed to prevent unauthorized access to the Site. A description of the TCRA implementation is provided in the Removal Action Completion Report (RACR) (USEPA 2012c). Costs for design and implementation of the TCRA were more than $9 million.

The temporary armored cap has been subject to ongoing inspections, monitoring, and maintenance, consistent with USACE and USEPA guidelines and the agency-approved Operations, Monitoring, and Maintenance (OMM) Plan (Appendix N of the RACR, Anchor QEA 2012a). Three separate post-construction survey and monitoring events (conducted in September 2011, January 2012, and April 2012) appeared to confirm the integrity of the temporary armored cap.

During the next inspection, in July 2012, an area along the western berm slope was noted to have areas where cap armor materials had moved down the slope, uncovering a small area of the geotextile layer (approximately 200 square feet, or 0.03 percent of the temporary armored cap footprint). There was no exposure of underlying materials or release of hazardous substances associated with this temporary condition. Consistent with the agency-approved OMM Plan, the Respondents implemented approved maintenance measures that involved grading specific locations to an overall flatter condition by placing additional armor rock over the cap surface in those locations. These maintenance activities were completed in July 2012 and were documented in a completion report that was submitted to USEPA (Anchor QEA 2012d).

Additional maintenance was performed in January 2013, when additional armor stone was placed in other cap areas. As discussed in more detail in Section 4.1.3, sediment caps commonly require localized maintenance during the initial post-construction period, and USACE and USEPA guidance identifies ongoing inspection and maintenance of the type required by the OMM Plan as an integral component in ensuring that sediment caps remain protective over the long-term.

During the post-construction period, the Respondents (Anchor QEA 2013a) and USEPA, in coordination with USACE (USACE 2013), conducted separate evaluations of the temporary armored cap design and construction. The USACE report conclusions are quoted as follows:

1. *Parameterization of the stone size equation. The inputs to the [stone size] equation were not provided. The design velocity from the hydrodynamic model may not account adequately for the slope changes due to limitations in spatial resolution. The factor of safety may not have [been] adequate for the uncertainties in construction, slopes, material gradation, waves, non-uniform flow, flow constrictions and overtopping.*[2]

2. *Slope. The slope of the face of the berm just below the crown was much steeper than the design slope and was not modified prior to capping. For the non-uniform recycled concrete used for Armor Cap B/C, the design slope should have been [1 vertical to 3 horizontal] 1V:3H or flatter to prevent excessive displacement and loss of gravel and sand sized particles.*[3]

3. *Armor cap material gradation. The uniformity of the armor cap material was not specified. The material specifications allowed too much gravel and sand sized particles to be used, which could be eroded from the cap because they did not meet internal stability and retention criteria. Greater uniformity of the armor cap is preferable in the high energy regimes of the cap, particularly the southwestern corner of the berm.*[4]

4. *Repair should ensure that the final surface throughout the repair area and adjacent areas has a slope of 1V:3H or flatter.*

In accordance with these conclusions and recommendations, the Respondents conducted additional cap enhancement work during January 2014. A description of the completed work was provided in the TCRA Cap Enhancement Completion Report (Anchor QEA 2014). This enhancement work was conducted using stone that was larger than the minimum stone size recommended by USACE, in an attempt to provide a more stable and protective cap configuration and exceeding design criteria specified in USACE and USEPA sediment capping design guidance (USACE 1998).

[2] Note that these input parameters have been provided to USEPA and USACE.
[3] Note that the enhancements completed in January 2014 used natural stone material, placed at the USACE recommended 1V:3H slope.
[4] Note that Armor Rock C, as described in the TCRA RAWP (Anchor QEA 2011), was considered sufficient by USACE for cap enhancement in their report. Armor Rock D, which is even larger than Armor Rock C, was used for the enhancement work completed in January 2014.

In January 2013 five areas in the Eastern Cell of the cap with less than the required armor cover thickness and/or exposed geotextile were identified. In one of those areas there is a need for placement of geotextile fabric in addition to armor stone. The cause of these areas of deficient cap cover is unknown. These areas were repaired in January 2013 with the addition of additional stone and geotextile.

On December 9 and 10, 2015, EPA performed an underwater inspection that identified an area of deficient thickness and/or missing armor cover resulting in exposure of the underlying paper mill waste material to the San Jacinto River. The deficient area is located on the northwestern section of the armored cap where no geotextile was installed. The area is irregularly shaped with dimensions of approximately 22 feet by 25 feet. Some armored rock cover was still present, but coverage was not complete nor was there adequate thickness. The USACE found that the defect area was most probably caused by sinking of the cap over time due to either an improper filter/support layer under the rock cap or unusual decomposition of organic matter under the area (USACE 2016a). Sediment sampling completed in December 2015 identified dioxin/furan in the exposed waste material as high as 43,700 ng/kg TEQ. Maintenance activities to place geotextile and additional rock cover over and extending beyond the deficient area began on December 29, 2015, and were completed on January 4, 2016.

On February 24, 2016, during an extremely low tide, a visual inspection of the cap was performed. A large majority of the Eastern Cell was exposed during this abnormally low tide event. Five small areas (approximately 1 foot by 3 feet at the largest areas) of exposed geotextile with no rock cover were observed in the central part of the Eastern Cell where the cap should have had a one-foot thickness minimum. The cause of these deficient rock areas is unknown, although some of the areas may have been geotextile overlap portions associated with the cap construction. During March 2016 probing of the entire Eastern Cell of the cap to check thickness was completed and identified a number of additional areas of deficient armor cover thickness and/or exposed geotextile. Rock was added to all of these areas in the Eastern Cell in March 2016 to achieve a minimum thickness of one foot.

2.5.5.1 Effectiveness of the Time Critical Removal Action

The TCRA's implementation has generally reduced potential risks from dioxins and furans associated with baseline conditions but has required many repairs and extensive maintenance. However, on one occasion a 500 ft^2 area on the northwest portion of the temporary cap was found to be missing armor stone and paper mill waste with dioxin over 43,000 ng/kg was exposed to the environment for an unknown amount of time. This

deficiency was not discovered by the regular inspection program, but instead by a special investigation performed by the EPA Dive Team.

A summary of the instances of missing armor stone and subsequent cap repairs follows:

- July 2012: Approximately 200 square feet (ft2) of stone eroded and geotextile exposed (armor materials had moved down slope). Following EPA approval of the repair plan, additional stone was added to achieve the required cap thickness. Repairs were completed August 3, 2012.

- January 2013: Five areas missing part or all of armor stone with exposed geotextile in some areas of the Eastern Cell. Following EPA approval of a repair plan, additional stone was added to achieve the required cap thickness. Repairs were completed January 30, 2013.

- January 2014: The USACE evaluated the design & construction of the cap and found that improvements were needed, including flatter slopes and larger rock in some areas. Following EPA approval of a repair plan, additional rock was added in accordance with the USACE recommendations, with construction completed on January 13, 2014.

- December 2015: Following an inspection by the EPA Dive Team, approximately 500 ft^2 of cap was missing or deficient in cover (no geotextile present, paper mill waste exposed to the river, waste material concentration measured at 43,700 ng/kg dioxin exposed to river). The EPA ordered repair of this area, and following EPA approval of a repair plan, geotextile & new rock was added to repair the area with construction completed on January 4, 2016.

- February 2016: Missing rock in portions of eastern cell (five areas up to 6 ft^2 each with some exposed geotextile). The EPA ordered repair of this area, and after EPA approval of the repair plan, new rock was added to repair the area with construction completed on March 15, 2016.

- March 2016: Approximately 500 locations in the Eastern Cell were probed to check for cap thickness and eight additional areas of missing rock were found. During repairs, additional areas of missing rock and exposed geotextile were found. Following EPA approval of the repair plan, new rock was added over a total area of 170 ft^2 with construction completed on March 31, 2016.

- June 2016: Following an inspection by the EPA Dive Team, ten areas of missing rock were found in the Western Cell up to 300 ft^2. Following EPA approval of the repair plan, new rock was added to repair the areas with construction completed on June 17, 2016.

The temporary cap was designed to withstand a hundred-year storm, yet the above cases of eroded or missing armor stone all occurred with flooding below the design hundred year storm. In addition, the routine maintenance required by the original OMM plan did not reveal the deficiencies discovered in 2015 and 2016.

The following sections discuss effects of TCRA implementation on sediment, water, and tissue.

2.5.5.1.1 Sediment

Implementation of the TCRA appears to have eliminated, with one known exception, the transport of waste associated COCs from the Northern Impoundments. The effect of the temporary cap on overall sediment quality within the USEPA's Preliminary Site Perimeter was evaluated in the RAM by performing a "hilltopping" evaluation comparing the surface-weighted average concentration (SWAC) of $TEQ_{DF,M}$ within the USEPA's Preliminary Site Perimeter for various prospective remedial action levels (RALs), including SWACs before TCRA implementation and following TCRA completion. As documented in the RAM, the $TEQ_{DF,M}$ SWAC was reduced by more than 80 percent by implementing the TCRA. In addition, on-going natural recovery continues to reduce surface sediment concentrations outside of the temporary cap, as indicated by the long-term chemical fate model simulations presented in Appendix A. However, the simulations did not consider the impact of a dioxin release that may result for a future extreme storm or hurricane, nor the impacts of a barge strike that may breach the cap or other future events that might affect the integrity of the cap.

2.5.5.1.2 Water

Sampling of surface water and porewater with solid phase micro-extraction (SPME) fibers was conducted after construction of the temporary armored cap was completed. The sampling indicated that 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD) and 2,3,7,8-tetrachlorodibenzofuran (TCDF) were not present in surface water over the temporary armored cap.

2.5.5.1.3 Tissue

Upon completion of the temporary cap construction in July 2011, waste materials in the waste pits were rendered inaccessible, except for the cap deficiencies identified above, for

direct contact by humans, benthos, fish, and aquatic dependent wildlife. The completion of the temporary cap construction therefore would be expected to lead to reductions in tissue concentrations in catfish and clams within the USEPA's Preliminary Site Perimeter.

2.5.6 Sources of COCs

The chemical fate and transport modeling, discussed in Appendix A, concluded that ongoing deposition of sediment within the USEPA's Preliminary Site Perimeter may continue to reduce concentrations of dioxins and furans in sediment. However, deposition rates are low in most areas, particularly shallow areas. Further, changes in the river geometry as a result of extreme erosion similar to that which was documented during the 1994 flood may prevent the predicted deposition from occurring. As noted in the RI Report, a number of historical and current sources of dioxins, furans, and other COCs remain as ongoing contributors to COC concentrations present within the USEPA's Preliminary Site Perimeter, although comparison of the paper mill waste in the impoundments with background samples as part of the waste "fingerprinting" analysis indicate that the paper mill waste is the source of the TCDD and TCDF found in the Preliminary Site Perimeter. Other sources of dioxin can be distinguished from the less highly chlorinated dioxin and furan congeners found in the paper mill waste, which contains high concentrations of TCDD and TCDF.

The chemical analyses of groundwater, soils, and sediments presented in both the Preliminary Site Characterization Report (PSCR; Integral and Anchor QEA 2012) and the RI Report demonstrated that other regional sources – such as atmospheric inputs, industrial effluents, publicly owned treatment works, and storm water runoff – contribute other types of dioxins and furans and other COCs (metals, and PCBs) found in the Site area and surrounding aquatic environment. In the area of investigation south of I-10, historical and ongoing industrial marine services are known to contribute chemicals, including COCs for ecological receptors to soils.

In the peninsula south of I-10, soils and subsurface soils contain dioxins and furans from a mixture of sources including paper mill wastes, as well as other background or site-specific sources. The un-mixing analysis for soils collected from the area of investigation south of I-10 indicates that there are three distinctive dioxin and furan source types contributing to the presence of dioxins and furans in soils sampled south of I-10 including one that resembles paper mill wastes, one that resembles background dioxin and furan sources, and a third mixture unique to this area. The dioxin and furan mixture towards the southern end of Soil Investigation Area 4 in shallower soils is consistent with the fingerprint characteristic of paper mill wastes, based on fingerprints of samples collected from within the impoundments north of I-10. In deeper soils at the southern and northern ends of the area of investigation on the peninsula south of I-10, the dioxin and furan mixture describes a different source type

that is not observed elsewhere within the USEPA's Preliminary Site Perimeter, and does not appear to match apparent source types in other soils or sediment samples collected from within the USEPA's Preliminary Site Perimeter nor any known anthropogenic source pattern in the USEPA Dioxin Reassessment database (USEPA 2004).

The general spatial distribution of sources that differ from the paper mill wastes in soils suggests that dioxin and furan containing material was deposited into, or on the peninsula south of I-10, at a point in time prior to disposal of paper mill wastes. Finally, outside of Soil Investigation Area 4, the dioxin and furan mixtures are generally dominated by a fingerprint consistent with general urban background sources. The un-mixing analysis demonstrates that paper mill wastes are mostly confined to the area within USEPA's estimated perimeter of the impoundment. Spatial patterns of dioxins and furans and other chemicals within subsurface soils in the area of investigation south of I-10, as well as waste materials (such as paint chips, construction debris, plastics, and asphalt shingles) and chemicals not associated with paper mill wastes, also support the conclusion that wastes other than paper mill wastes have contributed to the presence of more highly chlorinated dioxins and furans in soils in the area of investigation south of I-10 (see RI Report Section 6.6).

2.5.6.1 Bioaccumulation

The data analyses and literature review presented in the Technical Memorandum on Bioaccumulation Modeling (Integral 2010), including evaluation of region-specific multivariate datasets, indicates that the majority of dioxin and furan congeners do not consistently bioaccumulate in fish or invertebrate tissue. This is due to biological controls on uptake and excretion in both fish and invertebrates (Integral 2010). As a result, systematic predictions of bioaccumulation from concentrations of dioxins and furans in abiotic media (both sediment and water) are only possible for tetrachlorinated congeners.

The more highly chlorinated congeners, such as OCDD, appear to have the lowest bioconcentration potential either because they are less bioavailable because of their rapid adsorption to sediment particles (Servos et al. 1989a, 1989b) or because their large molecule size may interfere with transport across biological membranes (Bruggeman et al. 1984; Muir et al. 1986a, 1986b), (ATSDR, Toxicological Profile for Dioxin, 1998). In most vertebrate species, the 2,3,7,8-substituted PCDDs are the congeners which are predominantly retained. If chlorine atoms are present on all 2,3,7,8 positions, the biotransformation rate of PCDDs is strongly reduced, resulting in significant bioaccumulation. In most species the liver and adipose tissue are the major storage sites. (WHO, IARC, 1997).

Analyses presented in the BERA (Integral 2013a) indicated that concentrations of 2,3,7,8-TCDD and 2,3,7,8-TCDF in the tissues of clams and killifish (which have limited spatial

movements) were higher in those clams and killifish taken in proximity to the Northern Impoundments (prior to the temporary cap construction). Consistent with the literature (USEPA 2009b), benthic species (clams and catfish) had higher concentrations of dioxins and furans than predatory fish species, suggesting that concentrations of dioxins and furans are not predicted by position in the food chain, but are accumulated more as a function of proximity to sediment in which dioxins and furans are present. The fact that concentrations in clam tissue correlate reasonably well with concentrations in sediments adjacent to where they were collected reinforces the "proximity hypothesis" in support of the conceptual framework for bioaccumulation of dioxin and furans, outlined in the Technical Memorandum on Bioaccumulation Modeling (Integral 2010).

3 BASIS FOR REMEDIAL ACTION

The basis for undertaking remedial action is to address the potential risks associated with the presence of dioxin and furan containing waste material resulting from historical paper mill waste disposal in the Northern Impoundments, as well paper mill wastes present in the Southern Impoundment south of I-10. This section discusses the development of PRGs, reviews the RAOs established by USEPA for the area within the USEPA's Preliminary Site Perimeter, and reviews the Applicable or Relevant and Appropriate Requirements (ARARs) that have been identified in previous documents.

Dioxin and furans, the primary contaminants of concern at the Site, are classified as probable human carcinogens. Dioxins are highly toxic and can cause reproductive and developmental problems, damage to the immune system, and can interfere with hormones in addition to causing cancer. The human health risk assessment identified non-cancer hazards greater than one for some recreational fisher exposure scenarios (direct exposure to beach areas identified and the ingestion of catfish, clam, or crab from fishing areas identified, Figure 3-1 and Figure 3-2), for some recreational visitor exposure scenarios (direct exposure to the beach areas identified), and for some future construction worker exposure scenarios.

A Baseline Human Health Risk Assessment (human health risk assessment) and Baseline Ecological Risk Assessments (ecological risk assessments) were conducted to estimate the potential for current/future risk or hazard from exposure to contaminants from the Site. The human health risk assessment and ecological risk assessments were conducted to determine potential pathways by which people (human receptors) or animals (ecological receptors) could be exposed to upland or aquatic contamination in waste material, sediment, soil, water, or biota; the amount of contamination receptors of concern may be exposed to; and the toxicity of those contaminants if no action were taken to address contamination at the Site. Some of the human health risk determinations subsequently were modified by the Environmental Protection Agency based on further risk analysis as documented in memoranda included as part of the Site administrative record.

The risk assessments were conducted on the baseline conditions that existed before the installation of the temporary armored cap over the northern waste pits that was completed during a removal action. This temporary cap was built to stabilize the northern waste pits and prevent direct human exposures until a permanent remedy could be selected for the Site. These assessments provide the basis for taking action and identify the contaminants and exposure pathways that need to be addressed by the remedial action.

Hazard quotients greater than one indicate the potential of contaminants of concern (e.g. dioxin) may cause adverse health effects to those that are exposed in the manner specified in the tables. There were no cancer risks above the upper limit of the Environmental Protection Agency's target cancer risk range ($1x10^{-4}$) for all beach areas identified in the human health risk assessment except for Beach Area E, which had an excess cancer risk of 6.6×10^{-4} for a recreational fisher exposed through ingestion and dermal contact with waste material and sediment.

The basis for action at the Site are the unacceptable hazards, determined by the risk assessments, to the recreational fisher (Hazard Index = 65), to the recreational visitor (Hazard Index 66), and to the construction worker (Hazard Index = 46). The three tables below provide more information on these hazards. For the recreational fisher and the recreational visitor, risk assessments were done for areas both north and south of I-10. For the construction worker, the risk assessment applies to the area south of I-10.

Non-Cancer Hazards for a Recreational Fisher

Chemical	Primary Target Organ	Non-Cancer Hazard Quotient			Exposure Route Total
		Incidental Ingestion of Sediment	Dermal Contact with Sediment	Consumption of Fish or Shellfish	
Scenario 1A: Direct Exposure Beach Area A; Ingestion of Catfish from Fish Collection Area 2/3					
Dioxins and dioxin-like Polychlorinated Bi-Phenyls	Reproductive/Developmental	0.0006	0.0016	1.8	1.8
Scenario 2A: Direct Exposure Beach Area B/C; Ingestion of Catfish from Fish Collection Area 2/3					
Dioxins and dioxin-like Polychlorinated Bi-Phenyls	Reproductive/Developmental	0.0081	0.0229	1.8	1.8
Scenario 3A: Direct Exposure Beach Area E; Ingestion of Catfish from Fish Collection Area 2/3					
Dioxins and dioxin-like Polychlorinated Bi-Phenyls	Reproductive/Developmental	16	47	1.8	65
Scenario 3B: Direct Exposure Beach Area E; Ingestion of Clam from Fish Collection Area 2					
Dioxins and dioxin-like Polychlorinated Bi-Phenyls	Reproductive/Developmental	16	47	0.27	64
Scenario 3C: Direct Exposure Beach Area E; Ingestion of Crab from Fish Collection Area 2/3					
Dioxins and dioxin-like Polychlorinated Bi-Phenyls	Reproductive/Developmental	16	47	0.008	63
Scenario 4A: Direct Exposure Beach Area D; Ingestion of Catfish from Fish Collection Area 1					
Dioxins and dioxin-like Polychlorinated Bi-Phenyls	Reproductive/Developmental	0.0027	0.0076	1.8	1.8
Note: Polychlorinated Biphenyls - PCBs Dioxins – see Glossary					

Non-Cancer Hazards for a Recreational Visitor

Chemical	Primary Target Organ	Non-Cancer Hazard Quotient				Total
		Incidental Ingestion of Sediment	Incidental Ingestion of Soil	Dermal Contact with Sediment	Dermal Contact with Soil	
Scenario 3: Direct Exposure Beach Area E						
Dioxin	Reproductive/ Developmental	17	0.03	49	0.0021	66
Note: Dioxin – 2,3,7,8-tetrachlorodibenzo-p-dioxin toxicity equivalent quotient						

Non-Cancer Hazards for a Future Construction Worker

Chemical	Primary Target Organ	Non-Cancer Hazard Quotient		Total
		Incidental Ingestion of Soil	Dermal Contact with Soil	
Scenario DS-1: Direct Exposure to Surface and Subsurface Soils				
Dioxin	Reproductive/Developmental	9.6	0.49	10
Scenario DS-2: Direct Exposure to Surface and Subsurface Soils				
Dioxin	Reproductive/Developmental	44	2.2	46
Scenario DS-4: Direct Exposure to Surface and Subsurface Soils				
Dioxin	Reproductive/Developmental	32	1.6	34
Scenario DS-5: Direct Exposure to Surface and Subsurface Soils				
Dioxin	Reproductive/Developmental	2.2	0.11	2.3
Note: Dioxin – 2,3,7,8-tetrachlorodibenzo-p-dioxin toxicity equivalent quotient				

Baseline risks to ecological receptors associated with the wastes in the impoundments north of I-10 are the result of exposures to dioxins localized to the immediate vicinity of the impoundments. Baseline ecological risks include reproductive risks to mollusks from dioxin, but primarily in the area that surrounds the former waste impoundments north of I-10, and low risks of reproductive effects in individual mollusks in sediments adjacent to the upland sand separation area, but not to populations of mollusks. Baseline risks include moderate risks to individual birds like the killdeer or spotted sandpiper whose foraging area could regularly include the shoreline adjacent to the impoundments north of I-10, but low risk to populations because of the low to moderate probability that individual exposures reach effects levels. Baseline risks include risks to individual small mammals with home ranges that include areas adjacent to the impoundments such as the marsh rice rat, but low to negligible risks to small mammal populations because of the moderate probability that exposures will reach levels associated with reproductive effects in individuals, and because small mammals reproduce rapidly. Baseline risks to benthic macroinvertebrate communities and populations of fish, birds, mammals, and reptiles resulting from the presence of metals, bis(2-ethylhexyl)

phthalate, Polychlorinated Bi-Phenyls, carbazole, and phenol on the Site are negligible. Risks to fish populations from all chemicals of potential concern are negligible.

There are negligible risks to populations of wading birds represented by the great blue heron, and to populations of diving birds like the neotropic cormorant. There are negligible risks to populations of terrestrial mammals such as the raccoon. There are low to negligible risks to individual terrestrial insectivorous birds like the killdeer from exposure to zinc, and negligible risks to populations of such birds. Although the upper bound of estimated daily intakes of zinc by individual killdeer is about equal to conservative effects thresholds, the exposure estimate is influenced by the use of generic models to estimate zinc concentrations in the foods of the killdeer, and this model likely overestimates ingested tissue concentrations, resulting in overestimates of exposure and risk. The highest exposures of killdeer to zinc occur outside of the northern impoundment perimeter, and background exposures less than 30 percent were lower than on the Site. In addition, the low probability of individual exposures exceeding effects levels indicates low risk to populations. There are also low to negligible risks to individual terrestrial insect eating birds from exposure to dioxins. The ecological risk assessments identified risk to ecological receptors as summarized in the tables below.

Ecological Risks

Receptor of Concern	Feeding Guild	Contaminant of Concern	Baseline Risk Identified
Benthic Macroinvertebrates			
Mollusks	Filter feeders	2,3,7,8-TCDD	Reproductive risks to mollusks (primarily in the area which surrounds the waste impoundments)
Individual mollusks	Filter feeders	2,3,7,8-TCDD	Low risks of reproductive effects (sediments adjacent to the upland sand separation area)
Birds			
Spotted sandpiper	Invertivore (probing)	Dioxin	Low risk to populations
Killdeer	Invertivore (terrestrial)	Dioxin	Low risk to populations
Mammals			
Marsh rice rat	Omnivore	Dioxin	Low to negligible risk to populations

Note:
2,3,7,8-TCDD – 2,3,7,8-tetrachlorodibenzo-p-dioxin
Dioxin – toxicity equivalent quotient for 2,3,7,8-tetrachlorodibenzo-p-dioxin calculated using toxicity equivalent factors for mammals

3.1 *Recommended Preliminary Remediation Goals*

The RAOs are focused on remedial measures applicable to waste material, sediments and soils within the USEPA's Preliminary Site Perimeter to reduce potential exposure pathways to humans and ecological receptors. Therefore, the PRGs utilized in the development of remedial alternatives are those developed for waste materials, soils and sediments. All of the PRGs used in the evaluation of alternatives were approved by USEPA, and are based on $TEQ_{DF,M}$ concentrations that are protective of human health, based on the Reasonable Maximum Exposure (RME) scenario for the subject hypothetical receptors.

Based on consideration of reasonable potential future uses within the USEPA's Preliminary Site Perimeter, three PRGs were developed for use in the FS Report for evaluation of the remedial alternatives of waste materials, sediments and soils. The reasonable potential future users within the USEPA's Preliminary Site Perimeter used in the development of alternatives include hypothetical recreational fisher and hypothetical recreational visitor for waste materials, sediments, and hypothetical construction and hypothetical commercial workers for soils. The Texas Department of State Health Services was unable to identify any subsistence fishing uses, so a PRG for that scenario was not developed.

PRGs were not developed for total PCBs. Concentrations of PCBs in waste materials, soils and sediments were either significantly correlated with concentrations of dioxins or were generally below detection limits; the PCB sediment patterns may correlate with dioxins because the two chemical groups have low solubility, tend to bind to organic carbon, are persistent, and behave similarly in aquatic environments. Therefore, no remedial action objective was developed for PCBs because remediation of material contaminated with dioxins will also remediate the co-located polychlorinated bi-phenyls. Also, the estimated lifetime cancer risks for all receptors from exposures to total PCBs and arsenic did not exceed the upper bound of the cancer risk of $1x10^{-4}$ that USEPA regards as acceptable, as is outlined in the Exposure Assessment Memorandum (EAM) and the BHHRA. An evaluation of PCBs and mercury concentrations in soils/sediments was presented in the RI Report, and it was concluded that the PCB concentrations are not highly elevated and contribute very little dioxin-like toxicity. The elevated mercury concentrations in the soils on the sand separation area are higher than in the wastes within the Northern Impoundments, indicating that elevated mercury concentrations are not related to paper mill waste. Therefore, the evaluation of remedial alternatives is focused on the risk-based PRGs for $TEQ_{DF,M}$.

The PRGs are as follows:

- The risk-based PRG for sediment outside the footprint of the temporary armored cap, 30 ng/kg TEQs, is based on exposure to dioxins and furans by a hypothetical

recreational fisher for a noncancer hazard quotient equal to 1[2]. Figures 3-1 and 3-2 present $TEQ_{DF,M}$ concentrations in surface and subsurface waste material, respectively, outside the footprint of the temporary armored cap. This PRG is also protective of the Site ecological risks.

- The risk-based PRG for waste material within the footprint of the temporary cap, 200 ng/kg TEQs, is based on the recreational visitor potential exposure scenario and a noncancer hazard quotient equal to 1. Figures 3-3 and 3-4 present $TEQ_{DF,M}$ concentrations in surface and subsurface waste material, respectively, within the footprint of the temporary armored cap relative to this PRG.
- The risk-based PRG For waste material and soil in the area south of I-10, 240 ng/kg TEQs, was derived based on the reasonable maximum exposure scenario for a hypothetical future construction worker using a noncancer hazard quotient equal to 1. The development of the PRG considers exposure to soil through the total depth interval (0- to 10-feet) to which a hypothetical future construction worker could be exposed.

For the river areas outside of the temporary armor cap, the surface area–weighted average dioxin concentration (SWAC) in sediment just south of the waste pits is 16.1 ng/kg, and the SWAC in sediment located adjacent to and upstream of the waste pits, including the sand separation area, is 11.2 ng/kg. The average SWAC for sediment within the Preliminary Site Perimeter, including both upstream and downstream areas, is 12.5 ng.kg. Because the average dioxin concentrations in sediment both upstream and downstream of the waste pits, including the sand separation area, are significantly less than the 30 ng/kg PRG for sediment, active remediation of the sediment outside of the waste pits is not required. Using an average dioxin concentration for the sediments outside the impoundments is appropriate because of the movement and range of the aquatic organisms that may be exposed to the dioxins in the sediment. While dioxin has been found in excess of the 200 ng/kg in the sand separation area, these levels are found only in the subsurface sediment as deep as six feet, and the 200 ng/kg PRG is based on direct surface contact with waste materials. To date, two subsurface sediment sample results over 300 ng/kg (maximum 349 ng/kg) were found in the sand separation area, but based on other samples, the EPA does not believe these two results are representative and additional sampling may be conducted there during the Remedial Design.

[2] The noncancer $TEQ_{DF,M}$ PRG is always lower than the PRG for the cancer endpoint for any given media and exposure scenario, and is therefore the more conservative PRG.

3.2 *Remedial Action Objectives*

The RAOs discussed in this section were established to support the initial development and refinement of Preliminary Remediation Goals (PRGs) during the RI/FS process and inform USEPA's selection of final remediation goals (or final clean-up levels) in the ROD.

The RAOs provided the first step in the process to define the chemicals and media to be addressed by the cleanup. The RAOs address specific exposure pathways and receptors, and provide the basis for defining PRGs. The RAOs for the areas within the USEPA's Preliminary Site Perimeter are provided below.

RAO 1: Prevent releases of dioxins and furans from the former waste impoundments to sediments and surface water of the San Jacinto River.

RAO 2: Reduce human exposure to dioxins and furans from consumption of fish by remediating paper mill waste and sediments affected by paper mill waste to appropriate cleanup levels.

RAO 3: Reduce human exposure to dioxins and furans from direct contact with paper mill waste, soil, and sediment by remediating affected media to appropriate cleanup levels.

RAO 4: Reduce exposures of benthic macroinvertebrates to paper mill waste-derived dioxins and furans by remediating sediment to appropriate cleanup levels.

In the area of investigation south of I-10, the hypothetical future construction worker scenario indicated the potential for risk above thresholds considered acceptable by USEPA, due to exposure to dioxins and furans in the upper 10-feet of the soil columns.

3.3 *Applicable or Relevant and Appropriate Requirements*

The development and evaluation of remedial alternatives, as presented in Section 5 of this document, includes an assessment of the ability of the remedial alternatives to address ARARs of environmental laws and other standards or guidance to-be-considered (TBC). Table 3-1 provides a summary of potential ARARs and TBCs that are considered in this FS Report. The list in Table 3-1 includes certain citations that are not applicable to the USEPA's Preliminary Site Perimeter to document the rationale for eliminating these regulations, standards, or guidelines from consideration. Many of the ARARs and TBCs in Table 3-1 are relevant to only some of the remedial alternatives, but all of the requirements that may be relevant to any of the remedial alternatives are identified in the list.

After a remedy is selected, a detailed review of ARARs specific to the selected remedial action will be conducted and included in the Design Analysis Report for the selected action. No federal, state, or local permit is required for response action conducted entirely onsite, but substantive technical requirements of the ARAR must be met.

The ARARs in Table 3-1 can be broken out into three different categories, although some ARARs may belong to more than one of these categories:

- Chemical-specific requirements
- Location-specific requirements
- Performance, design, or other action-specific requirements

Chemical-specific ARARs are typically the environmental laws or standards that result in establishment of health- or risk-based numerical values. When more than one of these chemical-specific ARARs are applicable to site-specific conditions, a remedial alternative should generally comply with the most stringent or conservative ARAR. Chemical specific ARARs presented in Table 3-1 include Clean Water Act (CWA) criteria and State water quality and waste standards. The development of PRGs within the USEPA's Preliminary Site Perimeter considered chemical-specific ARARs, as well as other generally accepted benchmarks for protection of human health and the environment.

Location-specific ARARs include restrictions placed on concentrations of hazardous substances or the implementation of certain types of activities based on the location of a site. Some examples of specific locations include floodplains, wetlands, historic places, land use zones, and sensitive habitats. Location-specific ARARs presented in Table 3-1 include the Rivers and Harbors Act, Coastal Zone Management Act, and Federal Emergency Management Agency/National Flood Insurance Program regulations.

The action-specific ARARs are generally technology or activity-based limitations or guidelines for management of pollutants, contaminants, or hazardous wastes. These ARARs are triggered by the type of remedial activity selected to achieve the RAO and these requirements may indicate how the potential alternative must be achieved. Action-specific ARARs presented in Table 3-1 include CWA water quality certifications (Section 401) and discharges of dredged and fill material (Section 404), Clean Air Act, Endangered Species Act (ESA), and other wildlife protection acts.

The following sections discuss ARARs that have the most significance to the evaluation of remedial alternatives for the USEPA's Preliminary Site Perimeter. Action-specific ARARs do

not apply to all of the remedial alternatives. For example, requirements for waste management and hazardous materials transportation are most significant for remedial alternatives that involve removal of waste material, and would not apply at all to remedial alternatives that do not include removal of material from within the USEPA's Preliminary Site Perimeter. The types of actions that would trigger compliance with these requirements are also discussed.

3.3.1 Water Quality and Water Resources

3.3.1.1 Section 303 and 304 of the Clean Water Act and Texas Surface Water Quality Standards

Section 303 of the CWA requires states to promulgate standards for the protection of water quality based on Federal water quality criteria. Federal water quality criteria are established pursuant to Section 304. Texas Surface Water Quality Standards are relevant to the evaluation of short-term and long-term effectiveness of the remedial alternatives. The State of Texas has identified the Texas Surface Water Quality Standards as potential ARARs for this Site.

Substantive compliance with these ARARs for remedial alternatives involving removal of wastes will be achieved using:

- Best Management Practices (BMPs) incorporated into the design to support water quality and attainable use standards for this section of the San Jacinto River. These BMPs include the use of protective berms (either raised or constructed), sheet pile walls within the berms to strengthen and seal the berms and to aid dewatering, establish the top elevation of walls to provide protection from larger floods (i.e., 50-year return period floods), armoring the external side of the berms with removed armor cap material to control erosion, removing the armored cap and geotextile/geomembrane and waste material in the dry to the extent practicable, and silt fences to manage re-suspension.

- Installing the sheet pile walls at the top of the berms would provide more support for the wall, facilitate sealing joints between the sheet piles above the berm, and reduce the potential leakage through the wall and berms since the wall would not be exposed to the water column except during very high flow conditions. Excavation and backfilling in the dry will eliminate potential resuspension and residuals losses.

- To manage potential upland runoff, plastic sheeting would be used to cover any required upland stockpiles, and other erosion control measures to be described in the

plans and specifications of the final remedy.

- To reduce the waste material residuals having a high concentration of contaminants, a clean-up pass would be included in the removal plan to reduce the future exposure. Additionally, a multi-layer residuals cover would be placed in two lifts to limit intermixing of residuals with the fill so that the bioactive zone would be clean following remediation and would yield less diffusive flux than the existing temporary cap without a geomembrane. The specific design of the residuals cover, including armoring where appropriate, will be determined during the Remedial Design.

- During the course of construction activities suspended waste materials will accumulate within the enclosed area; however, considering the brackish nature of the site water flocculation and settling will maintain relatively low concentrations of total suspended solids, probably a concentration of less than 250 mg/L, within the enclosure. Upon removal of the sheet pile, this waste material laden water may be released allowing transport of contaminants offsite. At a minimum, it is suggested to allow time for particulates to settle after construction activities cease prior to sheet pile removal, the vast majority of the suspended solids should settle within a day. Flocculants may also be used to promote settling and create dense, strong flocs that would settle in minutes. Furthermore, dispersal of activated carbon may be used to adsorb dissolved contaminants. Once deposited on the bottom, the carbon would continue to treat contaminants on the surface.

- Water quality monitoring, performed as described in the Water Quality Monitoring Plan that will be developed to detect potential impacts on water quality and trigger the implementation of additional BMPs or an interruption of construction if necessary.

3.3.1.2 Section 401 Water Quality Certification of the Clean Water Act as Administered by Texas

Section 401 requires that the applicant for Federal permits obtain certification from the appropriate State agency that the action to be permitted will comply with State water quality standards. Although environmental permits are not required for on-site CERCLA response actions, the selected remedy will incorporate elements to comply with State water quality standards. Consultation with the TCEQ may be necessary to confirm that the final design of the selected alternative meets the substantive requirements of Section 401 of the CWA.

Documentation of substantive compliance with this ARAR would include:

- Coordinating with TCEQ regarding the information required in the Section 401 "Tier

2" Water Quality Certification questionnaire and incorporating agency feedback in the design, if needed.

- Providing documentation of the consultation to USEPA.

3.3.1.3 Section 404 and 404 (b)(1) of the Clean Water Act

Section 404 requires that discharges of fill to waters of the United States serve the public interest. In selecting a remedial alternative including discharge of fill, USEPA would be required to make the determination that the placement of materials into the San Jacinto River serves the public interest as necessary to remediate source material from within the USEPA's Preliminary Site Perimeter.

The area within the USEPA's Preliminary Site Perimeter includes wetlands in the area north of I-10, and a plan will need to be established that addresses the requirements (to the extent practicable) of Section 404 and 404(b)(1). The Respondents previously prepared a report on potentially jurisdictional waters of the U.S. (including wetlands) (Anchor QEA 2010; Anchor QEA 2011) as part of the TCRA implementation in compliance with the 1987 USACE Wetlands Delineation Manual and Interim Regional Supplement to the USACE Wetland Delineation Manual: Atlantic and Gulf Coastal Plan Region. A supplemental draft 404(b)(1) report may need to be prepared for consideration by USEPA depending on the nature of the selected remedy.

Specific BMPs anticipated to be included in construction actions, to minimize the impacts of discharges of fill into the water, include:

- The use of armored berms, sheet piles, and silt curtains and debris booms around in-water work areas
- The use of upland erosion controls such as plastic covering of stockpiles
- The use of silt fencing around upland areas
- Construction of a stable upland haul route capable of handling construction traffic without creating ruts that would develop into a source of turbid water
- Monitoring and maintenance during construction to ensure these BMPs are functioning as designed

3.3.1.4 Texas Pollutant Discharge Elimination System

Within the State of Texas, the National Pollutant Discharge Elimination System (NPDES), which demonstrates compliance with Section 402 of the CWA, is administered by TCEQ and referred to as Texas Pollutant Discharge Elimination System (TPDES). To demonstrate substantive compliance with TPDES, the following measures will be taken:

- The contractor will be required to prepare a Storm Water Pollution Prevention Plan (SWPPP) in accordance with the general permit requirements of TXR150000 (the TPDES permit for construction activities).

- The contractor will be required to implement appropriate monitoring during construction.

3.3.1.5 Rivers and Harbor Act and Texas State Code Obstructions to Navigation

The USEPA's Preliminary Site Perimeter is within a navigable waterway, and the State of Texas regulates the obstruction of navigable waters within the State involving the construction of structures, facilities, and bridges or removal and placement of trees that would obstruct navigation (Riddell 2004). The State of Texas considers land within the bed and banks of rivers to be public and requires access for the public to such areas. With the exception of the TCRA Site, which is required to be restricted to minimize the potential for disturbance of the temporary armored cap by vehicular traffic or vandalism, the remedial alternatives will not limit public access.

Documentation of compliance with this ARAR would entail documenting, with State concurrence, the extent to which a remedial alternative would affect navigability of the San Jacinto River in the vicinity of the USEPA's Preliminary Site Perimeter.

3.3.2 Protected Species Requirements

This section addresses requirements of the ESA, the Fish and Wildlife Coordination Act, the Bald and Golden Eagle Protection Act, and the Migratory Bird Treaty Act. The area within the USEPA's Preliminary Site Perimeter surrounds a section of a major highway including an overpass; however, the USEPA's Preliminary Site Perimeter is upstream of Galveston Bay, which provides rearing, spawning, and adult habitat for numerous marine and estuarine fish and invertebrate species including blue crab, drum, flounder, oysters, spotted sea trout, and shrimp. Sea turtles, including the Federally listed green, hawksbill, Kemp's Ridley, leatherback, and loggerhead turtles occasionally enter Galveston Bay to nest and feed

National Oceanic and Atmospheric Administration (NOAA 2010a). The National Marine Fisheries Service (NMFS) includes the ESA-listed sea turtles in Trust resources, but these turtles are not likely to be present within the USEPA's Preliminary Site Perimeter. The design and overall goal of the remedial action is to improve habitat conditions through the anticipated reduction of potential exposure to COCs.

To address concerns regarding presence of protected species, the Respondents retained a qualified biologist to conduct a threatened and endangered species (TES) survey. The TES survey led to a determination that there is no likely presence of protected species and their habitat within the USEPA's Preliminary Site Perimeter (Anchor QEA 2010a).

Further documentation of compliance with the protected species requirements would include:

- Incorporation of BMPs into the design to prevent or minimize incidental construction-related releases that could potentially impact protected species off-site.
- Pursuant to CERCLA Section 121(e) and USEPA policy, consultation with the U.S. Fish and Wildlife Services (USFWS) and NMFS is needed to confirm that the implementation of the proposed remedy will have no effect on listed species or habitat.

3.3.3 Coastal Zone Management Act and Texas Coastal Management Plan

Federal agency activities that have reasonably foreseeable effects on any land or water use or natural resource of the coastal zone (also referred to as coastal uses or resources and coastal effects) must be consistent to the maximum extent practicable with the enforceable policies of a coastal State's Federally approved coastal management program (NOAA 2010b). The Texas General Land Office (GLO) administers the Texas Coastal Management Consistency certification process.

Substantive compliance with the certification would be demonstrated by:

- Evaluating the effects of the proposed remedy on critical areas (if any) and associated criteria including no net loss of critical area functions and values.
- Evaluating the remedy for compliance with the Texas Coastal Zone Management Consistency Determination and policies identified in the application for Consistency with the Texas Coast Management Program.

- Supporting the USEPA's consultation with the Galveston District USACE and Texas GLO.

3.3.4 Floodplain

The construction of any of the proposed Alternatives is not expected to cause any flooding in the vicinity of the Site, and therefore should not require the implementation of any flood control measures during the construction of any of the Alternatives under consideration for the Site (Appendix A).

3.3.5 Cultural Resources Management

No historic properties eligible for listing in the National Register of Historic Places (NRHP) are recorded within the USEPA's Preliminary Site Perimeter (Anchor QEA and Integral 2010a).

3.3.6 Noise Control Act

Noise abatement may be required if actions are identified as a public nuisance. Due to the temporary cap being bounded by water on three sides and adjacent to a highway overpass on the fourth side and the industrial activities in the area south of the I-10, noise from the construction activity is unlikely to constitute a public nuisance. If necessary, BMPs would be implemented to reduce the noise levels. If materials are delivered to or removed from the project area by truck, noise greater than 60 decibels in close proximity to sensitive receptors (schools, residential areas, hospitals, and nursing homes) will be avoided. Truck routes will be selected to avoid sensitive receptors to the extent possible.

3.3.7 Hazardous Materials Transportation and Waste Management

Remedial alternatives 5N, 5aN, 6N, and 4S (presented in Section 4) include removal and transportation of waste materials to an off-site disposal facility. Off-site disposal would also be required for limited quantities of waste, such as used personal protective equipment (PPE) and any debris or vegetated materials required to be removed during clearing and grading activities, associated with all of the remedial alternatives except for no further action. The contractor will be required to package any hazardous materials in appropriate containers and label containers in accordance with Texas Department of Transportation (TxDOT) requirements. The development of remedial alternatives anticipates that all disposal will be at a permitted landfill facility. If an off-site facility needs to be established for dewatering waste material or transloading waste from barges to trucks or rail cars, it may require a solid waste permit.

4 DEVELOPMENT OF REMEDIAL ALTERNATIVES

4.1 Remedial Technologies Screening

The RAM (Anchor QEA 2012b) identifies General Response Actions (GRAs) and provides initial screening of remedial technologies. In addition, the RAM describes the development of a set of preliminary remedial alternatives for the area north of I-10 to achieve a range of post-remedy SWACs. Subsequent to development of the RAM, the range of remedial alternatives was modified to include those that are described in this FS Report. The following supplemental information regarding GRAs is provided in the specific context of the final set of remedial alternatives considered in this FS Report.

4.1.1 Institutional Controls

ICs are administrative measures that are implemented to mitigate risks or to protect the integrity of engineered controls. ICs include "Proprietary Controls," which are restrictions placed on the use of private property, "Governmental Controls," which include restrictions on the use of public resources, "Enforcement Tools" that may be imposed by an agency to compel certain actions, and "Informational Devices," which include notices about the presence of contamination or fishing advisories.

Governmental controls, enforced by state or local government, may include bans on harvesting fish or shellfish, zoning restrictions, ordinances, statutes, building permits, or other restrictions. Zoning may be used by local governments to designate land use for specific purposes. Government ordinances or permits may also restrict or control land uses, and outline specific requirements before authorizing certain activities (e.g., building codes, drilling permit requirements). Some local ordinances place controls on access to or use of certain areas within a property.

Proprietary controls are based on real property law (EPA 2000). Enforceability of proprietary controls should be evaluated under applicable (state) law. Some proprietary controls are enforceable upon execution, others upon the sale or transfer of property. Examples include easements, covenants, and conservation easements. Easements are rights over the use of another's property, and include negative easements which limit uses that would otherwise be lawful. Access easements are sometimes used to ensure current and future property owners allow property access to operate, monitor, or maintain ECs or ICs. Covenants are agreements between the landowner and others connected to the land. They are typically used to establish an IC when property is transferred to another party. Use restrictions/ statutes/ environmental covenants are state statutes that provide owners of a contaminated property with authority to establish use restrictions. Conservations easements are state statutes that establish easements to

conserve property or natural resources. Enforcement and permit tools include permits, administrative orders, and consent decrees which are enforceable by state or federal agencies. Most enforcement agreements are binding on only the signatories and do not bind subsequent owners. Examples include administrative orders which are issued by an environmental regulatory agency directing property owners to perform (or not perform) certain actions. Consent decrees document an administrative or judicial court's approval of the settlement of an enforcement case filed in court. These typically specify actions to be taken (or not to be taken) by the settling parties. Permits are implemented by an environmental regulatory agency and may require compliance with a statutory or regulatory provision that may impact the reuse of the property.

Informational devices provide information to the public about risks from contamination and generally are not legally enforceable. Informational devices include deed notices, state registries of hazardous waste sites, and advisories. Deed notices are filed in public land records with the property deed that provide information about potential health risks from contamination left on the property. Advisories warn the public of potential risks associated with using contaminated land surface water or groundwater, generally issued by public health agencies.

In addition to the legal mechanisms mentioned above, the Uniform Environmental Covenants Act (UECA) is a model statute that can be adopted into law by each individual state or territory. The UECA provides legal framework to create, modify, enforce and terminate a valid real estate instrument (environmental covenant or IC) to restrict use of contaminated real estate or impose obligations under state law and precluded the application of traditional common law doctrines that might otherwise hinder the validity or enforcement of ICs adopted under state property law or other mechanisms. The UECA provides a legal mechanism to ensure LUCs can be readily found, maintained, and enforced over time.

Layering of ICs, using different types of ICs at the same time may enhance protectiveness. Applying ICs in series may help ensure both short- and long-term effectiveness. Using ICs in conjunction with physical barriers to limit access is also recommended.

The three most common types of ICs at sediment sites include fish consumption advisories and commercial fishing bans, waterway use restrictions, and land use restriction/structure maintenance agreements. Fishing advisories, restrictions or bans on fishing (including shell fishing) are typical ICs. Commercial fishing bans are government controls that ban commercial fishing for specific species or sizes of fish or shellfish (EPA 2005). Rather than a complete ban, advisories may be placed on certain locations and types of fishing. Advisories inform the public that they should not consume fish from an area or should limit the number of fish meals consumed over a specific time period. Advisories and bans are usually established by state departments of health and can be administered through signs, pamphlets or other outreach

materials. Warning signs should be in the language of the local community including new immigrants, and require periodic inspection and maintenance. Monitoring, enforcement and communication with local or state authorities are required. Consumption advisories are not enforceable controls and may have variable effectiveness. Surveys of anglers are often helpful to evaluate whether they consume the fish they catch and whether restrictions are effective. EPA's Fish Advisory Program compiles a national listing of fish advisories through its Office of Science and Technology.

Institutional controls may also be needed to protect the integrity of the remedy. Land use restrictions may be needed at near-shore or upland sites to limit or eliminate construction activities, digging or other activities that may disturb the contaminated materials. A deed restriction or notice may be adequate for an upland property, but for in-water remedies, restrictions may be more difficult due to ownership issues. Nearshore areas can, in some cases, be privately owned out to the end of piers. If privately owned, traditional ICs such as proprietary controls or enforcement tools can be considered. Federal, state and local laws place restrictions on and require permits for dredging, filling, or other construction activities in the aquatic environment. ICs may also be implemented through coordination through existing permitting processes.

Restrictions on vessel traffic to establish no-wake zones or restrictions against anchoring may be necessary to protect a cap. Restrictions on easements for installation of utilities and other in-water construction may also be needed, and should be placed on navigational charts. Navigational buoys or warning flags can be used to help warn boaters (ASTSWMO 2009). Changing the navigation status of a waterway may also be necessary. De-authorization or re-authorization of federally authorized navigation channels to a different width or depth would be required. The state may have authority to change harbor lines or the navigation status.

In general, the following ICs would be implemented where the waste material, soil, or sediment exceeds its PRG and does not allow for unlimited use and unrestricted access:

- Deed restrictions would be applied to parcels in which the dioxin concentrations exceed the relevant PRG.
- Notices would be attached to deeds of affected properties to alert potential future purchasers of the presence of dioxin concentrations exceeding the PRG.
- As a result of the long term persistence of dioxin, it is anticipated that the institutional controls will be essentially permanent measures.

The ICs for all northern area alternatives except Alternative 1N include establishing limitations on dredging and anchoring within the footprint of the temporary armored cap. Limitations on dredging and anchoring would be established by requesting that the U.S. Coast Guard District Commander establish a regulated navigation area. The intent of Alternative 6N is full removal of all materials exceeding the PRGs potentially allowing for less restricted future use of the property. However, if waste material residuals leave a layer of material exceeding PRGs, ICs will be needed for Alternative 6N, including a no-wake zone to protect the residuals cover. Additional measures are required to alert future property owners of the presence of subsurface materials exceeding PRGs and management requirements for any excavated soils or waste material exceeding the PRGs. For the northern nearshore areas and the upland area of the southern impoundment, the ICs would include land use restrictions against construction, excavation, or other disturbances that may expose contamination. The ICs would be established using proprietary controls such as covenants to alert future landowners of the potential risks and restrictions. The ICs would be needed until such time as resulting concentrations are shown to be acceptable.

The Texas Department of State Health Services has issued a fish advisory for the Houston Ship Channel and San Jacinto River below the Lake Houston Dam. This advisory recommends that children and women of childbearing age do not eat any fish or crab, and adult men and women past childbearing age should only consume one fish or crab meal per month. This advisory is expected to stay in place following remediation of the Site.

4.1.2 Monitored Natural Recovery

MNR is a remedy for contaminated sediment that typically uses ongoing, naturally occurring processes to contain, destroy, or reduce the bioavailability or toxicity of contaminants in sediment. MNR is technically and administratively implementable at the Site. The River at the location of the Site is generally depositional in nature, and MNR of dioxins and furans is a natural process that occurs when clean sediment particles are deposited over contaminated materials within the Site. Decreases in surface sediment concentrations were documented for all dioxin and furan congeners between 2005 and 2010 datasets within the Site in the Chemical of Potential Concern Technical Memorandum (Integral 2011). There would not be any short- or long-term impacts related to the implementation of the remedial action for MNR. MNR would entail periodic sampling and an analytical program that would be implemented to monitor the progress of natural recovery. However, deposition in the area of the Site is uneven, and there is the potential for high erosion events. For that reason, sampling would be conducted at a representative range of locations and at appropriate time intervals to allow trends in concentrations to be assessed and evaluate the effectiveness of the MNR. The scope of the MNR sampling and analysis, and any adaptive management actions

that could be taken as a result of the MNR assessment, would be determined during the Remedial Design.

4.1.3 Treatment

Treatment processes are screened and discussed in the RAM (Anchor QEA 2012b). Treatment alternatives considered in this FS include S/S of waste materials, soils and sediments with a reagent such as Portland cement. S/S was successfully performed during the temporary cap construction on a portion of the Western Cell materials. For costing purposes, the FS assumes a treatment reagent and dosage concentration similar to that which was used during the temporary cap construction, or 7 to 8 percent by weight Portland cement (USEPA 2012c).

To accomplish S/S, physical removal of the existing temporary armored cap materials, as well as the overlying surface waters will be required prior to mixing the reagent. This FS Report assumes that treatment areas in the Eastern Cell that are normally inundated would need to be surrounded by a sheet pile wall, and the water drawn down prior to initiating S/S. The sheet pile system used would need to be robust to withstand differential water levels inside and outside the treatment cell. Sheet pile walls can be overwhelmed during major storm and flood events in the river, however these risks could be mitigated through the design of the sheet pile wall enclosure. Finally, given the physical constraints of the Site, an off-site materials management facility is anticipated to be necessary for temporary stockpiling of cap materials, treatment reagents, and associated machinery to implement the S/S.

Several treatment technologies, including thermal (incineration and in-pile thermal desorption) and chemical (solvated electron technology and base catalyzed decomposition) processes, were also considered for use at the Site but were not included in a remedial alternative.

Incineration of dioxin contaminated material requires high temperatures (in excess of 1200°F) of sufficient residence time (30 to 90 minutes) (USEPA 1998a). Air mixed with the volatilized organic contaminants undergoes an oxidation reaction to form carbon dioxide and water vapor. Incomplete oxidation of contaminants may produce other harmful byproducts if sufficient temperatures and residence times are not achieved; however, operating conditions (temperatures, residence times, contaminant inflow, and excess air flow) are carefully controlled to maximize the destruction of contaminants and minimize the generation of products of incomplete combustion (PICs). Any portion of the material that cannot be incinerated (fly ash) is removed from the system; off-gases are captured and treated by a scrubber system prior to atmospheric release. Both the ash material produced

and the off-gas released from the incinerator system are assessed for contaminant content. To be permitted, an incinerator facility must meet local, state, and federal requirements for emissions standards. This technology can be applied both on-site with a portable incinerator and off-site at a dedicated facility. Prior to transportation off-site, it is likely that the dredged material would require dewatering. Dewatering improves handling; controls costs of transport, treatment, and disposal; and reduces the risk of releasing contaminants. Incineration is capable of removing dioxins from contaminated media and chemically altering the dioxin to harmless constituents. Incinerators operating in compliance with environmental permits have been shown to effectively and safely treat waste material, soil, sediment, and debris contaminated with dioxin and related compounds. The RAM included consideration of incineration as a component of disposal. At the time the RAM was developed, it was unclear whether there were landfill facilities that would accept dredged or excavated material from the Site. Subsequent to submittal of the RAM and the Draft FS Report, two landfill facilities were tentatively identified that indicated materials from the Site could potentially be disposed of at these locations without incineration. Therefore, further consideration of incineration as a component of disposal has been screened out in this Feasibility Study Report.

In-Pile Thermal Desorption technology uses a heated negative pressure environment to treat contaminated soils and sediments. Excavated material is placed in piles or “cells” for treatment. Each “cell” is constructed above ground with a foundation, containment berms, insulating walls and cover, and treatment wells. Thermal desorption is a slow process, requiring months to treat a batch of sediment. If the selected remedy includes removing a significant volume of sediment, using thermal desorption would require the use of a large amount of land either to house multiple treatment piles or to stage sediment awaiting treatment. Because of the large space requirement, a temporary thermal desorption facility would need to be established off-site and would need to obtain operating permits. For smaller volumes of sediment, the cost of siting a treatment facility would not be warranted. Thermal desorption was not retained because incineration would provide a more implementable thermal treatment option for a roughly similar cost.

The Solvated Electron TechnologyTM (SET) is an ex situ chemical dehalogenation treatment process. The process involves mixing the contaminated soil or sediment with a solvated electron solution (alkali metal or alkaline earth metal mixed in liquid anhydrous ammonia) in a treatment vessel. Chlorine is removed from the chlorinated organic molecules, leaving the parent contaminant molecule (non-chlorinated dioxin in this case) and metal salts, such as sodium chloride. The vessel is then heated using hot water or steam to remove the ammonia for reuse. Based on the available information, the SET chemical dehalogenation

treatment technology is not currently available for full-scale implementation in the United States. As a result, this process option was not retained for further evaluation.

Base-catalyzed decomposition (BCD) is another ex situ technology that has been applied in the United States and countries around the world. The patent holder of this technology in the United States is the USEPA. This treatment technology requires pre-treatment via thermal desorption to remove the contaminants from the soil/sediment matrix by volatilization. The volatilized contaminants pass through a condenser and are fed into a liquid tank reactor along with sodium hydroxide and a carrier oil. The mixture is then heated for 3 to 6 hours to temperatures above 326°C. The oil is tested post-treatment and the carbonaceous residues formed from the reaction are removed from the mixture; the carrier oil can then be reused for subsequent treatment applications. The soil and sediment treated via thermal desorption can be reused as fill material. Based on the available information, the BCD treatment technology is not currently available for full-scale implementation in the United States. As a result, this process option was not retained for further evaluation.

4.1.4 Containment

As described in the RAM, to the extent that containment is a component of the remedy, the containment would be designed, monitored, and maintained in accordance with USACE and USEPA capping guidance (USACE 1998. Ground water monitoring may be required to assure that a containment remedy would be successful in confining all dissolved phase contaminants within the containment area.

In situ capping, as discussed in USEPA guidance (USEPA 2005) is a demonstrated technology that has been selected by USEPA for sediment remediation sites across the United States (USACE 1998). Compared to removal-focused approaches, in situ capping has a disadvantage in that caps require monitoring and maintenance to ensure their protectiveness. Table 4-1a presents a summary of projects where capping was a component of the remedy.

The existing temporary armored cap was designed in accordance with USEPA and USACE capping guidance (USACE 1998). As described in the TCRA Removal Action Work Plan (Anchor QEA 2011) and required by the TCRA AOC, the armor rock was designed to withstand a 100-year storm event with an additional factor of safety to ensure its long-term protectiveness. The storm event defines the depth of water and the currents that the cap armor layer must resist. In addition to the 100-year event, storms with 5- and 10-year return intervals were also considered during the temporary cap design because it was recognized that more frequent storms could present more critical design conditions; for these more frequent storms, the water depth at the Site would be lower, which could result in higher shear stresses on the cap compared to a less frequent storm like the 100-year design event.

Cap design occurs with requirements for OMM in mind. Since being completed in July 2011, the temporary armored cap and associated fencing, access controls and signs have been routinely inspected and maintained by Respondents pursuant to a USEPA-approved OMM Plan. The OMM Plan was developed to address conditions that USACE and USEPA cap design guidance expressly presumes could occur post-construction (such as movement of rock cover in localized areas of the cap). The OMM Plan requires periodic monitoring and monitoring following key storm events to identify the need for possible cap maintenance, followed by appropriate repair activities (USEPA 2005; USACE 1998). The OMM Plan has been modified in an attempt to timely identify conditions not revealed by the original periodic monitoring and maintenance program, including the cap deficiencies discovered in 2015 and 2016..

Cap protection from future barge or other vessel operations in the temporary armored cap area would be assessed and detailed during the Remedial Design phase. For purposes of FS cost development, a conceptual submerged perimeter rock berm has been included as a protective perimeter barrier for the alternatives that include the Upgraded Cap to further ensure the long-term protectiveness of the cap by reducing potential for vessel impacts. Further, Alternative 3aN includes additional perimeter protection from barge strikes by adding protective pilings around the cap. Finally, given the physical constraints of the Site, an off-site staging area is anticipated to be necessary for temporary stockpiling of cap materials, similar to that which was utilized during construction of the temporary cap.

Capping is considered to be highly compatible with the temporary armored cap in accordance with the TCRA Removal Action Objectives (USEPA 2010a, Appendix A, V.A.2), because the existing temporary cap would not need to be disturbed to implement this remedial action.

4.1.5 Removal

Sediment removal has been the most frequent cleanup method used by the Superfund program at sediment sites. Excavation or dredging has been selected as a cleanup method for contaminated sediment at more than 100 Superfund sites (USEPA 2005). One of the advantages of removing contaminated sediment from the aquatic environment often is that, if it achieves cleanup levels for the site, it may result in the least uncertainty about long-term effectiveness of the cleanup, particularly regarding future environmental exposure to contaminated sediment. Removal of contaminated sediment can minimize the uncertainty associated with predictions of sediment bed or cap stability and the potential for future exposure and transport of contaminants. Another potential advantage of removing contaminated sediment is the flexibility it may leave regarding future use of the water body. Methods such as MNR and capping frequently include institutional controls (ICs) that limit

water body uses (USEPA 2005). Table 4-1b includes a list of representative projects where dredging has been chosen as the remedy. This Site would involve the removal of paper mill waste material, not contaminated sediment, but the Site has some similarities to these projects because the Northwest area and portions of the Eastern Cell are submerged. However, the majority of the waste material should be able to be excavated in the dry using BMPs.

Alternatives that involve full or partial removal of the temporary armored cap and excavation of impacted material from beneath the cap and in other locations all involve excavation and dredging to some extent. Virtually all dredging projects result in some degree of resuspension, release, and residuals. (USEPA 2005, Sections 6.5.5 (resuspension and releases) and 6.5.7 (residuals); NRC 2007; USACE 2008; Bridges et al. 2010). However, the use of BMPs, including sheet piles and excavation in the dry where possible, would eliminate or greatly reduce resuspension.

Operational and engineering controls (rigid barriers) would be used to the extent practicable to mitigate these potential releases. Further, the use of raised, armored berms to support the sheet piles would allow excavation in the dry in the Western Cell and portions of the Eastern Cell, and prevent localized scour adjacent to the barrier.

Residuals would be managed by backfilling the removed material footprint, or by placement of a clean sediment cover or engineered cap over the footprint. For purposes of this FS Report, it has been assumed that backfill and capping would be used to manage residuals for removal-based alternatives that do not achieve the PRG. The design of the residuals cover would be developed during the Remedial Design, but will likely include at least two layers of clean fill to prevent intermixing with the waste material residuals, and may include armoring where appropriate to protect the residuals cover.

Without the use of robust BMPs, including excavation in the dry, there likely would be increased dredging releases. Table 4-2 presents a summary of dredging release case studies, which report dredge releases from two to four percent of the contaminant removed. However, for Alternative 6N, which uses raised armored berms, sheet piles, and excavation in the dry for a majority of the material removed, etc., the USACE estimates that resuspension would be at least an order of magnitude less, or 0.2 percent; this estimated release amount could increase to 0.34% if sheet piles are determined to be impracticable for use in the Northwest area.

The estimated construction durations for the removal-based alternatives range from 13 months to 19 months. If a major storm or flood were to occur during construction of a removal-based remedy, any BMPs that may be instituted to control resuspension releases under normal flow conditions may be overwhelmed. In these circumstances, releases of

disturbed wastes to the river that are exposed as a result of construction activities may be exacerbated. It will be necessary to develop a contingency plan as part of the Remedial Design to minimize any releases in the event of a major storm or flood. Finally, given the physical constraints of the Site, an off-site materials management facility will be required for material staging, stabilization and processing for bulk transportation to an off-site landfill.

Upland excavations for the area of investigation south of I-10 would be accomplished with conventional earthwork equipment (excavators, dozers, loaders, etc.). Considerations related to upland excavations include maintaining stable sidewalls, and managing water for those excavations that must be performed below the groundwater table.

To maintain stable sidewalls, the excavation may be sloped to a stable angle of repose if space permits, or shoring could be used. Earthwork safety guidelines generally require any excavation deeper than 5-feet to have sloped or shored sidewalls, as provided for in 29 CFR 1926.651 and 1926.652 (Occupational Safety and Health Administration [OSHA] 2014).

Excavation water controls could include ditches and sumps, well point systems, or deep wells. The dewatering effluent may need to be treated prior to disposal or shipped to licensed facility depending on the quality of the water. The selection of appropriate dewatering technology and decisions about dewatering effluent treatment are remedial design elements.

4.1.6 Disposal

The RAM included consideration of incineration as a component of disposal. At the time the RAM was developed, it was unclear whether there were landfill facilities that would accept material removed from the Site. Subsequent to submittal of the RAM and the Draft FS Report, two landfill facilities were tentatively identified that indicated materials from the SJRWP Site could potentially be disposed of at these locations without incineration. Thus, further consideration of incineration as a component of disposal has been screened out in this FS Report.

The waste material will be treated as required for transportation and disposal at a permitted waste disposal facility determined during the Remedial Design. Transportation would be in compliance with applicable requirements and permanently managed in a permitted landfill cleared by the EPA's regional offsite rule contact. Treatment may include dewatering and stabilization with Portland cement or other suitable material as determined during the Remedial Design.

Given the limited upland space available adjacent to the temporary cap, an off-site facility with water access would be necessary to unload barges and process removed waste material prior to shipment to the landfill. The off-site facility would need to accommodate stockpiles for armor rock and removed material, and would need space to accommodate a waste material drying process (conceptually envisioned to be mixing in a drying reagent for this FS Report). The off-site facility would also need to accommodate any water treatment and disposal determined necessary during remedial design. Some operations, such as water treatment, could also be barge mounted. Finally, the off-site facility would need access to regional transportation infrastructure such as heavy-duty roads or rail.

Even with ready access to the regional transportation infrastructure, off-site disposal has posed a bottleneck for some sediment remediation projects (Anchor Environmental and Windward Environmental 2005; Anchor QEA 2009). The daily capacity of the landfill facility to receive material, and/or the daily capacity of the transportation infrastructure to accommodate a new waste stream can be limited. The durations presented in this FS Report have assumed there are no transportation or landfill bottlenecks, and that these facilities can receive material at the same rate as it is excavated or dredged. To the extent that any disposal bottlenecks occur, this would increase the overall duration of removal-based alternatives, exacerbating community, traffic, and safety impacts.

4.2 Assembly of Remedial Alternatives

The preliminary remedial alternatives were modified subsequent to submittal of the RAM. The most significant reason for the modifications was that PRGs for waste material, sediment and soil (as described in Section 3.1) had not been developed when the RAM was prepared. Based on a comparison of $TEQ_{DF,M}$ concentrations in waste material, sediment and soil to the PRGs, areas of affected waste material, sediment and soil potentially subject to remedial action have been identified and are discussed in the descriptions of the remedial alternatives in the following subsections. Remedial alternatives were developed for the FS for the areas north and south of I-10. The remedial alternatives for the area north of I-10 are:

- **Alternative 1N – temporary armored cap and Ongoing OMM (No Further Action)**, which assumes the temporary armored cap would remain in place, together with fencing, warning signs and access restrictions established as part of the TCRA, and would be subject to the ongoing OMM program. The estimated cost of this alternative is $0.4 million.

- **Alternative 2N – Armored Cap, ICs, Ground Water Monitoring, and Monitored Natural Recovery (MNR),** which includes the actions described under Alternative 1N, institutional controls in the form of deed restrictions and notices to place restrictions

on dredging and anchoring to protect the integrity of the armored cap and to limit potential disturbance and resuspension of buried sediment near the upland sand separation area. MNR would be used to achieve the PRG for sediment (30 ng/kg) in the sand separation area and the Texas Surface Water Quality Standard in the San Jacinto River. Monitoring may involve collecting and analyzing sediment, tissue, surface water, and ground water samples and evaluating the data. This alternative is estimated to cost $2.0 million.

- **Alternative 3N – Upgraded Cap, ICs, Ground Water Monitoring, and MNR,** which includes the actions described under Alternative 2N plus additional enhancements to the temporary armored cap, many of which have already been implemented during the work performed in January 2014, consistent with the USACE recommendations. Institutional controls in the form of deed restrictions and notices would be implemented to place restrictions on dredging and anchoring to protect the integrity of the armored cap and to limit potential disturbance and resuspension of buried sediment near the upland sand separation area. MNR would be used to achieve the PRG for sediment (30 ng/kg) in the sand separation area and the Texas Surface Water Quality Standard in the San Jacinto River.

  This alternative will increase the long-term stability of the temporary armored cap (Upgraded Cap) and meet or exceed USACE design standards. This alternative also includes additional measures to protect the Upgraded Cap from potential vessel traffic (i.e. a protective perimeter barrier). This alternative would require an estimated 2 months of construction at an estimated cost of $4.1 million. An off-site staging area would likely be required for management of rock armor, similar to that which was utilized during the temporary cap construction. However, the exact location and configuration of the off-staging area are beyond the scope of this FS and may not be fully reflected in the FS estimated durations or costs.

- **Alternative 3aN - Enhanced Cap, Protective Pilings, ICs, Ground Water Monitoring, and MNR**, which includes enhancements to address the 80% erosion of the Upgraded Cap with Alternative 3N (See Appendix A of the Feasibility Study), and substantial erosion of the underlying paper mill waste material in modelling of a future severe storm. This alternative, 3aN, includes the actions described under Alternative 3N plus additional enhancements to the temporary armored cap recommended by the USACE.to create a cap with increased long-term stability. Institutional controls in the form of deed restrictions and notices would be implemented to place restrictions on dredging and anchoring to protect the integrity of the armored cap and to limit potential disturbance and resuspension of buried sediment near the upland sand separation area. MNR would be used to achieve the PRG for sediment (30 ng/kg) in

the sand separation area and the Texas Surface Water Quality Standard in the San Jacinto River.

The additional cap enhancements added for this alternative include pre-stressed concrete or concrete filled steel pipe pilings placed 30 feet apart around the perimeter of the cap to protect from barge strikes. The spacing is designed to catch a typical barge, which is 35 feet wide. An additional armor stone cap with a thickness of at least 24 inches would be placed over the armor cap for Alternative 3N. The armor stone would have a median diameter of 15 inches. This additional armor stone would cover 13.4 acres of the 17.1 acre armored cap. Also, a course gravel filter layer would be placed on 1.5 acres of the Northwest Area where there is currently no geotextile under the armor cap. The actual scope and design of the cap enhancements, and additional area needed to construct the required slopes, would be determined in the Remedial Design. This additional weight of rock on top of the waste pits may cause cap settling and/or pushing the waste material out the sides of the cap; the Remedial Design will consider the significance of the design issues related to this.

- **Alternative 4N – Partial Solidification/Stabilization, Upgraded Cap, ICs, Ground Water Monitoring, and MNR,** provides for solidification and stabilization (S/S) of the most highly contaminated material. A dioxin/furan value that exceeds 13,000 ng/kg $TEQ_{DF,M}$ within the USEPA's Preliminary Site Perimeter was used to define the most highly contaminated material. This alternative includes the actions described under Alternative 3N; however about 23 percent of the temporary armored cap (2.6 acres above the water surface and 1.0 acre in submerged areas) would be removed and about 52,000 cubic yards (CY) of materials beneath the cap with $TEQ_{DF,M}$ that exceeds a concentration of 13,000 ng/kg, would undergo S/S. After the S/S is completed, the Upgraded Cap would be constructed. Institutional controls in the form of deed restrictions and notices would be implemented to place restrictions on dredging and anchoring to protect the integrity of the armored cap and to limit potential disturbance and resuspension of buried sediment near the upland sand separation area. MNR would be used to achieve the PRG for sediment (30 ng/kg) in the sand separation area and the Texas Surface Water Quality Standard in the San Jacinto River.

  This alternative would require an estimated 17 months of construction to complete and is estimated to cost $15 million. An off-site staging area may be required for management of rock armor, stabilization reagents and associated treatment equipment. However, the exact location and configuration of the off-staging area are beyond the scope of this FS and may not be fully reflected in the FS estimated durations or costs.

- **Alternative 5N – Partial Removal, Upgraded Cap, ICs, Ground Water Monitoring, and MNR,** provides for removal of the most highly contaminated material. A dioxin/furan value that exceeds 13,000 ng/kg $TEQ_{DF,M}$ within the USEPA's Preliminary Site Perimeter was used to define the most highly contaminated material. Under this alternative the temporary armored cap would be partially removed and the 52,000 CY of material that would undergo S/S under Alternative 4N would instead be excavated and treated as required for off-site disposal. After the removal was completed, the Upgraded Cap would be constructed and the same ICs and monitoring that are part of Alternatives 2N to 4N would be implemented. Institutional controls in the form of deed restrictions and notices would be implemented to place restrictions on dredging and anchoring to protect the integrity of the armored cap and to limit potential disturbance and resuspension of buried sediment near the upland sand separation area. MNR would be used to achieve the PRG for sediment (30 ng/kg) in the sand separation area and the Texas Surface Water Quality Standard in the San Jacinto River.

  This alternative would require an estimated 13 months of construction at an estimated cost of $30 million. An off-site materials management facility will be required for material staging, stabilization and processing for bulk transportation to an off-site landfill. The exact location, configuration, siting and operational impacts, as well as potential delivery restrictions by the receiving facility (e.g., tons per day) are beyond the scope of this FS and may not be fully reflected in the FS estimated durations or costs.

- **Alternative 5aN - Partial Removal of Materials Exceeding the PRG, Upgraded Cap, ICs, Ground Water Monitoring, and MNR,** in which all material beneath the temporary armored cap in any location where the water depth is 10-feet or less and which has a of $TEQ_{DF,M}$ 200 nanograms per kilogram (ng/kg) or greater[5] – about 137,600 CY – would be excavated and treated as required for off-site disposal. To implement this alternative, about 11.3 acres (72 percent) of the temporary armored cap would be removed to allow for this material to be removed. After excavation of the material, the remaining areas of the temporary armored cap would be enhanced to create a Upgraded Cap, and the same ICs and monitoring that are part of the preceding alternatives would be implemented. Institutional controls in the form of deed restrictions and notices would be implemented to place restrictions on dredging and anchoring to protect the integrity of the armored cap and to limit potential disturbance and resuspension of

[5] In defining this alternative, USEPA included an additional requirement that all material exceeding 13,000 ng/kg $TEQ_{DF,M}$, regardless of water depth, would be removed. However, all locations that exceed 13,000 ng/kg $TEQ_{DF,M}$ are in areas with 10-feet of water or less. Thus, the horizontal boundary defining this alternative (the 10-foot water depth) includes all locations exceeding 13,000 ng/kg $TEQ_{DF,M}$.

buried sediment near the upland sand separation area. MNR would be used to achieve the PRG for sediment (30 ng/kg) in the sand separation area and the Texas Surface Water Quality Standard in the San Jacinto River.

This alternative would require an estimated 19 months for construction and has an estimated cost of $69.6 million. An off-site materials management facility will be required for material staging, stabilization and processing for bulk transportation to an off-site landfill. The exact location, configuration, siting and operational impacts, as well as potential delivery restrictions by the receiving facility (e.g., tons per day) are beyond the scope of this FS and may not be fully reflected in the FS estimated durations or costs.

- **Alternative 6N – Full Removal of Waste Materials Exceeding the PRG, ICs, and MNR** in which all waste material above the PRG of 200 ng/kg in the waste pits would be removed. This would involve removal of most of the existing temporary armored cap and the removal of 152,000 CY of material, which would be treated as required for off-site disposal. The area where waste material has been removed would then be covered with two layers of clean fill and the clean fill would be armored where necessary. Institutional controls in the form of deed restrictions and notices would be implemented to place restrictions on dredging and anchoring to protect the integrity of the armored cap and to limit potential disturbance and resuspension of buried sediment near the upland sand separation area. MNR would be used to achieve the PRG for sediment (30 ng/kg) in the sand separation area and the Texas Surface Water Quality Standard in the San Jacinto River.

  The monitoring program will be designed during the Remedial Design, but may include the collection of fish, sediment, surface water, and ground water samples and evaluation of the data. This alternative would require an estimated 19 months of construction at an estimated cost of $87 million. An off-site materials management facility will be required for material staging, stabilization and processing for bulk transportation to an off-site landfill. The exact location, configuration, siting and operational impacts, as well as potential delivery restrictions by the receiving facility (e.g., tons per day) are beyond the scope of this FS and may not be fully reflected in the FS estimated durations or costs.

The remedial alternatives for selected locations within Soil Investigation Area 4 south of I-10 are:

- Alternative 1S – No Further Action
- Alternative 2S – ICs

- Alternative 3S – Enhanced ICs
- Alternative 4S – Removal and Off-site Disposal

A brief description of the primary elements for each alternative is provided in the remainder of this section, and Tables 4-3 and 4-4 provide a summary of material quantities and durations associated with each of the alternatives. Note that the footprint and assumptions for each alternative are based on the available RI data. Data gaps potentially exist that would need to be addressed during remedial design depending on the selected remedial alternative. For example, to the extent that the selected alternative includes solidification, laboratory bench scale testing would be performed during remedial design to select reagent types and dosages for solidification. Alternatively, if the selected alternative includes removal, additional data would be collected during remedial design to refine the delineation of work areas, and to understand whether changes have occurred in sediment bed concentrations due to shipping activities in the area of the SJRF operations (e.g., from propeller wash).

Following the general descriptions of alternatives provided in Sections 4.3 and 4.4 for the areas north and south of I-10, respectively, Section 5 provides a detailed evaluation of the remedial alternatives with consideration of criteria required by the NCP, 40 CFR Section 300.430(e)(9). Those criteria addressed include overall protection, compliance with ARARs, long-term effectiveness, reduction of toxicity, mobility or volume (TMV), short-term effectiveness, implementability and cost. Two additional criteria, State acceptance, and community acceptance, are not addressed. USEPA Region 6 Clean and Green Policy (USEPA 2009c) was also considered in the development of all of the alternatives.

4.3 Remedial Alternatives for the Area North of I-10

4.3.1 Alternative 1N – Temporary Armored Cap and Ongoing OMM (No Further Action)

This alternative serves as the baseline of comparison for the other remedial alternatives. The NCP requires the development and evaluation of a No Further Action alternative (40 CFR 300.430(e)(6)). As described in Section 2, the TCRA included capping the Site, selected stabilization of near surface soils in the Western Cell, installing a security fence, and posting warning signs. The temporary armored cap was selected following a USEPA-approved TCRA alternatives evaluation, and was designed in accordance with USEPA and USACE cap design guidance (USACE 1998) to provide containment under a variety of storm conditions, up to the 100-year storm event specified by USEPA. It was constructed at a cost of $9 million. In accordance with this guidance, an OMM plan was developed that was reviewed

and approved by USEPA. Periodic inspections continue to be conducted to assess the integrity of the temporary armored cap. The temporary armored cap has been further enhanced in accordance with the recommendations made by USACE (USACE 2013). Additional details on the history of the design and monitoring of the temporary armored cap are provided in Section 2.5.3.

Under this alternative, the controls installed as part of the TCRA and as a result of the TCRA reassessment would remain in place and no additional remedial action would be implemented. Since the temporary cap remedy was an early action that successfully reduced dioxin/furan exposure within the area by more than 80 percent (Anchor QEA 2012b) and additional work to enhance the temporary armored cap has since been completed, labeling Alternative 1N as the "No Action Alternative" is not accurate. However, under USEPA RI/FS (USEPA 1988), because the temporary cap construction was completed prior to the review of the array of potential remedies under the FS, the existing temporary cap remedy for procedural purposes is designated as being the "No Action" alternative. However, under this "No Action" option, the temporary armored cap would remain in place and would be subject to ongoing inspection and maintenance performed in accordance with the USEPA-approved OMM Plan.

In the San Jacinto River area surrounding the temporary cap (Preliminary Site Perimeter), including the sand separation area, the $TEQ_{DF,M}$ SWAC for sediment following completion of the temporary cap is approximately 12.5 ng/kg (Anchor QEA 2012b), which is well below the PRG for the hypothetical recreational fisher (30 ng.kg) or the hypothetical recreational visitors (200 ng/kg). No surface soil/sediment samples outside the temporary armored cap and within the Preliminary Site Perimeter have a $TEQ_{DF,M}$ concentration exceeding the waste material PRG of 200 ng/kg (Figure 3-1). The only sediment samples outside of the limits of the temporary armored cap with $TEQ_{DF,M}$ concentrations exceeding the PRG for hypothetical recreational visitors of 200 ng/kg are two subsurface sediment samples collected north of I-10 from one location (SJNE032, refer to Figure 2-4) near the sand separation area.

This alternative includes ongoing OMM of the Armored Cap, which includes inspection and periodic maintenance. The estimated cost of this alternative is $0.4 million (Appendix C).

4.3.2 Alternative 2N – Armored Cap, Institutional Controls and Monitored Natural Recovery

This alternative includes all of the elements discussed under Alternative 1N, plus ICs, Ground Water Monitoring, and MNR. ICs in the form of deed restrictions and notices would be implemented to place restrictions on dredging and anchoring to protect the integrity of

the armored cap and to limit potential disturbance and resuspension of buried sediment near the upland sand separation area. MNR would be used to achieve the Preliminary Remediation Goal for sediment (30 ng/kg) in the sand separation area and the Texas Surface Water Quality Standard in the San Jacinto River. Under this remedial alternative, the following ICs would be implemented:

- Restrictions on dredging and anchoring would be established to protect the integrity of the armored cap and to limit potential disturbance and resuspension of buried sediment near the sand separation area.
- Public notices and signage around the perimeter of the Site would be maintained or provided, as appropriate.

A periodic sampling and analytical program would also be implemented to monitor the progress of natural recovery and to insure that no contaminated ground water is migrating away from the site. The estimated cost for this alternative is $10.3 million (Appendix C).

4.3.3 Alternative 3N – Upgraded Cap, Institutional Controls, Ground Water Monitoring, and Monitored Natural Recovery

This alternative includes the actions described under Alternative 2N plus additional enhancements to the temporary armored cap to create the Upgraded Cap. This alternative will increase the long-term stability of the temporary armored cap consistent with isolation of impacted materials. ICs in the form of deed restrictions and notices would be implemented to place restrictions on dredging and anchoring to protect the integrity of the armored cap and to limit potential disturbance and resuspension of buried sediment near the upland sand separation area. MNR would be used to achieve the PRG for sediment (30 ng/kg) in the sand separation area and the Texas Surface Water Quality Standard in the San Jacinto River.

Cost estimates for this alternative also include additional measures to protect the Upgraded Cap from potential vessel traffic in the form of a protective perimeter barrier. In concept for this FS Report, these measures would include construction of a 5-foot high submerged rock berm outside the perimeter of the Upgraded Cap, in areas where vessels could potentially impact the cap. This concept was prepared as an FS-level assumption and would be more fully developed during the Remedial Design.

The temporary cap was constructed to provide immediate containment of the materials in the Site. As required in USEPA's Action Memorandum for the TCRA (USEPA 2010a, Appendix A), the containment method was chosen to be compatible with the final remedy

and meet applicable design criteria for degree of safety. As with any design, the degree of safety can be increased. For the temporary cap, that would involve flattening the slopes of the existing temporary cap by adding additional armor rock material to enhance the effectiveness and permanence of the temporary cap remedy by increasing the degree of safety for the armor rock design to create the Upgraded Cap.

The temporary armored cap was originally designed with an armor layer to provide containment of waste materials exceeding the PRG in the Northern Impoundments, as well as layers of geotextile and geomembrane. Armor materials were sized using a factor of safety of 1.3, which is greater than the suggested minimum factor of safety of 1.1 (USACE 1998) to provide additional protection of the temporary armored cap against catastrophic failure. In January 2014, further enhancements were made to the temporary armored cap in accordance with USACE recommendations (USACE 2013). To conduct the enhancement, the Respondents placed additional armor rock along the central and southern berms to flatten the slopes to 3 horizontal to 1 vertical (3H:1V), using rock sizes that meet or exceed USACE design criteria. The Upgraded Cap adds further robustness to the enhanced temporary armored cap design by using an even higher factor of safety of 1.5 for sizing the armor stone, and by flattening submerged slopes from 2 horizontal to 1 vertical (2H:1V) to 3H:1V and flattening the slopes in the surf zone from 3H:1V to 5 horizontal to 1 vertical (5H:1V), including areas that were enhanced by the Respondents in January 2014. In addition, the Upgraded Cap uses larger rock sized for the "No Displacement" design scenario. However, there is high degree of uncertainty on whether the implemented and planned cap upgrades in Alternative 3N will provide permanent isolation of impacted materials. The 2016 USACE Alternatives Evaluation Report that modelled Alternative 3N did not consider changing river conditions in its evaluation of the long term permanence of a cap; new channels eroding during flooding as well as changes in channel cross section due to bank erosion, shoreline breaches, etc. during a high flow event caused by a major flood or hurricane is beyond the ability of existing sediment transport models to simulate. Such changes occurred during the 1994 storm. In addition, the uncertainty associated with estimates of the effects of some of the potential failure mechanisms, e.g., propwash, stream instability, is very high (USACE 2016b). Finally, even more severe hurricanes that exceed Hurricane Ike, which was used in modelling, are possible (Hurricane Ike was a Category 2 hurricane). The modelling performed by the USACE of a hypothetical synoptic occurrence of Hurricane Ike and the October 1994 flood; the modelling estimated that approximately 80% of the upgraded Alternative 3N cap incurred erosion during the simulated extreme storm. The possibility that a more severe storm will occur are increased given the hundreds of years that the dioxin waste will remain hazardous. Therefore, there is a high degree of uncertainty regarding the long term permanence of the cap, even with the improvements suggested by the USACE.

The anticipated extent of the additional rock that would be placed during construction of a Upgraded Cap is shown in Figures 4-1 and 4-2, and would entail construction of 5H:1V slopes along the central, western and southern berms, and 3H:1V slopes over the submerged portion of the Northwestern Area, requiring placement of approximately 3,400 CY of armor rock.

Based on the production rates that were realized during the temporary cap construction, the duration of construction for this alternative is estimated to be 2 months (Table 4-3). During construction of the temporary cap, obtaining access to the work area from the uplands was a demonstrated challenge; construction of Alternative 3N will require that access from the uplands be obtained, and obtaining such access could be a challenge again. In addition, an off-site, river-side material staging area would be required to load the armor rock onto a barge for placement on the temporary armored cap. There are limited river-side facilities upstream of the I-10 Bridge that can be accessed by heavy construction equipment. Because of the limited clearance height of the I-10 Bridge, downstream river-side facilities have the disadvantage that the size of equipment that can traverse between the work area and the off-site staging area would be limited by I-10 bridge clearance.

This alternative is estimated to require 750-hours of heavy equipment operations, resulting in greenhouse gas, PM, and ozone-generating emissions, and 260 truck trips causing greenhouse gas, PM, and ozone-generating emissions, as well as traffic impacts. However, there are other sources of air emissions and traffic in the region, including the industrial activities that occur adjacent to the Site and the presence of I-10. Equipment and vehicle emissions of hydrocarbons and nitrogen oxides lead to the generation of smog, including ozone, which is a particular concern in Harris County which has been classified by USEPA as a "severe" non-attainment area for the 1997 8-hour ozone standard and a "moderate" non-attainment area for the 2008 8-hour ozone standard. Moreover, Harris County has not yet been classified for the 2012 fine particle particulate matter ($PM_{2.5}$) annual National Ambient Air Quality Standard (TCEQ 2013).

Using construction worker injuries and fatality rates published by the U.S. Department of Labor (USDL 2011), Alternative 3N is estimated to result in nearly 0.15 lost time injuries, and approximately 0.0006 fatalities as a result of construction. Although both of these safety statistics are below 1.0, they are useful for comparison purposes to the safety-related issues of the other alternatives. Further discussion of this comparison is provided in Section 6. Worker safety issues would be addressed during remedial design, and measures would include, at a minimum, development of detailed health and safety plans to help mitigate these risks.

The cost of this alternative is estimated to be $4.1 million (Appendix C).

4.3.3a Alternative 3aN – Upgraded Cap, Protective Pilings, ICs, Ground Water Monitoring, and MNR

This alternative includes the actions described under Alternative 3N plus additional enhancements suggested by the USACE. The additional enhancements are added to address the potential 80% erosion of the Upgraded Cap with Alternative 3N (Appendix A), and substantial erosion of the underlying paper mill waste material in a potential future severe storm that may occur with the cap design included under Alternative 3N. Cost estimates for this alternative also include additional measures to protect the Upgraded Cap from potential vessel traffic in the form of protective pilings. This alternative will increase the long-term stability of the temporary armored cap. ICs in the form of deed restrictions and notices would be implemented to place restrictions on dredging and anchoring to protect the integrity of the armored cap and to limit potential disturbance and resuspension of buried sediment near the upland sand separation area. MNR would be used to achieve the PRG for sediment (30 ng/kg) in the sand separation area and the Texas Surface Water Quality Standard in the San Jacinto River.

For costing purposes, the additional cap enhancements added for this alternative include pre-stressed concrete or concrete filled steel pipe pilings placed 30 feet apart around the perimeter of the cap to protect from barge strikes. The spacing is designed to catch a typical barge, which is 35 feet wide. An additional armor stone cap with a thickness of at least 24 inches would be placed over the armor cap for Alternative 3N. The armor stone would have a median diameter of 15 inches. This additional armor stone would cover 13.4 acres of the 17.1 acre armored cap. Also, a course gravel filter layer would be placed on 1.5 acres of the Northwest Area where there is currently no geotextile under the armor cap. The actual scope and design of the cap enhancements, and additional area needed to construct the required slopes, would be determined in the Remedial Design. This additional weight of rock on top of the waste pits may cause cap settling and/or pushing the waste material out the sides of the cap; the Remedial Design will consider the significance of and design issues related to this. Monitored Natural Recovery would be used to achieve the PRG for sediment in the Sand Separation Area and the Texas Surface Water Quality Standard in the San Jacinto River.

The temporary armored cap was originally designed with an armor layer to provide containment of waste materials exceeding PRGs in the Northern Impoundments, as well as layers of geotextile and geomembrane. The armor materials were sized using a factor of safety of 1.3, which is greater than the suggested minimum factor of safety of 1.1 (USACE 1998) to provide additional protection of the temporary armored cap against catastrophic failure. In January 2014, further enhancements were made to the temporary armored cap in accordance with USACE recommendations (USACE 2013). The Alternative 3aN Enhanced Cap adds robustness to the enhanced temporary armored cap design by flattening submerged

slopes from 2 horizontal to 1 vertical (2H:1V) to 3H:1V and flattening the slopes in the surf zone from 3H:1V to 5 horizontal to 1 vertical (5H:1V), including areas that were enhanced by the Respondents in January 2014.

As stated in the discussion of Alternative 3N, the USACE 2016 Alternative Evaluation report did not consider changing river conditions in its evaluation of the long term permanence of a cap; new channels eroding during flooding as well as changes in channel cross section due to bank erosion, shoreline breaches, etc. during a high flow event caused by a major flood or hurricane is beyond the ability of existing sediment transport models to simulate. Such changes occurred during the 1994 storm. In addition, the uncertainty associated with estimates of the effects of some of the potential failure mechanisms, e.g., propwash, stream instability, is very high (USACE 2016b). Even more severe hurricanes that exceed Hurricane Ike, which was used for modelling, are possible (Hurricane Ike was a Category 2 hurricane). While the USACE speculated that increasing the median diameter of the rock used in the armor cap, as proposed in Alternative 3aN, would reduce the amount of scour that occurred during the extreme hypothetical storm (the synoptic occurrence of Hurricane Ike and the October 1994 storm), this was not modelled. The possibility that a more severe storm will occur are increased given the hundreds of years that the dioxin waste will remain hazardous especially given changing climate conditions (Melillo, et. al. Eds, 2014, Third National Climate Assessment, 2014). Therefore, there is a high degree of uncertainty regarding the long term permanence of the cap, even with the improvements (Alternative 3aN) for an enhanced cap.

The duration of construction for this alternative is estimated to be 15 months (Table 4-3). The implementability issues discussed for Alternative 3N also apply to Alternative 3aN, with increased truck loads, emissions, and worker safety issues in relation to the increased construction required for this Alternative. An off-site, river-side material staging area would be required to load the armor rock onto a barge for placement on the temporary armored cap. There are limited river-side facilities upstream of the I-10 Bridge that can be accessed by heavy construction equipment. Because of the limited clearance height of the I-10 Bridge, downstream river-side facilities have the disadvantage that the size of equipment that can traverse between the work area and the off-site staging area would be limited by I-10 bridge clearance.

The cost of this alternative is estimated to be $24.8 million (Appendix C).

4.3.4 Alternative 4N – Partial Solidification/Stabilization, Upgraded Cap, Institutional Controls, Ground Water Monitoring, and Monitored Natural Recovery

This remedial alternative provides for solidification and stabilization (S/S) of the most highly contaminated material. A dioxin/furan value that exceeds 13,000 ng/kg $TEQ_{DF,M}$ within the USEPA's Preliminary Site Perimeter was used to define the most highly contaminated material. The extent of the area for partial S/S was defined, based on sediment and soil chemistry results presented in the RI Report, as the Western Cell and a portion of the Eastern Cell that is currently covered by the temporary cap. Based on the analysis of sediment core samples presented in Figure 2-4, the maximum depth of S/S in the Western Cell would be to approximately 10-feet below the current base of the temporary armored cap and on average approximately 5-feet below the current base of the temporary armored cap in the Eastern Cell and Northwestern Area. An Upgraded Cap as described in Alternative 3N is also included in this remedial alternative. ICs in the form of deed restrictions and notices would be implemented to place restrictions on dredging and anchoring to protect the integrity of the armored cap and to limit potential disturbance and resuspension of buried sediment near the upland sand separation area. MNR would be used to achieve the PRG for sediment (30 ng/kg) in the sand separation area and the Texas Surface Water Quality Standard in the San Jacinto River.

Figure 4-3 presents a plan view of the partial S/S remedial alternative. Figure 4-4 presents a cross section of this remedial alternative to give a typical representation of the depth of S/S.

S/S treatment could be accomplished using large-diameter augers or conventional excavators, similar to those that were used to treat portions of the sediment in the Western Cell during the TCRA. Both technologies are discussed in the RAM. Before treating the sediment, the affected portions of the temporary armored cap armor rock would need to be removed and stockpiled for reuse, if possible, or washed to remove adhering sediment and disposed in an appropriate upland facility. The geotextile and geomembrane would need to be removed and disposed of as contaminated debris. S/S reagents, such as Portland cement, would be delivered to the project work area, stockpiled, and mixed with sediment, as needed, to treat the sediment in situ. Submerged areas to be stabilized would need to be isolated from the surface water with sheet piling and mostly dewatered prior to mixing with treatment reagents using conventional or long reach excavators in a fashion similar to the S/S work completed during the TCRA. For FS purposes, a sheet pile enclosure with a top elevation 2-feet above typical mean higher high water, or 3.5-feet North American Vertical Datum of 1988 (NAVD88), has been assumed. Following completion of the S/S operation in submerged areas the sheet pile enclosure would be removed. Finally, the Upgraded Cap, as described in Alternative 3N, would be constructed, including replacement of the armor rock layer

geomembrane and geotextile over the S/S footprint, and the measures described in Section 4.3.3 to protect the Upgraded Cap from vessel traffic would be implemented.

The estimated footprint of this alternative is approximately 2.6 acres in the Western Cell and 1.0 acre of submerged sediment spanning the Eastern Cell and the Northwestern Area (Figure 4-3). Based on the horizontal and vertical limits identified for this alternative, a total of approximately 52,000 CY of waste material would be treated.

Using production rates similar to that achieved during the TCRA, this alternative has an estimated construction duration of 17 months (Table 4-3). As with Alternative 3N, access to the work area from the uplands will be required and could be a challenge, and an off-site staging area would be necessary to manage the materials generated during removal of the temporary armored cap, and to stockpile and load the new armor rock materials to be placed for construction of the Upgraded Cap. Compared to Alternative 3N, this off-site facility would need to be larger because of the need to manage the Armor Cap rock that is removed.

This alternative is estimated to require 5,450-hours of heavy equipment operations, and approximately 1,600 truck trips causing higher greenhouse gas, PM, and ozone-generating emissions and traffic impacts than the previous three alternatives. However, there are other sources of air emissions and traffic in the region, including the industrial activities that occur adjacent to the Site and the presence of I-10.

Alternative 4N is estimated to result in more than one lost time injury, and approximately 0.004 fatalities as a result of construction. Worker safety issues would be addressed during remedial design, and measures would include, at a minimum, development of detailed health and safety plans to help mitigate these risks. Ground water monitoring would be implemented to ensure that there are no long-term unacceptable impacts to ground water resulting from the waste left in place.

The cost of this alternative is estimated to be $14.8 million (Appendix C).

4.3.5 Alternative 5N – Partial Removal, Upgraded Cap, Institutional Controls, Ground Water Monitoring, and Monitored Natural Recovery

This remedial alternative provides for removal of the most highly contaminated material. A dioxin/furan value that exceeds 13,000 ng/kg $TEQ_{DF,M}$ within the USEPA's Preliminary Site Perimeter was used to define the most highly contaminated material. The lateral and vertical extent and volume of sediment removed under this alternative is the same as the sediment to be treated as described in the previous section for Alternative 4N and is depicted on Figures 4-5 and 4-6. About 52,000 CY of material would be excavated and treated as

required for off-site disposal. Construction of a Upgraded Cap, ICs, and MNR, as described in Alternative 3N, are also included in this remedial alternative.

ICs in the form of deed restrictions and notices would be implemented to place restrictions on dredging and anchoring to protect the integrity of the armored cap and to limit potential disturbance and resuspension of buried sediment near the upland sand separation area. MNR would be used to achieve the PRG for sediment (30 ng/kg) in the sand separation area and the Texas Surface Water Quality Standard in the San Jacinto River.

To mitigate potential water quality issues, submerged areas would need to be isolated using berms, sheet piles, and/or turbidity barrier/silt curtains prior to excavating sediment. Upland areas would not need to be isolated with sheet piling, but the excavation would require continuous dewatering and may need to be timed to try to avoid high water and times of year when storms are most likely.

Excavated sediment would be dewatered and potentially treated to eliminate free liquids prior to transporting it for disposal. Effluent from excavated sediment dewatering would need to be handled appropriately, potentially including treatment prior to disposal. Following completion of the excavation, the work area would be backfilled to replace the excavated sediment and then the Upgraded Cap would be constructed, including replacing the armor rock layer above the excavation footprint and the geomembrane and geotextile layers.

The construction duration for this alternative is estimated to be 13 months (Table 4-3). This alternative is estimated to require almost 7,000-hours of heavy equipment operations and more than 9,300 truck trips causing higher greenhouse gas and PM, ozone generating emission, and traffic impacts as compared to the previous four alternatives.

As with Alternatives 3N and 4N, access to the work area from the uplands will be required and could be a challenge. An off-site facility would need to be identified and secured to manage materials removed (including dewatering, transloading, and shipping) and to stockpile and load imported armor rock. Given the nature of the material being managed at the facility, locating a suitable property and willing landowner could be difficult.

Off-site transport of materials for disposal presents a risk for spills and accidents, which could result in exposure of these materials to the general public. Alternative 5N is estimated to result, on average, in more than 1 non-fatal lost time injury, and approximately 0.006 fatalities as a result of construction. Worker safety issues would be addressed during remedial design, and measures would include, at a minimum, development of detailed health and safety plans to help mitigate these risks. Ground water monitoring would be implemented to ensure that there are no long-term unacceptable impacts to ground water resulting from the waste left in place.

The cost of this alternative is estimated to be $29.8 million (Appendix C).

4.3.6 Alternative 5aN – Partial Removal of Materials Exceeding the PRG, Upgraded Cap, Institutional Controls and Monitored Natural Recovery

For this removal alternative, the PRG for waste materials for a hypothetical recreational visitor (200 ng/kg $TEQ_{DF,M}$) was considered for the area within the temporary armored cap which is either above the water or where the water depth is 10 feet or less. As an additional criterion, locations exceeding 13,000 ng/kg $TEQ_{DF,M}$ are also included regardless of water depth; however, all samples exceeding 13,000 ng/kg $TEQ_{DF,M}$ are located in areas where the water depth is 10 feet or less. About 137,600 CY would be excavated and treated as required for off-site disposal. ICs in the form of deed restrictions and notices would be implemented to place restrictions on dredging and anchoring to protect the integrity of the armored cap and to limit potential disturbance and resuspension of buried sediment near the upland sand separation area. MNR would be used to achieve the PRG for sediment (30 ng/kg) in the sand separation area and the Texas Surface Water Quality Standard in the San Jacinto River.

The lateral and vertical extents of the removal under this remedial alternative are presented in Figures 4-7 and 4-8. As with the Alternatives 4N and 5N, the existing temporary armored cap (consisting of cap rock, geomembrane and geotextile) which currently isolates and contains impacted material would need to be removed prior to beginning excavation work.

This alternative also includes an engineered barrier to manage water quality during construction. In shallow water areas (water depths up to approximately 3 feet), this barrier would be constructed as an earthen berm, extending to an elevation at least 2 feet above the high water elevation in consideration of wind-generated waves and vessel wakes. The berm would be limited to a total height of 4 to 5 feet above the existing mudline for constructability reasons: as the berm height increases, the base width increases and it can be challenging to efficiently construct taller berms because they become wider at their base than the reach of a typical excavator. In areas with water depths deeper than about 3 feet, the berm would transition into a sheet pile barrier around the work area. Figure 4-7 depicts the approximate limits where the earthen berm and sheet pile barriers could potentially be constructed.

Work would be conducted in the wet. Excavated sediment would be offloaded, dewatered and stabilized at a dedicated offloading location, as necessary, to eliminate free liquids for transportation and disposal. Following removal of impacted sediment, the area from which sediments are removed would be covered with a residuals management layer of clean cover material. In the deeper water areas of the Site where removal is not conducted, the existing temporary armored cap would be maintained.

This alternative entails removal of approximately 137,600 CY of waste material from the waste pits, which would require a relatively large offloading and sediment processing facility to efficiently accomplish the work. As with Alternative 5N, the challenges with locating such a facility could be significant and are magnified because a larger site would potentially be needed to manage the greater volume of material removed (including dewatering, transloading, and shipping) and to stockpile and load imported armor rock. Alternative 5aN is estimated to have a construction duration of 19 months (Table 4-3).

This alternative is estimated to require approximately 15,665 hours of heavy equipment operations and over 12,855 truck trips, resulting in higher greenhouse gas and PM, ozone generating emissions, and traffic impacts as compared to the previous five alternatives. However, there are other sources of air emissions and traffic in the region, including the industrial activities that occur adjacent to the Site and the presence of I-10. Off-site transport of materials for disposal presents a higher risk for spills and accidents compared to Alternative 5N, which could result in exposure of these materials to the general public. Using an additive drying amendment such as lime or Portland cement could result in fugitive dust emissions at the offloading/processing area, however measures would be implemented to control dust.

Alternative 5aN is estimated to result in approximately 3 lost time non-fatal injuries, and approximately 0.01 fatalities as a result of construction. Worker safety issues would be addressed during remedial design, and measures would include, at a minimum, development of detailed health and safety plans to help mitigate these risks.

The cost of this alternative is estimated to be $69.6 million (Appendix C).

4.3.7 Alternative 6N – Full Removal of Waste Materials Exceeding the PRG, Institutional Controls, and Monitored Natural Recovery

For the full removal alternative, the hypothetical recreational visitor exposure scenario was considered for area north of I-10. The PRG for waste materials for protection of the hypothetical recreational visitor is a $TEQ_{DF,M}$ concentration of 200 ng/kg. The lateral and vertical extents of the removal under this remedial alternative are presented in Figures 4-9 and 4-10. This would involve removal of most of the existing temporary armored cap and the removal of 152,000 CY of material, which would be treated as required for off-site disposal. The work area would be isolated with best management practices (BMPs) to reduce resuspension releases to the maximum extent practicable. Best management practices may include raised/armored berms, sheet piles, excavation procedures including excavation in the dry where practicable, and/or with turbidity barrier/silt curtains. Containment structures to reduce resuspension would consist of berms and sheet pile walls or caissons to an elevation of about +10 NAVD88 (protection from 25-year or 50-year flood stage, Appendix A). If

performing excavation of the waste materials in the dry, the top of the berms would preferably be no lower than +5 NAVD88 (protection from 5-year or 10-year flood stage, Appendix A). The specific BMPs and their design and application will be determined during the Remedial Design. ICs in the form of deed restrictions and notices would be implemented to place restrictions on dredging and anchoring to prevent disturbance of any residuals and to limit potential disturbance and resuspension of buried sediment near the upland sand separation area. MNR would be used to achieve the PRG for sediment (30 ng/kg) in the sand separation area and the Texas Surface Water Quality Standard in the San Jacinto River.

As with the partial removal alternatives, cap rock, geomembrane and geotextile from the existing temporary armored cap, which currently isolates and contains impacted material, would need to be removed prior to beginning excavation within the waste pits. Similarly, upland excavation could require dewatering to allow excavation of impacted sediment in relatively dry conditions. Excavated sediment would be further dewatered and stabilized at the offloading location, as necessary, to eliminate free liquids for transportation and disposal. Some operations, such as water treatment, could be barge mounted. Following removal of the waste material, the area from which sediments are removed would be covered with two residuals management layers of clean sediment to reduce intermixing.

This alternative entails removal of approximately 152,000 CY of waste material from the waste pits, which would require a relatively large offloading and sediment processing facility to efficiently accomplish the work, which would require barge unloading, sediment re-handling, dewatering, stockpiling, transloading, and shipping to the off-site landfill facility. Additional activities would include management and disposal of dewatering effluent, including treatment if necessary.

Alternative 6N is estimated to have a construction duration of 19 months (Table 4-3). The monitoring program will be designed during the Remedial Design, but may include the collection of fish, sediment, and surface water samples and evaluation of the data. Similar to the issues described for Alternatives 5N and 5aN, locating an adjacent facility with sufficient space and availability for more than a year of use for staging, offloading, and waste processing is considered to be a challenge to the implementability of Alternative 6N.

This alternative is estimated to require approximately 11,800 hours of heavy equipment operations and approximately 13,300 truck trips, resulting in higher greenhouse gas and PM, ozone generating emissions, and traffic impacts as compared to the Alternatives 1N through 5N. However, there are other sources of air emissions and traffic in the region, including the industrial activities that occur adjacent to the Site and air emissions related to the presence of I-10. Off-site transport of materials for disposal presents a higher risk for spills and accidents compared to Alternative 5N, which could result in exposure of these materials to the general

public. However, transportation of hazardous substances with the appropriate controls in place to prevent spills is a commonplace activity at Superfund sites. Using an additive drying amendment such as lime or Portland cement could result in fugitive dust emissions at the offloading/processing area, however, measures would be implemented to control dust as determined during the Remedial Design.

Alternative 6N is estimated to result in more than 3 lost time non-fatal injuries, and approximately 0.01 fatalities as a result of construction. Worker safety issues would be addressed during the Remedial Design, and measures would include, at a minimum, development of detailed health and safety plans to help prevent and mitigate these risks.

The cost of this alternative is approximately $87 million (Appendix C).

4.4 Remedial Alternatives for the Area South of I-10

4.4.1 Alternative 1S – No Further Action

This alternative serves as the baseline of comparison for the other remedial alternatives. The NCP requires the development and evaluation of this alternative (40 CFR 300.430(e)(6)). Under this remedial alternative for the area of investigation south of I-10, impacted soil would remain in place and no steps would be taken to alert future landowners or construction workers of the presence, at depth, of $TEQ_{DF,M}$ concentrations exceeding the PRG for soil. The estimated cost for this alternative, is $0.

4.4.2 Alternative 2S – Institutional Controls and Ground Water Monitoring

The PRG for soil for the hypothetical future construction worker is based on exposure assumptions that include contact with the soil interval from the surface to 10 feet below grade.

The BHHRA concluded that there are no unacceptable risks associated with surface soil (soil from 0 to 6 inches below ground surface). The arithmetic mean of $TEQ_{DF,M}$ concentrations in surface soil is 13.3 ng/kg, which is well below the soil screening level (51 ng.kg) that allows for unlimited use and unrestricted exposure. The highest $TEQ_{DF,M}$ concentration observed in surface soil, 36.9 ng/kg (Sample SJSB023, refer to Figure 2-5), is also below this soil screening level.

This alternative would apply to locations in the area south of I-10 where the average $TEQ_{DF,M}$ concentration in the upper 10-feet of soil below grade exceeds the risk-based PRG for soil for the hypothetical future construction worker (240 ng/kg).

Under this remedial alternative, the following ICs would be implemented:

- Deed restrictions would be applied to parcels in which the depth-weighted average $TEQ_{DF,M}$ concentrations in upper 10-feet of soil exceed the soil PRG for a hypothetical future construction worker (Figure 4-11).
- Notices would be attached to deeds of affected properties to alert potential future purchasers of the presence of waste and soil with $TEQ_{DF,M}$ concentrations exceeding the soil PRG.

The estimated cost for this remedial alternative is $1.02 million (Appendix C).

4.4.3 Alternative 3S – Enhanced Institutional Controls and Ground Water Monitoring

This remedial alternative would incorporate the ICs identified in Section 4.4.2 and add physical features to enhance the effectiveness of the ICs. The physical features would include bollards to define the areal extent of the remedial action areas at the surface and a marker layer that would alert workers digging in the area that deeper soil may be impacted. Figure 4-11 shows the locations of the remedial action areas south of I-10.

Implementation of this remedial alternative may include the following steps:

- Removing up to 2 feet of surface soil.
- Temporarily stockpiling the soil on-site.
- Placing the marker layer (such as a geogrid or similar durable and readily visible material) at the bottom of the excavation.
- Returning the soil to the excavation and re-establishing vegetative cover.
- Placing bollards at the corners of the remedial action areas.

The duration of construction for this remedial alternative is estimated to be 1 month (Table 4-4). This alternative is estimated to require approximately 160 hours of heavy equipment operations, resulting in greenhouse gas, PM, and ozone-generating emissions. However, there are other sources of air emissions and traffic in the region, including the industrial activities that occur adjacent to the Site and the presence of I-10. Alternative 3S is estimated to result in 0.015 lost time injury and 0.0001 fatalities as a result of construction. The estimated cost for this remedial alternative is $1.4 million (Appendix C).

4.4.4 Alternative 4S – Removal and Off-site Disposal

This remedial alternative involves excavation and replacement of soil in the three remedial action areas shown in Figure 4-11. Soil would be removed within these areas to a depth of 10 feet below grade. Implementation of this remedial alternative would require dewatering (groundwater lowering) to allow excavation of impacted soil in relatively dry conditions and may need to be timed to try to avoid high water and periods when storms are most likely. Excavated soil would be further dewatered, as necessary, and potentially treated to eliminate free liquids prior to transporting it for disposal. Effluent from excavation and subsequent dewatering would need to be handled appropriately, potentially including treatment prior to disposal. Excavated soil would be disposed of at an existing permitted landfill, the excavation would be backfilled with imported soil, and vegetation would be re-established. Pavement on Market Street adjacent to Remedial Action Area South 1 (Figure 4-11) would be repaired.

An existing building (an elevated frame structure) and a concrete slab within Remedial Action Area South 3 (Figure 4-11) would need to be demolished and removed prior to excavating the underlying soil. These features would be replaced, if necessary.

The removal volume (50,000 CY) was calculated assuming a conservative excavation side slope of 2 horizontal to 1 vertical. Transportation and disposal costs were estimated assuming that all of the excavated material would be transported to a licensed landfill for disposal. During remedial design, potential cost savings associated with segregating clean soil and using it as backfill may be explored.

Appropriate containment and controls for dust and runoff would be provided for any soil stockpiles or soil amendment areas that may be required. Trucks would be inspected and decontaminated, as necessary, before they would be released from the site to avoid tracking soil from the work site onto public roads.

The duration of construction for this remedial alternative is estimated to be 7 months (Table 4-4). This alternative is estimated to require approximately 900 hours of heavy equipment operations and more than 7,000 truck trips, resulting in greenhouse gas and PM, and ozone-generating emissions. However, there are other sources of air emissions and traffic in the region, including the industrial activities that occur adjacent to the Site and the presence of I-10. Alternative 4S is estimated to result in 0.088 lost time injury and 0.0004 fatalities as a result of construction. The estimated cost for this remedial alternative is $9.9 million (Appendix C).

5 DETAILED ANALYSIS OF REMEDIAL ALTERNATIVES

As discussed in Section 4, the detailed evaluation of remedial alternatives is based on consideration of the following criteria, as required by the NCP, 40 CFR Section 300.430(e)(9):

1. Overall protectiveness of human health and the environment
2. Compliance with ARARs
3. Long-term effectiveness and permanence
4. Reduction of toxicity, mobility or volume through treatment
5. Short-term effectiveness
6. Implementability
7. Cost
8. State/Support Agency acceptance
9. Community acceptance

The first two criteria, overall protectiveness and compliance with ARARs, are identified as threshold criteria in 40 CFR Section 300.430(f). Remedial alternatives must satisfy the threshold criteria to be selected as the final remedy, although ARAR waivers may be considered in some circumstances. The next five criteria are identified as primary balancing criteria. The comparative analysis considers the anticipated performance of the remedial alternatives relative to these balancing criteria. The final two criteria, identified as modifying criteria, are considered by USEPA in preparing the ROD based on consultation with the State environmental agency and public comments received in response to the FS Report and the proposed plan. Item 39 of the Statement of Work attached to the UAO states that the modifying criteria are not to be considered in the comparative analysis in this FS Report. Information related to the modifying criteria are therefore not provided in this section.

The first seven criteria, as presented in 40 CFR 300.430(f), are briefly defined below:

- *Overall protectiveness of human health and the environment* is an evaluation of whether the remedial alternative can adequately protect human health and the environment. This may be expressed as an assessment of whether the remedial alternative addresses all of the RAOs, which are identified and described in Section 2.

- *Compliance with ARARs* is an evaluation of whether the remedial alternative addresses or can be implemented in compliance with all of the ARARs, which are identified in Table 3-1. Section 121 (d) of CERCLA and NCP §300.430(f)(1)(ii)(B) require that remedial actions at CERCLA sites at least attain legally applicable or relevant and appropriate Federal and State requirements, standards, criteria, limitations which are collectively referred to as "ARARs," unless such ARARs are waived under CERCLA section 121(d)(4) and NCP §300.430(f)(1)(ii)(C).

- *Long-term effectiveness and permanence* is an evaluation of the ability of the remedial alternative to reliably maintain protection of receptors.

- *Reduction of toxicity, mobility or volume through treatment* is an evaluation of the degree to which treatment or recycling of affected media is used to reduce the TMV of contaminated media, particularly principal threats.

- *Short-term effectiveness* is an evaluation of both the time required for the remedial alternative to achieve full protection and the degree to which potential risk to human health and the environment is increased during implementation of the remedy, considering measures that may be used to mitigate short-term risks until cleanup levels are achieved. The short-term effectiveness evaluation also includes an evaluation of the sustainability of the remedial alternative in conformance with the USEPA Region 6 Clean and Green Policy (USEPA 2009c).

- *Implementability* is an evaluation of the technical and administrative feasibility of a remedy from design through construction and operation. Factors such as availability of services and materials, administrative feasibility, and coordination with other governmental entities are also considered. Technical factors include consideration of whether the remedial alternative involves the use of well demonstrated technologies, readily available equipment and materials, and whether any physical conditions of the project work area may impede implementation. Administrative factors include consideration of whether implementation of the remedial alternative might be impeded by the need to obtain approvals from nearby landowners or public agencies.

- *Cost* is an evaluation of construction and long-term operation, maintenance, and monitoring costs. A present-worth cost analysis is typically used to evaluate the total cost of remedial alternatives. Both CERCLA and the NCP, require that remedies be cost-effective (42 U.S. Code [U.S.C.] §9621(a); 40 CFR §300.430(f)(1)(ii)(D)): "Each remedial action selected shall be cost-effective" (40 CFR §300.430(f)(1)(ii)(D)). Cost-effectiveness is defined as "costs are proportional to its overall effectiveness." (40 CFR §300.430(f)(1)(ii)(D)). Pursuant to the USEPA's 1999 guidance, A Guide to Preparing Proposed Plans, Records of Decision, and Other Remedy Selection Documents, "cost-

effectiveness is concerned with the reasonableness of the relationship between the effectiveness afforded by each alternative and its costs compared to other available options." Moreover, "if the difference in effectiveness is small but the difference in cost is very large, a proportional relationship between the alternatives does not exist" (Federal Register 1990). These proportionality requirements were reiterated by USEPA in the above-cited guidance. The present costs presented below are based on a 7% discount rate.

This section describes the individual analyses for each of the alternatives for the areas north and south of I-10. Table 5-1 summarizes the key discussion points from this section for each of the evaluation criteria for area north of I-10. Table 5-2 summarizes the same information for the area south of I-10.

5.1 Area North of I-10

5.1.1 Alternative 1N – Temporary Armored Cap and Ongoing OMM (No Further Action)

5.1.1.1 Overall Protection of Human Health and the Environment

This alternative will only remain protective if it is properly maintained for the length of time (hundreds of years) that the impounded waste retains its toxicity, and its integrity is not compromised by extreme weather events, barge strikes and/or changes in the river channel which could result in a future release. As discussed in Section 2.5, for the area north of I-10 the temporary cap resulted in capping and isolation of all sediment samples with $TEQ_{DF,M}$ concentrations exceeding the applicable soil PRG, except for those located within a small area of subsurface sediment near the sand separation area (located to the northwest of the waste pits). Based on data from the RI study, the subsurface sediment near the sand separation area is isolated from potential receptors by several feet of sediment with $TEQ_{DF,M}$ concentrations below the sediment PRG for hypothetical recreational fisher.

5.1.1.2 Compliance with ARARs

Alternative 1N would not result in construction impacts or other changes to baseline conditions that would trigger any action-, chemical-, or location-specific ARARs identified in Table 3-1. Under these post-TCRA conditions, there are no documented exceedances of surface water quality standards within the USEPA's Preliminary Site Perimeter due to the presence of dioxins and furans from the impoundments.

5.1.1.3 Long-Term Effectiveness

Alternative 1N would not affect long-term residual risks nor would it affect or enhance the reliability of existing controls. The long-term effectiveness of this remedial alternative was evaluated considering the potential for natural forces or human activity to expose the waste material or sediment with $TEQ_{DF,M}$ concentrations that exceed the applicable risk-based PRGs. Sediment in the vicinity of the sand separation area is stable and net sedimentation in this area is expected to provide continued isolation at this buried location; however, propeller wash from tug boat operations, or severe flooding and/or storms could disturb these sediments. Monitoring will be required to determine sedimentation is occurring.

The dioxin within the waste pits was generally isolated from potential receptors by the temporary cap, but the temporary cap has required many repairs and extensive maintenance. Examples include, in December 2015, an area of missing rock that was found by the EPA Dive Team. This area was not identified by the regular inspections that had been done since the temporary cap construction was completed. Dioxin at 43,000 ng/kg was under water exposing the environment and potential receptors to the dioxin. Repairs to this area were completed in 2016. Other instances of thin or absent rock cover were identified in 2012, 2013, and in 2016. No flood since the cap was constructed in 2011 has exceeded a 100-year return period design flood.

Work implementing USACE 2013 recommendations to enhance the cap's long-term stability was completed in January 2014. This remedial alternative does not include alerting future landowners of the temporary cap to the potential risks associated with activities that may involve exposing the capped sediment, and does not include placing restrictions on dredging or anchoring at the temporary cap. The protection provided by the temporary armored cap would be continued through long-term monitoring and maintenance, which will be required for as long as the dioxin/furan represents an unacceptable risk should exposure occur. Monitoring may involve collecting and analyzing sediment, tissue, surface water, and ground water samples and evaluating the data. Dioxins and furans are persistent contaminants that will not readily break down. While there is much uncertainty regarding how long the waste materials will represent an unacceptable risk should exposure occur, however, the EPA estimates that, for dioxins that are not exposed to sunlight, the dioxin half-life ranges from 25 to 100 years.

5.1.1.4 Reduction of Toxicity, Mobility or Volume

Alternative 1N would not include additional reduction of TMV through treatment. However, it is important to note that sediment in the Western Cell was treated with

Portland cement during the temporary cap construction for equipment access that also reduced the mobility of the waste material. Over the long-term, ongoing deposition may result in declines in surface sediment concentrations. Natural deposition is expected to cover the site; however, deposition rates are low in most areas, particularly shallow areas. Further, should the river geometry change as a result of extreme erosion that was documented during the 1994 flood, then the predicted deposition may not occur.

In addition, disturbance from propeller wash due to activities from barge operations in the San Jacinto River could cause locally greater erosion than that modeled during flood events depending on the water depth, the size of the vessel, and the duration of vessel operations. Such disturbance could cause changes in concentration of $TEQ_{DF,M}$ in the area of erosion and its vicinity. Alternative 1N does not include measures to protect against barge strikes. Sediment in the footprint of the temporary armored cap is generally isolated from exposure at the surface by layers of geotextile, geomembrane, and cap rock except for areas in the underwater portions of the northwest part of the cap, for example, that do not contain geotextile or geomembrane.

5.1.1.5 Short-Term Effectiveness

There are no short-term risks to the community, ecological receptors, or workers associated with the implementation of this remedial alternative.

5.1.1.6 Implementability

There are no technical or administrative implementability issues associated with this remedial alternative. Monitoring the temporary armored cap, which is required under the USEPA-approved OMM Plan and is part of this remedial alternative, should not pose implementability challenges.

5.1.1.7 Cost

The estimated cost associated with this remedial alternative is $0.4 million (Appendix C) for temporary armored cap construction and for implementing the existing OMM Plan for the temporary armored cap, signs, buoys and fencing. Costs include monitoring, maintenance events, and USEPA 5-year reviews as described in Appendix C, and are based on access to the Site being available from the river and through the TxDOT right-of-way (ROW). Long term monitoring events will be required for as long as an unacceptable risk from the dioxin/furan remain.

5.1.2 Alternative 2N – Armored Cap, Institutional Controls, Ground Water Monitoring, and Monitored Natural Recovery

5.1.2.1 Overall Protection of Human Health and the Environment

This alternative will only remain protective if it is properly maintained for the length of time (hundreds of years) that the impounded waste retains its toxicity, and its integrity is not compromised by extreme weather events, barge strikes and/or changes in the river channel which could result in a future release. This remedial alternative would achieve the RAOs through a combination of ICs, MNR, ground water monitoring, and existing engineering controls. MNR would be used to achieve the PRG for sediment (30 ng/kg) in the sand separation area and the Texas Surface Water Quality Standard in the San Jacinto River. As noted in Section 5.1.1, the temporary armored cap is protective of human health and the environment in the near term. Waste material and sediment with $TEQ_{DF,M}$ concentrations exceeding the applicable PRGs are isolated from potential receptors by the temporary armored cap or by sediment with $TEQ_{DF,M}$ concentrations below the PRGs. ICs would be used to:

- Alert property owners of the presence of subsurface materials exceeding PRGs.
- Describe the need for protective equipment and training if excavation of subsurface materials exceeding PRGs is required in the waste pit footprint.
- Describe requirements for the management of any excavated soil or sediment exceeding PRGs.
- Describe the need to restore the temporary armored cap following any disturbance.
- Establish limitations on dredging and anchoring within the footprint of the temporary armored cap by requesting, in accordance with 33 CFR 165.5, that the U.S. Coast Guard District Commander establish a regulated navigation area.

Affected sediment near the sand separation area, which is already isolated from potential receptors by several feet of sediment with $TEQ_{DF,M}$ concentrations below the PRG, may be further isolated by deposition of additional sediment through ongoing natural recovery processes. Monitoring may involve collecting and analyzing sediment, tissue, surface water, and ground water samples and evaluating the data. Monitoring of sediment conditions in this area would be performed to confirm that deposition of new sediment was continuing to maintain surface $TEQ_{DF,M}$ concentrations below the PRG for hypothetical recreational

visitors. The MNR plan would include methods for assessing whether deposition or erosion were occurring at monitoring stations between monitoring events. Monitoring may involve collecting and analyzing sediment, tissue, surface water, and ground water samples and evaluating the data. Ground water monitoring would be implemented to ensure that there are no long-term unacceptable impacts to ground water resulting from the waste left in place. The actual scope and timeline of monitoring would be determined in coordination with USEPA during remedial design and during implementation of the monitoring program over the years.

5.1.2.2 Compliance with ARARs

Alternative 2N would involve a minimal amount of physical activity for the implementation of ICs (e.g., landowner notifications; restrictions on dredging and anchoring) and ongoing implementation of existing engineering controls. For the same reasons presented in the ARAR compliance discussion under Alternative 1N (Section 5.1.1.2), due to the minimal amount of active construction involved, Alternative 2N is also expected to generally meet the substantive requirements of the ARARs presented in Section 3.4.

5.1.2.3 Long-Term Effectiveness

The long-term effectiveness of this remedial alternative is primarily derived from the temporary cap completed in 2011 and the ICs that would help protect the integrity of the cap. Long-term effectiveness is also provided by the layers of surface soil and sediments with concentrations below PRGs and the monitoring that would confirm the continued deposition of clean sediment isolating the affected sediment outside of the footprint of the temporary armored cap. Long-term simulations conducted with the fate and transport model indicate the surface sediment concentrations averaged over the USEPA's Preliminary Site Perimeter are predicted to decline by a factor of 2 over an approximate 10- to 15-year time period (see Appendix A); monitoring would be conducted to verify actual reductions in sediment concentrations.

The long-term effectiveness of this alternative is dependent on the continued integrity of the armored cap. The dioxin within the waste pits was generally isolated from potential receptors by the temporary cap, but the temporary cap has required many repairs and extensive maintenance. Examples include, in December 2015, an area of missing rock that was found by the EPA Dive Team. This area was not identified by the regular inspections that had been done since the temporary cap construction was completed. Dioxin at 43,000 ng/kg was under water exposing the environment and potential receptors to the dioxin. Repairs to this area were completed in 2016. Other instances of thin or absent rock cover

were identified in 2012, 2013, and in 2016. No flood since the cap was constructed in 2011 has exceeded a 100-year return period design flood. Other concerns with long-term effectiveness include those associated with Alternative 1N: disturbance of the cap from propwash, barge strikes, storms, flooding, and/or changes in the river channel.

Risk reduction is achieved by the temporary armored cap and the clean soil and sediment layers, which protect against exposure through the applicable potential pathways, and by the use of ICs and monitoring to verify that the isolation layers remain effective. Monitoring and maintenance will be required for as long as the dioxin/furan represents an unacceptable risk should exposure occur. Dioxins and furans are persistent contaminates that will not readily break down. While there is much uncertainty regarding how long the waste materials will represent an unacceptable risk should exposure occur, however, the EPA estimates that, for dioxins that are not exposed to sunlight, the dioxin half-life ranges from 25 to 100 years. Ground water monitoring would be implemented to ensure that there are no long-term unacceptable impacts to ground water resulting from the waste left in place.

5.1.2.4 Reduction of Toxicity, Mobility or Volume

There is no additional reduction of TMV due to treatment associated with this remedial alternative beyond that which was achieved during the temporary cap construction. As noted in Section 5.1.1.4, some waste material in the Western Cell was treated during the TCRA, contributing to the reduction of mobility.

5.1.2.5 Short-Term Effectiveness

There are no short-term risks to the community, ecological receptors, or workers associated with the implementation of this remedial alternative. The remedy would achieve full protection in the waste pits immediately. As additional clean sediment continues to be deposited in aquatic areas within the USEPA's Preliminary Site Perimeter, $TEQ_{DF,M}$ concentrations in the near surface sediment interval may continue to decline and the buried sediment near the sand separation area with $TEQ_{DF,M}$ concentrations exceeding the PRG may be further isolated from potential receptors. Ongoing deposition may result in declines in surface sediment concentrations, however, deposition rates are low in most areas, particularly shallow areas. Further, should the river geometry change as a result of extreme erosion similar to that which was documented during the 1994 flood, then the predicted deposition may not occur.

5.1.2.6 Implementability

There are no technical implementability issues associated with this remedial alternative. Alternative 2N would involve a minimal amount of physical activity for the implementation of ICs (e.g., landowner notifications; restrictions on dredging and anchoring) and on-going implementation of existing engineering controls. Monitoring would involve collecting and analyzing sediment samples and evaluating the data, which are routine procedures for qualified environmental consultants and laboratories. Establishing ICs is routine; there are no anticipated administrative implementability issues associated with this remedial alternative.

5.1.2.7 Cost

The estimated present worth cost associated with this remedial alternative is $2.0 million (Appendix C). The capital costs for this remedial alternative are associated with preparation of sampling plans, deed restrictions and notices, and a soil management plan. The long-term costs are for collecting and analyzing environmental samples, evaluating the data, preparing reports to document MNR, conduct of 5-year reviews by USEPA, and future monitoring and maintenance of the temporary armored cap, as described in Appendix C. The cost estimate for this alternative assumes available access to the Site by water from a location along the river and by land through the TxDOT ROW. The actual number of monitoring events will be determined during the Remedial Design.

5.1.3 Alternative 3N – Upgraded Cap, Institutional Controls, Ground Water Monitoring and Monitored Natural Recovery

5.1.3.1 Overall Protection of Human Health and the Environment

This alternative will only remain protective if the cap is properly maintained for the length of time (hundreds of years) that the impounded waste retains its toxicity, and its integrity is not compromised by extreme weather events, barge strikes and/or changes in the river channel which could result in a future release. This remedial alternative would achieve the RAOs through a combination of active remedial construction, monitoring and cap maintenance, MNR addressing additional sediment deposition and implementation of ICs. MNR would be used to achieve the PRG for sediment (30 ng/kg) in the sand separation area and the Texas Surface Water Quality Standard in the San Jacinto River. Monitoring may involve collecting and analyzing sediment, tissue, surface water, and ground water samples and evaluating the data.

The active component will include construction of further enhancements to the temporary armored cap beyond the approved temporary armored cap constructed in 2011 and the enhancement work performed in January 2014. Additional enhancements will include

adding additional armor rock to the cap, which will further flatten the slopes, and measures to construct a protective perimeter barrier to protect the Upgraded Cap from vessel traffic. The Upgraded Cap would be designed for a 500 year flood event, and meet or exceed USACE and USEPA cap design criteria. The alternative includes, in concept, the construction of a submerged rock berm as the protective perimeter barrier. Cap monitoring, inspections and maintenance, as needed, would be incorporated into the final remedy to ensure the long-term effectiveness of the remedy.

MNR would address the affected sediment near the sand separation area, which is already isolated from potential receptors by several feet of sediment with $TEQ_{DF,M}$ concentrations below the sediment PRG and may be further isolated by deposition of additional clean sediment as described in Appendix A. Ground water monitoring would be implemented to ensure that there are no long-term unacceptable impacts to ground water resulting from the waste left in place.

For purposes of MNR, monitoring of sediment conditions in this area would be performed to confirm that deposition of new sediment was continuing to maintain $TEQ_{DF,M}$ concentrations in surface sediments below the PRG for protection of hypothetical recreational visitors. The MNR plan would include methods for assessing whether deposition or erosion were occurring at monitoring stations between monitoring events. The actual scope and timeline of monitoring would be determined in coordination with USEPA during remedial design.

ICs would be used to:

- Alert property owners of the presence of subsurface materials exceeding PRGs
- Describe the need for protective equipment and training if excavation of subsurface materials exceeding PRGs is required in the footprint of the Upgraded Cap
- Describe requirements for the management of any excavated soil or sediment exceeding PRGs
- Describe the need to restore the cap or clean cover soil in these areas following any disturbance
- Establish limitations on dredging and anchoring within the footprint of the Upgraded Cap by requesting, in accordance with 33 CFR 165.5, that the U.S. Coast Guard District Commander establish a regulated navigation area.

5.1.3.2 Compliance with ARARs

Implementation of Alternative 3N would involve the placement of fill material (the additional armor rock) into the San Jacinto River to create the Upgraded Cap. The placement of fill would trigger compliance with CWA Section 404(b)(1) and potentially other ARARs related to surface water quality standards. However, Alternative 3N is expected to generally meet the substantive requirements of the ARARs in Table 3-1 through implementation of the BMPs and the agency coordination actions outlined in Section 3.4. Construction of the Upgraded Cap would require the placement of approximately 3,400 CY of additional cap armor rock material. Based on the results of modeling (Appendix A), the long-term change to the maximum water surface elevation following placement of the additional armor rock is negligible.

5.1.3.3 Long-Term Effectiveness

The long-term effectiveness of the existing temporary armored cap in this alternative is enhanced by adding armor rock to the cap and flattening the slopes of the cap. Flattening the slopes to create the Upgraded Cap, as shown in Figures 4-1 and 4-2, would enhance the structural integrity and long-term reliability of the cap. The armor rock that will be used to create the Upgraded Cap will meet or exceed sediment cap design guidance and the recommendations made by USACE in its review of the cap design and construction in 2013, and a protective perimeter barrier would further increase the long-term effectiveness of the Upgraded Cap by protecting the cap from vessel traffic. An assessment of the Upgraded Cap (Alternative 3N) has determined that the cap would remain protective when subjected to the erosive forces under a 500-year flood event. However, the Upgraded Cap would not be able to reliably contain the waste material during a potential extreme storm as identified by the USACE in the 2016 Alternatives Evaluation report. The National Climate Assessment predicts an increasing number of extreme storms due to climate change. The USACE also acknowledged considerable uncertainty with regard to failure mechanisms related to propwash and potential changes in the channel of the San Jacinto River.

This alternative also may be effective over the long-term because of declines in sediment surface concentrations due to natural recovery (Appendix A) throughout USEPA's Preliminary Site Perimeter. Ongoing deposition may result in declines in surface sediment concentrations, however, deposition rates are low in most areas, particularly shallow areas. Further, should the river geometry change as a result of extreme erosion that was documented during the 1994 flood, then the predicted deposition may not occur. Monitoring would confirm the continued deposition of new sediment isolating the affected sediment outside of the footprint of the temporary armored cap. Ground water monitoring would be

implemented to ensure that there are no long-term unacceptable impacts to ground water resulting from the waste left in place.

The dioxin within the waste pits was generally isolated from potential receptors by the temporary cap, but the temporary cap has required many repairs and extensive maintenance. Examples include, in December 2015, an area of missing rock that was found by the EPA Dive Team. This area was not identified by the regular inspections that had been done since the temporary cap construction was completed. Dioxin at 43,000 ng/kg was under water exposing the environment and potential receptors to the dioxin. Repairs to this area were completed in 2016. Other instances of thin or absent rock cover were identified in 2012, 2013, and in 2016. No flood since the cap was constructed in 2011 has exceeded a 100-year return period design flood.

Monitoring and maintenance will be required for as long as the dioxin/furan represents an unacceptable risk should exposure occur. Dioxins and furans are persistent contaminates that will not readily break down. While there is much uncertainty regarding how long the waste materials will represent an unacceptable risk should exposure occur, however, the EPA estimates that, for dioxins that are not exposed to sunlight, the dioxin half-life ranges from 25 to 100 years.

5.1.3.4 Reduction of Toxicity, Mobility or Volume

There is no additional reduction of TMV due to treatment associated with this remedial alternative beyond that achieved during the temporary cap construction. However, some of the impacted sediments at the Site, found in the Western Cell, were treated and mobility reduced via S/S during the construction.

5.1.3.5 Short-Term Effectiveness

Short-term risks to the community, ecological receptors, or workers associated with the implementation of this remedial alternative are limited to minimal turbidity associated with placement of armor rock, potential accidents during construction of the Upgraded Cap, air emissions from construction equipment, and truck traffic in the community. The evaluation of air emissions and truck traffic was conducted to provide a comparative basis from which to understand the relative impact of construction for each remedial action. It is acknowledged that there are other sources of air emissions and traffic in the region, including the industrial activities that occur adjacent to the Site, and the presence of I-10.

Because of the limited duration of construction for this alternative (2 months), these risks are considered to be low. As compared to Alternatives 4N, 5N, 5aN, and 6N, this alternative is also estimated to require the fewest truck trips (260) during construction. The short duration of construction is correlated with relatively low greenhouse gas, PM, and ozone-generating emissions from the construction equipment. Water quality impacts from turbidity associated with placing the new armor rock are also low for this alternative because the armor rock fines that would create the turbidity would be from the rock acquired for the project and therefore not be chemically impacted. Further, risks of impacts due to storm events during construction are considered negligible because implementation does not require removing the existing temporary armored cap to complete the work, and there are no rigid barriers that could restrict flow during potential flood events.

Finally, because construction work, and in particular over-water work, presents a higher risk of accidental injury or death to workers, the limited duration of this alternative results in a relatively low safety risk. The remedy, like Alternatives 1N and 2N, would achieve full protection within the Site upon completion of construction. As additional sediment continues to be deposited within the USEPA's Preliminary Site Perimeter, $TEQ_{DF,M}$ concentrations in surface sediments would continue to decline to background levels (Appendix A) and the buried sediment near the sand separation area with $TEQ_{DF,M}$ concentrations exceeding the sediment PRG would be further isolated from potential receptors.

5.1.3.6 Implementability

There are limited implementability concerns associated with this remedial alternative. Construction of the Upgraded Cap will require the placement of additional cap material on underwater slopes. The feasibility of this construction technique was successfully demonstrated during the temporary cap construction, and experienced local contractors are available to complete this work. Monitoring may involve collecting and analyzing sediment, tissue, surface water, and ground water samples and evaluating the data, which are routine procedures for qualified environmental consultants and laboratories. Establishing ICs is fairly routine, so no administrative implementability issues are anticipated to be associated with this remedial alternative.

Technical implementability issues include obtaining access to the project work area, limited availability of off-site locations for staging, material management, and barge access, and the low clearance under the I-10 Bridge, which limits the size of marine-based equipment that can access the project work area from the water. During the TCRA, a single off-site location was identified that could accommodate the armor rock stockpiling and barge loading, and that was available for lease during the temporary cap construction. The rock was stockpiled

for barge loading over an approximate 1-acre footprint at the off-site staging area located upstream from the Site and along the San Jacinto River. This same location might not necessarily be available during the remedial construction phase.

5.1.3.7 Cost

The estimated present worth cost associated with this remedial alternative is $4.1 million (Appendix C). The capital costs for this remedial alternative are primarily associated with the construction of the Upgraded Cap, including development and operation of the off-site staging area. However, because the exact location and configuration of the off-site staging area are beyond the scope of this FS these elements may not be fully reflected in the FS estimated durations or costs.

The costs of preparing sampling plans, deed restrictions and notices, and a soil management plan are the same as those for Alternative 2N. The long-term costs are for monitoring and maintenance of the Upgraded Cap, collecting and analyzing environmental samples, evaluating the data, and preparing reports to document MNR. The cost estimate for this alternative also includes Upgraded Cap monitoring and maintenance and USEPA 5-year reviews as described in Appendix C, and also assumes available access to the Site by water from a location along the river and by land through the TxDOT ROW. The number of monitoring events is subject to approval by USEPA and may be changed.

5.1.3a Alternative 3aN - Enhanced Cap, Protective Pilings, ICs, Ground Water Monitoring, and MNR

5.1.3a.1 Overall Protection of Human Health and the Environment

This alternative will only remain protective if the cap is properly maintained for the length of time (hundreds of years) that the impounded waste retains its toxicity, and its integrity is not compromised by extreme weather events, barge strikes and/or changes in the river channel which could result in a future release. This remedial alternative would achieve the RAOs through a combination of active remedial construction, monitoring and cap maintenance, MNR addressing additional sediment deposition and implementation of ICs. MNR would be used to achieve the PRG for sediment (30 ng/kg) in the sand separation area and the Texas Surface Water Quality Standard in the San Jacinto River. Monitoring may involve collecting and analyzing sediment, tissue, surface water, and ground water samples and evaluating the data.

The active component will include construction of further enhancements to the temporary armored cap, even beyond the approved temporary armored cap constructed in 2011 and

modified in January 2014, and the improvements included for Alternative 3N. For costing purposes, the additional cap enhancements added for this alternative include pre-stressed concrete or concrete filled steel pipe pilings placed 30 feet apart around the perimeter of the cap to protect from barge strikes. The spacing is designed to catch a typical barge, which is 35 feet wide. An additional armor stone cap with a thickness of at least 24 inches would be placed over the armor cap for Alternative 3N. The armor stone would have a median diameter of 15 inches. This additional armor stone would cover 13.4 acres of the 17.1 acre armored cap. Also, a course gravel filter layer would be placed on 1.5 acres of the Northwest Area where there is currently no geotextile under the armor cap. The actual scope and design of the cap enhancements, and additional area needed to construct the required slopes, would be determined in the Remedial Design. This additional weight of rock on top of the waste pits may cause cap settling and/or pushing the waste material out the sides of the cap; the Remedial Design will consider the significance of and design issues related to this. MNR would be used to achieve the PRG for sediment in the Sand Separation Area, which is already isolated from potential receptors by several feet of sediment with $TEQ_{DF,M}$ concentrations below the sediment PRG and would be further isolated by deposition of additional clean sediment as described in Appendix A. MNR would also be used to achieve the Texas Surface Water Quality Standard in the San Jacinto River. Ground water monitoring would be implemented to ensure that there are no long-term unacceptable impacts to ground water resulting from the waste left in place. The actual scope and timeline of monitoring would be determined in coordination with USEPA during remedial design.

ICs would be used to:

- Alert property owners of the presence of subsurface materials exceeding PRGs.
- Describe the need for protective equipment and training if excavation of subsurface materials exceeding PRGs is required in the footprint of the Upgraded Cap.
- Describe requirements for the management of any excavated soil or sediment exceeding PRGs.
- Describe the need to restore the cap or clean cover soil in these areas following any disturbance.
- Establish limitations on dredging and anchoring within the footprint of the Upgraded Cap by requesting, in accordance with 33 CFR165.5, that the U.S. Coast Guard District Commander establish a regulated navigation area.

5.1.3a.2 Compliance with ARARs

Implementation of Alternative 3aN would involve the placement of fill material (the additional armor rock) into the San Jacinto River to create the Upgraded Cap. The placement of fill would trigger compliance with CWA Section 404(b)(1) and potentially other ARARs related to surface water quality standards. However, Alternative 3aN is expected to generally meet the substantive requirements of the ARARs in Table 3-1 through implementation of the BMPs and the agency coordination actions outlined in Section 3.4. Construction of the Enhanced Cap would require the placement of approximately 51,900 CY of additional cap armor rock material compared to Alternative 3N. Based on the results of modeling (Appendix A), the long-term change to the maximum water surface elevation following placement of the additional armor rock under this alternative is negligible.

5.1.3a.3 Long-Term Effectiveness

The long-term effectiveness of the existing temporary armored cap in this alternative is enhanced by adding larger armor rock to the cap. The armor rock that will be used to create the Enhanced Cap (Alternative 3aN) will meet or exceed cap design guidance and the recommendations made by USACE in its review of the cap design and construction, and a protective perimeter barrier would further increase the long-term effectiveness of the Upgraded Cap by protecting the cap from vessel traffic. However, the Enhanced Cap may not be able to reliably contain the waste material during an extreme storm as identified by the USACE. The USACE modeled the effect of an extreme storm for the cap described in Alternative 3N, showing an estimated 80% erosion of the cap, and while the USACE speculated that use of larger rock as in Alternative 3aN would reduce scour during such an extreme storm, it was not modeled. Ongoing deposition may result in declines in surface sediment concentrations, however, deposition rates are low in most areas, particularly shallow areas. Further, should the river geometry change as a result of extreme erosion that was documented during the 1994 flood, then the predicted deposition may not occur. Monitoring would confirm the continued deposition of new sediment isolating the affected sediment outside of the footprint of the temporary armored cap. Ground water monitoring would be implemented to ensure that there are no long-term unacceptable impacts to ground water resulting from the waste left in place.

The dioxin within the waste pits was generally isolated from potential receptors by the temporary cap, but the temporary cap has required many repairs and extensive maintenance. Examples include, in December 2015, an area of missing rock that was found by the EPA Dive Team. This area was not identified by the regular inspections that had been done since the temporary cap construction was completed. Dioxin at 43,000 ng/kg was under water

exposing the environment and potential receptors to the dioxin. Repairs to this area were completed in 2016. Other instances of thin or absent rock cover were identified in 2012, 2013, and in 2016. No flood since the cap was constructed in 2011 has exceeded a 100-year return period design flood. As for the other capping alternatives, the USACE acknowledged considerable uncertainty regarding potential future failure mechanisms including changes in the river bed of the San Jacinto River.

Monitoring and maintenance be required for as long as the dioxin/furan represents an unacceptable risk should exposure occur. Dioxins and furans are persistent contaminants that will not readily break down. While there is much uncertainty regarding how long the waste materials will represent an unacceptable risk should exposure occur, however, the EPA estimates that, for dioxins that are not exposed to sunlight, the dioxin half-life ranges from 25 to 100 years.

5.1.3a.4 Reduction of Toxicity, Mobility or Volume

There is no additional reduction of TMV due to treatment associated with this remedial alternative beyond that achieved during the temporary cap construction. However, some of the impacted sediments at the Site, found in the Western Cell, were treated and mobility reduced via S/S during the construction.

5.1.3a.5 Short-Term Effectiveness

Short-term risks to the community, ecological receptors, or workers associated with the implementation of this remedial alternative are limited to minimal turbidity associated with placement of armor rock, potential accidents during construction of the Enhanced Cap, air emissions from construction equipment, and truck traffic in the community. The evaluation of air emissions and truck traffic was conducted to provide a comparative basis from which to understand the relative impact of construction for each remedial action. It is acknowledged that there are other sources of air emissions and traffic in the region, including the industrial activities that occur adjacent to the Site, and the presence of I-10.

Water quality impacts from turbidity associated with placing the new armor rock are also low for this alternative because the armor rock fines that would create the turbidity would be from the rock acquired for the project and therefore not be chemically impacted. Further, risks of impacts due to storm events during construction are considered negligible because implementation does not require removing the existing temporary armored cap to complete the work, and there are no rigid barriers that could restrict flow during potential flood events.

The remedy, like Alternatives 1N 2N, and 3N would achieve full protection within the Site upon completion of construction. As additional sediment continues to be deposited within the USEPA's Preliminary Site Perimeter, $TEQ_{DF,M}$ concentrations in surface sediments would continue to decline to background levels (Appendix A) and the buried sediment near the sand separation area with $TEQ_{DF,M}$ concentrations exceeding the sediment PRG should be further isolated from potential receptors.

5.1.3a.6 Implementability

There are limited implementability concerns associated with this remedial alternative. Construction of the Enhanced Cap will require the placement of additional cap material on underwater slopes. The feasibility of this construction technique was successfully demonstrated during the temporary cap construction, and experienced local contractors are available to complete this work. Monitoring may involve collecting and analyzing sediment, tissue, surface water, and ground water samples and evaluating the data, which are routine procedures for qualified environmental consultants and laboratories. Establishing ICs is fairly routine, so no administrative implementability issues are anticipated to be associated with this remedial alternative.

Technical implementability issues include obtaining access to the project work area, limited availability of off-site locations for staging, material management, and barge access, and the low clearance under the I-10 Bridge, which limits the size of marine-based equipment that can access the project work area from the water. During the TCRA, a single off-site location was identified that could accommodate the armor rock stockpiling and barge loading, and that was available for lease during the temporary cap construction. The rock was stockpiled for barge loading over an approximate 1-acre footprint at the off-site staging area located upstream from the Site and along the San Jacinto River. This same location might not necessarily be available during the remedial construction phase.

5.1.3a.7 Cost

The estimated present worth cost associated with this remedial alternative is $24.8 million (Appendix C). The capital costs for this remedial alternative are primarily associated with the construction of the Enhanced Cap, including development and operation of the off-site staging area. However, because the exact location and configuration of the off-site staging area are beyond the scope of this FS these elements may not be fully reflected in the FS estimated durations or costs.

The costs of preparing sampling plans, deed restrictions and notices, and a soil management plan are the same as those for Alternative 3N. The long-term costs are for monitoring and maintenance of the Enhanced Cap, collecting and analyzing environmental samples, evaluating the data, and preparing reports to document MNR. The cost estimate for this alternative also includes Upgraded Cap monitoring and maintenance and USEPA 5-year reviews as described in Appendix C, and also assumes available access to the Site by water from a location along the river and by land through the TxDOT ROW. The number and scope of monitoring events will be determined during the Remedial Design.

5.1.4 Alternative 4N – Partial Solidification/Stabilization, Upgraded Cap, Institutional Controls, Ground Water Monitoring and Monitored Natural Recovery

5.1.4.1 Overall Protection of Human Health and the Environment

This alternative will only remain protective if the cap is properly maintained for the length of time (hundreds of years) that the impounded waste retains its toxicity, and its integrity is not compromised by extreme weather events, barge strikes and/or changes in the river channel which could result in a future release. This remedial alternative would achieve the RAOs through a combination of treatment, enhanced engineering controls, ICs and MNR. S/S would be used to immobilize soil/sediment in the Site with the most highly contaminated material. A dioxin/furan value that exceeds 13,000 ng/kg $TEQ_{DF,M}$ within the USEPA's Preliminary Site Perimeter was used to define the most highly contaminated material. S/S may add another level of protection to the temporary armored cap. A Upgraded Cap as described under Alternative 3N would be constructed following the S/S process. MNR would be used to achieve the PRG for sediment (30 ng/kg) in the sand separation area and the Texas Surface Water Quality Standard in the San Jacinto River.

Affected sediment near the sand separation area, which is already isolated from potential receptors by several feet of sediment with $TEQ_{DF,M}$ concentrations below the PRG, may be further isolated by deposition of additional sediment as described in Appendix A.

Ongoing deposition may result in declines in surface sediment concentrations, however, deposition rates are low in most areas, particularly shallow areas. Further, should the river geometry change as a result of extreme erosion similar to that which was documented during the 1994 flood, then the predicted deposition may not occur. Monitoring may involve collecting and analyzing sediment, tissue, surface water, and ground water samples and evaluating the data. Monitoring of sediment conditions in this area would be performed to confirm that deposition of clean sediment was continuing to maintain $TEQ_{DF,M}$

concentrations in surface sediments to below the PRG for hypothetical recreational visitors. Ground water monitoring would be implemented to ensure that there are no long-term unacceptable impacts to ground water resulting from the waste left in place.

The MNR plan would include methods for assessing whether deposition or erosion were occurring at monitoring stations between monitoring events. The actual scope and timeline of monitoring would be determined in coordination with USEPA during remedial design.

ICs would be used to:

- Alert property owners of the presence of subsurface materials exceeding PRGs
- Describe the need for protective equipment and training if excavation of subsurface materials exceeding PRGs is required in the Upgraded Cap
- Describe requirements for the management of any excavated soil or sediment exceeding PRGs
- Describe the need to restore the cap or clean cover soil in these areas following any disturbance
- Establish limitations on dredging and anchoring within the footprint of the Upgraded Cap as described for Alternatives 2N and 3N.

This remedy, like Alternatives 1N through 3N, would achieve protection of human health and the environment in the Site upon implementation. As with the previous alternatives, additional clean sediment may continue to be deposited within the area of the USEPA's Preliminary Site Perimeter through ongoing natural recovery processes. $TEQ_{DF,M}$ concentrations in the surface sediments may decline, and the buried sediment near the sand separation area with $TEQ_{DF,M}$ concentrations exceeding the PRG may be further isolated from potential receptors. While ongoing deposition may result in declines in surface sediment concentrations, however, deposition rates are low in most areas, particularly shallow areas. Further, should the river geometry change as a result of extreme erosion similar to that which was documented during the 1994 flood, then the predicted deposition may not occur.

5.1.4.2 Compliance with ARARs

Implementation of Alternative 4N would trigger additional compliance requirements beyond those discussed in Section 5.1.3 due to the removal and replacement of the existing

temporary armored cap, as well as the implementation of the S/S treatment. The removal and replacement of cap material would trigger compliance with CWA Section 404(b)(1) and other ARARs related to surface water quality standards. The S/S may result in a 20 percent increase in the volume of the sediment in the area of treatment because of bulking due to the addition of the stabilization amendment. Application of the S/S to approximately 52,000 CY of sediment is estimated to result in 60,000 to 65,000 CY of amended sediment. This increase in volume could trigger a need to review potential flood storage impacts with Federal Emergency Management Agency (FEMA) and Harris County. Based on preliminary hydrodynamic modeling, the long- term change to the maximum water surface elevation following stabilization under this alternative is estimated to be 0.01 feet, which is an indication that the effect of S/S is negligible and cannot be quantified within the predictive capability of the flood model. Should Alternative 4N be identified as the remedy, additional evaluations would be conducted to determine the potential habitat impacts related to the construction of the Permanent Cap, dredging, and backfill.

It is anticipated that Alternative 4N, through implementation of the BMPs and the agency coordination actions outlined in Section 3.4, would generally meet the substantive requirements of the remainder of the ARARs in Table 3-1.

5.1.4.3 Long-Term Effectiveness

The long-term effectiveness of this remedial alternative is primarily derived from the construction of the Upgraded Cap and treating approximately 52,000 CY of sediment by S/S, combined with the natural recovery processes described previously. Flattening the slopes, where appropriate, as shown in Figures 4-3 and 4-4, would further increase the stability and long-term reliability of the containment as described in Section 5.1.3, and the protective perimeter barrier would provide additional long-term effectiveness. The stabilization of sediment with the highest $TEQ_{DF,M}$ concentrations exceeding 13,000 ng/kg would enhance the shear strength of the stabilized sediments. This alternative is also effective over the long-term because of declines in sediment surface concentrations due to natural recovery (Appendix A) throughout USEPA's Preliminary Site Perimeter. Ongoing deposition may result in declines in surface sediment concentrations, however, deposition rates are low in most areas, particularly shallow areas. Further, should the river geometry change as a result of extreme erosion similar to that which was documented during the 1994 flood, then the predicted deposition may not occur. As described in Section 5.1.2, ICs would protect the integrity of the Upgraded Cap. Monitoring would confirm the continued deposition of clean sediment isolating the affected sediment outside of the footprint of the Upgraded Cap. Because the waste material will remain in place in the San Jacinto River for this alternative, and Principal Threat waste above 300 ng/kg and up to 43,000 ng/kg would remain untreated,

the potential exists that a release of waste material could occur as a result of a future extreme storm or hurricane, or the impact of a barge strike that may breach the cap during the hundreds of years that the dioxin/furan will remain hazardous. Ground water monitoring would be implemented to ensure that there are no long-term unacceptable impacts to ground water resulting from the waste left in place.

The dioxin within the waste pits was generally isolated from potential receptors by the temporary cap, but the temporary cap has required many repairs and extensive maintenance. Examples include, in December 2015, an area of missing rock that was found by the EPA Dive Team. This area was not identified by the regular inspections that had been done since the temporary cap construction was completed. Dioxin at 43,000 ng/kg was under water exposing the environment and potential receptors to the dioxin. Repairs to this area were completed in 2016. Other instances of thin or absent rock cover were identified in 2012, 2013, and in 2016. No flood since the cap was constructed in 2011 has exceeded a 100-year return period design flood.

Over the long-term, ongoing deposition may also act to reduce concentrations in sediments impacted by sediment residuals and releases within the USEPA's Preliminary Site Perimeter, however, as noted, deposition rates are low in most areas, particularly shallow areas.

5.1.4.4 Reduction of Toxicity, Mobility or Volume

This remedial alternative includes the use of S/S treatment to reduce the potential mobility of waste material and sediment exceeding 13,000 ng/kg. Approximately 52,000 CY of waste material in the waste pits would be treated in situ. Remedies that incorporate treatment address a key goal set by USEPA for cleanup projects, as documented in 40 CFR 300.430 (e)(9)(D), "The degree to which alternatives employ recycling or treatment that reduces toxicity, mobility or volume shall be assessed, including how treatment is used to address the principal threats posed by the site" and 40 CFR 300.430 (f)(1)(E), "Each remedial action shall utilize permanent solutions and alternative treatment technologies or resource recovery technologies to the maximum extent practicable."

5.1.4.5 Short-Term Effectiveness

Potential resuspension and releases, as discussed in Section 4.1, present short-term risks for this alternative because mixing the stabilization reagent requires removing areas of the cap and disturbing the waste material, and engineered barrier controls are subject to leakage. The modeling presented in Appendix A demonstrates short-term water column impacts.

Treatment of the soil/sediment within the waste pits would require first removing the existing temporary armored cap armor rock, geotextile and geomembrane in the affected area. This would increase the potential risk of a release during construction of the most impacted in situ soil/sediment at the Site. To evaluate the risk of removing the temporary armored cap, a 3-year storm event was considered, which has an average predicted water surface elevation of 3.5 feet NAVD88 and would inundate portions of the work area, including the sheet pile enclosure shown in Figure 4-3. Such an event could result in resuspension and upstream/downstream transport of the waste material from the inundated portion of the construction footprint where the cap is removed. The removal of cap materials also increases the risk of releasing sediment adhering to those cap materials. These two mechanisms result in an increase in the short-term risk of recontamination beyond the limits of the work area.

Shallow mixing augers may be used to implement S/S with minimal exposure of workers to the impacted soil/sediment; however, isolating the soil/sediment with a sheet pile barrier has been included as a component of this alternative to manage the risk of exposure mentioned above, and to facilitate effective solidification in relatively dry conditions. In situ solidification of wet soil/sediments below surface water has not been widely demonstrated at full scale, and the presence of free water has been shown to inhibit the chemical reactions necessary to achieve effective S/S (e.g., Manitowoc River, Renholds 1998; Kita and Kubo 1983).

In addition, the use of sheet piles increases the risk of recontamination and resuspension of soil/sediments during sheet pile installation and removal (Ecology 1995), and potential cross-contamination associated with driving sheet piling through impacted materials into non-impacted material. However, the area and mass of contamination impacted by the sheet piles leading to potential recontamination and resuspension of contaminated sediment during installation and removal are a small fraction of the reduction in potential releases achieved by their use over that of other BMPs such as silt curtains. Further, cross-contamination associated with driving sheet piling through impacted materials into non-impacted material does not pose additional risk because there would not be any exposure to the underlying materials, besides being of limited mass.

In addition to these environmental risks, construction for this alternative is estimated to require 1,600 truck trips. This alternative would have higher greenhouse gas, PM, and ozone impacts associated with construction emissions from equipment as compared to the previous alternatives. However, there are other sources of air emissions and traffic in the region, including the industrial activities that occur adjacent to the Site and the presence of I-10. From a worker safety perspective, there is also a moderate risk of accidental injury to workers during construction.

5.1.4.6 Implementability

The implementation of this remedial alternative, particularly the treatment of soil/sediment after removal of the temporary armored cap, would be more challenging than implementation of Alternative 3N or 3aN. Stabilization of soil/sediment in the floodplain and subtidal areas will require precautions, such as the use of a sheet pile barrier wall to minimize potential releases of materials once the temporary armored cap is removed. Even with those precautions, because of the disturbance of sediments caused by removing the temporary armored cap, and the additional handling of previously undisturbed sediments during the S/S process, the release of some of these impacted materials into the river or onto the surface of the undisturbed parts of the temporary armored cap may be unavoidable, particularly if a storm or high water levels were to occur during construction. The results from chemical fate model simulations presented in Appendix A indicate that short-term increases in surface water concentrations could occur during the construction.

In addition, stabilization in areas that are normally below surface water increases the difficulty in successful implementation of this alternative. Construction of the Upgraded Cap following S/S would be implementable with challenges as generally noted under Alternative 3N for armor rock placement. Monitoring would involve collecting and analyzing sediment samples and evaluating the data, which are routine procedures for qualified environmental consultants and laboratories. Establishing ICs is routine, so there are no significant administrative implementability issues associated with this remedial alternative. As with Alternative 3N and 3aN, technical implementability issues include obtaining access to the project work area, limited availability of off-site locations for staging, material management, and barge access, and the low clearance under the I-10 bridge, which limits the size of marine-based equipment that can access the project work area from the water. As described under Alternative 3N, a 1-acre footprint was required for the off-site staging area to manage the rock stockpile. Because this alternative also requires treatment reagents, additional space could be necessary for the off-site staging area. This location used for the off-site staging area during the temporary cap construction might not necessarily be large enough to accommodate the work, or might not be available during the remedial construction phase.

5.1.4.7 Cost

The estimated present worth cost associated with this remedial alternative is $14.8 million (Appendix C). The capital costs for this remedial alternative are primarily associated with the S/S process and construction of the Upgraded Cap, including development and operation of the off-site staging area. However, because the exact location and configuration of the off-

site staging area are beyond the scope of this FS these elements may not be fully reflected in the FS estimated durations or costs.

The costs of preparing sampling plans, deed restrictions and notices, and a soil management plan are the same as those for remedial Alternative 2N. The long-term costs are for monitoring the condition of the Upgraded Cap, collecting and analyzing environmental samples, evaluating the data, preparing reports to document MNR, and monitoring and maintenance of the Upgraded Cap. The estimated cost of this alternative includes USEPA 5-year reviews and also assumes available access to the Site by water from a location along the river and by land through the TxDOT ROW. The assumed number of monitoring events is discussed in Appendix C; the actual number of monitoring events is subject to approval by USEPA.

5.1.5 Alternative 5N – Partial Removal, Upgraded Cap, Institutional Controls, Ground Water Monitoring and Monitored Natural Recovery

5.1.5.1 Overall Protection of Human Health and the Environment

This alternative will only remain protective if the cap is properly maintained for the length of time (hundreds of years) that the impounded waste retains its toxicity, and its integrity is not compromised by extreme weather events, barge strikes and/or changes in the river channel which could result in a future release. This remedial alternative achieves the RAOs through a combination of soil/sediment removal, enhanced engineering controls, MNR and ICs. Following removal of portions of the existing temporary armored cap, soil and sediment with $TEQ_{DF,M}$ concentrations greater than the USEPA-identified limit of 13,000 ng/kg $TEQ_{DF,M}$ would be removed, dewatered, and transported off-site for disposal. The sediment removal area would be backfilled and a Upgraded Cap as described in Alternative 3N would be constructed following removal of the soil/sediment. MNR would be used to achieve the PRG for sediment (30 ng/kg) in the sand separation area and the Texas Surface Water Quality Standard in the San Jacinto River.

Affected sediment near the sand separation area, which is already isolated from potential receptors by several feet of sediment with $TEQ_{DF,M}$ concentrations below the sediment PRG, may be further isolated by deposition of additional sediment as described in Appendix A. Monitoring may involve collecting and analyzing sediment, tissue, surface water, and ground water samples and evaluating the data. Monitoring of sediment conditions in this area would be performed to confirm that deposition of new sediment was continuing to maintain $TEQ_{DF,M}$ concentrations in surface sediments below the sediment PRG for protection of hypothetical recreational visitors. The MNR plan would include methods for assessing

whether deposition or erosion was occurring. Appendix C describes cost assumptions used in this FS Report for MNR monitoring. Ground water monitoring would be implemented to ensure that there are no long-term unacceptable impacts to ground water resulting from the waste left in place. The actual scope and timeline of monitoring would be determined in coordination with USEPA during remedial design.

ICs would be used to:

- Alert property owners of the presence of remaining subsurface material exceeding PRGs
- Describe the need for protective equipment and training to limit exposure to contaminants if future additional excavation is required in the footprint of the Upgraded Cap
- Describe requirements for the management of any excavated soil or sediment
- Describe the need to restore the cap or clean cover soil in these areas following any disturbance
- Establish limitations on dredging and anchoring within the footprint of the Upgraded Cap as described in Alternatives 2N to 4N.

5.1.5.2 Compliance with ARARs

Implementation of Alternative 5N would include the removal of portions of the existing temporary armored cap, removal of underlying soil/sediment, and transportation of sediment to an upland disposal facility. The removal of the temporary armored cap and placement of rock for Upgraded Cap construction would trigger compliance with CWA Section 404(b)(1) and along with the dredging action would trigger other ARARs related to surface water quality standards. Should Alternative 5N be identified as the remedy, additional evaluations would be conducted to determine the potential habitat impacts related to the construction of the Upgraded Cap, dredging, and backfill.

The removal of sediment would require the construction of an off-site material handling facility near the work area to offload barges, manage waste, stockpile and dewater sediment, and load these materials onto trucks or rail cars for off-site disposal. The construction and operation of the material handling facility may require substantial compliance with relevant permit requirements.

Removal of impacted soil from the remedial action areas to an off-site disposal facility would require compliance with ARARs related to dust emissions, storm water controls, and disposal. Appropriate storm water and air-quality controls would be used to protect air and water quality. Equipment leaving the work site would be decontaminated as needed to prevent tracking impacted soil on public roads, and each load of soil would be tracked to confirm that the material was received by the designated disposal facility.

Construction of the Upgraded Cap would require the placement of approximately 3,400 CY of additional cap armor rock material. Hydrodynamic modeling was performed to confirm that the placement of the additional armor rock would not significantly affect flood-storage capacity in the San Jacinto River (Appendix A). Based on the results of this modeling, the long-term change to the maximum water surface elevation following placement of the additional armor rock under this alternative is estimated to be -0.01 to -0.02 feet, which is an indication that the effect of rock placement is negligible and immeasurable within the predictive capability of the flood model.

Alternative 5N would be expected, through implementation of the BMPs and the agency coordination actions outlined in Section 3.4, to generally meet the substantive requirements of the ARARs in Table 3-1.

5.1.5.3 Long-Term Effectiveness

The long-term effectiveness of this remedial alternative is primarily derived from the construction of the Upgraded Cap and removing a substantial percentage of the highest concentration material (approximately 52,000 CY) from the Site, combined with natural recovery as described previously. Because the waste material under 13,000 ng/kg will remain in place in the San Jacinto River for this alternative, the potential exists that a release of waste material could occur as a result of a future extreme storm or hurricane, or the impact of a barge strike that may breach the cap during the hundreds of years that the dioxin/furan will remain hazardous.

The dioxin within the waste pits was generally isolated from potential receptors by the temporary cap, but the temporary cap has required many repairs and extensive maintenance. Examples include, in December 2015, an area of missing rock that was found by the EPA Dive Team. This area was not identified by the regular inspections that had been done since the temporary cap construction was completed. Dioxin at 43,000 ng/kg was under water exposing the environment and potential receptors to the dioxin. Repairs to this area were completed in 2016. Other instances of thin or absent rock cover were identified in 2012, 2013, and in 2016.

No flood since the cap was constructed in 2011 has exceeded a 100-year return period design flood.

Ongoing deposition from natural recovery processes may also act to reduce concentrations impacted by sediment residuals and releases within the USEPA's Preliminary Site Perimeter over the long-term, however, deposition rates are low in most areas, particularly shallow areas.

The removal of waste material with $TEQ_{DF,M}$ concentrations exceeding 13,000 ng/kg eliminates a potential future source of high concentration sediments from the waste pits. Flattening the slopes, where appropriate, as shown in Figures 4-3 and 4-4, and the other work to be performed in constructing the Upgraded Cap, would further increase the stability and long-term reliability of the containment as described in Section 5.1.3. This alternative is also effective over the long-term because of declines in sediment surface concentrations due to natural recovery throughout USEPA's Preliminary Site Perimeter. As described in Section 5.1.2, ICs would protect the integrity of the Upgraded Cap and the layer of clean surface soil. Monitoring would confirm the continued deposition of clean sediment isolating the affected sediment outside of the footprint of the Upgraded Cap. Ground water monitoring would be implemented to ensure that there are no long-term unacceptable impacts to ground water resulting from the waste left in place.

5.1.5.4 Reduction of Toxicity, Mobility or Volume

This remedial alternative would reduce the volume of material exceeding the waste material PRGs within the USEPA's Preliminary Site Perimeter. Approximately 52,000 CY of paper mill waste material in the waste pits would be removed for disposal. Sediment dewatering by amendment prior to transporting for disposal may reduce the potential mobility of contaminants during transportation and at the disposal facility.

5.1.5.5 Short-Term Effectiveness

Potential resuspension and releases, as discussed in Section 4.1.1, present short-term risks for this alternative because of the dredging, and engineered barrier controls are subject to leakage. However, the actual levels would be reduced by the use of BMPs during construction, including de-watering and excavation in the dry.

Removal of sediment under this alternative would require first removing the existing temporary armored cap armor rock, geotextile and geomembrane in the affected area. This would increase the potential risk of a release during removal of soil/sediment with concentrations exceeding 13,000 $TEQ_{DF,M}$. To evaluate the risk of removing the temporary

armored cap, a 3-year storm was considered, which has an average predicted water surface elevation of 3.5 feet NAVD88 and would inundate portions of the work area, including the sheet pile enclosure shown in Figure 4-3. Such an event could result in resuspension and upstream/downstream transport of sediments from the inundated portion of the construction footprint where the cap is removed. For this reason, it may be necessary to conduct the work by removing only small portions of the cap at a time, and provide cover for any residuals before starting the next area.

In addition to a storm event as described above, releases would also be expected during dredging with potential sediments impacted by releases of dioxins and furans potentially settling onto areas within the USEPA's Preliminary Site Perimeter, and potentially causing temporary increases in surface water and tissue concentrations for various COCs. However, the actual levels would be reduced by the use of BMPs during construction, including de-watering and excavation in the dry. Even with those precautions, it would be difficult to avoid releasing any of these materials exceeding their PRGs into the river or onto the surface of the undisturbed parts of the Upgraded Cap. That risk would be increased if a storm or high water levels were to occur during construction, as described previously. It will be necessary to prepare a contingency plan as part of the Remedial Design in order to develop best practices to prevent, contain or manage any such release.

Additional environmental risks include the possibility of spills during transportation to the disposal facility and possible releases from the off-site landfill itself. In addition to these environmental risks, as compared to the previous four alternatives, construction for this alternative is estimated to require 9,300 truck trips. This alternative would have higher greenhouse gas and PM. impacts and ozone generating emissions associated with construction emissions from equipment operating within the project work area, as well as from equipment required for transportation and disposal of excavated sediments. However, there are other sources of air emissions and traffic in the region, including the industrial activities that occur adjacent to the Site and the presence of I-10. From a worker safety perspective, there is a low to moderate risk of accidental injury to workers during construction. The remedy would achieve protection in the Site upon completion of construction. As additional clean sediment continues to be deposited throughout the USEPA's Preliminary Site Perimeter, $TEQ_{DF,M}$ concentrations in surface sediments may continue to decline and the buried sediment near the sand separation area with $TEQ_{DF,M}$ concentrations exceeding the sediment PRG would be further isolated from potential receptors.

5.1.5.6 Implementability

There are several implementability concerns associated with this remedial alternative. As discussed above, removal of sediment in the floodplain would require the use of engineering controls to minimize any releases of impacted sediment during construction and some releases to the surrounding environment could occur as described in Section 4.1.

Further, on-site space is very limited to accommodate contractor access, staging, stockpiling materials, and managing excavated sediment for transportation to an off-site disposal site. An off-site facility would need to be identified and secured to manage dredged materials (including dewatering, transloading, and shipping) and to stockpile and load imported armor rock. Given the nature of the material being managed at the off-site facility, locating a suitable property and willing landowner could be a challenge. During the temporary cap construction, a single off-site location was identified that could accommodate the armor rock stockpiling and barge loading, and that was available for lease during the construction. The rock was stockpiled for barge loading over an approximate 1-acre footprint at the off-site staging area located upstream from the site and along the San Jacinto River. This same location might not necessarily be compatible with managing dredged waste material, which can require a relatively large footprint for processing, and/or might not be available during the remedial construction phase. For example, the Port Gamble Interim Action dredging, which required excavation of 16,500 CY of material, required a dredge material stockpile footprint of approximately 3 acres in size (Hart Crowser 2007).

Replacement of the cap following sediment removal and backfilling would be implementable as noted for Alternative 3N. Monitoring would involve collecting and analyzing sediment samples and evaluating the data, which are routine procedures for qualified environmental consultants and laboratories. Establishing ICs is routinely done, so there are not anticipated to be administrative implementability issues associated with this remedial alternative either.

5.1.5.7 Cost

The estimated present worth cost associated with this remedial alternative is $29.8 million (Appendix C). The capital costs for this remedial alternative are primarily associated with the sediment removal and disposal and construction of the Upgraded Cap, including development and operation of the off-site staging area. However, because the exact location and configuration of the off-site staging area are beyond the scope of this FS these elements may not be fully reflected in the FS estimated durations or costs.

The costs of preparing sampling plans, deed restrictions and notices, and a soil management plan are the same as those for Alternative 2N. The long-term costs are for monitoring the condition of the Upgraded Cap, collecting and analyzing environmental samples, evaluating

the data, preparing reports to document the MNR, maintenance of the Upgraded Cap, and USEPA 5-year reviews. Assumptions regarding monitoring and maintenance are described in Appendix C. The actual monitoring requirements and number of monitoring events will be subject to approval by USEPA and would be determined during remedial design. The estimated cost of this alternative assumes available access to the Site by water from a location along the river and by land through the TxDOT ROW.

5.1.6 Alternative 5aN – Partial Removal of Materials Exceeding the PRG, Upgraded Cap, Institutional Controls, Ground Water Monitoring and Monitored Natural Recovery

5.1.6.1 Overall Protection of Human Health and the Environment

This alternative will only remain protective if the capn is properly maintained for the length of time (hundreds of years) that the impounded waste retains its toxicity, and its integrity is not compromised by extreme weather events, barge strikes and/or changes in the river channel which could result in a future release. This remedial alternative would achieve the RAOs through a combination of waste material removal, capping, ICs and MNR. Waste material in the TCRA Site where the water depth is 10 feet or less and with $TEQ_{DF,M}$ concentrations exceeding the hypothetical recreational visitor PRG (200 ng/kg), plus waste material that exceed 13,000 ng/kg $TEQ_{DF,M}$ in any water depth, would be removed, dewatered, and transported to a permitted landfill for disposal. MNR would be used to achieve the PRG for sediment (30 ng/kg) in the sand separation area and the Texas Surface Water Quality Standard in the San Jacinto River.

This alternative would require partial removal of the armored cap. Soil/sediment removal would be performed behind an engineered barrier, including a berm in shallow water areas of the project work site, and a sheet pile in deeper water areas of the project work site. Following removal of the soil/sediment, a two layer residuals cover would be placed.

An Upgraded Cap as described under Alternative 3N would be constructed in the area of the Site where the waste material PRG is exceeded but the water is deeper than 10-feet.

Affected sediment near the sand separation area, which is already isolated from potential receptors by several feet of sediment with $TEQ_{DF,M}$ concentrations below the sediment PRG, may be further isolated by deposition of additional sediment as described in Appendix A. Monitoring may involve collecting and analyzing sediment, tissue, surface water, and ground water samples and evaluating the data. Monitoring of sediment conditions in this area would be performed to confirm that deposition of new sediment was continuing to maintain

$TEQ_{DF,M}$ concentrations in surface sediments below the PRG for protection of hypothetical recreational visitors and fishers. The MNR plan would include methods for assessing whether deposition and erosion were occurring. Ground water monitoring would be implemented to ensure that there are no long-term unacceptable impacts to ground water resulting from the waste left in place. MNR monitoring assumptions are described in more detail in Appendix C. The actual scope and timeline of monitoring would be determined in coordination with USEPA during remedial design.

ICs would be used to:

- Alert property owners of the presence of remaining subsurface material exceeding PRGs
- Describe requirements for the management of any excavated soil or sediment
- Describe the need to restore the Upgraded Cap or clean cover soil in these areas following any disturbance
- Establish limitations on dredging and anchoring within the footprint of the Upgraded Cap as described in Alternatives 2N to 5N.

5.1.6.2 Compliance with ARARs

Alternative 5aN would generally trigger the same compliance requirements as Alternative 5N. If Alternative 5aN is identified as the preferred alternative, additional evaluations would need to be conducted to determine the potential habitat impacts related to impacts of dredging and placement of clean residual layer management materials to document compliance with CWA Section 404(b)(1) and other natural resource based ARARs.

Removal of impacted soil from the remedial action areas to an off-site disposal facility would require compliance with ARARs related to dust emissions, storm water controls, and disposal. Appropriate storm water and air-quality controls would be used to protect air and water quality. Equipment leaving the work site would be decontaminated as needed to prevent tracking impacted soil on public roads, and each load of soil would be tracked to confirm that the material was received by the designated disposal facility.

Removal of sediments and placement of a residuals cover would result in a net lowering of the mudline in the work area. Hydrodynamic modeling was performed to evaluate the effect of this change on flood-storage capacity in the San Jacinto River (Appendix A). Based on the

results of this modeling, the long-term change to the maximum water surface elevation following dredging and residuals management placement is estimated to be -0.04 to -0.05 feet, which may not be measurable using the predictive capability of the flood model.

BMPs will be incorporated into the Remedial Design as necessary to support water quality and attainable use standards for this section of the San Jacinto River as described in Section 3.3.1 above. On-site water discharges will comply with the substantive technical requirements of the Clean Water Act, but do not require a permit. A water treatment system will be designed as necessary during the Remedial Design to meet the discharge requirements.

5.1.6.3 Long-Term Effectiveness

The long-term effectiveness of this remedial alternative is primarily derived from the removal of soil and sediment and the enhancement of the existing temporary armored cap. Approximately 137,600 CY of soil and sediment would be removed from beneath the existing temporary armored cap. The anticipated limits of the excavation are shown in Figures 4-5 and 4-6. The dredging activity would result in a reduction in the volume of soil/sediment with concentrations above 200 mg/kg $TEQ_{DF,M}$; however, a residual layer of impacted material with $TEQ_{DF,M}$ above 200 mg/kg may remain at the bottom of the excavated surfaces due to dredging-related releases as described in Section 4.1. The concentration of those residual materials would likely require at least two layers of clean sediment residuals cover across the dredge footprint. Because the waste material will remain in place in the San Jacinto River for this alternative, the potential exists that a release of waste material could occur as a result of a future extreme storm or hurricane, or the impact of a barge strike that may breach the cap during the hundreds of years that the dioxin/furan will remain hazardous. Over the long-term, ongoing deposition may also act to reduce concentrations associated with dredge residuals and releases within the USEPA's Preliminary Site Perimeter, however, deposition rates are low in most areas, particularly shallow areas. Ground water monitoring would be implemented to ensure that there are no long-term unacceptable impacts to ground water resulting from the waste left in place.

5.1.6.4 Reduction of Toxicity, Mobility or Volume

This remedial alternative would remove most of the waste materials exceeding the waste material PRGs from within the USEPA's Preliminary Site Perimeter. Approximately 137,600 CY of waste material would be removed from within the USEPA's Preliminary Site Perimeter for disposal. Sediment dewatering by amendment prior to transporting the waste material to a landfill for disposal would reduce the potential mobility of constituents during

transportation and at the disposal facility. Water generated from sediment dewatering would need to be treated on-site for discharge, or collected and transported off-site for disposal.

5.1.6.5 Short-Term Effectiveness

Potential resuspension and releases, as discussed in Section 4.1.1, present short-term risks for this alternative. The engineered barrier controls are subject to leakage and may occur during construction even with the use of BMPs. The water column impacts associated with Alternative 5aN is estimated to increase the annual average water column concentration of TCDD, however, the actual levels would be reduced by the use of BMPs during construction, including de-watering and excavation in the dry.

Removal of waste material from the waste pits would require first removing the existing temporary armored cap in the affected area. This would increase the potential risk of a release during construction of sediments containing the highest concentrations of dioxins and furans detected within USEPA's Preliminary Site Perimeter if a storm or flood event were to compromise the perimeter barrier, when sediments that are currently capped would be exposed. To evaluate the risk of removing the temporary armored cap, a 3-year storm was considered, which has an average predicted water surface elevation of 3.5 feet NAVD88 and would inundate portions of the work area, including overtopping the perimeter berm and the sheet pile enclosure. Such an event could result in resuspension and upstream/downstream transport of the waste material from the inundated portion of the construction footprint where the cap is removed. For this reason, the USACE recommended removing only small areas of the cap at time to minimize potential releases.

In addition, short-term water quality impacts would occur due to dredging operation releases (Appendix A). Surface water 2,3,7,8-TCDD concentrations within the USEPA's Preliminary Site Perimeter would be predicted to increase, however, the actual levels would be reduced by the use of BMPs during construction. These releases would also be expected to increase tissue concentrations in the early years following remedy implementation and also result in slight increases in surface sediment concentration in surrounding areas.

In addition to these environmental risks, construction for this alternative is estimated to require 12,855 truck trips. Relative to the other alternatives, this alternative would have high greenhouse gas, PM, and ozone impacts associated with construction emissions from equipment operating in the work areas, as well as from equipment required for off-site transportation and disposal of excavated sediments. However, there are other sources of air emissions and traffic in the region, including the industrial activities that occur adjacent to the Site and the presence of I-10. From a worker safety perspective, there is a moderate to

high risk of accidental injury to workers during construction. The remedy would be intended to achieve full protection upon completion of construction; however, there could be short-term releases of dioxins and furans to the surrounding environment during implementation that would be unavoidable and could affect the water column, increase sediment concentrations beyond the work area, and increase tissue concentrations of COCs.

5.1.6.6 Implementability

There are implementability concerns associated with this remedial alternative. On-site space is limited to accommodate access, staging and stockpiling materials and excavated sediment for transportation to an off-site disposal site. The considerations discussed under Alternative 5N for locating and securing an off-site material handling area are also applicable to this alternative. Given the scope and scale of this alternative, it is likely that a relatively large river-side property near the work area would need to be leased for the duration of the work to accommodate staging, material processing, stockpiling, and transloading of materials. The logistical concerns over locating and securing a suitable off-site material handling area would be more for this remedial alternative than for the partial removal (Alternative 5N) because of the longer duration of the project (19 months versus 13 months) and the greater extent of the removal area, which would leave less on-site upland space for managing materials, as well as the greater volume of material removed which could require a larger off-site location. There may be greater community impacts (traffic, noise, air emissions, etc.) during implementation. Finally, the volume of material removed could have an impact on the capacity of available landfills; thus the acceptance of this amount of material for disposal is uncertain. Establishing ICs is routinely done, so there are not any anticipated administrative implementability issues associated with this remedial alternative.

5.1.6.7 Cost

The estimated present worth cost associated with this remedial alternative is $69.6 million. The capital costs for this remedial alternative are primarily associated with the waste material removal and disposal and construction of the Upgraded Cap, including development and operation of the off-site staging area. However, because the exact location and configuration of the off-site staging area are beyond the scope of this FS these elements may not be fully reflected in the FS estimated durations or costs.

The long-term costs are for monitoring the condition of the Upgraded Cap, collecting and analyzing environmental samples, evaluating the data, preparing reports to document the MNR, maintenance of the Upgraded Cap, and USEPA 5-year reviews. Cost assumptions regarding monitoring and maintenance are described in Appendix C. The actual monitoring

requirements and number of monitoring events will be subject to approval by USEPA and would be determined during remedial design. Further details on the cost assumptions for this alternative are presented in Appendix C.

5.1.7 Alternative 6N – Full Removal of Waste Materials Exceeding the PRG, MNR, and Institutional Controls

5.1.7.1 Overall Protection of Human Health and the Environment

Alternative 6N best realizes the Threshold Criteria (protecting human health and the environment) because the waste material would be removed and therefore not subject to a potential future release. This remedial alternative would achieve the RAOs through a combination of waste material and /sediment removal and ICs (for the residuals following removal). Waste material in the temporary cap site exceeding the waste material PRG (200 ng/kg) would be removed, dewatered, and transported to a permitted landfill for disposal. As for Alternatives 5N and 5aN, complete removal of materials exceeding the PRG may not be possible for all areas because of dredging residuals, which will leave a layer material exceeding PRGs that will need to be managed by placing a two layer post-dredge clean cover. MNR would be used to achieve the PRG for sediment (30 ng/kg) in the sand separation area and the Texas Surface Water Quality Standard in the San Jacinto River. Monitoring may involve collecting and analyzing sediment, tissue, surface water, and ground water samples and evaluating the data.

ICs would be used to:

- Alert property owners of the presence of remaining subsurface material exceeding PRGs.
- Describe requirements for the management of any excavated soil or sediment.
- Describe the need to restore the residuals cover soil in areas exceeding the PRGs following any disturbance.
- Establish limitations on dredging and anchoring within the footprint of the residuals cover.
- Alert property owners of the presence of remaining subsurface material exceeding PRGs, if necessary.

5.1.7.2 Compliance with ARARs

Implementation of Alternative 6N would generally trigger the same compliance requirements as Alternatives 5N and 5aN. Selection of Alternative 6N will require additional evaluations to be conducted to determine the potential habitat impacts related to impacts of waste material and sediment removal and placement of clean residual layer management materials to document compliance with CWA Section 404(b)(1) and other natural-resource based ARARs. Removal of waste materials and sediments and placement of a residuals cover would result in a net lowering of the mudline in the work area. The construction of any of the proposed Alternatives is not expected to cause any flooding in the vicinity of the Site, and therefore should not require the implementation of any flood control measures during the construction of any of the Alternatives under consideration by the EPA.

BMPs will be incorporated into the Remedial Design as necessary to support water quality and attainable use standards for this section of the San Jacinto River as described in Section 3.3.1 above. On-site water discharges will comply with the substantive technical requirements of the Clean Water Act, but do not require a permit. A water treatment system will be designed as necessary during the Remedial Design to meet the discharge requirements.

5.1.7.3 Long-Term Effectiveness

The long-term effectiveness of this remedial alternative is derived from the removal of waste material and sediment exceeding their respective PRGs. Approximately 152,000 CY of waste material would be removed from the waste pits. The anticipated limits of the excavation are shown in Figures 4-5 and 4-6. The removal activity would reduce the volume of waste material with concentrations above 200 mg/kg; however, a residual layer of contaminated materials may remain at the bottom of the excavated surfaces as explained relative to Alternative 5aN. The concentration of those residual materials would be similar to the removed materials and would likely require two clean sediment residuals cover layers across the dredge footprint for greater protectiveness. Sediment in the vicinity of the sand separation area is currently stable and net sedimentation in this area is expected to provide continued isolation at this buried location; however, propeller wash from tug boat operations could disturb these sediments. Monitoring would confirm the continued deposition of clean sediment isolating the affected sediment outside of the footprint of the Permanent Cap.

Alternative 6N would not result in the potential for a future release due to an extreme storm or hurricane, nor the impacts of a barge strike or erosion from propwash or changes in the river bed channel as is the case for all of the other alternatives because the waste material has

been removed. Over the long-term, ongoing deposition should also act to reduce dioxin $TEQ_{DF,M}$ concentrations in sediment associated with dredge residuals and releases within the USEPA's Preliminary Site Perimeter.

5.1.7.4 Reduction of Toxicity, Mobility or Volume

This remedial alternative would use sediment dewatering by amendment to reduce the mobility of COCs during transportation and at the disposal facility. Approximately 152,000 CY of waste material and sediment with $TEQ_{DF,M}$ concentrations exceeding their PRGs would be removed from within the USEPA's Preliminary Site Perimeter for disposal. Water generated from sediment dewatering would need to be treated on-site for discharge, or collected and transported off-site for disposal.

5.1.7.5 Short-Term Effectiveness

Potential resuspension and releases, as discussed in Section 4.1.1, present short-term risks for this alternative. However, these short term risks would be mitigated by the use of BMPs and engineering controls to reduce resuspension. Containment structures to reduce resuspension would consist of berms and sheet pile walls or caissons to an elevation of about +10 NAVD88 (protection from 25-year or 50-year flood stage). If performing excavation of the waste materials in the dry, the top of the berms would preferably be no lower than +5 NAVD88 (protection from 5-year or 10-year flood stage). The USACE estimated in the 2016 Alternatives Evaluation report that there could be releases of approximately 0.2% of the total waste material if all excavations in the northern waste pits can be performed behind sheet pile walls with most of the excavation in the dry and the Northwest Cell can be protected by sheet pile walls; and approximately 0.34% of the total waste materials could be released if the removal of the Northwest Cell is performed behind silt curtains.

Removal of waste material from the Site would require first removing the existing temporary armored cap in the affected area. This would increase the potential risk of a release during removal of sediment with the highest $TEQ_{DF,M}$ concentrations within the USEPA's Preliminary Site Perimeter, particularly if a storm or flood event occurred, when the sediment that is currently capped would be exposed. To evaluate the risk of removing the temporary armored cap, a 3-year storm was considered, which has an average predicted water surface elevation of 3.5 feet NAVD88 and would inundate portions of the work area. This risk can be reduced through the removal of only small areas of the cap at any one time.

In addition to these environmental risks, construction for this alternative is estimated to require 17,500 truck trips. Relative to the other alternatives, this alternative would have

higher greenhouse gas, PM, and ozone impacts associated with construction emissions from equipment operating in the work areas, as well as from equipment required for off-site transportation and disposal of excavated sediments. However, there are other sources of air emissions and traffic in the region, including the industrial activities that occur adjacent to the Site and the presence of I-10. From a worker safety perspective, there is a moderate to high risk of accidental injury to workers during construction. The remedy would be intended to achieve full protection upon completion of construction; however, there may be releases of dioxins and furans to the surrounding environment during implementation that would be unavoidable and would affect the water column, increase sediment concentrations beyond the work area, and increase tissue concentrations of COCs in the short-term.

5.1.7.6 Implementability

There are several implementability concerns associated with this remedial alternative. As discussed above, removal of waste materials in the floodplain would require the use of engineering controls to minimize the release of contaminated sediment during construction; nevertheless some loss is expected based on documented case histories and published guidance even with the use of those controls. It would be extremely difficult to avoid releasing impacted materials into the river, particularly if a storm or high water levels occur during construction. During the Remedial Design, it will be necessary to identify BMPs to minimize the potential release of impacted materials into the river, and to develop a contingency plan to minimize, if possible, any releases that do occur.

Further, on-site space is limited to accommodate access, staging and stockpiling materials and excavated sediment for transportation to an off-site disposal site. The considerations discussed under Alternatives 5N and 5aN for locating and securing an off-site material handling area are also applicable to this alternative. However, the logistical concern over locating and securing an off-site facility would be more significant for this remedial alternative than for Alternative 5N because of the longer duration of the project and the greater volume of material removed than that required for Alternatives 5N and 5aN, and which would have greater community impacts (traffic, noise, air emissions, etc.) during implementation. Given the scope and scale of this alternative, it is likely that a larger river-side property near the work area would need to be leased for the duration of the work to accommodate staging, material processing, stockpiling, and transloading of materials. The need for such an area adds additional complexity to this alternative. Finally, the volume of material removed could have an impact on the capacity of available landfills; thus the acceptance of this amount of material for disposal is less certain. Establishing ICs is routine, so there are no anticipated administrative implementability issues associated with this part of the remedial alternative.

5.1.7.7 Cost

The estimated present worth cost associated with this remedial alternative is $87 million. The capital costs for this remedial alternative are primarily associated with the waste material removal and disposal, including development and operation of the off-site staging area. However, because the exact location and configuration of the off-site staging area are beyond the scope of this FS these elements may not be fully reflected in the FS estimated durations or costs.

The long-term costs are for collecting and analyzing environmental samples, evaluating the data, and preparing reports to document USEPA 5-year reviews. The costs of preparing sampling plans, deed restrictions and notices, and a soil management plan are the same as those for remedial Alternative 2N. Cost assumptions regarding monitoring and maintenance for this alternative are described in Appendix C. The actual monitoring requirements and number of monitoring events will be subject to approval by USEPA and would be determined during remedial design. Further details on the cost assumptions for this alternative are presented in Appendix C.

5.2 Area South of I-10

5.2.1 Alternative 1S – No Further Action

5.2.1.1 Overall Protection of Human Health and the Environment

This remedial alternative would not be protective of human health and the environment. Although the subsurface soil is isolated from potential receptors by several feet of soil with $TEQ_{DF,M}$ concentrations below the soil PRG for the hypothetical future construction worker, this exposure scenario considers excavation and potential exposure to subsurface soil to a depth of 10-feet below grade. In the absence of controls, soil that is currently isolated from receptors by depth could potentially be excavated and placed on the surface.

5.2.1.2 Compliance with ARARs

Alternative 1S would not result in construction impacts or other changes to baseline conditions that would trigger any action-, chemical-, or location-specific ARARs identified in Table 3-1.

5.2.1.3 Long-Term Effectiveness

The long-term effectiveness of this remedial alternative was evaluated considering the potential for natural forces or human activity to expose the sediment or soil with $TEQ_{DF,M}$ concentrations that exceed the soil PRG. If no action is taken to alert future property owners or construction workers to the presence of subsurface soil with $TEQ_{DF,M}$ concentrations above the PRG, workers performing excavation in the specific areas shown in Figure 4-11 could be exposed to elevated $TEQ_{DF,M}$ concentrations.

5.2.1.4 Reduction of Toxicity, Mobility or Volume

There is no reduction of TMV due to treatment associated with this remedial alternative.

5.2.1.5 Short-Term Effectiveness

There are no short-term risks to the community, ecological receptors, or workers associated with the implementation of this remedial alternative.

5.2.1.6 Implementability

There are no technical or administrative implementability issues associated with this remedial alternative.

5.2.1.7 Cost

The estimated present worth cost associated with this remedial alternative is $0 (Appendix C).

5.2.2 Alternative 2S – Institutional Controls and Ground Water Monitoring

5.2.2.1 Overall Protection of Human Health and the Environment

This remedial alternative would achieve the RAOs through the implementation of ICs. The following ICs would be implemented:

- Deed restrictions would be applied in the area south of I-10 where the depth-weighted average $TEQ_{DF,M}$ concentrations in upper 10-feet of subsurface soil exceed the soil PRG for the hypothetical future construction worker.

- Notices would be attached to deeds of affected properties to alert potential future purchasers of the presence of waste and soil with $TEQ_{DF,M}$ concentrations exceeding the soil PRG.

Notifying future property owners and construction workers would address the exposure pathway to impacted soil. Potential health risks to hypothetical future construction workers would be addressed by the implementation of this remedial alternative. The ICs would provide protection against anthropogenic disturbance of the clean surface soil and the underlying impacted soil. Ground water monitoring would be implemented to ensure that there are no long-term unacceptable impacts to ground water resulting from the waste left in place.

5.2.2.2 Compliance with ARARs

The implementation of ICs would not involve activities that would trigger ARARs. Therefore, no compliance issues are anticipated for this remedial alternative.

5.2.2.3 Long-Term Effectiveness

Soil in the area of investigation south of I-10 with the $TEQ_{DF,M}$ concentrations greater than the PRG is isolated from potential receptors by a layer of at least 2-feet of soil with $TEQ_{DF,M}$ concentrations well below the PRG for hypothetical construction workers. Long-term effectiveness is provided by the ICs, which would alert future owners to the presence and location of soil with elevated $TEQ_{DF,M}$ concentrations, identify the need for appropriate PPE, and identify restrictions on the placement of soil excavated from the affected areas. Ground water monitoring would be implemented to ensure that there are no long-term unacceptable impacts to ground water resulting from the waste left in place.

5.2.2.4 Reduction of Toxicity, Mobility or Volume

There is no reduction of TMV due to treatment associated with this remedial alternative.

5.2.2.5 Short-Term Effectiveness

There are no short-term risks to the community, ecological receptors, or workers associated with the implementation of this remedial alternative. The remedy would achieve protection in the area south of I-10 immediately upon completion.

5.2.2.6 Implementability

There are no technical implementability issues associated with this remedial alternative. Establishing ICs is routine and the current property owners have generally been cooperative with activities required for the remedial investigation.

5.2.2.7 Cost

The estimated present worth cost associated with this remedial alternative is $1.02 million (Appendix C). The capital costs for this remedial alternative are associated with preparation of deed restrictions and notices and a soil management plan, and conducting USEPA 5-year reviews.

5.2.3 Alternative 3S – Enhanced Institutional Controls and Ground Water Monitoring

5.2.3.1 Overall Protection of Human Health and the Environment

This remedial alternative would achieve the RAOs through a combination of ICs and engineering controls. ICs would be the same as those described in Section 5.2.2. The engineering controls used to enhance the effectiveness of the ICs (subsurface marker layer and bollards) would alert to potential future construction workers of the presence of deeper soil with elevated $TEQ_{DF,M}$ concentrations. Ground water monitoring would be implemented to ensure that there are no long-term unacceptable impacts to ground water resulting from the waste left in place.

5.2.3.2 Compliance with ARARs

This remedial alternative would involve limited excavation and stockpiling of shallow soil to place the marker layer and bollards. Construction activities would comply with ARARs, including the control of dust and storm water.

5.2.3.3 Long-Term Effectiveness

This remedial alternative would control the potential risk to hypothetical future construction workers by providing warnings and information on how to control exposure to soil with $TEQ_{DF,M}$ concentrations exceeding the PRG. The marker layer and bollards would identify the limits of the impacted areas and alert potential future construction workers to the presence of impacted soil and the need to take the precautions associated with excavating the

impacted soil. Ground water monitoring would be implemented to ensure that there are no long-term unacceptable impacts to ground water resulting from the waste left in place.

5.2.3.4 Reduction of Toxicity, Mobility or Volume

There is no reduction of TMV due to treatment associated with this remedial alternative.

5.2.3.5 Short-Term Effectiveness

There are minimal short-term risks to the community, ecological receptors, or workers associated with the implementation of this remedial alternative. Impacted soil would not be disturbed by the shallow excavation or the bollard installation, and measures would be implemented to control dust, storm water runoff, and tracking of soil on equipment leaving the site. The remedy would achieve full protection in the area south of I-10 immediately upon implementation.

5.2.3.6 Implementability

There are no technical implementability issues associated with this remedial alternative. Placement of the marker layer and bollards are standard construction items, requiring no specialized equipment. Other than safety training required for workers at all cleanup sites, there are no specialized requirements for workers. Establishing ICs is routine, but landowners may raise objections to the presence of the bollards to be installed in implementing this alternative, which may create obstacles to the implementability of this alternative.

5.2.3.7 Cost

The estimated present worth cost associated with this remedial alternative is $1.4 million (Appendix C). The capital costs for this remedial alternative are associated with excavation and replacement of soil, placement of the marker layer, installation of bollards, and the preparation of deed restrictions, notices, and a soil management plan, and conducting USEPA 5-year reviews.

5.2.4 Alternative 4S – Removal and Off-site Disposal, Institutional Controls

5.2.4.1 Overall Protection of Human Health and the Environment

This remedial alternative achieves the RAOs through removal of impacted soil in the potential exposure depth interval and replacement with unimpacted imported fill. Institutional controls may be necessary to prevent exposure to contamination below the 10 foot cleanup interval. Institutional controls may be necessary to prevent exposure to contamination below the 10 foot cleanup interval, and to notify owners regarding subsoil dioxin and furan concentrations that are above the soil protective level (51 ng/kg) allowing for unlimited use and unrestricted access.

5.2.4.2 Compliance with ARARs

Removal of impacted soil from the remedial action areas delineated on Figure 4-11 to an off-site disposal facility would require compliance with ARARs related to dust emissions, storm water controls, and disposal. Appropriate storm water and air-quality controls would be used to protect air and water quality. Equipment leaving the work site would be decontaminated as needed to prevent tracking impacted soil on public roads, and each load of soil would be tracked to confirm that the material was received by the designated disposal facility.

5.2.4.3 Long-Term Effectiveness

The long-term effectiveness of this remedial alternative is primarily derived from the removal and secure disposal of soil in the 0- to 10-foot depth interval with $TEQ_{DF,M}$ concentrations exceeding the PRG. Approximately 50,000 CY of soil would be removed from the three remedial action areas south of I-10. The anticipated limits of the excavations are shown in Figure 4-11. The excavated areas would be restored to existing grade and vegetative cover would be re-established. As all of the soil in the affected depth interval (0- to 10-feet below grade) would be replaced with unimpacted, imported fill, the residual risk would be negligible.

5.2.4.4 Reduction of Toxicity, Mobility or Volume

This remedial alternative would involve no reduction of TMV through treatment. The soil may be landfilled without treatment of the COCs. Some of the soil may require dewatering to eliminate free liquids for transportation and disposal. Drying by amendment with Portland cement would incidentally reduce the potential mobility of COCs adsorbed to the soil.

5.2.4.5 Short-Term Effectiveness

Excavation of impacted soil would temporarily increase the potential for exposure to COCs. Dust suppression would be implemented during excavation and backfilling operations to control potential inhalation hazards. Storm water controls would be implemented to minimize the potential for releasing impacted soil, although the potential exists for a release if an extreme storm or high-water event floods the Site while one of the excavations is open. The excavations should be backfilled as soon as practical to minimize the potential for such a release. Additional environmental risks include the possibility of spills during transportation to the disposal facility and possible releases from the off-site landfill itself. In addition to these environmental risks, as compared to the previous three remedial alternatives, the construction of this alternative would have higher greenhouse gas and PM impacts, and ozone generation emissions associated with construction emissions from equipment operating within the project work area, as well as from equipment required for transportation and disposal of excavated soil. However, there are other sources of air emissions and traffic in the region, including the industrial activities that occur adjacent to the Site and the presence of I-10. This remedial alternative, like Alternatives 1S through 3S, would achieve full protection in the area south of I-10 immediately upon completion of construction.

5.2.4.6 Implementability

There are no significant implementability concerns associated with this remedial alternative. Excavated soil may be loaded directly into trucks for transportation to the disposal facility to eliminate the need for stockpiles of impacted soil. Dewatering (groundwater lowering) may be necessary to allow excavation to 10-feet below grade in sufficiently dry conditions, but excavation of soil to 10-feet is a standard construction operation that will not require specialized equipment or workers. Two landfills have been contacted that have indicated preliminarily that they would be able to accept the soil. The compliance status of the selected disposal facility would be confirmed, in conformance to the Off-site Rule, by communication with the USEPA Regional Off-Site Contact prior to beginning construction. The most significant implementability concern may be the temporary additional truck traffic on Market Street and access roads to I-10. Provisions may need to be made to time this traffic or to accommodate the increased volume.

5.2.4.7 Cost

The estimated present worth cost associated with this remedial alternative is $9.9 million (Appendix C). The capital costs for this remedial alternative are primarily associated with the excavation and disposal of soil and conducting USEPA 5-year reviews.

6 COMPARATIVE ANALYSIS OF REMEDIAL ALTERNATIVES

This section compares the alternatives relative to each of the FS evaluation criteria listed under the NCP. Tables 5-1 and 5-2 summarize the criteria for each alternative and provide the basis for the comparative evaluation discussion in this section. Table 6-1 provides an evaluation summary for all of the criteria, assessed using the criteria "Low," "Medium" and "High", where "Low" represents the least favorable, and "High" represents the most favorable assessment of the alternative relative to the specific criterion.

6.1 Area North of I-10

6.1.1 Threshold Criteria

The containment alternatives (2N through 5aN) will only remain protective if they are properly maintained for the length of time (hundreds of years) that the impounded waste retains its toxicity, and their integrity is not compromised by extreme weather events, barge strikes and/or changes in the river channel which could result in a future release. Alternative 6N best realizes the Threshold Criteria (protecting human health and the environment and addressing ARARs) because the waste material would be removed and therefore not subject to a potential future release. As noted in the RAM, the surface-weighted average $TEQ_{DF,M}$ concentration in surface sediments (which are associated with a variety of dioxin sources in addition to paper mill waste that was placed in the impoundments) was reduced by more than 80 percent by the implementation of the temporary cap. However, the protectiveness of all capping alternatives is dependent on the continued integrity of the cap, which, given the dynamic river environment in which the pits are located, has a high degree of uncertainty.

6.1.2 Long-Term Effectiveness

Construction of the temporary armored cap reduced SWAC $TEQ_{DF,M}$ within the USEPA's Preliminary Site Perimeter by approximately 80 percent. While the final remedial action is being selected and constructed, natural recovery will continue to reduce SWAC $TEQ_{DF,M}$ because of the ongoing input of sediment with low $TEQ_{DF,M}$ concentrations from upstream sources. However, the long-term effectiveness of all capping alternatives is dependent on the continued integrity of the cap.

Sediment in the vicinity of the sand separation area is stable and net sedimentation in this area is expected to provide continued isolation at this buried location; however, propeller

wash from tug boat operations, without ICs, could disturb these sediments as could changes to the river bed from future weather events.

Alternative 1N does not include ICs and MNR nor ground water monitoring; the site is not assessed over time, so the long-term effectiveness of this alternative ranks lower than all of the other alternatives. The existing temporary armored cap is not further enhanced in Alternatives 1N or 2N compared to Alternative 3N and 3aN, which could increase the need for future long-term monitoring and maintenance under Alternatives 1N and 2N.

The dioxin within the waste pits was generally isolated from potential receptors by the temporary cap, but the temporary cap has required many repairs and extensive maintenance. Examples include, in December 2015, an area of missing rock that was found by the EPA Dive Team. This area was not identified by the regular inspections that had been done since the temporary cap construction was completed. Dioxin at 43,000 ng/kg was under water exposing the environment and potential receptors to the dioxin. Repairs to this area were completed in 2016. Other instances of thin or absent rock cover were identified in 2012, 2013, and in 2016. No flood since the cap was constructed in 2011 has exceeded a 100-year return period design flood.

The USACE performed evaluations in the 2016 Alternatives Evaluation report to address the permanence of the existing repaired temporary cap with the proposed modifications outlined in the capping Alternative 3N. The expected long-term releases from capping are generally very small in the absence of cap erosion or a major disturbance by a barge strike. However, the USACE found that a potential severe storm could erode a sizable portion of the Alternative 3N cap, which consists of upgrades to the temporary cap that exists currently. The most severe event simulated was the hypothetical synoptic occurrence of Hurricane Ike (Category 2 hurricane) and the October 1994 flood, with a peak discharge of approximately 390,000 cubic feet per second occurring at the time of the peak storm surge height at the Site. This storm flow is about is about 8% higher than the river flow during the 1994 storm. Approximately 80 percent (12.5 acres) of the 15.7 acre Alternative 3N cap incurred severe erosion during the simulated flood. The maximum scour depth in any grid cell within the cap boundary during this potential extreme event was 2.4 feet resulting in erosion and release of the paper mill waste material containing dioxin

The existing repaired cap with the proposed modifications outlined in the capping Alternative 3N and 3aN may be permanent in the absence of extreme weather events, but will require many repairs and extensive maintenance. However, the uncertainty inherent in any quantitative analysis technique used to estimate the long-term (hundreds of years) reliability of the cap is very high. This includes the empirical analysis developed by Maynord (2000) to

estimate the potential scour of the cap due to prop wash generated by ship traffic since a lot of the site data needed to properly perform this analysis were not available. The latter analysis probably has the smallest uncertainty associated with any of the evaluations performed to assess the long term reliability of the cap, and its estimated uncertainty is at least ± one order of magnitude. So, if the estimate of prop induced scour is 10 cm, then the range of uncertainty would be from 1 cm to 100 cm. This estimate of the uncertainty takes into account the lack of a complete data set for the Site and the uncertainty in Maynord's empirically based methodology itself. Further, changes in channel planform morphology due to bank erosion, shoreline breaches, etc. during a high flow event caused by a major flood or hurricane as occurred in other areas of the San Jacinto River during the 1994 storm is beyond the ability of existing sediment transport models to simulate.

The impact of continued subsidence on the integrity and reliability of the existing cap to prevent any release of contaminated material would be dependent on the long-term rate of subsidence. The latter is not well known and cannot be predicted with any reliability. In general, subsidence and the slow rise in sea level would both result in slightly deeper water depths over the Eastern Cell and Northwestern Area of the cap, but the USACE does not believe that these effects would be substantial enough to affect the tidal, river and wind induced circulation in the San Jacinto River estuary.

Regarding the potential impacts of barge strikes, strikes pose significant impacts only from loaded barges and only in proximity of the Northwestern Area. Strikes on the present 1V:2H or the proposed upgraded 1V:3H slope could cause sloughing from gouging and displacement of armor and slope instability from grounding due to the added loadings on the slope from the grounded weight of the barge, exposing a sizeable area of highly contaminated sediment. Low to moderate impacts can occur in the same area from the grounding of an empty barge on the mildly sloped area above the steep slope. This would expose a relatively small area having high levels of contamination in the area immediately north of the Western Cell and directly north and east of the northern end of the center berm.

The impacts of strikes during high flow flood conditions are much greater due to potential erosion of exposed sediment; however, flood conditions occur only about 1% of the time. Strike protection control measures, such as pilings, caissons or a wall, could be used in a 500 to 700 foot reach along the base of the slope in the deep water (15 feet) of the Northwest Area, which are components of Alternatives 3N (wall) and 3aN (wall and pilings). These control measures could prevent all but very low impact strikes.

Alternatives 4N, 5N, 5aN, and 6N, which involve either S/S or partial or full removal, all result in increased long-term protectiveness compared to Alternatives 1N, 2N, 3N, and 3aN because either the resistance to erosion or damage is increased (Alternative 4N), or the potential loss to erosion or damage is reduced due to the removal of part (Alternatives 5N

and 5aN) or all (Alternative 6N) of the waste material. All of the alternatives that involve removal of part or all of the cap will result in releases during construction, however these releases would be mitigated by using BMPs including excavation in the dry where possible, berms, sheet piles, silt curtains, cap removal in sections, etc. The actual design and application of Best Management Practices for construction will be determined during the Remedial Design.

All of the alternatives involving either partial or full removal, including Alternatives 5N, 5aN, and 6N, would have re-suspension of sediment. Alternative 5N uses silt curtains to control the re-suspension of sediment. Silt curtains are the lease effective controls. Alternative 5aN uses more effective re-suspension controls including sheet piles and earthen berms. Alternative 6N adds removal in the dry in addition to sheet piles and earthen berms and results in the most effective control of re-suspension.

There will also be a requirement for a residuals management cover or backfill over the excavated areas for Alternatives 5N, 5aN, and 6N.

Alternative 6N has the greatest long-term effectiveness and protectiveness of all the alternatives because the waste material would be removed and not subject to the potentially severe conditions in the San Jacinto River, and because any construction related releases would result in sediment concentrations initially well below the PRG with further sediment concentration declines over the long term. The impact of dredge residuals will be reduced by the use of BMPs, including using a two layer residuals cover system.

6.1.3 Reduction of Toxicity, Mobility or Volume

Alternatives 1N and 2N do not include additional measures to reduce TMV. However, a portion of the waste materials in the Western Cell were previously solidified during the temporary cap construction as shown in Figures 4-1, 4-3, 4-5, 4-7, and 4-9. No other reduction of toxicity, mobility or volume will be achieved by treatment in any of the alternatives, with the exception Alternative 4N and the dewatering of excavated waste material that may occur in Alternatives 5N, 5aN and 6N. Thus, these alternatives are comparable in reduction of TMV. Alternative 3N and 3aN further reduce potential mobility within the waste pits by increasing the protection of the armored slopes, and thus rank more favorably than Alternatives 1N and 2N. Alternatives 4N and 5N take additional measures through S/S (Alternative 4N) or removal (Alternative 5N) of approximately 52,000 CY of sediments and soils, and are comparatively better than Alternative 3N for reduction of TMV. Potential mobility of the highest concentration materials addressed in Alternatives 4N and 5N would be increased during remedy implementation, somewhat offsetting any reduction

in TMV. Alternative 5aN removes approximately 137,600 CY of sediment, and thus compares more favorably for reduction of TMV than Alternatives 4N and 5N, but subject again to possible issues related to mobility of materials during remedy implementation. Alternative 6N has the greatest volume of removal – 152,000 CY. This alternative is more effective in reducing the toxicity, mobility, and volume of waste compared to all of the other alternatives.

6.1.4 Short-Term Effectiveness

The short-term impacts of remediation activities are primarily related to resuspension of sediment, erosion of residuals, and the concurrent release of contaminants. Enhancement of the TCRA cap under Alternative 3N or 3aN would be expected to produce very little short-term impacts, while removal under Alternative 6N would be expected to increase short-term exposures to contaminants. Approximately 0.2% of the contaminant mass is predicted to be released under Alternative 6N using BMPs (Appendix A, Table 12-19) when sheet piles are used to isolate all waste pit areas during removal and to perform excavation in the dry where feasible; if use of sheet piles is not feasible in the Northwest Cell, this estimated amount increases to approximately 0.34%.

Depending on the selection of BMPs, flooding and high flow conditions during removal operations could significantly increase the erosion of waste material residuals. Releases from flood flows over the containment structure regardless of the removal alternative will be dependent on the height of the containment structure and the flood stage. A sheet pile wall built in and supported by an armored waste pit berm and along the southern shoreline to an elevation of about +10 ft would protect the waste pit excavation from releases from more common floods (e.g., the 25-yr or 50-yr flood stage, Appendix A). Excavation would be performed in the dry to the extent practicable. Removals may be performed in small sections at a time such that the armor stone and geotextile within the small section would be removed, and then the sediment removed and a thin layer of sacrificial fill placed before advancing to the next section and repeating the process. Under these removal operations, it would also be advisable to limit or restrict removal activities to a period when there is a lower probability of tropical storms and flooding conditions. The actual design of protective sheet piles and berms will be determined during the Remedial Design.

The USACE found that fish tissue contaminant concentrations are directly related to the releases to the water column, but are also related to the entirety of their food sources which are largely impacted by the water column concentrations and releases. Consequently, depending on the BMPs employed and the feeding range of the fish species, fish tissue contaminant concentrations may be dozens of times higher (for Alternative 6N) than existing

tissue concentrations for several years before returning to near existing values (Appendix A). The release amount referenced in the USACE's Alternative Evaluation Report, 2 grams of dioxin, or 0.34% of the amount removed, is based on using silt curtains in the Northwestern Area. However, using robust BMPs, including sheet piles in the Northwestern Area, would reduce the release by 40% and therefore the estimated fish tissue contaminant concentrations decreases by 40% as well (Appendix A, Table 12-19).

The capping alternatives, such as 3N or 3aN, would not result in any significant short-term fish tissue contaminant increases, however, the capping alternatives would leave the waste material in place with the resulting long-term risk of a severe hurricane or storm scouring the waste pits and creating a much larger release.

Alternatives 1N and 2N do not entail any construction, and thus have no short-term impacts. Alternative 3N has the shortest duration of the remaining alternatives, does not result in water column, sediment, or tissue impacts (except for minor turbidity during armor rock placement), and has the lowest risk to worker safety, the lowest greenhouse gas and PM emissions, and the least traffic and ozone (smog) impact. Further, Alternative 3N does not disturb the temporary armored cap or require handling of sediments. Alternative 3aN has a longer construction time than 3N and therefore more short-term impacts, but would also have greater long-term permanence because of the armor upgrades. Compared to Alternatives 4N, 5N, 5aN, and 6N, which have longer durations, Alternative 3N and 3aN rank more favorably for short-term effectiveness.

Alternatives 4N, 5N, 5aN, and 6N each have risk of short-term impacts associated with residuals and releases during construction. Because of their longer duration these alternatives also have a higher likelihood that a high-water event during construction could overtop perimeter water quality control features, which would exacerbate short-term impacts because the armor cap needs to be removed to accomplish the work. However, raised berms and sheet pile walls, as well as removing a section of the waste material while other areas remain capped, will mitigate the impact of flooding during construction. The actual scope and design of BMPs will be determined during the Remedial Design.

Alternative 4N has a longer construction duration than Alternatives 5N and 6N and all entail removing portions of the temporary armored cap and managing a volume of sediments. Compared to Alternative 3N, there is higher risk to worker safety (8 to 9 times the number of injuries and fatalities) and higher environmental impacts (8 to 9 times the number of hours of operation and truck trips) due to releases that would be expected during construction. Alternative 4N is considered similar to Alternative 5N for emissions of ozone precursors, PM (smog-forming) and greenhouse gases; under Alternative 4N, construction is limited to work

within the USEPA's Preliminary Site Perimeter and does not result in additional emissions during off-site shipment of sediments, but this is counterbalanced by the shorter duration of Alternative 5N.

Alternative 5aN has the longest construction duration. Alternatives 5aN and 6N are the least favorable for short-term effectiveness. The greater number of work hours has attendant higher worker safety risk (20 times the number of injuries and fatalities compared to Alternative 3N) and higher emissions of ozone precursors, PM (smog-forming) and greenhouse gases (20 times the number of equipment operating hours and truck trips compared to Alternative 3N), and the time required for Alternatives 5aN and 6N to achieve protection is also longer. The levels of post-removal sediment and water contaminant concentrations would be reduced by the use of BMPs during construction, including excavation in the dry, etc.

Construction of any of the proposed Alternatives is not expected to cause any flooding in the vicinity of the Site (Appendix A), and therefore should not require the implementation of any flood control measures during the construction of any of the Alternatives under consideration for the Site.

6.1.5 Implementability

Alternatives 1N and 2N do not have any implementability issues because they do not entail construction. Both are more favorable from an implementability standpoint compared to Alternatives 3N, 4N, 5N, 5aN, and 6N. Alternative 3N is a short-duration project that entails proven technology (i.e., the same activities were demonstrated during construction of the temporary armored cap) that can be deployed with readily-available materials and local, experienced contractors.

Implementability concerns, such as Site access, limited staging areas, restrictions on equipment size, and availability of off-site staging area properties are greater for Alternatives 4N, 5N, 5aN, and 6N compared to Alternatives 3N and 3aN because of the much larger scope and scale of these alternatives. Identifying and securing an off-site staging area is considered an even greater challenge for Alternatives 5N, 5aN, and 6N compared to Alternative 4N because removed sediment would need to be managed at the off-site staging area, which requires a larger footprint, and given the nature of the material removed, might make finding a willing landowner difficult. Proper management of cap material and excavated wastes, and on-site processing and management for removed sediments for off-site transportation to neighboring roadways, will be critical for effective implementation of Alternatives 5N, 5aN, and 6N. Finding a suitable off-site facility for Alternatives 5N, 5aN, and 6N is considered a

more significant implementability challenge than Alternative 4N because the former alternatives will manage removed sediments at the facility. Compared to Alternative 5N, this issue is magnified for Alternatives 5aN and 6N because of the greater volume of material that must be handled at the off-site facility. Based on these factors, Alternatives 3N and 3aN are less favorable than Alternatives 1N and 2N, but more favorable than the remaining alternatives.

Alternative 4N requires the removal of the temporary armored cap, and requires S/S to be completed for an area of sediments that is typically submerged and would need to be dewatered, which is considered a technical challenge. Engineering controls for Alternative 4N may not be adequate to prevent the release of sediments exceeding PRGs to the surrounding environment; this would be especially true during potential high flow events that could occur during construction. Alternative 4N is considered to be less favorable for implementability compared to Alternative 3N.

Alternatives 5N, 5aN, and 6N also require removal of the temporary armored cap and management of waste material for off-site disposal. Similar to Alternative 4N, engineering controls may not be adequate to prevent the release of sediments exceeding PRGs to the surrounding environment. For Alternatives 4N through 6N there is a 30 to 40 percent chance that a high water event could occur during construction resulting in overtopping of the engineering controls. Thus, all of these alternatives are considered equally less favorable as Alternative 4N for implementability compared to Alternatives 1N, 2N, 3N, and 3aN.

6.1.6 Cost

Appendix C provides the detailed estimates that were developed for this FS Report. Costs range from lowest to highest in order from Alternative 1N to Alternative 6N: Alternative 1N is estimated to cost $0.4 million; Alternative 2N is estimated to cost $2.0 million; Alternatives 3N and 4N differ by a factor of 3.6, with estimated costs of $4.1 and $14.8 million, respectively; Alternative 3aN has estimated costs of $24.8 million; Alternative 5N is estimated to cost $29.8 million; Alternative 5aN is estimated to cost $69.6 million; and Alternative 6N is estimated to cost $87 million. Estimated costs include development and operation of the off-site staging area. However, because the exact location and configuration of the off-site staging area are beyond the scope of this FS these elements may not be fully reflected in the FS estimated durations or costs.

6.1.7 Summary of Comparative Benefits and Risks

The waste material is highly toxic and may be highly mobile in a severe storm and therefore is considered a Principal Threat Waste. The Environmental Protection Agency considers material at the Site with more than 300 ng/kg dioxin to be a Principal Threat Waste. This concentration was calculated by multiplying the sediment PRG of 30 ng/kg by a factor of 10.

The location of materials, either partially submerged within the San Jacinto River (northern impoundments) or on a small peninsula on the San Jacinto River (southern impoundment), is in a river environment that is subject to dramatic change, creating concerns about the permanence of an armored cap. The area has a high threat of repeated storm surges and flooding from hurricanes and tropical storms, which, if the material was left in place, could result in a release of hazardous substances. The history of repeated temporary armor cap maintenance to replace missing or eroded armor stone, with flooding that has been less severe than the design 100-year flood, also creates concerns about the long-term permanence of an armored cap.

Alternatives 1N, 2N, 3N, and 3aN have similar impacts to sediments and water column concentrations. Alternative 4N would increase the shear strength of soils and sediments through treatment, which would further increase their stability beyond that provided by the temporary armored cap. Alternatives 5N, 5aN, and 6N would remove impacted sediments from the Site and thus provide higher long-term protectiveness. Alternative 3N relies on the Upgraded Cap, but retains the capped material at the Site that would result in the potential for a future release due to an extreme storm or hurricane or the impacts of a barge strike; while more protective than Alternative 3N, under Alternative 3aN the paper mill waste material remains in the dynamic river environment of the San Jacinto River, with a high degree of uncertainty as to the long-term integrity of the cap. Alternatives 1N and 2N do not enhance the existing temporary armored cap, and so provide lower long-term protectiveness than all of the other alternatives. Alternative 1N does not include ground water monitoring and would not be able to ensure that there are no long-term unacceptable impacts to ground water resulting from the waste left in place. All of the other alternatives, except Alternative 6N, which removes the waste above the PRG, do include ground water monitoring to ensure that there are no long-term unacceptable impacts to ground water resulting from the waste left in place.

Additionally there is risk of harm to the environment during implementation of the remedies associated with Alternatives 4N, 5N, 5aN, and 6N, although these risks would be mitigated by the use of BMPs and engineering controls as discussed under Short-Term Effectiveness. Risks from short-term environmental impacts during and following construction (water column, sediment, and localized tissue impacts) and worker safety

(estimated injury and fatality rates) are significantly (7 to 20 times) higher for Alternatives 4N, 5N, 5aN, and 6N than for Alternatives 1N, 2N, or 3N.

Alternatives 4N, 5N, 5aN, and 6N are less sustainable alternatives, as assessed, considering potential ozone precursor, PM and greenhouse gas emissions from the construction activity, and will result in more community impact from traffic including on-going daily distractions and the potential for accidents and off-site spills (6 to nearly 70 times the number of truck trips). However, there will be only an incremental increase of traffic in comparison with the other sources of air emissions and traffic in the region, including the industrial activities that occur adjacent to the Site and the nearby presence of I-10. These alternatives are expected to require a relatively large off-site facility for management of materials and related activities (armor rock and removed sediment stockpiling, sediment dewatering, transloading, and off-site shipping), which could be difficult to obtain.

6.2 Area South of I-10

Other than Alternative 1S, the remedial alternatives for the area south of I-10 considered in this FS Report meet both of the threshold criteria: protectiveness and compliance with ARARs. The potentially affected receptor (hypothetical future construction worker) would be protected from exposure to soil with elevated $TEQ_{DF,M}$ concentrations by warnings and restrictions (Alternatives 2S and 3S) or removal of impacted soil (Alternative 4S). Alternative 4S is the only alternative that provides for complete removal of the Principal Threat Waste from the southern impoundment.

Alternative 1S does not include ground water monitoring and would not be able to ensure that there are no long-term unacceptable impacts to ground water resulting from the waste left in place. All of the other alternatives, except Alternative 4S, which removes the waste above the soil PRG, do include ground water monitoring to ensure that there are no long-term unacceptable impacts to ground water resulting from the waste left in place.

The pockets of subsurface soil with $TEQ_{DF,M}$ concentrations exceeding the hypothetical future construction worker risk-based PRG in the area south of I-10 are isolated from the surface by several feet of soil with dioxin levels less than the soil screening level allowing for unlimited use and unrestricted access (51 ng/kg). $TEQ_{DF,M}$ concentrations for specific sample intervals are shown in Figure 2-5. Potential exposure to soil exceeding the PRG in this area is limited to circumstances involving excavation into the affected depth zone or potential contact with excavated soil if it were to be left at the surface. The hypothetical future construction worker PRG is based on exposure to soil from 0- to 10-feet below the surface.

With reasonable care, any of the remedial alternatives could be implemented in compliance with ARARs. Soil that is removed (Alternative 4S) would be transported in compliance with Department of Transportation standards and permanently managed in a permitted landfill cleared by the USEPA's regional off-site rule contact. BMPs would be implemented to control dust, storm water, and potential releases of impacted soil.

6.2.1 Long-Term Effectiveness

As noted in the previous section, soil with $TEQ_{DF, M}$ concentrations exceeding the soil risk-based PRG is isolated from the surface by clean overburden. The only route of potential exposure is through excavation into the impacted depth interval. Through the use of appropriate PPE and proper management of excavated soil, the potential risks posed by the impacted soil can be reliably and effectively managed. The physical markers (Alternative 3S) would draw attention to the ICs and enhance their effectiveness. Alternative 4S would achieve long-term effectiveness by permanently removing the impacted soil from the 0- to 10-foot depth interval from the Site and securely disposing of the soil in a permitted landfill. While the ICs, particularly with the addition of physical markers (Alternative 3S), would provide reliable long-term protection, they rely on the integrity of future owners, construction workers, and employees to comply with the restrictions. Therefore, complete removal of the impacted soil in the depth interval of potential excavation (Alternative 4S) may provide a somewhat higher level of long-term effectiveness because it is not subject to inappropriate future use of the area.

Alternative 1S does not include ground water monitoring and would not be able to ensure that there are no long-term unacceptable impacts to ground water resulting from the waste left in place. All of the other alternatives, except Alternative 4S, which removes the soil above the PRG, do include ground water monitoring to ensure that there are no long-term unacceptable impacts to ground water resulting from the waste left in place.

6.2.2 Reduction of Toxicity, Mobility and Volume

Alternatives 2S and 3S do not include any treatment of impacted soil. Alternative 4S would include some treatment of excavated soil, as needed to eliminate free liquids for transportation and disposal. The treatment may involve amendment of the soil with Portland cement, which would reduce the potential mobility of COCs. Water removed from the excavation would be treated, if necessary, to reduce toxicity prior to discharge.

6.2.3 Short-Term Effectiveness

Alternative 2S does not entail any construction, and thus has no short-term impacts. Excavations (Alternative 3S and 4S) would require BMPs to control dust and storm water. Short-term impacts associated with Alternative 3S would be minimal given the shallow depth of excavation, limited volume of material that would be moved, and absence of significant concentrations of COCs in the shallow soil. Alternative 4S would require exposing soil with $TEQ_{DF,M}$ concentrations exceeding the PRG, which introduces the potential for exposure to COCs through direct contact with the soil, inhalation or ingestion of impacted dust, and contact with impacted soil suspended in runoff. However, measures would be implemented to mitigate these issues, including a health and safety plan, runoff controls, dust control measures, etc. The volume of soil and the duration of the project would also be greater than for Alternative 3S, and Alternative 4S would require off-site transportation of the soil to a disposal facility, increasing the potential for exposure to COCs, emissions of greenhouse gasses, nitrogen oxides (NOx), and PM, and potential tracking of COCs off-site. However, measures would be implemented to reduce the amount of any materials lost during transportation. The Remedial Design will determine the actual type and scope of the control measures to be used to address these issues.

6.2.4 Implementability

There are no significant implementability concerns associated with Alternatives 2S and 3S. None of the alternatives requires specialized equipment, techniques, or personnel. Coordination with property owners would be required to establish ICs and for access to the project work site. Alternative 4S would involve more physical activity for implementation, including off-site transportation of impacted soil, but the operations are routine for remedial actions. The additional implementability concerns are the increased truck traffic on Market Street and the potential for flooding while impacted soil is exposed during implementation of Alternative 4S. Provisions may need to be made to handle the additional volume of traffic. The duration of the excavation should not exceed 7 months and implementation could be timed for periods when high water is least likely.

6.2.5 Cost

Appendix C provides the detailed estimates that were developed for this FS. Costs range from lowest to highest in order from Alternative 1S to Alternative 4S. Alternative 1S (No Action) is estimated to cost $143,000, Alternative 2S (ICs) is estimated to cost $1.02 million, Alternative 3S (Enhanced ICs) is estimated to cost $1.4 million, and Alternative 4S is estimated to cost $9.9 million.

6.2.6 Summary of Comparative Benefits and Risks

Alternative 4S would result in the permanent removal of impacted soil from the 0- to 10-foot interval. Risk management achieved by ICs is somewhat less for the area south of I-10, even with the addition of the physical markers that are part of Alternative 3S. Alternatives 2S and 3S would not require exposing impacted soil or transporting material off-site and would be simpler to implement. Alternative 4S is the only alternative that provides for complete removal of the Principal Threat Waste from the southern impoundment. The cost of Alternative 4S, $9.9 million, is 7 times the cost of Alternative 3S and almost 10 times the cost of Alternative 2S. However, Alternatives 2S and 3S do not address the Principal Threat Waste, which Alternative 4S does by removal and disposal. Also, Alternative 4S offers increased long-term effectiveness by removing the impacted soil, although at an increased cost.

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DRAFT FINAL INTERIM FEASIBILITY STUDY REPORT

APPENDIX A:

EVALUATION OF THE SAN JACINTO WASTE PITS FEASIBILITY STUDY REMEDIATION ALTERNATIVES

U.S. ARMY CORPS OF ENGINEERS
ENGINEER RESEARCH AND DEVELOPMENT CENTER

SAN JACINTO RIVER WASTE PITS SUPERFUND SITE