San Jacinto River Waste Pits Superfund Site

Comments
of
International Paper Company
and
McGinnes Industrial Maintenance Corporation
on
Environmental Protection Agency Region 6
Proposed Remedial Action Plan

Appendix G

Additional Documents not included by Region 6
in the Administrative Record

January 12, 2017

Appendix G[1]

Additional Documents not included by Region 6 in the Administrative Record

DOC NO	DOC DATE	PAGE COUNT	TITLE	ADDRESSEE	AUTHOR
G-1	1/18/2012	2	[APPROVAL OF OMM PLAN]	Keith, David, C (ANCHOR QEA, LLC)	Leos, Valmichael (U.S. ENVIRONMENTAL PROTECTION AGENCY)
G-2	3/21/2014	207	DRAFT FINAL INTERIM FEASIBILITY STUDY REPORT FOR SAN JACINTO WASTE PITS SUPERFUND SITE	(U.S. ENVIRONMENTAL PROTECTION AGENCY)	(ANCHOR QEA)
G-3	3/21/2014	173	DRAFT FINAL INTERIM FEASIBILITY STUDY REPORT FOR SAN JACINTO WASTE PITS SUPERFUND SITE – APPENDICES A - C	(U.S. ENVIRONMENTAL PROTECTION AGENCY)	(ANCHOR QEA)
G-4	8/2015	211	EVALUATION OF THE SAN JACINTO WASTE PITS FEASIBILITY STUDY REMEDIATION ALTERNATIVES	(U.S. ENVIRONMENTAL PROTECTION AGENCY)	(U.S. ARMY CORPS OF ENGINEERS)
G-5	2/16/2016	40	MONTHLY PROGRESS REPORT NO. 75 – JANUARY 2016/FEBRUARY 2016 - SAN JACINTO RIVER WASTE PITS	(U.S. ENVIRONMENTAL PROTECTION AGENCY)	(ANCHOR QEA)
G-6	3/15/2016	41	MONTHLY PROGRESS REPORT NO. 76 – FEBRUARY 2016/MARCH 2016 - SAN JACINTO RIVER WASTE PITS	(U.S. ENVIRONMENTAL PROTECTION AGENCY)	(ANCHOR QEA)
G-7	5/27/2016	18	EPA REGION 6 RESPONSE TO BOARD COMMENTS (DOCID 9787624)	(NATIONAL REMEDY REVIEW BOARD)	(U.S. ENVIRONMENTAL PROTECTION AGENCY)

[1] Documents titles are set forth in the format of the Administrative Record.

DOC NO	DOC DATE	PAGE COUNT	TITLE	ADDRESSEE	AUTHOR
G-8	6/2016	239	EVALUATION OF THE SAN JACINTO WASTE PITS FEASIBILITY STUDY REMEDIATION ALTERNATIVES	(U.S. ENVIRONMENTAL PROTECTION AGENCY)	(U.S. ARMY CORPS OF ENGINEERS)
G-9	11/23/2016	1	[JOINDER IN SUPPORT OF GALVESTON MARITIME BUSINESS ASSOCIATION TO APPLY A PERMANENT ARMORED CAP]	Curry, Ron (U.S. ENVIRONMENTAL PROTECTION AGENCY)	Boney, W. Brad (TEXAS OUTDOOR COASTAL COUNSEL)
G-10	12/21/2016	2	[JOINDER IN SUPPORT OF GALVESTON MARITIME BUSINESS ASSOCIATION TO FOLLOW USACE RECOMMENDATION FOR CAPPING INSTEAD OF DREDGING]	Curry, Ron (U.S. ENVIRONMENTAL PROTECTION AGENCY)	Besserman, Kenneth (TEXAS RESTAURANT ASSOCIATION)

APPENDIX G

David Keith

From: Valmichael Leos <Leos.Valmichael@epamail.epa.gov>
Sent: Wednesday, January 18, 2012 12:52 PM
To: David Keith
Cc: Andrew Shafer; John Laplante; John Verduin; March Smith; Phil Slowiak; Randy Brown; Teri Freitas; Wendell Mears; hernandez.jessica@epa.gov; Garyg Miller
Subject: EPA conditional approval of OMMP implementation

Follow Up Flag: Follow up
Flag Status: Flagged

David,

Despite that fact that we do not have a final completion report we should continue forward with the TCRA cap monitoring and inspections. Please consider this email conditional approval of the OMM plan so that we may proceed with the scheduling of the cap inspection and monitoring. Also, I agree that weekly summary reports are no longer needed, Its move to monthly and revisit this later after the first cap inspection.

Valmichael Leos
On Scene Coordinator (OSC)
Emergency Readiness Section
US Environmental Protection Agency Region 6
1445 Ross Ave. (6SF-PE)
Dallas, Texas 75202
Office: 214-665-2283
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From: David Keith <dkeith@anchorqea.com>
To: March Smith <msmith4@wm.com>, Andrew Shafer <dshafer@wm.com>, Phil Slowiak <philip.slowiak@ipaper.com>, John Laplante <jlaplante@anchorqea.com>, Wendell Mears <wmears@anchorqea.com>, John Verduin <jverduin@anchorqea.com>, Randy Brown <rbrown@anchorqea.com>, Teri Freitas <tfreitas@anchorqea.com>
Cc: Valmichael Leos/R6/USEPA/US@EPA
Date: 01/18/2012 08:53 AM
Subject: San Jacinto Weekly Reports and OMMP implementation

Folks – I spoke with Valmichael this morning and he agrees that we can move the currently weekly reports for the TCRA to a monthly report until the RACR is finalized. At that point, we may move to a quarterly report associated with the quarterly OMM Plan monitoring. He will send us an email confirming our conversation, and he will also be sending us an email providing conditional approval of the OMM Plan so we can start the quarterly monitoring program this month.

Wendell – Valmichael would like to be at the Site while Hydrographic Consultants is conducting the survey work, but cannot be there on Wednesday 1/25. Please coordinate with Rob Roman to get some final dates for the survey and pass that information on to Valmichael and the rest of us.

Thanks,
David

David Keith, Ph.D., P.G, C.HG.
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DRAFT FINAL INTERIM FEASIBILITY STUDY REPORT
SAN JACINTO WASTE PITS SUPERFUND SITE

Prepared for

McGinnes Industrial Maintenance Corporation

International Paper Company

U.S. Environmental Protection Agency, Region 6

Prepared by

Anchor QEA, LLC

614 Magnolia Avenue

Ocean Springs, Mississippi 39564

March 2014

DRAFT FINAL INTERIM FEASIBILITY STUDY REPORT SAN JACINTO RIVER WASTE PITS SUPERFUND SITE

Prepared for

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Prepared by

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March 2014

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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
PCL	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 microextraction
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
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 as a companion to the related Remedial Investigation (RI) Report (Integral and Anchor QEA 2013). Both this Draft Final Feasibility Study Report (FS Report) and the RI Report were 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 an armored cap to isolate and contain waste in those impoundments (Armored Cap). The FS Report presents seven remedial alternatives for the Northern Impoundments (Alternatives 1N, 2N, 3N, 4N, 5N, 5aN, and 6N). The alternatives range from continued maintenance of the existing 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 protective concentration level (PCL) for a hypothetical future construction worker. There are no risks to ecological receptors from dioxins.

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, reportedly 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, as well as dredging and sand mining by others within the river and marsh to the west and northwest of the Northern Impoundments through the 1990s and early 2000s, resulted in 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 capped and isolated waste material and impacted sediments.

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 and has not been 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 TCRA to stabilize and isolate materials within the Northern Impoundments. The TCRA 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 an 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) (Armored Cap). The TCRA also included installation of fencing around the TCRA Site, establishment of access controls, and the posting of warning signs.

The 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 Armored Cap 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. Although a 100-year event was specified for the TCRA 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, and the Armored Cap was determined to withstand this larger-magnitude storm (Appendix B).

Since being completed in July 2011, the Armored Cap has isolated and contained impacted material. The 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 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, as well as monitoring following key storm events, to identify the need for possible cap maintenance and procedures to implement appropriate repair activities (USEPA 2005; USACE 1998).

In July 2012, early in the post-construction period, disruption of a localized area of the armor layer (the rock above the geotextile layer) of the Armored Cap occurred and was promptly 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 Armored Cap.

Maintenance events during the first few years after sediment cap construction are not unusual. At least two other sediment caps with demonstrated performance over the last 20+ years have followed this progression. The St. Paul Waterway cap (USEPA 2004b) and the Eagle Harbor cap (USEPA 2012d), constructed in the late 1980s and early 1990s respectively, required some early maintenance in their first few years. Subsequent monitoring has demonstrated the continued protectiveness of these sediment caps.

The 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 validity of the design was confirmed with the USACE recommending enhancements (e.g., placing additional armor rock and constructing flatter slopes) to further ensure the long-term protectiveness of the Armored Cap. In January 2014, the Respondents implemented all of the USACE recommendations (Anchor QEA 2014).

Remedial Action Objectives and Protective Concentration Levels

Remedial Action Objectives (RAOs) for the Site were developed by the Respondents in collaboration with USEPA. Additionally, PCLs for soil and sediment were developed as part of the RI/FS process. The PCLs are consistent with reasonably anticipated futures uses and applicable to the areas north and south of I-10 for which remedial alternatives were developed.

All of the remedial alternatives presented in this FS Report were developed with USEPA to satisfy these RAOs and PCLs. As discussed in Section 3.2 of this FS Report, implementation of the TCRA has achieved the RAOs for the area north of I-10. For example, construction of the Armored Cap has eliminated direct contact exposure for people, fish and shellfish to wastes in the Northern Impoundments and sediments exceeding the PCL.

For the area south of I-10, 0- to 10-foot depth-weighted average concentrations of $TEQ_{DF,M}$ only exceed the PCL for a hypothetical future construction worker in discrete subsurface locations, and no potential pathway for dioxin and furan transport to surface water and sediment or to groundwater has been identified. The RI Report demonstrates that the RAOs are achieved in this area assuming no construction occurs in locations where the PCL is exceeded.

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, or were included at USEPA's direction. 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 Armored Cap.

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

- **Alternative 1N – Armored Cap and Ongoing OMM (No Further Action),** which assumes the 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 ongoing OMM. The estimated cost of this alternative is $9.5 million. This estimate includes the cost of Armored Cap design and construction and USEPA 5-year reviews; these same costs are included in the estimate for each of the other alternatives for the area north of I-10.
- **Alternative 2N – Armored Cap, ICs and Monitored Natural Recovery (MNR),** which includes the actions described under Alternative 1N, ICs in the form of deed restrictions and notices, and periodic monitoring to assess the effectiveness of sediment natural recovery processes. This alternative is estimated to cost $10.3 million.
- **Alternative 3N – Permanent Cap, ICs and MNR,** which includes the actions described under Alternative 2N plus additional enhancements to the Armored Cap, many of which have already been implemented during the January 2014 efforts, consistent with the USACE recommendations. This alternative will increase the long-term stability of the Armored Cap consistent with permanent isolation of impacted materials (Permanent Cap) and meet or exceed USACE design standards. The Permanent Cap will use rock sized for the "No Displacement" design scenario, which is more conservative than the "Minor Displacement" scenario used in the Armored Cap's design. This remedial alternative also includes additional measures to protect the Permanent Cap from potential vessel traffic (e.g., rock berm). This alternative would require an estimated 2 months of construction at an estimated cost of $12.5 million. An off-site staging area may be required for management of rock armor materials, similar to that which was utilized during the TCRA 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 4N – Partial Solidification/Stabilization, Permanent Cap, ICs and MNR,** which includes the actions described under Alternative 3N; however, about 23 percent of the 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 with $TEQ_{DF,M}$ that exceeds a concentration set by USEPA of 13,000 nanograms per kilogram (ng/kg), would undergo solidification and stabilization (S/S). After the S/S is completed, the Permanent Cap would be re-constructed and the same ICs and MNR as in Alternatives

2N and 3N would be implemented. This alternative would require an estimated 17 months of construction to complete and is estimated to cost $23.2 million. 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, Permanent Cap, ICs and MNR,** in which the 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 Permanent Cap would be re-constructed and the same ICs and MNR that are part of Alternatives 2N to 4N would be implemented. This alternative would require an estimated 13 months of construction at an estimated cost of $38.1 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 PCL, Permanent Cap, ICs and MNR,** in which all material beneath the 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 PCL for a hypothetical recreational visitor of 220 ng/kg[1] – about 137,600 cy – would be excavated for off-site disposal. To implement this alternative, about 11.3 acres (72 percent) of the Armored Cap would be removed to allow for this material to be dredged. After excavation of the material, the remaining areas of the Armored Cap would be enhanced to create a Permanent Cap, and the same ICs and MNR that are part of the preceding four alternatives would be implemented. This alternative would require an estimated 19 months for construction and has an estimated cost of $77.9 million. An off-site materials management facility will be required for material staging,

[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 $TEQ_{DF,M}$.

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 Materials Exceeding the PCL, ICs and MNR,** in which all material above the PCL of 220 ng/kg located beneath the Armored Cap or at depth in an area to the west would be removed. This would involve removal of the existing Armored Cap in its entirety and the removal of 200,100 cy of material. The dredged area would then be covered with a layer of clean fill. This alternative would require an estimated 16 months of construction at an estimated cost of $99.2 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.

Each of these alternatives meets the CERCLA threshold criteria that a remedy: 1) provides for overall protection of human health and the environment; and 2) complies with the Applicable or Relevant and Appropriate Requirements (ARARs) identified for the Site.

Comparative Evaluation of Alternatives for Area North of I-10

Alternatives 1N and 2N rely on continued containment of materials exceeding the PCLs within the existing Armored Cap, as enhanced in 2014 to address the USACE's recommendations. These two alternatives each include a requirement, based on the approved OMM Plan, to monitor and maintain the 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 a Permanent Cap that exceeds USACE and USEPA design guidance by placing additional armor rock and constructing flatter slopes. In addition, the Permanent Cap uses larger rock sized for the “No Displacement” design scenario, which more conservative than the “Minor Displacement” scenario used in the Armored Cap’s design, and other CERCLA caps, such as Onondaga Lake and Fox River (Appendix B). In addition, Alternative 3N includes the construction of a protective perimeter barrier or other measures around the perimeter of the Permanent Cap to address concerns regarding potential damage from vessel traffic.

Alternatives 1N, 2N, and 3N are containment alternatives that provide substantial long-term protectiveness while avoiding environmental impacts applicable to Alternatives 4N, 5N, 5aN and 6N, all of which require disruption of the existing Armored Cap to conduct stabilization or removal/disposal of impacted materials. Alternative 3N provides additional long-term protectiveness compared to Alternatives 1N and 2N due to the additional cap enhancements that meet or exceed USACE design standards and measures to minimize potential damage to the Permanent Cap from vessel traffic.

Engineering analysis of the stability of a Permanent Cap (Alternative 3N) has determined that the cap would remain protective when subjected to the erosive forces under any of the flow scenarios (including a 500-year flood event) evaluated in the hydrodynamic modeling (Appendix B). 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.

Alternatives 4N, 5N, 5aN, and 6N include disruption of the existing 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 sediments 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) materials that exceed the PCL of 220 ng/kg for a hypothetical recreational visitor. Alternative 4N would stabilize 52,000 cy of the waste material from beneath the 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 200,100 cy (Alternative 6N). Alternatives 5N and 5aN may reduce the amount of long-term OMM associated with the capping and treatment-based alternatives (1N thorough 4N) , while 6N would eliminate OMM completely.

Alternative 3N has an estimated construction duration of 2 months and would likely require an off-site staging area for armored rock. 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 dredged sediments. The availability and location of an off-site facility could significantly 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 all or part of the Armored Cap and either dredging or stabilizing the underlying waste deposits. Stabilization under Alternative 4A is consistent with USEPA's preference for treatment. However, despite the use of robust engineering and operational controls in conjunction with these alternatives, experience at other sediment sites indicates that resuspension of impacted sediments and release of waste material and dioxins/furans into the water column will likely occur. These issues have been documented at other sediment remediation projects (Table 5-2) in spite of significant efforts made to prevent or control such releases (USACE 2008a; Bridges et al. 2010; Anchor Environmental 2005; Anchor QEA and Arcadis 2010). Such releases can result in increased fish tissue concentrations of contaminants for several years following completion of dredging (Patmont et al. 2013). Moreover, the conservative design necessary to overcome the higher level of uncertainty associated with the implementation of these removal/disposal alternatives can result in significant cost increases.

Best Management Practices (BMPs) may be successful in mitigating potential resuspension and release under normal flow conditions. During construction, however, BMPs could be overwhelmed during significant storm and flood events. For alternatives 4N, 5N, 5aN, and 6N, which require removal of the Armored Cap during construction, the consequences of flooding could be significant as the exposed and disturbed materials would be at risk of spreading beyond the remedial area. For the estimated construction durations of these alternatives, there is a 30 to 40 percent likelihood[1] that such a flood could occur during construction. The potential for release during implementation is a factor that USEPA guidance requires be considered during the comparative net risk analysis of remedial alternatives. See USEPA 2005, Section 6.5.5 and Section 7.4 for reference.

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 than Alternatives 1N and 2N for short-term effectiveness because it includes active construction considerations such as truck traffic, worker safety, water quality, and construction equipment emissions of particulate matter (PM), greenhouse gases, and ozone.

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[2] 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.

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

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." In addition, "if the difference in effectiveness is small but the difference in cost is very large, a proportional relationship between the alternatives does not exist" as discussed in the preamble to National Contingency Plan (NCP) (Federal Register 1990).

[1] Likelihood of flooding assessed by evaluating the duration of construction as compared to flood frequency, assuming a water surface elevation that could overtop perimeter controls such as berms and sheetpiles. See Appendix B and FS Report Section 5 for additional details and discussion.

[2] Safety risks assessed based on estimated durations and labor needs for each alternative, using U.S. Department of Labor safety statistics. Air emissions assessed based on hours of equipment usage estimated for each alternative. See FS Report Section 4 for additional details.

Costs for the remedial action alternatives range from $9.5 to over $99 million.

Alternatives 1N and 2N have similar costs, primarily related to long -term OMM of the Armored Cap. Alternative 3N has a higher cost than Alternatives 1N and 2N as it also includes construction of the Permanent Cap and a protective barrier to ensure the long-term integrity of the Permanent Cap.

Costs for Alternatives 4N, 5N, 5aN, and 6N are significantly higher than for Alternatives 1N, 2N, and 3N. This reflects the challenges of establishing and operating an off-site staging and processing area, removal of the 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.

Figure ES-1 compares the overall project cost and projected effectiveness for each of the alternatives discussed above.

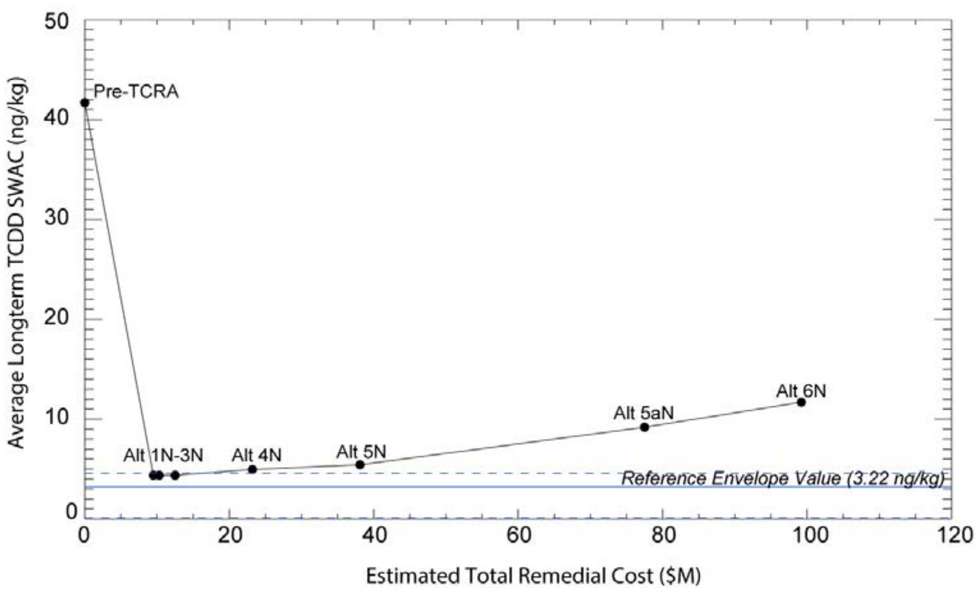

Figure ES-1 – Overall Project Cost and Effectiveness[3]

[3] Reference Envelope Value calculated as the upper tolerance limit on background concentration data. See RI Report Section 4 for further details.

This figure demonstrates that Alternatives 1N, 2N, and 3N provide an equal reduction in the SWAC of dioxins and furans in sediments in the river within USEPA's Preliminary Site Perimeter. For Alternatives 4N, 5N, 5aN, and 6N, the SWAC for dioxins and furans in sediments in the river are predicted to increase due to 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 construction could potentially reduce the protectiveness of the remedy. These alternatives are also incrementally and substantially more expensive because of their complexity and duration. Even if it were to be assumed that no resuspension, other impacts, or residuals would occur during implementation of Alternative 4N, 5N, 5aN, or 6N (which experience with other environmental dredging projects demonstrates will not likely be the case), no incremental protectiveness in the SWAC would likely occur as a result of the implementation of any of these alternatives. These alternatives would not be considered cost-effective under the NCP as they would not provide meaningful additional protectiveness in comparison to the disproportionate incremental cost.

Remedial Alternatives for Area South of I-10

The area south of I-10 is part of a peninsula on which significant 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. Significant 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 any 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, in three discrete locations, come into contact with the dioxins and furans within the upper 10 feet of soil. The PCL for $TEQ_{DF,M}$ protective of a hypothetical future construction worker for $TEQ_{DF,M}$ was calculated to be 450 ng/kg, and is applicable to the average concentration in a soil column of 10 feet.

Remedial alternatives were developed for the three 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 PCL for the hypothetical future construction worker. $TEQ_{DF,M}$ concentrations in the upper 10-feet of soil exceed the PCL at four locations, with the highest $TEQ_{DF,M}$ concentrations occurring at 5-feet below the ground surface or deeper (Figure 3-5). 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 $140,000 (Alternative 1S – No Further Action), $270,000 (Alternative 2S – ICs), $660,000 (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, but the risk management achieved by ICs is nearly equivalent, particularly 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. 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 en route to the disposal facility. The cost of Alternative 4S, $9.9 million, is 15 times the cost of Alternative 3S and more than 35 times the cost of Alternative 2S. Alternative 4S does not satisfy the NCP requirement that a remedy be cost-effective, because it does not provide meaningful additional protectiveness in comparison to the disproportionate incremental cost.

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 effectively 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.

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) on behalf of International Paper Company and McGinnes Industrial Maintenance Corporation (collectively referred to as the Respondents for the Site). 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 screening of remedial technologies and the development of preliminary remedial alternatives. The Draft RAM was conditionally approved by USEPA on November 14, 2012 (USEPA 2012b) and the revised, final version was submitted to USEPA on December 3, 2012 (Anchor QEA 2012b). This FS Report develops and 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 BERA and BHHRA were conditionally approved by USEPA on February 26, 2013 and May 22, 2013, respectively. The Final BERA and BHHRA were submitted to USEPA on May 6, 2013 and May 22, 2013, respectively.

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) as required by the Unilateral Administrative Order (UAO; USEPA 2009a). 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 protective concentration levels (PCLs) 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 metals and 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.

This document satisfies the requirement of the Statement of Work in the UAO for the submittal of a FS Report following receipt of USEPA approval of the Final RI Report (Integral and Anchor QEA 2013). 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 finalized and will be incorporated into a USEPA Record of Decision (ROD) for the SJRWP Site.

The UAO describes a basic history of the SJRWP Site, but it addresses only 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 TCRA stabilized and isolated pulp waste and sediments within the original 1966 perimeter berm of the Northern Impoundments to prevent any releases of dioxins and furans and other chemicals of potential concern (COPCs) to the environment (Anchor QEA 2011, 2012a). More information about the TCRA is provided in Section 2.5.3.

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, 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 impoundments were built in the mid-1960s for disposal of paper mill wastes, reportedly barged from the Champion Paper Inc. paper mill in Pasadena, Texas. These wastes are considered to be a source of dioxins and furans present 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 stormwater runoff, are discussed in Section 2.5.4. 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, as well as dredging and sand mining by others within the river and marsh to the west and northwest of the Northern Impoundments through the 1990s and early

2000s, resulted in exposure of the contents of the Northern Impoundments to surface waters. 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 (Upland Sand Separation Area) (Figure 1-2). In addition, barge maintenance and cleaning activities conducted on and adjacent to the Upland 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. For example, as described in the RI Section 5.4, in addition to regional sources of dioxins and furans, there are surface water drainage channels through two chemical manufacturing facilities upstream of the Site (Integral and Anchor QEA 2013).

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 (ADV-49[1]) 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 TCRA implementation, 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 TCRA. The completion of the TCRA resulted in reduced public access to the Northern Impoundment area. Perimeter fencing was installed and warning buoys and signs were placed around the TCRA Site. In addition, access to the TCRA Site 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).

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 TCRA 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 Upland 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

[1] http://www.dshs.state.tx.us/seafood/survey.shtm and http://www.tpwd.state.tx.us/regulations/outdoor-annual/fishing/general-rules-regulations/fish-consumption-bans-and-advisories.

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

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). The typical tidal range in the river is about 1 to 2 feet, with neap and spring tide conditions corresponding to minimum and maximum tidal ranges, respectively. Tropical storms and wind storms from the north can have significant effects on water levels within the USEPA's Preliminary Site Perimeter. Tropical storms can cause storm surges with water levels that are 4 to 6 feet higher than typical tidal elevations, and storms with strong winds from the north can cause water to be transported out of the Galveston Bay system, which can result in water levels that are much lower than low tide elevations.

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). The average flow rate in the river is 2,200 to 2,600 cubic feet per second (cfs), based on a flood frequency analysis presented in the RI Report (Integral and Anchor QEA 2013). Floods in the river primarily occur during tropical storms (e.g., hurricanes) or intense thunderstorms. Flood events with return intervals of 25 years or more have flow rates of 200,000 cfs or greater (Integral and Anchor QEA 2013). In October 1994, an approximate 100-year flood event had a peak discharge of 360,000 cfs, and a maximum river stage height of 27 feet above mean sea level (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).

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 significantly 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 Armored Cap where vessel access is constrained (Section 2.2.1), natural forces are expected to provide the dominant bed-shear stress.
- Although the rate of subsidence has significantly decreased during the last 35 to 40 years, due to controls on groundwater usage within Harris County, the effect of

subsidence in the future, if it occurs on bed sediments in the San Jacinto River, will be to reduce the potential for erosion. Subsidence lowers the sediment bed elevation, and thus, increases water depth and decreases current velocities, which in turn reduces potential for bed erosion.

- 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 effect of sea level rise on bed sediment in the San Jacinto River will be to reduce the potential for erosion because rising sea level increases water depths, which generally decreases current velocities.

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 PCLs (discussed in Section 3.1) for the areas within the USEPA's Preliminary Site Perimeter. Evaluation of the radioisotope coring data from within the USEPA's Preliminary Site Perimeter indicates the net sedimentation rate (NSR) is approximately 0.4 to 3.9 centimeters per year (cm/year) in depositional areas (Anchor QEA 2012c). The effects of changes in sediment load from upstream sources on long-term sedimentation were evaluated during the modeling study and are discussed in the Chemical Fate and Transport Modeling Report (Anchor QEA 2012c), as well as in Appendix A of this report. Sedimentation rates may change with time if land use restrictions, discharge limitations, or other regulatory developments related to stormwater 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 an in-depth discussion of the process involved to identify COCs within the USEPA's Preliminary Site Perimeter, and 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). 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.

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 TCRA. Outside of the TCRA Site, $TEQ_{DF,M}$ 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 PCLs in Section 3.1.

The RI Report also examined concentrations of polychlorinated biphenyls (PCBs) and mercury in the TCRA 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 Upland 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 are not the primary source of mercury in the aquatic environment under investigation.

2.5.2 Area of Investigation South of I-10

Available historical documentation indicates that 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 three individual 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 full 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 PCLs 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 PCL 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 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 an armored isolation cap (Armored Cap), completed in July 2011, that was designed in accordance with U.S. Army Corps of Engineers (USACE) and USEPA guidelines. During the design of the TCRA, 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 2-6). In general, the TCRA 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 (cy) of material in the upper 3 feet of material over a 1.2 acre portion of the area, and a geomembrane cover layer prior to armor rock installation. The 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 TCRA upland perimeter was fenced and signage was installed to prevent unauthorized access to the TCRA 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 Armored Cap has been subject to ongoing quarterly 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) confirmed the integrity of the Armored Cap. During the next inspection, in July 2012, an isolated area along the western berm slope was noted to have discrete areas where finer-grained cap armor materials had moved down the slope, uncovering a small area of the top geotextile layer (approximately 200 square feet, or 0.03 percent of the 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. This work was completed and documented in a completion report prepared for USEPA (Anchor QEA 2013b, Appendix B). (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.) Subsequent quarterly inspection and monitoring has continued to verify the integrity of the Armored Cap.

During the post-construction period, the Respondents (Anchor QEA 2013a) and USEPA, in coordination with USACE (USACE 2013), conducted separate evaluations of the 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.[4]

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.*[5]
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.*[6]
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, therefore providing an even more stable and protective cap configuration and exceeding design criteria specified in USACE and USEPA sediment capping design guidance (USACE 1998).

[4] Note that these input parameters have been provided to USEPA and USACE.

[5] Note that the enhancements completed in January 2014 used natural stone material, placed at the USACE recommended 1V:3H slope.

[6] 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.

2.5.3.1 Effectiveness of the Time Critical Removal Action

The post-TCRA evaluation confirms that the TCRA's implementation has reduced potential risks from dioxins and furans associated with baseline conditions. The following sections discuss effects of TCRA implementation on sediment, water, and tissue.

2.5.3.1.1 Sediment

Implementation of the TCRA has eliminated the potential transport of waste associated COCs from the Northern Impoundments. The effect of the TCRA 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 TCRA Site, as indicated by the long-term chemical fate model simulations presented in Appendix A.

2.5.3.1.2 Water

Sampling of surface water and porewater with solid phase microextraction (SPME) fibers was conducted after construction of the 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 Armored Cap. Data generated from this porewater assessment support evaluation of remedial alternatives that incorporate the Armored Cap into the final remedy.

The chemical fate and transport modeling presented in Appendix A was used to evaluate the potential for reductions in surface water concentrations associated with implementation of the TCRA. The model results showed that as a result of the Armored Cap, annual average concentration estimates of 2,3,7,8-TCDD predicted by the model in surface water have decreased by approximately 85 percent in the area of the TCRA Site and by 40 percent when averaged over the USEPA's Preliminary Site Perimeter. As discussed in Appendix A, the concentrations predicted by the model for post-TCRA conditions reflect dioxin/furan inputs associated with a number of sources, including transport from upstream, atmospheric deposition, surface runoff, point discharges (industrial and municipal treatment plant effluents), and fluxes from surface sediment outside the Armored Cap.

2.5.3.1.3 Tissue

Upon completion of the TCRA construction in July 2011, sediments in the TCRA Site were rendered inaccessible for direct contact by humans, benthos, fish, and aquatic dependent wildlife. The completion of TCRA construction therefore would be expected to lead to reductions in tissue concentrations in catfish and clams within the USEPA's Preliminary Site Perimeter.

2.5.4 Sources of COCs

The chemical fate and transport modeling, discussed in Section 2.5.5 and Appendix A, concluded that ongoing deposition of sediment within the USEPA's Preliminary Site Perimeter will continue to reduce concentrations of dioxins and furans in sediment. 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.

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 stormwater runoff – contribute dioxins and furans and other COCs (metals, and PCBs) found in the TCRA 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.

The "unmixing" evaluations based on fingerprinting of dioxin and furan mixtures in soil and sediment samples described in the RI Report demonstrate that there are sources other than paper mill wastes of dioxins and furans in sediment and soils within USEPA's Preliminary Site Perimeter, including within the Northern Impoundments and Soil Investigation Area 4.

Sediments within the USEPA's Preliminary Site Perimeter contain a specific distribution of individual dioxin and furan congeners that is likely attributable to the urban background and specific regional sources surrounding the USEPA's Preliminary Site Perimeter, as well as at least one point source within the USEPA's Preliminary Site Perimeter.

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 unmixing 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 unmixing 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 dioxins and furans in soils in the area of investigation south of I-10 (see RI Report Section 6.6).

2.5.5 Chemical Fate and Transport

Section 5.6 of the RI Report contains a summary of the chemical fate and transport processes affecting the concentrations of dioxins and furans within the USEPA's Preliminary Site Perimeter. The most significant points of this discussion are summarized below:

- Sediment-water interactions – Dioxins and furans are hydrophobic and preferentially bind to particulate matter (PM). Particulate-associated dioxins and furans within the sediment bed enter the water column through sediment deposition and erosion processes described in Section 2.5. Deposition of sediments with low concentrations of chemicals may support natural recovery.
- Partitioning and dissolved phase flux – Because dioxins and furans are hydrophobic, they will be present primarily in particulate form, and their fate is therefore determined largely by sediment transport processes. Dioxins and furans within the sediment matrix include dissolved-phase dioxins and furans in porewater through partitioning processes, which can result in a transfer of dissolved-phase mass to the water column under certain conditions.
- Transport in the water column – Dioxins and furans present in the water column in any phase are transported by surface water currents, which are affected by hydrodynamic processes within the larger San Jacinto River.
- External sources – Publicly owned treatment plant outfalls, other point-source discharges, stormwater runoff and atmospheric deposition are all sources of dioxins and furans within USEPA's Preliminary Site Perimeter. As documented in the RI Report, groundwater is not a significant source of dioxins or furans to the San Jacinto River. The modeling described in Appendix A includes contributions from these external sources.

A detailed description of the modeling is provided in the Chemical Fate and Transport Modeling Report (Anchor QEA 2012c), and supporting documentation. More detailed discussions of dioxin and furan bioaccumulation in aquatic biota are presented in the Technical Memorandum on Bioaccumulation Modeling (Integral 2010), Section 5.6 of the RI Report (Integral and Anchor QEA 2013), and in the BERA (Integral 2013a).

2.5.5.1 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. However, even these correlations are weak, and are associated with high uncertainty (Integral 2010). 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 TCRA 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).

2.5.6 Fate and Transport Modeling

A comprehensive fate and transport model was developed to support the RI/FS. The fate and transport model development and calibration is provided in the Chemical Fate and Transport Modeling Study Report (Anchor QEA 2012c). The primary goal of the modeling study was to simulate physical and chemical processes that are controlling chemical fate and transport of selected dioxins and furans within the aquatic environment of the area within the USEPA's Preliminary Site Perimeter. Specifically, the primary objectives of the chemical fate and transport analysis were threefold:

- Develop a CSM for sediment transport and chemical fate and transport.

- Develop and apply quantitative methods (i.e., computer models) that can be used to evaluate the effectiveness of various remedial alternatives during the FS.
- Address specific questions about sediment transport and chemical fate and transport processes within the USEPA's Preliminary Site Perimeter.

The mathematical modeling framework that was applied consists of three models that were linked together: hydrodynamic, sediment transport, and chemical fate and transport. These models were developed, calibrated, and tested (as described in Anchor QEA 2012c) and together form a quantitative framework that can be used as a management tool that can help guide remedial decision making. The calibration and validation of the model framework indicates that it can simulate hydrodynamics, sediment transport, and chemical fate and transport within the Model Study Area (i.e., San Jacinto River from Lake Houston Dam to the confluence with the HSC) with sufficient accuracy to support its use to make relative comparisons among remedial alternatives in the FS Report. The above notwithstanding, the models do have uncertainty due to data limitations, particularly for dioxins and furans in surface water.

Overall, the modeling framework provides a useful management tool to develop future predictions of dioxin and furan concentrations in sediment and surface water within the USEPA's Preliminary Site Perimeter. Specific FS model applications, which are presented in Appendix A, included the following:

- Long-term simulations of post-TCRA future conditions (i.e., starting from current conditions, which include the presence of the Armored Cap over the TCRA Site) were conducted. These simulations provide estimates of rates of natural recovery (i.e., reductions in estimated water column and surface sediment dioxin and furan concentrations over time) in various portions of the Model Study Area, which are representative of conditions anticipated for Alternatives 1N through 3N described in Section 4 below.
- In addition, long-term simulations of alternatives containing in-water sediment remediation (i.e., Alternatives 4N through 6N described in Section 4 below) were also conducted. Future sediment and water column dioxin and furan concentrations from these simulations were used to evaluate potential short- and long-term impacts associated with the construction activities (i.e., sediment resuspension and release

during sediment remediation and effects of dredge residuals).

Results from the fate and transport modeling conducted to support the alternatives analysis are described in detail in Appendix A to this FS Report. Appendix A also includes a description of model uncertainty analyses that were conducted to develop uncertainty bounds around its predictions, as well as a summary of certain sensitivity analyses that were performed with the hydrodynamic and sediment transport models at the request of USEPA in its letter approving the draft final report for the modeling study.

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 sediment resulting from historical paper mill waste disposal in the Northern Impoundments, as well paper mill wastes present in the Soil Investigation Area 4, south of I-10. This section discusses the development of PCLs, 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.

3.1 Recommended Protective Concentration Levels

The RAOs are focused on remedial measures applicable to sediments and soils within the USEPA's Preliminary Site Perimeter to reduce potential exposure pathways to humans and ecological receptors. Therefore, the PCLs utilized in the development of remedial alternatives are those developed for soils and sediments. All of the PCLs 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.

PCLs were developed as described in the RI Report and the May 14, 2013 letter from Anchor QEA to USEPA Region 6 (Anchor QEA 2013). The PCLs for the hypothetical recreational visitor and hypothetical future construction worker were presented in the RI Report, which was approved by USEPA; the PCL for the hypothetical future outdoor commercial worker was developed in cooperation with the USEPA during preparation of the FS using methodologies contained in USEPA guidance documents and presented in the May 14, 2013 letter. The development of PCLs considered all potential exposure pathways associated with hypothetical receptor exposure scenarios approved by USEPA, including reasonably anticipated future uses of specific areas within the USEPA's Preliminary Site Perimeter, and all COCs for each medium. Based on consideration of reasonable potential future uses within the USEPA's Preliminary Site Perimeter, four PCLs were developed for use in the FS Report for evaluation of the remedial alternatives of 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 sediments, and hypothetical construction and hypothetical commercial workers for soils. Exposure assumptions for hypothetical subsistence fisher scenarios provided in the RI Report are not consistent with the anticipated future uses within USEPA's Preliminary Site Perimeter, so the PCL for that scenario was not used in the development of alternatives.

PCLs were also developed for total PCBs and arsenic for soils and sediments, and for total PCBs, arsenic, and mercury in tissue in the RI Report. Cancer-based PCLs for total PCBs and arsenic were developed at the request of USEPA. However, 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. Also, 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. Moreover, concentrations of each dioxin-like PCB congener in sediments were either significantly correlated with concentrations of TCDD and TCDF (Integral 2011), indicating that remediation for dioxins and furans will also address these PCBs (Anchor QEA and Integral 2010a, Appendix C), or were generally below detection limits. The elevated mercury concentrations in the soils on the Upland 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 PCLs for $TEQ_{DF,M}$.

The $TEQ_{DF,M}$ PCL for sediment outside the footprint of the Armored Cap is based on exposure to dioxins and furans by a hypothetical recreational visitor, as evaluated in the BHHRA. For a noncancer hazard quotient equal to 1[2], the $TEQ_{DF,M}$ concentration in sediment for this PCL is 220 nanograms per kilogram (ng/kg) (Integral and Anchor QEA 2013). Although the PCL for the hypothetical recreational fisher would also be appropriate, the PCL for the hypothetical recreational visitor is more conservative. Figures 3-1 and 3-2 present $TEQ_{DF,M}$ concentrations in surface and subsurface sediment, respectively, outside the footprint of the Armored Cap. The measured $TEQ_{DF,M}$ concentrations in sediments exceeded this PCL in only one location,

[2] The noncancer $TEQ_{DF,M}$ PCL is always lower than the PCL for the cancer endpoint for any given media and exposure scenario, and is therefore the more conservative PCL (see RI Report Tables 5-29 and 5-31).

northwest of the TCRA Site near the Upland Sand Separation Area, in two subsurface sample intervals at depths of 4 and 6 feet below ground surface.

The PCL for soil/sediment within the footprint of the TCRA is based on the reasonable future use of this area, which is industrial or commercial. A PCL was derived as presented in the May 14, 2013 letter (Anchor QEA 2013) for a hypothetical future outdoor commercial worker assumed to be exposed to soil/sediment in the TCRA footprint. For a noncancer hazard quotient equal to 1, the PCL as a $TEQ_{DF,M}$ concentration in soil/sediment is 1,300 ng/kg. Figures 3-3 and 3-4 present $TEQ_{DF,M}$ concentrations in surface and subsurface sediment, respectively, within the footprint of the Armored Cap relative to this PCL.

The PCL for soil within USEPA's Preliminary Site Perimeter is based on exposure to dioxins and furans by a hypothetical future recreational visitor, as evaluated in the BHHRA. For a noncancer hazard quotient equal to 1, the $TEQ_{DF,M}$ concentration in soil for this PCL is 1,300 ng/kg (Integral and Anchor QEA 2013). The measured $TEQ_{DF,M}$ concentrations in surface soils do not exceeded this PCL in any locations outside of the TCRA footprint.

For soil in the area south of I-10, a PCL was derived based on the reasonable maximum exposure scenario for a hypothetical future construction worker. For a noncancer hazard quotient equal to 1 the $TEQ_{DF,M}$ PCL for soil is 450 ng/kg (Integral and Anchor QEA 2013). The development of the PCL considers exposure to soil through the total depth interval (0- to 10-feet) to which a hypothetical future construction worker could be exposed. Figure 3-5 presents the depth-weighted average $TEQ_{DF,M}$ concentrations for the 0- to 10-foot depth interval for samples in the area south of I-10 relative to this PCL. At the request of USEPA, the $TEQ_{DF,M}$ soil exposure point concentration for a hypothetical future construction worker at those same locations was calculated in the 0- to 5-foot depth interval. The 0- to 5-foot depth-weighted average $TEQ_{DF,M}$ concentration in soil exceeds the PCL for the hypothetical future construction worker at three locations at stations, SJSB012, SJSB023, and SJSB025. These three locations are co-located with the four locations at which the 0- to 10-foot depth-weighted average $TEQ_{DF,M}$ exceeded the soil PCL for the hypothetical future construction worker (Figure 3-5).

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 along with a brief summary of the extent to which RAOs have been addressed through implementation of the TCRA. The RI Report provides additional detail support for the development of the RAOs.

RAO 1: Eliminate loading of dioxins and furans from the former paper mill waste impoundments north and south of I-10, to sediments and surface waters of the San Jacinto River.

As outlined in the RI Report (Integral and Anchor QEA 2013), the RACR (USEPA 2012c), and subsequent ongoing TCRA monitoring, the Armored Cap has achieved RAO 1. Groundwater and porewater monitoring of the TCRA Site demonstrate that dissolved transport and loading of dioxins and furans through these pathways has been effectively addressed (Integral and Anchor QEA 2013).

The potential pathway for dioxin and furan loading to surface water and sediment from the possible impoundment south of I-10 described in the PSCR was surface runoff of soil particles. In comments on the Draft PSCR and on the Draft RI Report, USEPA raised concerns about migration of dissolved dioxins and furans with groundwater. The results of the RI Report indicate that $TEQ_{DF,M}$ concentrations in surface soils are below PCLs for the areas within Soil Investigation Area 4 south of I-10 and that pockets of dioxin-bearing waste are buried beneath several feet of soil; therefore, surface runoff of soil particles to surface water in this area is not an ongoing concern, and risk to hypothetical future commercial workers is also not a concern. Groundwater monitoring in the area south of I-10 also indicates that there is no potential for transport and loading of dioxins and furans to the aquatic environment through a groundwater pathway. Therefore, existing conditions in the area of investigation south of I-10 are consistent with RAO 1.

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

Implementation of the TCRA has substantially reduced exposures of aquatic biota to wastes from within the Northern Impoundments, and therefore has reduced potential human exposures via fish and shellfish consumption. Implementation of the TCRA has achieved these objectives through elimination of direct contact exposure for fish and shellfish to wastes in the Northern Impoundments and impacted sediments. Implementation of ICs (fencing and warning signs) have also mitigated potential human exposures to fish and shellfish within USEPA's Preliminary Site Perimeter.

RAO 3: Reduce human exposures to paper mill waste-derived dioxins and furans from direct contact with intertidal sediment by remediating sediments affected by paper mill wastes to appropriate cleanup levels.

Estimated baseline risks under hypothetical exposure scenarios that involved direct contact with all areas within the USEPA's Preliminary Site Perimeter other than the Northern Impoundments, but did not involve ingestion of fish and shellfish, were below risk and hazard thresholds of concern. Implementation of the TCRA has substantially reduced potential cancer and noncancer dioxin hazards to people within USEPA's Preliminary Site Perimeter. An analysis of post-TCRA human health risk (Appendix F to the BHHRA Report) for the hypothetical recreational visitor and hypothetical recreational fisher found that both the noncancer and cancer hazard indices were reduced to below 1 for these receptors by implementation of the TCRA. Therefore, RAO 3 has been successfully achieved through implementation of the TCRA. $TEQ_{DF,M}$ concentrations in surface sediment in all intertidal and subtidal areas outside of the TCRA Site are below applicable PCLs provided in Section 3.1.

RAO 4: Reduce human exposures to paper mill waste-derived dioxins and furans from direct contact with upland soils to appropriate cleanup levels.

The Armored Cap prevents exposure to soils containing paper mill waste within the TCRA Site unless the soil is exposed through excavation.

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 column, in three specific locations. However, the dioxin and furan concentrations that cause the elevated exposures are in pockets of soil, each of which is at least 4-feet below the surface, and are therefore isolated from human contact as long as subsurface exposure during construction does not occur.

RAO 5: Reduce exposures of fish, shellfish, reptiles, birds, and mammals to paper mill waste-derived dioxins and furans by remediating sediment affected by paper mill wastes to appropriate cleanup levels.

Baseline risks associated with dioxins and furans to benthic macroinvertebrate communities and populations of fish, birds, mammals, and reptiles in the area north of I-10 and the aquatic environment were determined in the BERA to be negligible, except for risks to shorebirds (represented by the spotted sandpipers) and small mammals (represented by the marsh rice rat) that could live or forage in direct contact with the wastes or intertidal sediments in the impoundments north of I-10. Baseline ecological risks include reproductive risks to mollusks from exposure to 2,3,7,8-TCDD, primarily in the area of the Northern Impoundments. Baseline ecological risks elsewhere within the USEPA's Preliminary Site Perimeter were negligible, or were very low and the result of exposures to chemicals from sources other than paper mill wastes.

Analysis of post-TCRA risks to those ecological receptors that were potentially at risk under baseline conditions indicates that, because the TCRA eliminated exposures to dioxins and furans through direct ingestion of or direct contact with waste materials within the 1966 perimeter of the Northern Impoundments, the post-TCRA conditions do not pose a risk for ecological receptors. Remediation of sediments and soils within the TCRA footprint and ongoing natural recovery of sediments in areas outside of the TCRA footprint have reduced COC concentrations in sediments, water, and biota. This RAO has been achieved through implementation of the TCRA.

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. Finally, USEPA may find during its review of remedial alternatives that the most suitable remedial alternative does not meet an ARAR. The NCP provides for waivers of ARARs under certain circumstances (see 40 Code of Federal Regulations [CFR] 300.430(f)(1)(ii)(C)).

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. The implementation of the remedy generally will not require Federal, State, or local permits because of the permit equivalency of the CERCLA remedy-selection process (40 CFR 300.400(e)(i)), but remedial actions will be completed in conformance with substantive technical requirements of applicable regulations.

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 PCLs 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 sediment, 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.

Demonstration of substantive compliance with these ARARs 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 silt fences to manage potential upland runoff, plastic sheeting to cover any required upland stockpiles, and other erosion control measures to be described in the plans and specifications of the final remedy.
- 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 Corps of Engineers 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, if necessary to minimize the impacts of discharges of fill into the water, include:

- The use of a 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 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). Moreover, the BERA concluded that under baseline and post-TCRA conditions, there is no risk to the protected species that were evaluated.

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

A hydrologic evaluation (Appendix B) subject to USEPA approval was performed to evaluate the impacts of the remedial alternatives on the water levels in the San Jacinto River. The evaluation of potential effects of the remedial alternatives on flooding is discussed in the detailed evaluation of the remedial alternatives in Section 5. USEPA's review of the FS Report and selection of the remedy will consider whether the placement of fill will significantly affect water levels within the floodplain of the San Jacinto River.

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 TCRA Site 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 sediments 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 sediment 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 (USEPA 2012a).

4.1.2 Monitored Natural Recovery

MNR would entail periodic sampling and an analytical program that would be implemented to monitor the progress of natural recovery. Sampling would be conducted at a representative range of locations and at appropriate time intervals to allow trends in concentrations to be assessed. 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 remedial design and based on discussions with USEPA.

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 soils and sediments with a reagent such as Portland Cement. S/S was successfully performed during the TCRA 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 TCRA, or 7 to 8 percent by weight Portland cement (USEPA 2012c).

To accomplish S/S, physical removal of the existing 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 sheetpile wall, and the water drawn down prior to initiating S/S. The sheetpile system used would need to be robust to withstand differential water levels inside and outside the treatment cell. Sheetpile walls can be overwhelmed during significant storm and flood events in the river. In these circumstances, it is likely that releases of wastes that are exposed as a result of construction activities would occur. Finally, given the physical constraints of the TCRA 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.

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). In addition, the specific recommendations by USACE to enhance the Armored Cap (see Section 2) are incorporated into any alternative that includes capping as an element.

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 similar to the SJRWP Site where capping was a component of the remedy. Caps constructed for these projects isolate dioxin-contaminated soils and sediments or related constituents, and are located in river or marine environments where a portion of the cap is above the typical water surface, and/or a portion of the cap is submerged. These caps have been monitored, and in some cases maintained, in accordance with approved OMM plans. Monitoring has demonstrated that these caps are protective.

The existing 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 TCRA 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. In accordance with the NCP (40 CFR §300.415(d)), the Armored Cap was also designed to contribute to efficient performance of long-term remedial actions at the Site.

Although a 100-year event was specified for the TCRA design, to assess the potential risk of an even larger storm, events up to the 500-year storm were evaluated for the FS, and intermediate storms with 25- and 50-year return intervals were also modeled (Appendix B). As is shown in Appendix B, the critical design storms for the TCRA Site occur between the 10- and 100-year return intervals. For less frequent, larger storms, the greater depth of water at the TCRA Site due to flooding results in lower velocities, and thus lower shear stresses acting on the cap.

Surface flow and wave break modeling was performed to evaluate potential erosive forces to support the selection of cap materials to resist those forces (Appendix B). The modeling considers wind and vessel generated waves breaking in the surf zone, as well as river currents under a variety of design storm and flood scenarios. This modeling is described in more detail in Appendix B.

Cap design occurs with requirements for OMM in mind. Since being completed in July 2011, the 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 first few years following cap construction is a period where monitoring and maintenance is more frequent. At least two other sediment caps with demonstrated performance over the last 20+ years have followed this progression. The St. Paul Waterway cap (USEPA 2004b) and the Eagle Harbor cap (USEPA 2012d), constructed in the late 1980s and early 1990s respectively, required some early maintenance in their first few years. Subsequent monitoring has demonstrated the continued protectiveness of these sediment caps.

Cap protection from future barge or other vessel operations in the 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 Permanent Cap to further ensure the long-term protectiveness of the cap by reducing potential for vessel impacts. Finally, given the physical constraints of the TCRA 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 TCRA.

Capping is considered to be highly compatible with the Armored Cap in accordance with the TCRA Removal Action Objectives (USEPA 2010a, Appendix A, V.A.2), because the existing Armored 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. Dredging or excavation 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 with conditions similar to this Site where dredging has been chosen as the remedy.

Alternatives that involve full or partial removal of the Armored Cap and excavation of impacted material from beneath the cap and in other locations all involve dredging. As discussed in the RAM (Anchor QEA 2012b), virtually all dredging projects result in some degree of resuspension, release, and residuals, despite use of BMPs (USEPA 2005, Sections 6.5.5 (resuspension and releases) and 6.5.7 (residuals); NRC 2007; USACE 2008; Bridges et al. 2010). Empirical data from numerous sediment remediation projects indicate that residual contamination is a common occurrence that frequently limits the overall protectiveness of removal (Patmont and Palermo 2007; NRC 2007). USEPA guidance on sediment remediation states that "there should not be necessarily a presumption that removal of contaminated sediments from a water body will be necessarily more effective or permanent than capping or MNR." (USEPA 2005).

Operational and engineering controls (rigid and flexible barriers) would be used to the extent practicable to mitigate these potential releases; however, case studies have shown that engineering controls used to control impacts from dredging such as sheetpiles may have limited effectiveness, are subject to leakage, accumulate resuspended sediments at the base of the walls which is impossible to completely capture, and have other technical limitations (USACE 2008b; Anchor Environmental 2005; Anchor QEA and Arcadis 2010). Further, use of rigid barriers can result in unintended consequences, such as concentration of dissolved-phase chemicals, localized scour adjacent to the barrier, and/or the spread of contaminants during structure removal (Ecology 1995; Konechne et al. 2010; Anchor QEA and Arcadis 2010). Flexible barriers such as turbidity curtains will suffer from suspended sediment losses because these types of barriers are not truly water-tight (USACE 2008a; USACE 2008b; Francingues and Palermo 2006; Anchor Environmental 2005; Anchor QEA and Arcadis 2010). Proper design and installation of engineered barriers would be critical for minimizing the issues described above.

Dredging residuals would be managed by backfilling the dredge footprint, or by placement of a clean sediment cover or engineered cap over the dredge 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 PCL, and a nominal 6-inch-thick cover of clean sediment would be used to manage dredging residuals for removal-based alternatives that achieve the PCL.

Construction-related releases associated with removal-based alternatives reduce the long-term effectiveness of these approaches. Table 4-2 presents a summary of dredging release case studies. Post-construction monitoring data have shown that dredging-based cleanup remedies can increase fish tissue concentration of contaminants, even several years following completion of dredging (e.g., at the Commencement Bay and Duwamish Waterway Superfund Sites; Patmont et al. 2013). To the extent that dredging-related releases occur, they reduce the overall effectiveness of a dredging remedy and under USEPA sediment remediation guidance (USEPA 2005, Sections 6.5.5 and 7.4), this should be considered during the comparative net risk analysis of the remedial alternatives under consideration.

Dredging-based alternatives would require the removal of all or portions of the existing Armored Cap to access the target material. Based on the history of resuspension, releases and residuals that occur despite use of BMPs (as identified by USEPA, the National Academy of Sciences, the USACE, and others), it is likely that some of these risks would occur at this Site in connection with the removal alternatives being considered. Under the USEPA sediment remediation guidance (USEPA 2005), these factors should be taken into consideration when comparing the dredging remedies to the overall effectiveness of those alternatives that do not involve additional soil and sediment dredging/excavation.

The estimated construction durations for the removal-based alternatives range from 13 months to 19 months. If a significant storm or flood were to occur during construction of a dredging-based remedy, any BMPs that may be instituted to control dredging residual releases under normal flow conditions would be overwhelmed. In these circumstances, it is likely that releases of disturbed wastes to the river that are exposed as a result of construction activities would be greatly exacerbated. The risk of this type of occurrence is discussed for each dredging-based alternative under the short-term effectiveness evaluations in Section 5. Finally, given the physical constraints of the TCRA 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, wellpoint 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 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 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.

Given the limited upland space available adjacent to the TCRA Site, an off-site facility with water access would be necessary unload barges and process dredged sediment prior to shipment to the landfill. The off-site facility would need to accommodate stockpiles for armor rock and dredged material, and would need space to accommodate a sediment 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. 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 in discussions with USEPA Region 6 subsequent to submittal of the RAM. The most significant reason for the modifications was that PCLs for 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 sediment and soil to the PCLs, areas of affected 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 at the direction of and in coordination with USEPA Region 6 for the areas north and south of I-10. The remedial alternatives for the area north of I-10 are:

- **Alternative 1N – Armored Cap and Ongoing OMM (No Further Action)**, which assumes the 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 ongoing OMM. The estimated cost of this alternative is $9.5 million. This estimate includes the cost of Armored Cap design and construction and USEPA 5-year reviews; these same costs are included in the estimate for each of the other alternatives for the area north of I-10.
- **Alternative 2N – Armored Cap, ICs and Monitored Natural Recovery (MNR),** which includes the actions described under Alternative 1N, ICs in the form of deed

restrictions and notices, and periodic monitoring to assess the effectiveness of sediment natural recovery processes. This alternative is estimated to cost $10.3 million.

- **Alternative 3N – Permanent Cap, ICs and MNR,** which includes the actions described under Alternative 2N plus additional enhancements to the Armored Cap, many of which have already been implemented during the work performed in January 2014, consistent with the USACE recommendations. This alternative will increase the long-term stability of the Armored Cap consistent with permanent isolation of impacted materials (Permanent Cap) and meet or exceed USACE design standards. This alternative also includes additional measures to protect the Permanent 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 $12.5 million. An off-site staging area would likely be required for management of rock armor, similar to that which was utilized during the TCRA 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 4N – Partial Solidification/Stabilization, Permanent Cap, ICs and MNR,** which includes the actions described under Alternative 3N; however about 23 percent of the 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 set by USEPA of 13,000 ng/kg, would undergo solidification and stabilization (S/S). After the S/S is completed, the Permanent Cap would be constructed. This alternative would require an estimated 17 months of construction to complete and is estimated to cost $23.2 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, Permanent Cap, ICs and MNR,** in which the 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 Permanent Cap would be constructed and the same ICs and MNR that are part of Alternatives 2N to 4N would be implemented. This alternative would require an estimated 13 months of construction

at an estimated cost of $38.1 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 PCL, Permanent Cap, ICs and MNR,** in which all material beneath the Armored Cap in any location where the water depth is 10-feet or less and which has a of $TEQ_{DF,M}$ 220 nanograms per kilogram (ng/kg) or greater[7] – about 137,600 cy – would be excavated for off-site disposal. To implement this alternative, about 11.3 acres (72 percent) of the Armored Cap would be removed to allow for this material to be dredged. After excavation of the material, the remaining areas of the Armored Cap would be enhanced to create a Permanent Cap, and the same ICs and MNR that are part of the preceding alternatives would be implemented. This alternative would require an estimated 19 months for construction and has an estimated cost of $77.9 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 Materials Exceeding the PCL, ICs and MNR,** in which all material above the PCL of 220 ng/kg beneath the Armored Cap and at depth in an area to the west would be removed. This would involve removal of the existing Armored Cap in its entirety and the removal of 200,100 cy of material. The dredged area would then be covered with a layer of clean fill. This alternative would require an estimated 16 months of construction at an estimated cost of $99.2 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,

[7] 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 $TEQ_{DF,M}$.

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 4-6 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 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 – 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 TCRA Site, selected stabilization of near surface soils in the Western Cell, installing a security fence, and posting warning signs. The 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 robust 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, costs which are included in this and each of the other alternatives for the area north of I-10. In accordance with this guidance, an OMM plan was developed that was reviewed and approved by USEPA. Periodic inspections continue to be conducted to verify the integrity of the Armored Cap. The 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 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 TCRA remedy was a comprehensive and protective early action that successfully reduced dioxin/furan exposure within the TCRA Site area by more than 80 percent (Anchor QEA 2012b) and additional work to enhance the 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 TCRA construction was completed prior to the review of the array of potential remedies under the FS, the existing TCRA remedy for procedural purposes is designated as being the "No Action" alternative. However, under this "No Action" option, the 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 area of the TCRA Site, the $TEQ_{DF,M}$ SWAC for soil/sediment following completion of the TCRA is approximately 12 ng/kg (Anchor QEA 2012b), which is well below the PCL for hypothetical recreational visitors (220 ng/kg). No surface soil/sediment samples outside the

Armored Cap and within the Preliminary Site Perimeter have a $TEQ_{DF,M}$ concentration exceeding this PCL (Figure 3-1). The only sediment samples outside of the limits of the Armored Cap with $TEQ_{DF,M}$ concentrations exceeding the PCL for hypothetical recreational visitors are two subsurface sediment samples collected north of I-10 from one location (SJNE032, refer to Figure 2-4) near the Upland Sand Separation Area. These samples are buried beneath at least 3 feet of sediment with $TEQ_{DF,M}$ concentrations below the PCL.

This alternative includes ongoing OMM of the Armored Cap, which includes inspection and periodic maintenance, and USEPA 5-year reviews as required under the NCP in 40 CFR 300.430 (f)(iv)(2). The estimated cost of this alternative is $9.5 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 and MNR. 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 Upland Sand Separation Area where one location exists with $TEQ_{DF,M}$ concentrations exceeding the sediment PCL.
- Public notices and signage around the perimeter of the TCRA 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. Modeling, presented in Appendix A, projects that ongoing sedimentation will reduce $TEQ_{DF,M}$ concentrations in surface sediment over time. Specifically, natural recovery from sediment inputs within the USEPA's Preliminary Site Perimeter is predicted to further reduce the SWAC for 2,3,7,8-TCDD and 2,3,7,8-TCDF within the USEPA's Preliminary Site Perimeter by a factor of 2 over a period of 10- to 15-years. The estimated cost for this alternative is $10.3 million (Appendix C).

4.3.3 Alternative 3N – Permanent Cap, Institutional Controls and Monitored Natural Recovery

This alternative includes the actions described under Alternative 2N plus additional enhancements to the Armored Cap to create the Permanent Cap. This alternative will increase the long-term stability of the Armored Cap consistent with permanent isolation of impacted materials. Cost estimates for this alternative also include additional measures to protect the Permanent 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 Permanent 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 remedial design.

The Armored Cap was constructed to provide immediate containment of the materials in the TCRA 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 Armored Cap, that would involve flattening the slopes of the existing Armored Cap by adding additional armor rock material to enhance the effectiveness and permanence of the Armored Cap remedy by increasing the degree of safety for the armor rock design, to create the Permanent Cap. Such measures are consistent with and exceed the recommendations made by USACE in its review of the Armored Cap performance (see Section 2), and will result in an enhanced cap that will be protective under worst-case storm and/or flood events.

The Armored Cap was originally designed with a robust armor layer to provide reliable containment of materials exceeding PCLs in the Northern Impoundments, as well as layers of geotextile and geomembrane. As described in Appendix B, 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 Armored Cap against catastrophic failure. In January 2014, further enhancements were made to the 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 Permanent Cap adds further robustness to the enhanced 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 Permanent Cap uses larger rock sized for the "No Displacement" design scenario, which is more conservative than the "Minor Displacement" scenario used in the Armored Cap's design, and other CERCLA caps, such as Onondaga Lake and Fox River (Appendix B). Upon completion, the Permanent Cap will be constructed to a standard that exceeds USEPA and USACE design guidance, and meets or exceeds the recommended enhancements suggested by USACE in their 2013 evaluation of the Armored Cap.

The anticipated extent of the additional rock that would be placed during construction of a Permanent 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 TCRA construction, the duration of construction for this alternative is estimated to be 2 months (Table 4-3). During construction of the TCRA, obtaining access to the work area from the uplands was a demonstrated implementability challenge; construction of Alternative 3N will require that access from the uplands be obtained, and obtaining such access could be a challenge. 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 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 (Table 4-4). 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 (Table 4-5). 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 $12.5 million (Appendix C).

4.3.4 Alternative 4N – Partial Solidification/Stabilization, Permanent Cap, Institutional Controls and Monitored Natural Recovery

This remedial alternative is included per the direction of USEPA Region 6 to provide for S/S of material that exceeds 13,000 ng/kg $TEQ_{DF,M}$ within the USEPA's Preliminary Site Perimeter. 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 of the TCRA Site that is currently covered by the Armored 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 Armored Cap and on average approximately 5-feet below the current base of the Armored Cap in the Eastern Cell and Northwestern Area. A Permanent Cap, ICs, and MNR, as described in Sections 4.1.2 and 4.1.3, are also included in this remedial alternative.

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 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 sheetpiling 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 sheetpile 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 sheetpile enclosure would be removed. Finally, the Permanent 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 Permanent 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 soil and sediment 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 Armored Cap, and to stockpile and load the new armor rock materials to be placed for construction of the Permanent 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 (Table 4-4) than the previous three alternatives.

Alternative 4N is estimated to result in more than one lost time injury, and approximately 0.004 fatalities as a result of construction (Table 4-5). 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 $23.2 million (Appendix C).

4.3.5 Alternative 5N – Partial Removal, Permanent Cap, Institutional Controls and Monitored Natural Recovery

This remedial alternative is also included as directed by USEPA Region 6 and involves removing sediments/soils that exceed 13,000 ng/kg $TEQ_{DF,M}$ from areas of the TCRA Site that are currently contained by the Armored Cap. 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. Construction of a Permanent Cap, ICs, and MNR, as described in Alternative 3N, are also included in this remedial alternative.

To mitigate potential water quality issues, submerged areas would need to be isolated using a turbidity barrier/silt curtain prior to excavating sediment. Upland areas would not need to be isolated with sheetpiling, 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 Permanent 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 (Table 4-4) 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 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 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 (Table 4-5). 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 $38.1 million (Appendix C).

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

This alternative was developed by USEPA during its review of the Draft FS for the Site and is included at the direction of USEPA. For this removal alternative, the PCL for hypothetical recreational visitor (220 ng/kg $TEQ_{DF,M}$) was considered for the area within the 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.

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 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 sheetpile barrier around the work area. Figure 4-7 depicts the approximate limits where the earthen berm and sheetpile 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 TCRA Site where removal is not conducted, the existing Armored Cap would be maintained.

This alternative entails removal of approximately 137,600 cy of sediment from the TCRA Site, 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 dredged material (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).

Installation of a sheetpile containment is expected to pose a significant implementability challenge considering the presence of the existing Armored Cap (creating hard driving conditions), the relatively shallow water (limiting the size of barge-mounted pile-driving equipment that can be used), and documented challenges that have been experienced on other projects where sheetpile barriers were used (See Section 4.1.4).

This alternative is estimated to require approximately 15,665 hours of heavy equipment operations and over 12,855 truck trips, resulting in significantly higher greenhouse gas and PM, ozone generating emissions, and traffic impacts (Table 4-4) as compared to the previous five alternatives. Off-site transport of materials for disposal presents a significantly 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 significant fugitive dust emissions at the offloading/processing area.

Alternative 5aN is estimated to result in approximately 3 lost time non-fatal injuries, and approximately 0.01 fatalities as a result of construction (Table 4-5). 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 $77.9 million (Appendix C).

4.3.7 Alternative 6N – Full Removal of Materials Exceeding the PCL, 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 PCL for protection of the hypothetical recreational visitor is a $TEQ_{DF,M}$ concentration of 220 ng/kg.

The lateral and vertical extents of the removal under this remedial alternative are presented in Figures 4-9 and 4-10. As with the partial removal alternatives, cap rock, geomembrane and geotextile from the existing Armored Cap, which currently isolates and contains impacted material, would need to be removed prior to beginning excavation within the TCRA Site. Similarly, upland excavation could require dewatering to allow excavation of impacted sediment in relatively dry conditions, and excavation of submerged sediment would require isolation of the work area with a turbidity barrier/silt curtain. Excavated sediment would be further dewatered and stabilized at the 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 sediment.

This alternative entails removal of approximately 200,100 cy of sediment from the TCRA footprint and the area near the Upland Sand Separation Area, which would require a relatively large offloading and sediment processing facility to efficiently accomplish the work, which would require barge unloading, sediment rehandling, 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 16 months (Table 4-3). 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 sediment processing is considered to be a significant challenge to the implementability of Alternative 6N.

This alternative is estimated to require approximately 15,500 hours of heavy equipment operations and approximately 17,500 truck trips, resulting in significantly higher greenhouse gas and PM, ozone generating emissions, and traffic impacts (Table 4-4) as compared to the Alternatives 1N through 5N. Off-site transport of materials for disposal presents a significantly 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 significant fugitive dust emissions at the offloading/processing area.

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 (Table 4-5). 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 approximately $99.2 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 PCL.

The estimated cost for this alternative, which includes future USEPA 5-year review costs, is $140,000. These USEPA 5-year review costs are also included in cost estimates for the other alternatives.

4.4.2 Alternative 2S – Institutional Controls

The PCL 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. Therefore, the PCL should be compared to the average soil concentration in the top 10-feet of soil, which is how the data are presented in Figure 3-5.

The BHHRA (Integral 2013b) 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 PCL for a hypothetical outdoor commercial worker (1,300 ng/kg). The highest $TEQ_{DF,M}$ concentration observed in surface soil, 36.9 ng/kg (SJSB023, refer to Figure 2-5), is also well below this PCL.

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 PCL for the hypothetical future construction worker (450 ng/kg). $TEQ_{DF,M}$ concentrations in the upper 10-feet of soil exceed the PCL at four locations (SJSB012, SJSB019, SJSB023, and SJSB025) shown in Figure 3-5.

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

- Deed restrictions would be applied parcels in which the depth-weighted average

$TEQ_{DF,M}$ concentrations in upper 10-feet of subsurface soil exceed the soil PCL for the 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 PCL.

The estimated cost for this remedial alternative is $270,000 (Appendix C).

4.4.3 Alternative 3S – Enhanced Institutional Controls

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 4-6). This alternative is estimated to require approximately 160 hours of heavy equipment operations, resulting in greenhouse gas, PM, and ozone-generating emissions (Table 4-7). Alternative 3S is estimated to result in 0.015 lost time injury and 0.0001 fatalities as a result of construction (Table 4-8). The estimated cost for this remedial alternative is $9.5 million (Appendix C).

4.4.4 Alternative 4S – Removal and Off-site Disposal

This remedial alternative is included as directed by USEPA and 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 4-6). 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 (Table 4-7). Alternative 4S is estimated to result in 0.088 lost time injury and 0.0004 fatalities as a result of construction (Table 4-8). 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 protection
2. Compliance with ARARs
3. Long-term effectiveness
4. Reduction of toxicity, mobility or volume
5. Short-term effectiveness
6. Implementability
7. Cost
8. State acceptance
9. Community acceptance

The first two criteria, overall protection 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 are 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 protection* 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.

- *Long-term effectiveness* is an evaluation of the ability of the remedial alternative to reliably maintain protection of receptors.
- *Reduction of TMV* 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. 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 factors that may impede the implementation of the remedy, considering technical and administrative factors. 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.

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 – Armored Cap and Ongoing OMM (No Further Action)

5.1.1.1 Overall Protection of Human Health and the Environment

This remedial alternative (which includes the Armored Cap and continued OMM of the Armored Cap) is protective of human health and the environment. As discussed in Section 2.5, for the area north of I-10 the TCRA resulted in capping and isolation of all sediment samples with $TEQ_{DF,M}$ concentrations exceeding the applicable PCLs, except for those located within a small area of subsurface sediment near the Upland Sand Separation Area (located to the west of the TCRA Site). The subsurface sediment near the Upland Sand Separation Area is isolated from potential receptors by several feet of sediment with $TEQ_{DF,M}$ concentrations below the PCL for hypothetical recreational visitors.

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. The fate and transport model described in Appendix A predicts significant improvements in water quality within the USEPA's Preliminary Site Perimeter as a result of the Armored Cap construction. 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, even though there are ongoing external sources of dioxins and furans from atmospheric deposition, upstream sediment loads, stormwater runoff and point source discharges. Therefore, the continuation of post-TCRA conditions is expected to result in ongoing water quality compliance. Because no construction activity is included in this alternative, there are no substantive permit conditions that would need to be met.

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 sediment or soil with $TEQ_{DF,M}$ concentrations that exceed the applicable PCLs. The sediment transport modeling (Appendix A) results indicate that sediment in the vicinity of the Upland 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 associated with the SJRF operations could disturb these sediments. The Armored Cap effectively isolates sediment within the TCRA Site from potential receptors and has been designed to resist erosive forces during extreme events in the San Jacinto River. Work implementing USACE recommendations to enhance the cap's long-term stability was also completed in January 2014. This remedial alternative does not include alerting future landowners of the TCRA Site 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 TCRA Site. The protection provided by the Armored Cap would be continued through long-term monitoring and maintenance.

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 with the highest $TEQ_{DF,M}$ concentrations were treated with Portland cement during the TCRA reducing the mobility of impacted sediment. Model predictions presented in Appendix A indicate that net erosion depths during extreme flood events will be limited to less than 15 centimeters in this area, and that over the long-term, ongoing deposition will result in declines in surface sediment concentrations in this area. However, disturbance from propeller wash, for example, due to activities from the adjacent SJRF operations, could cause locally greater erosion than that modeled for extreme 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 immediate vicinity. Sediment in the footprint of the Armored Cap is also isolated from exposure at the surface by layers of geotextile, geomembrane, and cap rock.

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 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 $9.5 million (Appendix C) for Armored Cap construction and for implementing the existing OMM Plan for the 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 TCRA Site being available from the river and through the TxDOT right-of-way (ROW). It is understood that the number of monitoring events is subject to further discussion with and approval by USEPA.

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

5.1.2.1 Overall Protection of Human Health and the Environment

This remedial alternative would achieve the RAOs through a combination of ICs, MNR, and existing engineering controls. As noted in Section 5.1.1, the Armored Cap is protective of human health and the environment. Sediment with $TEQ_{DF,M}$ concentrations exceeding the applicable PCLs are isolated from potential receptors by the Armored Cap or by sediment with $TEQ_{DF,M}$ concentrations below the PCLs. ICs would be used to:

- Alert property owners of the presence of subsurface materials exceeding PCLs

- Describe the need for protective equipment and training if excavation of subsurface materials exceeding PCLs is required in the TCRA footprint
- Describe requirements for the management of any excavated soil or sediment exceeding PCLs
- Describe the need to restore the Armored Cap following any disturbance
- Establish limitations on dredging and anchoring within the footprint of the 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 Upland Sand Separation Area, which is already isolated from potential receptors by several feet of sediment with $TEQ_{DF,M}$ concentrations below the PCL, would be further isolated by deposition of additional sediment through ongoing natural recovery processes as described in Section 2.6 and Appendix A. 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 PCL for 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 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 Armored Cap and the ICs that would protect the integrity of the Armored Cap. Long-term effectiveness is also provided by the layers of surface soil and sediments with concentrations below PCLs and the monitoring that would confirm the continued deposition of clean sediment isolating the affected sediment outside of the footprint of the 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 highest $TEQ_{DF,M}$ concentrations within the USEPA's Preliminary Site Perimeter—in the footprint of the Armored Cap—are already isolated from potential receptors by the Armored Cap.

Risk reduction is achieved by the 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.

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 TCRA. As noted in Section 5.1.1.4, sediments with the highest $TEQ_{DF,M}$ concentrations were 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 TCRA Site 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 would continue to decline and the buried sediment near the Upland Sand Separation Area with $TEQ_{DF,M}$ concentrations exceeding the PCL would be further isolated from potential receptors.

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 $10.3 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 Armored Cap, as described in Appendix C. The cost estimate for this alternative assumes available access to the TCRA Site by water from a location along the river and by land through the TxDOT ROW. It is understood that the actual number of monitoring events will be subject to further discussion with and approval by USEPA.

5.1.3 Alternative 3N – Permanent Cap, Institutional Controls and Monitored Natural Recovery

5.1.3.1 Overall Protection of Human Health and the Environment

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.

The active component will include construction of further enhancements to the Armored Cap, even beyond the approved and protective 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 Permanent Cap from vessel traffic. The Permanent Cap would be designed to be protective under 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 Upland Sand Separation Area, which is already isolated from potential receptors by several feet of sediment with $TEQ_{DF,M}$ concentrations below the PCL and would be further isolated by deposition of additional clean sediment as described in Section 2.5 and Appendix A.

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 PCL 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 PCLs
- Describe the need for protective equipment and training if excavation of subsurface materials exceeding PCLs is required in the footprint of the Permanent Cap
- Describe requirements for the management of any excavated soil or sediment exceeding PCLs
- 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 Permanent 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 Permanent 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 Permanent 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 B). 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.

5.1.3.3 Long-Term Effectiveness

The long-term effectiveness of the existing 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 Permanent Cap, as shown in Figures 4-1 and 4-2, would further enhance the structural integrity and long-term reliability of the cap. Surface flow and wave break modeling, described in more detail in Appendix B, was performed to evaluate potential erosive forces associated with a variety of storms and extreme flow events. The results of the modeling were used to confirm that the rock selected for the cap would further resist movement and provide reliable, and enhanced long-term containment of material beneath the Permanent Cap. The armor rock that will be used to create the Permanent Cap will meet or exceed sediment cap design guidance and the recommendations made by USACE in its review of the TCRA design and construction, and a protective perimeter barrier would further increase the long-term effectiveness of the Permanent Cap by protecting the cap from vessel traffic. 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. Monitoring would confirm the continued deposition of new sediment isolating the affected sediment outside of the footprint of the Armored Cap.

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 TCRA. However, some of the impacted sediments at the Site, found in the Western Cell, were treated and mobility reduced via S/S during the TCRA. Risk reduction is further achieved by the construction of the Permanent Cap, the clean soil and sediment layers interrupting potential exposure pathways at locations outside the Permanent Cap, and by the use of ICs and monitoring to verify that the isolation layers remain effective.

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 Permanent 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 significant sources of air emissions and traffic in the region, including the industrial activities that occur adjacent to the TCRA 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 (Table 4-4). The short duration of construction is correlated with relatively low greenhouse gas, PM, and ozone-generating emissions from the construction equipment (Table 4-4). 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 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 (Table 4-5). The remedy, like Alternatives 1N and 2N, would achieve full protection within the TCRA 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 Upland Sand Separation Area with $TEQ_{DF,M}$ concentrations exceeding the PCL 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 Permanent Cap will require the placement of additional cap material on underwater slopes. The feasibility of this construction technique was successfully demonstrated during the TCRA construction, and experienced local contractors are available to complete this work. 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 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 TCRA 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 $12.5 million (Appendix C). The capital costs for this remedial alternative are primarily associated with the construction of the Permanent 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 Permanent Cap, collecting and analyzing environmental samples, evaluating the data, and preparing reports to document MNR. The cost estimate for this alternative also includes Permanent Cap monitoring and maintenance and USEPA 5-year reviews as described in Appendix C, and also assumes available access to the TCRA 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.

5.1.4 Alternative 4N – Partial Solidification/Stabilization, Permanent Cap, Institutional Controls and Monitored Natural Recovery

5.1.4.1 Overall Protection of Human Health and the Environment

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 TCRA Site with $TEQ_{DF,M}$ concentrations above the USEPA-designated level of 13,000 ng/kg. S/S may add another level of protection to the already environmentally-protective Armored Cap. A Permanent Cap as described under Alternative 3N would be constructed following the S/S process.

Affected sediment near the Upland Sand Separation Area, which is already isolated from potential receptors by several feet of sediment with $TEQ_{DF,M}$ concentrations below the PCL, would be further isolated by deposition of additional sediment as described in Section 2.5 and Appendix A. 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 PCL for 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 PCLs

- Describe the need for protective equipment and training if excavation of subsurface materials exceeding PCLs is required in the Permanent Cap
- Describe requirements for the management of any excavated soil or sediment exceeding PCLs
- 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 Permanent 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 TCRA Site upon implementation. As with the previous alternatives, additional clean sediment would 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 would continue to decline, and the buried sediment near the Upland Sand Separation Area with $TEQ_{DF,M}$ concentrations exceeding the PCL would be further isolated from potential receptors.

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 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.

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 Permanent 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 $TEQ_{DF,M}$ concentrations exceeding the USEPA-designated level of 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. As described in Section 5.1.2, ICs would protect the integrity of the Permanent Cap. Monitoring would confirm the continued deposition of clean sediment isolating the affected sediment outside of the footprint of the Permanent Cap.

A long-term fate and transport model simulation was conducted for Alternative 4N to evaluate the long-term effectiveness of this alternative and quantify potential water and sediment quality impacts as a result of releases during stabilization (see Section 4.2 of Appendix A). Results from this simulation indicate that surface sediment concentrations of TCDD averaged over the area within USEPA's Preliminary Site Perimeter increase by nearly 15 percent for the 21-year duration of the simulation period compared to natural recovery scenarios; these predicted increases are a result of releases of sediment and dissolved phase dioxins and furans during stabilization, even with the use of BMPs and a post-dredge backfill and cap. Over the long-term, ongoing deposition would also act to reduce concentrations in sediments impacted by dredge residuals and releases within the USEPA's Preliminary Site Perimeter.

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 soil/sediment exceeding PCLs. Approximately 52,000 cy of soil/sediment in the TCRA Site 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 disturbing the sediment, and engineered barrier controls are subject to leakage. The modeling presented in Appendix A demonstrates short-term water column impacts associated with Alternative 4N. Specifically, over the TCRA Site footprint, this alternative is estimated to increase the annual average water column concentration of TCDD by a factor of 10 in year 1 compared to existing conditions.

Treatment of the soil/sediment within the TCRA Site would require first removing the existing 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 TCRA Site. To evaluate the risk of removing the 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 significant portions of the work area, including the sheetpile enclosure shown in Figure 4-3. For the Alternative 4N construction duration of 17 months, there is an approximate 38 percent likelihood that this water surface elevation would be reached or exceeded (Appendix B). Such an event could result in significant resuspension and upstream/downstream transport of the TCRA sediments from the inundated portion of the construction footprint where the Armored 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 sheetpile 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., Manitowac River, Renholds 1998; Kita and Kubo 1983). The use of a sheetpile barrier does little to enhance the short-term effectiveness of this alternative because of documented effectiveness issues with engineered barriers discussed in Section 4.1, including:

- Incomplete isolation due to gaps in sheetpiles that may occur during installation
- The need to provide openings in the sheetpile to balance water pressures on both sides of the pile
- The potential for river-current-induced scour adjacent to the sheetpile

In addition to these documented issues with sheetpile barriers, the use of sheetpiles increases the risk of recontamination and resuspension of soil/sediments during sheetpile installation and removal (Ecology 1995), and potential cross-contamination associated with driving sheetpiling through impacted materials into non-impacted material.

In addition to these environmental risks, construction for this alternative is estimated to require 1,600 truck trips (Table 4-4). This alternative would have higher greenhouse gas, PM, and ozone impacts associated with construction emissions from equipment (Table 4-4) as compared to the previous alternatives. From a worker safety perspective, there is also a moderate risk of accidental injury (Table 4-5) 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 Armored Cap, would be significantly more challenging than implementation of Alternative 3N. Stabilization of soil/sediment in the floodplain and subtidal areas will require precautions, such as the use of a sheetpile barrier wall to minimize potential releases of materials once the Armored Cap is removed. Even with those precautions, because of the disturbance of sediments caused by removing the 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 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 of Alternative 4N presented in Appendix A indicate that short-term increases in surface water concentrations could occur, with such increases being significant at localized scales 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 Permanent 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, 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 TCRA 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 $23.2 million (Appendix C). The capital costs for this remedial alternative are primarily associated with the

S/S process and construction of the Permanent 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 Permanent Cap, collecting and analyzing environmental samples, evaluating the data, preparing reports to document MNR, and monitoring and maintenance of the Permanent Cap. The estimated cost of this alternative includes USEPA 5-year reviews and also assumes available access to the TCRA 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, Permanent Cap, Institutional Controls and Monitored Natural Recovery

5.1.5.1 Overall Protection of Human Health and the Environment

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 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 dredge area would be backfilled and a Permanent Cap as described in Alternative 3N would be constructed following removal of the soil/sediment.

Affected sediment near the Upland Sand Separation Area, which is already isolated from potential receptors by several feet of sediment with $TEQ_{DF,M}$ concentrations below the PCL, would be further isolated by deposition of additional sediment as described in Section 2.6 and Appendix A. 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 below the PCL 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. 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 PCLs
- Describe the need for protective equipment and training to limit exposure to contaminants if future additional excavation is required in the footprint of the Permanent 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 Permanent 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 Armored Cap, removal of underlying soil/sediment, and transportation of sediment to an upland disposal facility. The removal of the Armored Cap and placement of rock for Permanent 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 Permanent 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 will require substantial compliance with relevant permit requirements. Although land for the material handling facility may not be available within the USEPA's Preliminary Site Perimeter, the NCP (40 CFR 300.430(e)) defines on-site for this purpose as "the areal extent of contamination and all suitable areas in very close proximity to the contamination necessary for implementation of the response action."

Construction of the Permanent 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 B). 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 Permanent 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. Long-term effectiveness is reduced by the fact that this alternative will likely generate dredge residuals from the resuspension of dioxin-impacted sediments that have been documented on other projects as discussed in the RAM (Anchor QEA 2012b) and in Section 4. These dredge residuals would likely have concentrations that are similar to the concentrations of the materials that are dredged (e.g., greater than 13,000 ng/kg $TEQ_{DF,M}$).

A long-term fate and transport model simulation was conducted for Alternative 5N to evaluate the comparative long-term effectiveness of this alternative and quantify potential water and sediment quality impacts during dredging (see Section 4.2 of Appendix A). Results from this simulation indicate that surface sediment concentrations of TCDD averaged over the area within USEPA's Preliminary Site Perimeter increase by nearly 25 percent for the 21-year duration of the simulation period compared to natural recovery scenarios; these predicted increases are a result of releases of sediment and dissolved phase dioxins and furans during dredging, even with the use of engineering controls and a post-dredge backfill and cap. However, ongoing deposition from natural recovery processes would also act to reduce concentrations impacted by dredge residuals and releases within the USEPA's Preliminary Site Perimeter over the long-term.

The removal of sediment with $TEQ_{DF,M}$ concentrations exceeding 13,000 ng/kg eliminates a potential future source of high concentration sediments from the TCRA Site. Flattening the slopes, where appropriate, as shown in Figures 4-3 and 4-4, and the other work to be performed in constructing the Permanent 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 (Appendix A) throughout USEPA's Preliminary Site Perimeter. As described in Section 5.1.2, ICs would protect the integrity of the Permanent 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 Permanent Cap.

5.1.5.4 Reduction of Toxicity, Mobility or Volume

This remedial alternative would reduce the volume of material exceeding PCLs within the USEPA's Preliminary Site Perimeter. Approximately 52,000 cy of sediment in the TCRA Site 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. The modeling presented in Appendix A demonstrates short-term water column impacts associated with Alternative 5N. Specifically, over the TCRA Site footprint, this alternative is estimated to increase the annual average water column concentration of TCDD by a factor of about 50 in year 1 compared to existing conditions.

Removal of sediment under this alternative would require first removing the existing 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 Armored Cap, a 3-year storm was considered, which has an average predicted water surface elevation of 3.5 feet NAVD88 and would inundate significant portions of the work area, including the sheetpile enclosure shown in Figure 4-3. For the Alternative 5N construction duration of 13 months, there is an approximate 30 percent likelihood this water surface elevation would be reached or exceeded (Appendix B). Such an event could result in significant resuspension and upstream/downstream transport of sediments from the inundated portion of the construction footprint where the cap is removed.

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 (both dredge residuals, as well as dissolved phase), potentially settling onto areas of the Permanent Cap and other areas within the USEPA's Preliminary Site Perimeter, and potentially causing temporary increases in surface water and tissue concentrations for various COCs. For example, results from chemical fate model simulations presented in Appendix A indicate that short-term increases in surface water concentrations could occur, with such increases being significant at localized scales during the construction (e.g., an order of magnitude). To mitigate the potential impacts from resuspended sediments, the work area would need to be isolated with a turbidity barrier/silt curtain or other engineered barrier. There are, however, documented limitations in the effectiveness of these types of engineered controls as described in Section 4.1. Sheetpile or some other barrier would be required to dewater the project work area, if excavation were to be performed using land-based earth-moving equipment rather than a dredge. Even with those precautions, it would be very difficult to avoid releasing some of these materials exceeding PCLs into the river or onto the surface of the undisturbed parts of the Permanent Cap. That risk would be increased if a storm or high water levels were to occur during construction, as described previously.

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 (Table 4-4). 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 (Table 4-4). From a worker safety perspective, there is a low to moderate risk of accidental injury to workers during construction (Table 4-5). The remedy would achieve full protection in the TCRA Site upon completion of construction. Additional clean sediment continues to be deposited throughout the USEPA's Preliminary Site Perimeter, $TEQ_{DF,M}$ concentrations in surface sediments would continue to decline and the buried sediment near the Upland Sand Separation Area with $TEQ_{DF,M}$ concentrations exceeding the PCL would be further isolated from potential receptors.

5.1.5.6 Implementability

There are several significant implementability concerns associated with this remedial alternative. As discussed above, removal of sediment in the floodplain would require the use of extensive 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. The modeling of Alternative 5N presented in Appendix A shows that these releases could impact surface water and surface sediment concentrations on both short and long time scales.

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 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 TCRA 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 sediment, 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 with challenges 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 $38.1 million (Appendix C). The capital costs for this remedial alternative are primarily associated with the sediment removal and disposal and construction of the Permanent 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 Permanent Cap, collecting and analyzing environmental samples, evaluating the data, preparing reports to document the MNR, maintenance of the Permanent 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 TCRA 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 PCL, Permanent Cap, Institutional Controls and Monitored Natural Recovery

5.1.6.1 Overall Protection of Human Health and the Environment

This remedial alternative, developed by USEPA, would achieve the RAOs through a combination of soil/sediment removal, capping, ICs and MNR. Soil/sediment in the TCRA Site where the water depth is 10 feet or less and with $TEQ_{DF,M}$ concentrations exceeding the hypothetical recreational visitor PCL (220 ng/kg), plus soils 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. This PCL is very conservative for the area within the TCRA footprint considering the anticipated future industrial or commercial use of the property, but could allow for potentially less restricted future use.

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 sheetpile in deeper water areas of the project work site. Following removal of the soil/sediment, a 6-inch thick residuals cover would be placed.

A Permanent Cap as described under Alternative 3N would be constructed in the area of the TCRA Site where the PCL is exceeded but the water is deeper than 10-feet.

Affected sediment near the Upland Sand Separation Area, which is already isolated from potential receptors by several feet of sediment with $TEQ_{DF,M}$ concentrations below the PCL, would be further isolated by deposition of additional sediment as described in Section 2.6 and Appendix A. 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 below the PCL for protection of hypothetical recreational visitors. The MNR plan would include methods for assessing whether deposition and erosion were occurring. 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 PCLs
- Describe requirements for the management of any excavated soil or sediment
- Describe the need to restore the Permanent Cap or clean cover soil in these areas following any disturbance
- Establish limitations on dredging and anchoring within the footprint of the Permanent 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 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 B). 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.

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 Armored Cap. Approximately 137,600 cy of soil and sediment would be removed from beneath the existing 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 220 mg/kg $TEQ_{DF,M}$; however, it is expected that a residual layer of impacted material with $TEQ_{DF,M}$ above 220 mg/kg would 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 be similar to the removed materials and would likely require a clean sediment residuals cover across the dredge footprint.

A long-term fate and transport model simulation was conducted for Alternative 5aN to evaluate the comparative long-term effectiveness of this alternative and quantify potential water and sediment quality impacts during dredging (see Section 4.2 of Appendix A). Results from this simulation indicate that surface sediment concentrations of TCDD averaged over the USEPA's Preliminary Site Perimeter increase by approximately two- to three-fold for the 21-year duration of the simulation period compared to natural recovery scenarios; these predicted increases are a result of releases of sediment and dissolved phase dioxins and furans during dredging and from sediment residuals within the TCRA Site that would occur even with the use of engineering controls and a post-dredge residuals management cover. However, over the long-term, ongoing deposition would also act to reduce concentrations associated with dredge residuals and releases within the USEPA's Preliminary Site Perimeter

5.1.6.4 Reduction of Toxicity, Mobility or Volume

This remedial alternative would remove sediment exceeding PCLs from within the USEPA's Preliminary Site Perimeter. Approximately 137,600 cy of sediment would be removed from within the USEPA's Preliminary Site Perimeter for disposal. Sediment dewatering by amendment prior to transporting the sediment 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 releases are likely to occur during construction even with the use of BMPs. The modeling presented in Appendix A demonstrates short-term water column impacts associated with Alternative 5aN. Specifically, over the TCRA Site footprint, this alternative is estimated to increase the annual average water column concentration of TCDD by a factor of about 90 in year 1 compared to existing conditions.

Removal of sediment from the TCRA Site would require first removing the existing 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 Armored Cap, a 3-year storm was considered, which has an average predicted water surface elevation of 3.5 feet NAVD88 and would inundate significant portions of the work area, including overtopping the perimeter berm and the sheetpile enclosure. For the Alternative 5aN construction duration of 19 months, there is an approximate 40 percent likelihood that this water surface elevation would be reached or exceeded (Appendix B). Such an event could result in significant resuspension and upstream/downstream transport of the TCRA sediments from the inundated portion of the construction footprint where the cap is removed.

In addition, short-term water quality impacts would occur due to dredging operation releases (Appendix A). For example, the model simulation of Alternative 5aN indicates that for an assumed dredge release rate of 0.85 percent[4] (based on experience from other dredging projects where an engineered barrier was used; see Table 4-2), average surface water 2,3,7,8-TCDD concentrations within the USEPA's Preliminary Site Perimeter would be predicted to increase by more than an order of magnitude during dredging. 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 (Appendix A).

In addition to these environmental risks, construction for this alternative is estimated to require 12,855 truck trips (Table 4-4). This alternative would have high greenhouse gas, PM, and ozone impacts associated with construction emissions from equipment operating in the work areas (Table 4-4), as well as from equipment required for off-site transportation and disposal of excavated sediments. From a worker safety perspective, there is a moderate to high risk of accidental injury to workers during construction (Table 4-5). The remedy would be

[4] As discussed in Appendix A, this percentage applies to the constituent mass within the dredge prism, and is simulated as a dissolved phase release in the model.

intended to achieve full protection upon completion of construction; however, there could be potentially significant 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.

5.1.6.6 Implementability

There are several significant implementability concerns associated with this remedial alternative. Installation of a rigid sheetpile barrier, particularly through the rock cap layer of the Armored Cap, would be a significant challenge. Water conditions are generally shallow in most of the work area, precluding the use of larger marine-based equipment that requires deeper-draft barges. Thus, the size of the pile driving equipment would be limited to smaller cranes with less capability to handle dense driving conditions. The presence of the rock cap layer could also cause the sheets to deflect during installation, which could separate the sheetpile seams. Even with the use of a sheetpile barrier some loss is expected based on documented case histories (see Section 4).

Further, on-site space is very 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. However, the logistical concerns over locating and securing a suitable off-site material handling area would be much more significant 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 upland space for managing materials, as well as the greater volume of material removed which could require an even larger off-site location and which would have significantly greater community impacts (traffic, noise, air emissions, etc.) during implementation. 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 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 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 $77.9 million. The capital costs for this remedial alternative are primarily associated with the sediment removal and disposal and construction of the Permanent 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 Permanent Cap, collecting and analyzing environmental samples, evaluating the data, preparing reports to document the MNR, maintenance of the Permanent 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 Materials Exceeding the PCL, Institutional Controls and Monitored Natural Recovery

5.1.7.1 Overall Protection of Human Health and the Environment

This remedial alternative would achieve the RAOs through a combination of soil/sediment removal, MNR and ICs. Soil/sediment in the TCRA Site and near the Upland Sand Separation Area with $TEQ_{DF,M}$ concentrations exceeding the hypothetical recreational visitor PCL (220 ng/kg) would be removed, dewatered, and transported to a permitted landfill for disposal. As with Alternative 5aN, this PCL is very conservative for the area within the TCRA footprint considering the anticipated future industrial or commercial use of the property but could allow for potentially less restricted future use. At the same time, as for Alternatives 5N and 5aN, complete removal of materials exceeding the PCL may not be possible because of dredging residuals, which will leave a layer material exceeding PCLs that will need to be managed by placing a post-dredge clean cover. ICs would be used to:

- Alert property owners of the presence of remaining subsurface material exceeding PCLs, 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. If Alternative 6N 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 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 B). 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 within the predictive capability of the flood model.

5.1.7.3 Long-Term Effectiveness

The long-term effectiveness of this remedial alternative is primarily derived from the removal of soil and sediment exceeding the PCL. Approximately 200,100 cy of soil and sediment would be removed from the TCRA Site and from the area near the Upland Sand Separation Area. The anticipated limits of the excavation are shown in Figures 4-5 and 4-6. The dredging activity would reduce the volume of soil/sediment with concentrations above 220 mg/kg $TEQ_{DF,M}$; however, it is expected that a residual layer of contaminated materials would 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 a clean sediment residuals cover across the dredge footprint.

A long-term fate and transport model simulation was conducted for Alternative 6N to evaluate the comparative long-term effectiveness of this alternative and quantify potential water and sediment quality impacts during dredging (see Section 4.2 of Appendix A). Results from this simulation indicate that surface sediment concentrations averaged over the USEPA's Preliminary Site Perimeter increase by nearly a factor of 3 for the 21-year duration of the simulation period compared to natural recovery scenarios; these predicted increases are a result of releases of sediment and dissolved phase dioxins and furans during dredging and the presence of sediment residuals within the TCRA Site, even with the use of a post-dredge residuals management cover. However, over the long-term, ongoing deposition would also act to reduce $TEQ_{DF,M}$ concentrations in sediment associated with dredge residuals and releases within the USEPA's Preliminary Site Perimeter but not achieving the same levels at the end of the simulation period as modeled for Alternatives 1N through 3N.

5.1.7.4 Reduction of Toxicity, Mobility or Volume

This remedial alternative would use S/S treatment (sediment dewatering by amendment) to reduce the mobility of COCs during transportation and at the disposal facility. Approximately 200,100 cy of sediment with $TEQ_{DF,M}$ concentrations exceeding PCLs 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. The engineered barrier controls are subject to leakage and releases are likely to occur during construction even with the use of BMPs. The modeling presented in Appendix A demonstrates short-term water column impacts associated with Alternative 6N. Specifically, over the TCRA Site footprint, this alternative is estimated to increase the annual average water column concentration of TCDD by a factor of more than 100 in year 1 compared to existing conditions.

Removal of sediment from the TCRA Site would require first removing the existing 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 Armored Cap, a 3-year storm was considered, which has an average predicted water surface elevation of 3.5 feet NAVD88 and would inundate significant portions of the work area. For the Alternative 6N construction duration of 16 months, there is an approximate 36 percent likelihood that this water surface elevation would be reached or exceeded (Appendix B). Such an event could result in significant resuspension and upstream/downstream transport of the TCRA sediments from the inundated portion of the construction footprint where the cap is removed.

In addition, short-term water quality impacts would occur due to dredging operation releases (Appendix A). For example, the model simulation of Alternative 6N indicates that for an assumed dredge release rate of 3 percent[5] (based on experience from other dredging projects; see Table 4-2), average surface water 2,3,7,8-TCDD concentrations within the USEPA's Preliminary Site Perimeter would be predicted to increase by more than an order of magnitude during dredging. These releases would also be expected to increase tissue concentrations in the early years following remedy implementation and also result in increases in surface sediment concentration in surrounding areas (Appendix A). To minimize the potential for release of impacted sediment during construction, the work area would need to be protected with a turbidity barrier/silt curtain. As mentioned previously, however, there are documented limitations on the effectiveness of these types of controls.

In addition to these environmental risks, construction for this alternative is estimated to require 17,500 truck trips (Table 4-4). This alternative would have high greenhouse gas, PM, and ozone impacts associated with construction emissions from equipment operating in the work areas (Table 4-4), as well as from equipment required for off-site transportation and disposal of excavated sediments. From a worker safety perspective, there is a moderate to high risk of accidental injury to workers during construction (Table 4-5). The remedy would be intended to achieve full protection upon completion of construction; however, it is likely there would be potentially significant 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.

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[5] As discussed in Appendix A, this percentage applies to the chemical mass within the dredge prism, and is simulated as a dissolved phase release in the model.

5.1.7.6 Implementability

There are several significant implementability concerns associated with this remedial alternative. As discussed above, removal of sediment in the floodplain would require the use of extensive engineering controls to minimize the release of highly contaminated sediment during construction; nevertheless some loss is expected based on documented case histories and published guidance (e.g., USACE 2008) 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.

Further, on-site space is very 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 much more significant for this remedial alternative than for Alternative 5N because of the longer duration of the project and the greater extent of the removal area, which would leave less upland space for managing materials, as well as the greater volume of material removed which could require an even larger off-site location than that required for Alternative 5N, and which would have significantly greater community impacts (traffic, noise, air emissions, etc.) during implementation. 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 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 remedial alternative.

5.1.7.7 Cost

The estimated present worth cost associated with this remedial alternative is $99.2 million. The capital costs for this remedial alternative are primarily associated with the sediment 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, preparing reports to document the MNR and 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 PCL 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. Further, 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 applicable PCL. 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 PCL, 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 $140,000 (Appendix C). The capital costs for this remedial alternative are associated with conducting USEPA 5-year reviews.

5.2.2 Alternative 2S – Institutional Controls

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 PCL 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 PCL.

Notifying future property owners and construction workers would eliminate 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 long-term protection against anthropogenic disturbance of the clean surface soil and the underlying impacted soil.

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 PCL is isolated from potential receptors by a layer of at least 2-feet of soil with $TEQ_{DF,M}$ concentrations well below the PCL for hypothetical construction workers. Long-term effectiveness is provided by the ICs, which would alert future construction workers 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.

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 full protection in the area south of I-10 immediately.

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. Thus, there are not anticipated to be significant administrative implementability issues associated with the implementation of this remedial alternative.

5.2.2.7 Cost

The estimated present worth cost associated with this remedial alternative is $270,000 (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

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.

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 stormwater.

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 PCL. 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.

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, stormwater 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 $660,000 (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

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.

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, stormwater controls, and disposal. Appropriate stormwater 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 PCL. 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. Stormwater 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. 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

All of the remedial alternatives evaluated in this FS for the area north of I-10 satisfy the threshold criteria of protecting human health and the environment and addressing ARARs. 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 TCRA. Based on the fate and transport modeling, this reduction in sediment concentration translates to improvements in water quality throughout the USEPA's Preliminary Site Perimeter (see Table 3-2 in Appendix A), even though there are ongoing inputs of dioxins and furans from sources other than the impoundments, as discussed previously. The current (post-TCRA) condition within the USEPA's Preliminary Site Perimeter is such that there is little potential for exposure to $TEQ_{DF,M}$ concentrations exceeding the applicable soil and sediment PCLs.

- In the footprint of the Armored Cap, sediment with $TEQ_{DF,M}$ concentrations exceeding the hypothetical future commercial worker PCL is isolated from the surface by the cap. In part of the area, the affected sediment has already been treated with S/S, which further limits exposure potential. Potential exposure to sediment exceeding the PCL in this area is limited to a scenario in which the Armored Cap is compromised by excavation or a catastrophic erosion event, both of which are unlikely due to security fencing around the TCRA Site, the robust nature of the Armored Cap design and ongoing OMM of the cap. Capping has been selected as the remedy at other CERCLA sediment sites as discussed in Section 4.1.4 where similar concerns over catastrophic erosion or future excavation could be factors. Finally, the Permanent Cap would be constructed to meet or exceed capping design guidance developed by USACE and USEPA, with additional protective measures taken to safeguard the Permanent Cap from vessel traffic.

- For the rest of the USEPA's Preliminary Site Perimeter, the sediment PCL is for the hypothetical recreational visitor exposure scenario. The only sediment with $TEQ_{DF,M}$ concentrations exceeding this PCL is at one sampling location (SJNE032) near the Upland Sand Separation Area, and this sediment is overlain by at least 3-feet of sediment with $TEQ_{DF,M}$ concentrations below the PCL (Figure 3-2). This location is part of a secured industrial facility with limitations on access. Model predictions presented in Appendix A indicate that net erosion depths during extreme flood events will be limited to less than 6 inches in this area, and that over the long-term, ongoing deposition will result in declines in surface sediment concentrations in this area.

6.1.2 Long-Term Effectiveness

The long-term effectiveness evaluation of MNR-based remedies (Appendix A) projects that the SWAC $TEQ_{DF,M}$ will decrease by approximately a factor of two in a 10- to 15-year time frame within the USEPA's Preliminary Site Perimeter (Appendix A) due to natural sedimentation processes in the river. Construction of the Armored Cap reduced SWAC $TEQ_{DF,M}$ within the USEPA's Preliminary Site Perimeter by approximately 80 percent, and 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.

Alternative 1N does not include ICs and MNR is not assessed over time, so the long-term effectiveness of this alternative ranks lower than that for Alternatives 2N and 3N. The existing Armored Cap is not further enhanced in Alternatives 1N or 2N compared to Alternative 3N, which could increase the need for future long-term monitoring and maintenance under Alternatives 1N and 2N.

Although material is treated or removed under Alternatives 4N, 5N, 5aN, and 6N, removal of the Armored Cap to facilitate construction, as well as modeled releases during construction, will reduce the long-term effectiveness of these alternatives compared to Alternative 3N. The removal of impacted material under these alternatives (and therefore greater mass removal) does not equate to greater protectiveness (NRC 2007).

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

Based on the results of the modeling described in Appendix A, Alternative 6N has comparatively lower long-term effectiveness. As demonstrated in Appendix A, the modeled long-term $TEQ_{DF,M}$ sediment SWAC over USEPA's Preliminary Site Perimeter under this alternative is expected to be more than double that of the remedies that do not disturb the existing Armored Cap (and in Alternative 3N, provide for enhancements to it) due to dredging-related releases and dredging residuals. Similar, but slightly lower increases were also predicted for Alternative 5aN due to a lower dredge release rate represented in the model; likewise, similar increases were predicted for Alternatives 4N and 5N, albeit resulting in lower surface sediment concentrations at the end of the 21-year modeling period compared to Alternative 6N.

Figures 6-1a and 6-1b compare model-predicted surface sediment TCDD[6] concentrations at the end of the long-term fate model simulation for all of the alternatives. Results were averaged over the USEPA's Preliminary Site Perimeter and within the TCRA Site (Figure 6-1a), and by river mile in the vicinity of the TCRA Site (Figure 6-1b). These graphics illustrate the comparatively lower long-term effectiveness of Alternative 4N, 5N, 5aN, and 6N relative to Alternatives 1N through 3N, due to residuals and releases associated with the excavation/stabilization under these alternatives. While robust control measures would be implemented to help mitigate releases, these measures are subject to potential effectiveness limitations as discussed in Section 4.1. The long-term impacts of dredge residuals and releases during construction are also evident in the model-predicted water column concentrations at the end of the long-term simulation (see Figure 6-2, which shows model-predicted annual average water column TCDD concentrations at the end of the long-term model simulation for

[6] Although the FS focuses on SWAC $TEQ_{DF,M}$ as a metric of sediment quality, the TCDD results from Appendix A provide a reasonable surrogate for $TEQ_{DF,M}$ because TCDD represents the majority of the potential risk in the calculation of $TEQ_{DF,M}$.

all of the alternatives, averaged over the USEPA's Preliminary Site Perimeter and the TCRA Site). These predictions include several sources of dioxins and furans, including atmospheric deposition, upstream sources, and point sources, such as releases from wastewater treatment plant outfalls, in addition to the dioxin-impacted materials potentially released during dredging and S/S activities.

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 soils in the Western Cell were previously solidified during the TCRA as shown in Figures 4-1, 4-3, 4-5, 4-7, and 4-9. Thus, these alternatives are comparable in reduction of TMV. Alternative 3N further reduces potential mobility within the TCRA Site by increasing the protection of the armored slopes, and thus ranks 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. However, these materials are already effectively contained by the Armored Cap and dioxins and furans within the USEPA's Preliminary Site Perimeter have been shown to have very low solubility and are highly immobile. 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 – 200,100 cy – however, this is counterbalanced by potentially significant dredge water column and residual releases and thus this alternative is considered comparable to Alternatives 4N, 5N, and 5aN in terms of reduction of TMV and by the fact that impacted materials are already contained by the Armored Cap.

6.1.4 Short-Term Effectiveness

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 Armored Cap or require handling of sediments. Compared to Alternatives 4N, 5N, 5aN, and 6N, which have significantly longer durations, Alternative 3N ranks significantly 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. Figure 6-3 provides a comparison of the average Year 1 water column concentrations of TCDD for all alternatives, for both the USEPA Preliminary Site Perimeter, as well as for the TCRA Site, as predicted by the model. As shown in this figure, Alternatives 4N, 5N, 5aN, and 6N have a model-predicted increase in water column TCDD concentrations averaged over USEPA's Preliminary Site Perimeter of five-fold, twenty-fold, thirty-fold, and one hundred-fold, respectively, over alternatives 1N, 2N, and 3N.

Alternative 4N has a longer construction duration than Alternatives 5N and 6N and all entail removing portions of the Armored Cap and managing a significant volume of sediments. Compared to Alternative 3N, there is higher risk to worker safety (8 to 9 times the number of injuries and fatalities, Table 4-5) and higher environmental impacts (8 to 9 times the number of hours of operation and truck trips, Table 4-4) 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 significantly greater number of work hours has attendant higher worker safety risk (20 times the number of injuries and fatalities compared to Alternative 3N, Table 4-5) 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, Table 4-4), and the time required for Alternatives 5aN and 6N to achieve protection is also longer. Alternative 6N also has the most significant short-term environmental impact due to water column releases during dredging, and the expected localized increase in tissue concentrations from these releases, as well as generated dredge residuals, that the model predicts may increase the overall SWAC $TEQ_{DF,M}$ immediately following dredging.

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 Armored Cap) that can be deployed with readily-available materials and local, experienced contractors.

Implementability concerns, such as TCRA Site access, limited staging areas, restrictions on equipment size, and availability of off-site staging area properties are substantially greater for Alternatives 4N, 5N, 5aN, and 6N compared to Alternative 3N 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 dredged sediment would need to be managed at the off-site staging area, which requires a larger footprint, and given the nature of the dredged material, might make finding a willing landowner difficult. Proper management of cap material and excavated wastes, and on-site processing and management for dredged 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 dredged sediments at the facility. Compared to Alternative 5N, this issue is magnified for Alternatives 5aN and 6N because of the significantly greater volume of material that must be handled at the off-site facility. Based on these factors, Alternative 3N is less favorable than Alternatives 1N and 2N, but more favorable than the remaining alternatives.

Alternative 4N requires the removal of the Armored Cap, which is considered a technical challenge, 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 another technical challenge. Engineering controls for Alternative 4N may not be adequate to prevent the release of sediments exceeding PCLs to the surrounding environment and would be difficult to install; this would be especially true during potential high flow events that could occur during construction. Alternative 4N is considered to be unfavorable for implementability compared to Alternative 3N.

Alternatives 5N, 5aN, and 6N also require removal of the Armored Cap (as noted above, a technical challenge), and management of a significant volume of sediment and soil for off-site disposal. Similar to Alternative 4N, engineering controls may not be adequate to prevent the release of sediments exceeding PCLs to the surrounding environment, and for Alternative 5aN would be difficult to install; this would be especially true during potential high flow: 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. events that could occur during construction. Thus, all of these alternatives are considered equally as unfavorable as Alternative 4N for implementability.

6.1.6 Cost

Table 5-1 includes a summary of estimated costs for each alternative. 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 $9.5 million; Alternative 2N is estimated to cost $10.3 million; Alternatives 3N and 4N differ by a factor of almost 2, with estimated costs of $12.5 and $23.2 million, respectively; Alternative 5N is estimated to cost $38.1 million; Alternative 5aN is estimated to cost $77.9 million; Alternative 6N is estimated to cost $99.2 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 comparative benefits of each alternative have been assessed using the modeling described in Appendix A to predict the TCDD sediment and water column concentrations within the USEPA's Preliminary Site Perimeter at the end of construction, and at the end of the long-term simulation period. As discussed, these reductions follow the already-achieved reductions that occurred following completion of the TCRA. As is shown in Figures 6-1a, 6-1b, 6-2, and 6-3, removal and S/S-based alternatives 4N, 5N, 5aN, and 6N have potential short-term and long-term impacts due to releases during construction; in contrast, Alternatives 1N, 2N, and 3N do not 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 Armored Cap. Alternatives 5N, 5aN, and 6N would remove a significant mass of impacted sediments from the Site, and contain these materials in an off-site landfill facility. Alternative 3N relies on the Permanent Cap to provide a long-term protective remedy, but retains the capped material at the Site. Alternatives 1N and 2N do not enhance the existing Armored Cap, and so provide relatively lower long-term protectiveness than Alternative 3N.

Alternatives 1N, 2N and 3N do not disturb the Armored Cap, and thus are most consistent with the TCRA objective that the long-term remedy be compatible with the TCRA action (Section 2.5.3). Alternatives 4N and 5N require disturbing a portion of the Armored Cap, and thus are comparatively less compatible with the TCRA action. Alternatives 5aN and 6N require removing the Armored Cap entirely, and thus are the least compatible with the TCRA action.

Additionally there is significant risk of harm to the environment during implementation of the remedies associated with Alternatives 4N, 5N, 5aN, and 6N as discussed under Short-Term Effectiveness. Sections 6.5.5 (resuspension and releases) and 6.5.7 (residuals) of the Sediment Guidance (USEPA 2005) advise Project Managers to realistically estimate and evaluate the potential magnitude and impact of resuspension, releases and residuals on the reasonably anticipated effectiveness of dredging remedies, based on site-specific conditions (p. 6-23). Risks from 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; Table 4-4 and Table 4-5) higher for Alternatives 4N, 5N, 5aN, and 6N than for Alternatives 1N, 2N, or 3N. Section 7-4 (p. 7-13) of the Sediment Guidance (USEPA 2005) espouses the concept of “Comparative Net Risk” that was first set forth in the NRC Report on Risk Management (NRC 2001). The Sediment Guidance further recommends that Project Managers consider the overall or “net” potential reduction of each remedial alternative, by considering all of the advantages and disadvantages of each during implementation and afterwards (p. 7-14).

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; Table 4-4). These alternatives are expected to require a relatively large off-site facility for management of materials and related activities (armor rock and dredged sediment stockpiling, sediment dewatering, transloading, and off-site shipping), which could be difficult to obtain.

The cost of the additional mass removal without additional long-term benefits while posing increased short-term risks would be inconsistent with both CERCLA and the NCP, which require that remedies be cost-effective (42 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” (Preamble to NCP). These proportionality requirements were reiterated by USEPA in Section 7-1 “Risk Management Decision Making” (p. 7-1) of the Sediment Guidance (USEPA 2005), as follows, “A risk management process should be used to select a remedy designed to reduce the key human and ecological risks effectively. Another important risk management function generally is to compare and contrast the costs and benefits of various remedies.”

At this Site, the costs of Alternatives 4N, 5N, 5aN, and 6N are significantly higher than for Alternatives 1N, 2N, and 3N (by factors ranging from 4 times higher to more than 2 orders of magnitude higher). Alternatives 4N, 5N, 5aN, and 6N provide no predicted incremental risk reduction benefit because of their significantly increased risk during remedy implementation, while also having a disproportionate and significantly increased cost when compared to Alternatives 1N, 2N, and 3N.

Figure ES-1 compares the overall project cost and effectiveness for each of the alternatives discussed above. This is often called the "knee of the curve" analysis. This figure demonstrates that Alternatives 1N, 2N, and 3N provide an equal reduction in the SWAC for dioxins and furans in river sediments within USEPA's Preliminary Site Perimeter; however, there is a modest increase in costs associated with those alternatives, due to long-term operations, monitoring and maintenance of the Armored Cap, and structural enhancements to create the Permanent Cap in Alternative 3N. The SWAC for dioxins and furans in river sediments in Alternatives 4N, 5N, 5aN, and 6N are predicted to increase because of releases that are likely to occur to the water column during construction of those alternatives, as well as dredge residuals in the case of Alternatives 5aN and 6N, and they are increasingly expensive because of the complexity and duration of those alternatives, without providing proportional incremental risk reduction. Even if one rejected the "knee of the curve" graph's trajectory showing a decrease in the long-term protectiveness of the remedies with more dredging and removal due to issues with resuspension and release, a straight flatline of the graph rather than the decreasing protectiveness after Alternative 3N would result in the same conclusion: protectiveness and incremental cost would not be proportional for remedies 4N, 5N, 5aN, and 6N. As has been pointed out by the NRC Committee on Dredging Effectiveness (NRC 2007), greater mass removal typically does not equate to greater protectiveness, particularly when the inevitable resuspension and release of contaminants occur during dredging, despite employment of BMPs.

Therefore, at this Site, the remedy evaluation should follow the risk management and cost-effectiveness requirements of CERCLA, the NCP and the Sediment Guidance by focusing on the alternative whose costs are proportional to the remedy's anticipated effectiveness (risk reduction).

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).

The pockets of subsurface soil with $TEQ_{DF,\ M}$ concentrations exceeding the hypothetical future construction worker PCL in the area south of I-10 are isolated from the surface by several feet of clean soil. $TEQ_{DF,\ M}$ concentrations for specific sample intervals are shown in Figure 2-5. Potential exposure to soil exceeding the PCL 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 PCL is based on exposure to soil from 0- to 10-feet below the surface. Average $TEQ_{DF,\ M}$ concentrations in the 0- to 10-foot interval are shown in Figure 3-5.

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, stormwater, 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 PCL 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 construction workers 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.

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 stormwater. 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 PCL, 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. 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 tracking of COCs off-site.

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 and significant 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

Table 5-1 includes a summary of estimated costs for each alternative. 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 $140,000, Alternative 2S (ICs) is estimated to cost $270,000, Alternative 3S (Enhanced ICs) is estimated to cost $660,000, 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, but the risk management achieved by ICs is nearly equivalent for the area south of I-10, particularly 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. Excavation of impacted soil (Alternative 4S) would introduce short-term risks of exposure to COCs on-site and potentially off-site in the event of a release en route to the disposal facility. The cost of Alternative 4S, $9.9 million, is 15 times the cost of Alternative 3S and more than 35 times the cost of Alternative 2S. In summary, consistent with the risk management and cost-effectiveness provisions of CERCLA and the NCP discussed in Section 6.1.7 above, Alternatives 2S and 3S effectively mitigate 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 low risk associated with the impacted soil at depth. However, Alternative 4S offers marginally increased long-term effectiveness by removing the impacted soil at a significant increased cost, without offering any proportionate incremental risk reduction, due to increased short-term remedy implementation risks of exposure to COCs and potential traffic accidents.

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TABLES

Table 3-1
Applicable or Relevant and Appropriate Requirements Summary

Potential ARARs[1]	Citation	Summary	Comment
Federal			
Clean Water Act (CWA): Criteria and standards for imposing technology-based treatment requirements under §§ 309(b) and 402 of the Act	33 U.S.C. §§ 1319 and 1342 (implementing regulations at 40 CFR Part 125 Subpart A)	Both on-site and off-site discharges from CERCLA sites to surface waters are required to meet the substantive CWA (National Pollutant Discharge Elimination System) NPDES requirements (USEPA 1988).	On-site discharges must comply with the substantive technical requirements of the CWA but do not require a permit (USEPA 1988). Off-site discharges would be regulated under the conditions of a NPDES permit (USEPA 1988). Standards of control for direct discharges must meet technology-based requirements. Best conventional pollution control technology (BCT) is applicable to conventional pollutants. Best available technology economically achievable (BAT) applies to toxic and non-conventional pollutants. For CERCLA sites, BCT/BAT requirements are determined on a case-by-case basis using best professional judgment. This is likely to be a potential requirement only if treated water or excess dredge water is discharged during implementation.
CWA Sections 303 and 304: Federal Water Quality Criteria	33 U.S.C. §§1313 and 1314 (Most recent 304(a) list as updated to issuance of ROD)	Under §303 (33 U.S.C. §1313), individual states have established water quality standards to protect existing and attainable uses (USEPA 1988). CWA §301(b)(1)(C) requires that pollutants contained in direct discharges be controlled beyond BCT/BAT equivalents (USEPA 1988). CERCLA §121(d)(2)(B)(i) establishes conditions under which water quality criteria, which were developed by USEPA as guidance for states to establish location-specific water quality standards, are to be considered relevant and appropriate. Two kinds of water quality criteria have been developed under CWA §304 (33 U.S.C. §1314): one for protection of human health, and another for protection of aquatic life. These requirements include establishment of total maximum daily loads (TMDL).	The FS considers the ability of remedial alternatives to satisfy established water quality criteria. Best management practices (BMPs) would be established for remedial actions and applied during construction. Water quality would also be monitored during construction and additional BMPs may be implemented if necessary to protect water quality. Where water quality state standards contain numerical criteria for toxic pollutants, appropriate numerical discharge limitations may be derived for the discharge and considered (USEPA 1988). Where state standards are narrative, either the whole-effluent or chemical-specific approach may generally be used as a standard of care (USEPA 1988).
CWA Section 307(b): Pretreatment standards	33 U.S.C. §1317(b)	CERCLA §121(e) states that no Federal, state, or local permit for direct discharges is required for the portion of any removal or remedial action conducted entirely on-site (the aerial extent of contamination and all suitable areas in close proximity to the contamination necessary for implementation of the response action) (USEPA 1988).	If off-site discharges from a CERCLA response activity were to enter receiving waters directly or indirectly, through treatment at a Publicly Owned Treatment Works (POTWs), they must comply with applicable Federal, State, and Local substantive requirements and formal administrative permitting requirements (USEPA 1988). This requirement may be triggered by disposal methods for waste. Based on the current set of proposed alternatives, none of the alternatives involve discharge to a POTW, and therefore, this regulation is not likely to be applicable.
CWA Section 401: Water Quality Certification	33 U.S.C. §1341	Requires applicants for Federal permits for projects that involve a discharge into navigable waters of the U.S. to obtain certification from state or regional regulatory agencies that the proposed discharge will comply with CWA Sections 301, 302, 303, 306, and 307.	Proposed activities that are on-site would not require a Federal permit. Therefore, certification is not legally required for on-site actions. Certification would be required for off-site actions. For on-site or off-site actions, certification should occur as part of the state identification of substantive state ARARs (USEPA 1988). Compliance with water quality criteria is discussed under CWA Sections 303 and 304.

[1] ARARs are applicable or relevant and appropriate requirements of Federal or state environmental laws and state facility siting laws. CERCLA section 121(d) requires that remedial actions generally comply with ARARs. The USEPA has stated a policy of attaining ARARs to the greatest extent practicable on remedial or removal actions (USEPA 1988). USEPA also stated that certain nonpromulgated Federal and state advisories or guidelines would be considered in selecting remedial or removal actions; these guidelines are referred to as TBCs, or "to be considered."

Table 3-1
Applicable or Relevant and Appropriate Requirements Summary

Potential ARARs[1]	Citation	Summary	Comment
CWA Section 404 and 404(b)(1): Dredge and Fill	33 U.S.C. §1344 (b)(1) (implementing regulations at 33 CFR 320 and 330; 40 CFR 230)	Discharges of dredged and fill material into waters of the U.S. must comply with the CWA §404 (33 U.S.C. 1344) guidelines and demonstrate the public interest is served (USEPA 1988).	The San Jacinto site is a water of the U.S. (USEPA 2007). Dredge and fill permits are applicable to dredging, in-water disposal, capping, construction of berms or levees, stream channelization, excavation and/or dewatering within waters of the U.S. (USEPA 1988). Permits are not required, however, for on-site CERCLA actions. Under the 404(b)(1) guidelines, efforts should be made to avoid, minimize, and mitigate adverse effects on the waters of the U.S. and, where possible, select a practicable (engineering feasible) alternative with the least adverse effects. The substantive requirements of Section 404 will be considered in the development and evaluation of remedial alternatives to minimize adverse impacts to waters of the U.S.
Safe Drinking Water Act	42 U.S.C. §300f (implementing regulations at 40 CFR Part 141, et seq.)	The Safe Drinking Water Act is applicable to public drinking water sources at the point of consumption ("at the tap"). Maximum contaminant levels (MCLs) have been established for certain constituents to protect human health and to preserve the aesthetic quality of public water supplies.	Safe Drinking Water Act standards are applicable to public drinking water sources. The San Jacinto River is not a public water supply and does not recharge an aquifer used to supply drinking water. Therefore, the Safe Drinking Water Act is not applicable. The MCL for 2,3,7,8-tetrachlorodibenzodioxin may be considered for protecting water quality.
Federal Drinking Water Regulations (Primary and Secondary Drinking Water Standards)[2]	40 CFR 141 and Part 143	USEPA has established two sets of drinking water standards: one for protection of human health (primary) and one to protect aesthetic values of drinking water (secondary) (USEPA 1988). MCLs are applicable to public drinking water sources at the point of consumption.	Safe Drinking Water Act standards are applicable to public drinking water sources. The San Jacinto River is not a public water supply and does not recharge an aquifer used to supply drinking water. Therefore, the Safe Drinking Water Act is not applicable. The MCL for 2,3,7,8-tetrachlorodibenzodioxin may be considered for protecting water quality.
Resource Conservation And Recovery Act (RCRA): Hazardous Waste Management	42 U.S.C. §§6921 et seq. (implementing regulations at 40 CFR Parts 260 – 268)	RCRA is intended to protect human health and the environment from the hazards posed by waste management (both hazardous and nonhazardous). RCRA also contains provisions to encourage waste reduction. RCRA Subtitle C and its implementing regulations contain the Federal requirements for the management of hazardous wastes.	This requirement would apply to certain activities if the affected sediments contain RCRA listed hazardous waste or exhibit a hazardous waste characteristic. RCRA requirements are applicable only if waste is managed (treated, stored, or disposed of) after effective date of RCRA requirement under consideration or if CERCLA activity constitutes treatment, storage, or disposal as defined by RCRA. The sludge and sediment at the site are not listed hazardous waste, do not contain listed hazardous waste, and do not meet any of the characteristics of hazardous waste. Therefore, the RCRA rules for hazardous waste are neither applicable nor relevant and appropriate.
Toxic Substances Control Act (TSCA)	15 USC §2601 et. seq. (implementing regulations at 40 CFR 761)	Potentially applicable to PCB-contaminated sediment or surface water. Requires remedial action of certain PCB releases depending on the concentration of the source material and the date of the release (or the as-found concentration for releases where the date is undetermined). Disposal and treatment requirements are also specified for environmental media if removed depending on total PCB concentrations.	Total PCB concentrations in in soil and sediment are below the regulatory threshold (50 mg/kg, calculated as specified in 40 CFR 761) that would require remedial action or trigger certain requirements for waste management.
RCRA: General Requirements for Solid Waste Management	42 U.S.C. §§6941 et seq. (implementing regulations at 40 CFR 258)	Requirements for construction for municipal solid waste landfills that receive RCRA Subtitle D wastes, including industrial solid waste. Requirements for run-on/run-off control systems, groundwater monitoring systems, surface water requirements, etc.	This requirement would be relevant if a landfill was constructed for the disposal of non-hazardous solid waste. There are no specific Federal requirements for non-hazardous waste management; state regulations provide specific applicable requirements for siting, design, permitting, and operation of landfills.
Clean Air Act (CAA)	42 U.S.C. §§7401 et seq.	Would apply if dredging and/or excavation activities generate air emissions sufficient to require a permit, greater than 10 tons of any pollutant per year under the CAA operational permit (USEPA 2009).	None of the remedial alternatives is expected to trigger an operational permit.

[2] Underground injection is not anticipated as a part of the potential remedial action. Furthermore, the site is not located in a sole-source aquifer (USEPA 2008). It is also assumed that no wellhead protection area is located near the study area.

Table 3-1
Applicable or Relevant and Appropriate Requirements Summary

Potential ARARs[1]	Citation	Summary	Comment
Rivers And Harbors Act of 1899: Obstruction of navigable waters (generally, wharves; piers, etc.); excavation and filling-in	33 U.S.C. §401	Controls the alteration of navigable waters (i.e., waters subject to ebb and flow of the tide shoreward to the mean high water mark). Activities controlled include construction of structures such as piers, berms, and installation of pilings as well as excavation and fill. Section 10 may be applicable for any action that may obstruct or alter a navigable waterway.	No permit is required for on-site activities. However, substantive requirements might limit in-water construction activities.
Endangered Species Act	16 U.S.C. §§ 1531 et seq.	Federal agencies must ensure that actions they authorize, fund, or carry out are not likely to adversely modify or destroy critical habitat of endangered or threatened species. Actions authorized, funded, or carried out by Federal agencies may not jeopardize the continued existence of endangered or threatened species as well as adversely modify or destroy their critical habitats.	Based on a 2010 evaluation, as well as a desktop review of site photos and USFWS and NMFS species and habitat maps, no Federally listed threatened or endangered (T&E) species or their critical habitat are present on the site or utilize areas in the vicinity of the site. Therefore, this requirement is not relevant to the evaluation of remedial alternatives. NMFS includes endangered sea turtles in Trust resources impacted by contaminated surface water and sediments that may have been transported from the site. USEPA will consult with the resource agencies to gain concurrence on the determination that the proposed remedial alternative will have no effect on listed species.
Fish and Wildlife Coordination Act	16 U.S.C. §§661 et seq., 16 U.S.C. §742a, 16 U.S.C. § 2901	Requires adequate provision for protection of fish and wildlife resources. This title has been expanded to include requests for consultation with USFWS for water resources development projects (Mueller 1980). Any modifications to rivers and channels require consultation with the USFWS, Department of Interior, and state wildlife resources agency[3]. Project-related losses (including discharge of pollutants to water bodies) may require mitigation or compensation.	Applicable to any action that controls or modifies a body of water.
Bald and Golden Eagle Protection Act	16 U.S.C. §668a-d	Makes it unlawful to take, import, export, possess, buy, sell, purchase, or barter any bald or golden eagle, nest, or egg. "Take" is defined as pursuing, hunting, shooting, poisoning, wounding, killing, capturing, trapping and collecting, molesting, or disturbing.	This requirement is potentially relevant to CERCLA activities. No readily available information suggests bald or golden eagles frequent the project area; however, a qualified biologist would perform a site visit prior to a potential remedial action to confirm that bald and golden eagles do not frequent the project area.
Migratory Bird Treaty Act	16 U.S.C. §§703-712 (implementing regulations at 50 CFR §10.12)	Makes it unlawful to take, import, export, possess, buy, sell, purchase, or barter any migratory bird. "Take" is defined as pursuing, hunting, shooting, poisoning, wounding, killing, capturing, and trapping and collecting.	This requirement is potentially relevant to CERCLA activities. No readily available information suggests migratory birds frequent the project area, and aerial photography of the site suggests no suitable nesting or stopover habitat is present; however, a qualified biologist would perform a site visit prior to a potential remedial action to confirm that migratory birds do not frequent the project area.
Coastal Zone Management Act	16 USC §§1451 et seq. (implementing regulations at 15 CFR 930)	Federal activities must be consistent with, to the maximum extent practicable, State coastal zone management programs. Federal agencies must supply the State with a consistency determination (USEPA 1989).	The San Jacinto River lies within the Coastal Zone Boundary according to the Texas Coastal Management Plan (TCMP) prepared by the General Land Office (GLO). The FS considers whether the remedial alternatives would affect (adversely or not) the coastal zone, and the lead agency is required to determine whether the activity will be consistent with the State's CZMP (USEPA 1989). More information regarding the state requirements is provided under Texas Coastal Coordination Council (TCCC) Policies for Development in Critical Areas.
FEMA (Federal Emergency Management Agency), Department of Homeland Security (Operating Regulations)	42 U.S.C. 4001 et seq. (implementing regulations at 44 CFR Chapter 1)	Prohibits alterations to river or floodplains that may increase potential for flooding.	This requirement is relevant to CERCLA activities in floodplains and in the river because the project area is within a designated flood zone. The FS includes a brief review of the potential impacts of remedial alternatives on the floodplain, and there will be a full evaluation of the selected alternative as part of the remedial design process.
National Flood Insurance Program (NFIP) Regulations	42 U.S.C. subchapter III, §§4101 et seq.	Provides federal flood insurance to local authorities and requires that the local authorities not allow fill in the river that would cause an increase in water levels associated with floods.	The FS includes a brief review of the potential impacts of remedial alternatives on the floodplain, and there will be a full evaluation of the selected alternative as part of the remedial design process.

[3] Texas Parks and Wildlife Department.

Table 3-1
Applicable or Relevant and Appropriate Requirements Summary

Potential ARARs[1]	Citation	Summary	Comment
Title 40: Protection of the Environment - Statement of Procedures on Floodplain Management and Wetlands Protection	40 CFR Part 6 App. A; Executive Orders (EO) 11988 and 11990	Requires Federal agencies to conduct their activities to avoid, if possible, adverse impacts associated with the destruction or modification of wetlands and occupation or modification of floodplains. Executive Orders 11988 and 11990 require Federal projects to avoid adverse effects and minimize potential harm to wetlands and within flood plains. The EO 11990 requires Federal agencies to avoid to the extent possible the long and short-term adverse impacts associated with the destruction or modification of wetlands and to avoid direct or indirect support of new construction in wetlands wherever there is a practicable alternative (USEPA 1994).	This requirement is potentially relevant to disposal or treatment activities in the upland as well as any in-water facilities that might displace floodwaters. The waste pits are located within the floodway and Zone AE, or the 1% probability floodplain. The FS includes a brief review of the potential impacts of remedial alternatives on the floodplain, and there will be a full evaluation of the selected alternative as part of the remedial design process. Effects on the base flood, typically the 100-year or 1% probability flood, should be minimized to the maximum extent practicable (Code of Federal Regulations 1985 as amended). The agency also adopted a requirement that the substantive requirements of the Protection of Wetlands Executive Order must be met (USEPA 1994). Unavoidable impacts to wetlands must be mitigated (USEPA 1994)[4].
National Historic Preservation Act	16 U.S.C. §§ 470 et seq. (implementing regulations at 36 CFR 800)	Section 106 of this statute requires Federal agencies to consider effects of their undertakings on historic properties. Historic properties may include any district, site, building, structure, or object included in or eligible for the National Register of Historic Places (NRHP), including artifacts, records, and material remains related to such a property.	According to the San Jacinto River Waste Pits Remedial Investigation/Feasibility Study (RI/FS) cultural resources assessment, "no NRHP-eligible properties are documented in the area of concern. Because of the extensive disturbance to the site and minimal ground disturbance that will likely occur for the project, it is not likely that NRHP-eligible historic properties will be affected by RI/FS or eventual site remediation activities" (Anchor QEA 2009).
Noise Control Act	42 U.S.C. §§ 4901 et seq. (implementing regulations at 40 CFR Subchapter G §201 et seq.	Noise Control Act remains in effect but unfunded (USEPA 2010).	Noise is regulated at the state level. See Texas Penal Code under state ARARs.
Hazardous Materials Transportation Act	49 U.S.C. §§1801 et seq. (implementing regulations at 49 CFR. Subchapter C)	Establishes standards for packaging, documenting, and transporting hazardous materials.	This requirement would apply to remedial alternatives that involve transporting hazardous materials off-site for treatment or disposal.

[4] Each agency is expected to minimize the destruction, loss, or degradation of wetlands, and to preserve and enhance the natural and beneficial values of wetlands when implementing actions such as CERCLA sites (President of the United States 1977). If §404 of the Clean Water Act is considered an ARAR, then the 404(b)(1) guidelines established in a Memorandum of Understanding (MOU) between USEPA and Department of Army should be followed (USEPA 1994). When habitat is severely degraded, a mitigation ratio of 1:1 may be acceptable (USEPA 1994). However, any mitigation would be at the discretion of the agency and the USEPA may elect to orient mitigation towards "minimizing further adverse environmental impacts rather than attempting to recreate the wetlands original value on site or off site" (USEPA 1988).

Table 3-1
Applicable or Relevant and Appropriate Requirements Summary

Potential ARARs	Citation	Summary	Comment
State			
30 Texas Administrative Code (TAC) Part 1: Industrial Solid Waste and Municipal Hazardous Waste General Terms	30 TAC §§335.1 – 335.15	General Terms: Substantive requirements for the transportation of industrial solid and hazardous wastes; requirements for the location, design, construction, operation, and closure of solid waste management facilities.	Guidelines to promote the proper collection, handling, storage, processing, and disposal of industrial solid waste or municipal hazardous waste in a manner consistent with the purposes of Texas Health and Safety Code, Chapter 361. Solid nonhazardous waste provisions are applicable if material is transported to an upland disposal facility.
30 TAC Part 1: Industrial Solid Waste and Municipal Hazardous Waste: Notification	30 TAC Chapter 335 Subchapter P	Requires placement of warning signs in contaminated and hazardous areas if a determination is made by the executive director of the Texas Water Commission a potential hazard to public health and safety exists which will be eliminated or reduced by placing a warning sign on the contaminated property.	Warning signs and fencing were placed around the site as part of the Time Critical Removal Action. The FS includes additional institutional controls for all alternatives, including additional warning signs and fencing.
30 TAC Part 1: Industrial Solid Waste and Municipal Hazardous Waste: Generators	30 TAC Chapter 335, Subchapter C	Standards for hazardous waste generators either disposing of waste on-site or shipping off-site with the exception of conditionally exempt small quantity generators. The definition of hazardous involves state and Federal standards.	The sludge and sediment at the site are not listed hazardous waste, do not contain listed hazardous waste, and do not meet any of the characteristics of hazardous waste. Therefore, the rules for hazardous waste are neither applicable nor relevant and appropriate.
Texas Surface Water Quality Standards	30 TAC §307.4-7, 10	These state regulations provide: • General narrative criteria • Anti-degradation Policy • Numerical criteria for pollutants • Numerical and narrative criteria for water-quality related uses (e.g., human use) • Site specific criteria for San Jacinto basin	Surface water quality standards are potentially relevant to the determination of risks, but should not override any site-specific toxicity values or risks determined through the risk assessment process. It is also relevant to the identification of potential sources and the short-term and long-term effectiveness of removal alternatives. However, the surface water quality criterion for TEQ, expressed as a concentration in edible fish tissue in 30 TAC §307.6 (c) 11, is generally not being met throughout the Houston Ship Channel, San Jacinto Bay and Galveston Bay areas. In more than 90 percent of edible fish tissue samples and in more than 85 percent of edible crab tissue collected by Respondents, TCEQ and TDSHS outside of USEPA's Preliminary Site Perimeter from 2002 through 2011, TEQ concentrations exceeded this tissue-based standard. Therefore, applicability to evaluation of effectiveness is limited due to ambient conditions in the region.
Texas Water Quality: Pollutant Discharge Elimination System (TPDES)	30 TAC §279.10	These state regulations require stormwater discharge permits for either industrial discharge or construction-related discharge. The State of Texas was authorized by USEPA to administer the NPDES program in Texas on September 14, 1998 (Texas Commission on Environmental Quality 2009).	The proposed remedial alternatives evaluated in the FS do not include off-site remedial action beyond disposal of sediments in upland disposal facilities that would be previously permitted, and therefore no discharge permit for off-site remedial actions would be required.
Texas Water Quality: Water Quality Certification	30 TAC §279.10	These state regulations establish procedures and criteria for applying for, processing, and reviewing state certifications under CWA, §401. It is the purpose of this chapter, consistent with the Texas Water Code and the Federal CWA, to maintain the chemical, physical, and biological integrity of the state's waters.	The development and evaluation of remedial alternatives will include consideration of potential water-quality impacts, relevant to the Water Quality Certification in Texas. Although permits are not required for on-site CERCLA actions, water quality certification is relevant as part of identification of substantive state ARARs (USEPA 1988).
Texas Risk Reduction Program	30 TAC §350	Activated upon release of Chemicals of Concern (COC). The Risk Reduction Program uses a tiered approach incorporating risk assessment techniques to help focus investigations, to determine appropriate protective concentration levels for human health, and when necessary, for ecological receptors. Includes protective concentration levels.	Risk assessment was performed as part of the remedial investigation. Sediment and soil contaminated with COCs is isolated from potential receptors by existing soil and sediment or the TCRA cap such that there are no unacceptable risks to human health or the environment. The remedial alternatives would increase the permanence of the existing barriers to exposure, thereby enhancing the risk reduction.
Natural Resources Code, Antiquities Code of Texas	Texas Parks and Wildlife Commission Regulations 191.092-171	Requires that the Texas Historical Commission staff review any action that has the potential to disturb historic and archeological sites on public land. Actions that need review include any construction program that takes place on land owned or controlled by a state agency or a state political subdivision, such as a city or a county. Without local control, this requirement does not apply.	Assessment of historical resources during the TCRA produced no known eligible properties and determined that disturbance of any archaeological or historic resources is unlikely within the TCRA Site. Depending on the magnitude and specific boundaries of ground disturbance determined during the FS for the overall site, this ARAR will need to be re-evaluated relative to CERCLA activities outside of the TCRA boundaries. (Anchor QEA 2009).

Table 3-1
Applicable or Relevant and Appropriate Requirements Summary

Potential ARARs	Citation	Summary	Comment
Practice and Procedure, Administrative Code of Texas	13 TAC Part 2, Chapter 26	Regulations implementing the Antiquities Code of Texas. Describes criteria for evaluating archaeological sites and permit requirements for archaeological excavation.	This requirement is only applicable if an archaeological site is found; based on evaluations conducted as part of the RI/FS and TCRA processes, it is unlikely that archaeological resources would be found on the Site
State of Texas Threatened and Endangered (T&E) Species Regulations	31 TAC 65.171 - 65.176	No person may take, possess, propagate, transport, export, sell or offer for sale, or ship any species of fish or wildlife listed as threatened or endangered.	The presence or absence of state T&E species was evaluated in 2010, and concluded that no state T&E species were likely to occur on the Site or in the vicinity.
TCCC Policies for Development in Critical Areas	31 TAC §501.23	Dredging in critical areas is prohibited if activities have adverse effects or degradation on shellfish and/or jeopardize the continued existence of endangered species or results in an adverse effect on a coastal natural resource area (CNRA)[5]; prohibit the location of facilities in coastal natural resource areas unless adverse effects are prevented and /or no practicable alternative. Actions should not be conducted during spawning or nesting seasons or during seasonal migration periods. Specifies compensatory mitigation.	The FS evaluates the potential effects of remedial alternatives on Coastal Natural Resource Area (CNRAs), which includes coastal wetlands (Railroad Commission of Texas n.d.).
Texas Coastal Management Plan (CMP) Consistency	31 TAC, §506.12	Specifies Federal actions within the CMP boundary that may adversely affect CNRAs; specifically selection of remedial actions.	The San Jacinto River lies within the Coastal Zone Boundary (GLO TCMP). The FS will evaluate whether remedial alternatives may affect (adversely or not) the coastal zone and will provide a technical basis for the lead agency to determine whether the activity will be consistent with the State's CMP (USEPA 1989).
Texas State Code – obstructions to navigation	Natural Resources Code § 51.302 Prohibition and Penalty	Prohibits construction or maintenance of any structure or facility on land owned by the State without an easement, lease, permit, or other instrument from the State.	The FS evaluates whether the remedial alternatives include construction on state-owned land, and implementation of any alternative occurring on state lands presumes the obtainment of an easement, lease, permit, or other instrument from the State.
Noise Regulations	Texas Penal Code Chapter 42, Section 42.01	The Texas Penal Code regulates any noise that exceeds 85 decibels after the noise is identified as a public nuisance.	Noise abatement may be required if actions are identified as a public nuisance. Due to the isolation of the site, its location adjacent to a freeway with high volumes of traffic during normal working hours, and the industrial nature of the nearest properties, noise from construction activity associated with a potential remedial action is unlikely to constitute a public nuisance. Noise associated with truck traffic to and from the site should be considered for alternatives that involve transportation of materials off-site.

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[5] A CNRA is a coastal wetland, oyster reef, hard substrate reef, submerged aquatic vegetation, tidal sand, or mud flat.

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Table 4-1a
Selected Sediment Capping Projects

Sediment Project	Chemicals of Concern	Site Conditions	Cap Area	Date Constructed	References
St. Paul Waterway (Simpson Tacoma Kraft Superfund Site) Tacoma, Washington	Phenols, PAHs, dioxins, furans	Shallow, near shore sediments, down to -20 feet MLLW.	17 acres	1988	USACE 1998
West Waterway CAD Site Seattle, Washington	PCBs, metals	Subtidal river, active industrial waterway.	1.3 acres	1984	HDR 2013
Olympic View Resource Area Tacoma, Washington	Dioxin	Intertidal and subtidal areas. Water depth up to -15 feet MLLW.	0.4 acres	2003	Hart Crowser 2003
McCormick and Baxter Old Mormon Slough Stockton, California	Dioxins, PAHs	Dead-end waterway; 10 feet deep; maintenance-dredged for barge access; tidally influenced.	8.8 acres	2005	SMWG 2008
McCormick and Baxter Portland Plant Portland, Oregon	PAHs	0.5 mile reach of the Willamette River.	15 acres	2004	SMWG 2008
General Motors Superfund Site St. Lawrence River Massena, New York	PCBs	11-acre near shore site. Depth of river at cap no deeper than 4 feet.	1.7 acre	1995	USACE 1998
Housatonic River, Upper 1/2 Mile General Electric Site Pittsfield, Massachusetts	PCBs	Water depth typically 3-4 feet. Can range from 2-10 feet.	2-3 acres	2002	SMWG 2008
Lower Fox River OU2 – 5 Appleton to Green Bay, Wisconsin	PCBs	39 mile long river; shallow water up to 20 to 24 feet deep in navigation channel.	450 acres	ongoing	SMWG 2008
Koppers Superfund Site Charleston, South Carolina	PAHs, pentachoro-phenol, trace dioxin, lead, arsenic	Ashley River; intertidal system; 1,500 feet reach; cap mostly in intertidal zone; Under 6 feet of water at high tide.	3 acres	2001	SMWG 2008

Notes:

1. This table presents a summary of selected sediment remediation sites where capping was selected as a component of the remedy, and where site conditions (water levels, flow conditions, and/or COCs) are similar to the SJRWP Site.
2. This list is meant to be representative and is not exhaustive. In a 2005 summary prepared by USACE, capping was shown to have been selected as a remedy for sediment remediation at more than 80 sites in the United States.

Table 4-1b
Selected Sediment Dredging Projects

Sediment Project	Chemicals of Concern	Dredging Method	Volume Dredged (cy)	Date Constructed	References
Black Lagoon/Detroit River Trenton, MI	PCBs, PAHs, heavy metals (including mercury, lead and zinc), oil and grease	Mechanical	115,000	2004	USEPA 2009d
Duwamish Diagonal Seattle, WA	PCBs, mercury, and phthalates.	Mechanical	66,000	2003	SMWG 2008
Hudson River Phase 1 Glenns Falls, NY	PCBs	Hydraulic and Mechanical	293,000	2009	Anchor QEA and Arcadis 2010
Kinnickinnic River Milwaukee, WI	PCBs and PAHs	Mechanical	167,000	2009	USEPA 2009e
Lower Fox River - Phase 1 De Pere, WI	PCBs	Hydraulic	132,000	2007	Shaw et. al. 2008
Lower Saginaw River Saginaw, MI	PCBs	Mechanical	345,000	2001	SMWG 2008
Saginaw River - Wickes Park Midland, MI	Dioxins/Furans	Hydraulic	625	2007	USEPA 2008
St. Lawrence River (Reynolds) Massena, NY	PCBs, PAHs, PCDFs	Hydraulic and Mechanical	86,000	2001	Malcolm Pirnie and TAMS Consultants 2004
Tittabawassee River - Reach D Midland, MI	Dioxins/furans, PAHs, metals, chlorinated organic compounds	Hydraulic and Mechanical	19,200	2007	Dow 2009

Table 4-2
Release Case Studies

Project	Environmental Dredging Activity	BMPs	Source of Release Estimate	Contaminant Mass Released	Primary Reference
1995 Grasse River NTCRA Pilot Study	3,000 cy of sediment and debris removed using hydraulic dredge for sediments	Dredging operation BMPs and silt curtains	Caged fish monitoring	Adjacent fish tissue concentrations increased 50x; 0.9 km downstream fish tissue concentrations increased 5x	"Non-Time Critical Removal Action (NTCRA) Pilot Dredging in the Grasse River" presentation to the NAS Panel on Risk-management Strategy for PCB-Contaminated Sediments. November 8, 1999.
1999-2000 Fox River SMU 56/57 Dredging Pilot Study	82,000 cy removed using hydraulic cutterhead dredge	Dredging operation BMPs and silt curtains	Water quality monitoring data collected 100 to 200 feet downstream of the dredge, outside of silt curtains	Average **2.2%** of dredged PCB mass released into water column, with roughly 30% as dissolved phase PCBs	Steuer, J.J., 2000. A mass-balance approach for assessing PCB movement during remediation of a PCB-contaminated deposit on the Fox River, Wisconsin. USGS Water-Resources Investigations Report 00-4245.
2004 Duwamish/ Diagonal Early Action	70,000 cy removed using clamshell mechanical dredge	Dredging operation BMPs	Fate/transport and food web modeling to simulate measured fish tissue PCB increases during and after dredging	Fish tissue increases simulated assuming an average **3%** (range: 1 to 6%) of dredged PCB mass released and available for bioaccumulation	Stern, J. H., 2007. Temporal effects of dredge-related releases on fish tissue concentrations: Implications to achieving net risk reduction. SETAC North America 28th Annual Meeting, Nov. 2007, Milwaukee, WI.
2005 Grasse River Remedial Options Pilot Study	25,000 cy removed using hydraulic cutterhead dredge	Dredging operation BMPs and silt curtains	Water quality monitoring data collected more than 2,000 feet downstream of the dredge, outside of silt curtains	Average **3%** of dredged PCB mass released into water column, with more than 50% as dissolved phase PCBs	Connolly J.P., J.D. Quadrini , and L.J. McShea, 2007. Overview of the 2005 Grasse River Remedial Options Pilot Study. In: Proceedings, Remediation of Contaminated Sediments—2007. Savannah, GA. Columbus (OH): Battelle.
2005 Lower Passaic River Dredging Pilot Study	4,000 cy removed using clamshell mechanical dredge	Dredging operation BMPs and rinse tank	Water quality monitoring data collected 400 feet downstream of the dredge over the 5 day dredging event	Average **3 to 4%** (range: 1 to 6%) of dredged dioxin mass released into water column	Lower Passaic River Restoration Project Team, 2009. Revision and Updates to the Environmental Dredging Pilot Study. Project Delivery Team Meeting. March 2009.
2009 Hudson River Phase I Dredging	280,000 cy removed using clamshell mechanical dredge	Dredging operation BMPs and silt curtains	Water quality monitoring data collected more than 10,000 feet downstream of the dredge, outside of silt curtains	Average **3 to 4%** of dredged PCB mass released into water column, with 70 to 90% as dissolved phase PCBs	Anchor QEA and Arcadis, 2010. Phase 1 Evaluation Report: Hudson River PCBs Superfund Site. Report prepared for General Electric, Albany, New York. March 2010.

Table 4-3
Summary of Quantities and Durations - Area North of I-10

	Alternative 1N Armored Cap and Ongoing OMM (No Further Action)	Alternative 2N Armored Cap, Institutional Controls (ICs) and Monitored Natural Recovery (MNR)	Alternative 3N Permanent Cap, ICs, and MNR	Alternative 4N Partial Solidification/ Stabilization, Permanent Cap, ICs and MNR	Alternative 5N Partial Removal, Permanent Cap, ICs and MNR	Alternative 5aN Partial Removal of Materials Exceeding the PCL, Permanent Cap, ICs and MNR	Alternative 6N Full Removal of Materials Exceeding the PCL, ICs and MNR
Site Preparation							
TCRA Armor Rock Removal (cy)	N/A	N/A	0	8,500	8,500	27,400	29,900
Duration (days)	N/A	N/A	0	14	14	46	50
Sheetpile Install (lf)	N/A	N/A	0	800	0	1,200	0
Duration (days)	N/A	N/A	0	40	0	60	0
Perimeter Berm Install (lf)	N/A	N/A	0	0	0	820	0
Duration (days)	N/A	N/A	0	0	0	16	0
Sheetpile Removal (lf)	N/A	N/A	0	800	0	1,200	0
Duration (days)	N/A	N/A	0	40	0	60	0
Perimeter Berm Removal (lf)	N/A	N/A	0	0	0	820	0
Duration (days)	N/A	N/A	0	0	0	16	0
Construction of a Permanent Cap							
Armor Rock Placement (cy)	N/A	N/A	3,400	3,400	3,400	1,400	0
Rubble Mound Protection (cy)	N/A	N/A	1,600	1,600	1,600	1,600	0
Duration (days)	N/A	N/A	33	33	33	20	0
Treatment							
Sediment Solidification (cy)	N/A	N/A	0	52,000	0	0	0
Duration (days)	N/A	N/A	0	173	0	0	0
Removal							
Dredging (cy)	N/A	N/A	0	0	52,000	137,600	200,100
Residuals Cover/Backfill (cy)	N/A	N/A	0	0	52,000	13,700	19,800
Duration (days)	N/A	N/A	0	0	169	199	290
Armored Cap Restoration							
Armor Rock Replacement (cy)	N/A	N/A	0	8,000	8,000	0	0
Duration (days)	N/A	N/A	0	53	53	0	0
TOTAL DURATION (months)	**N/A**	**N/A**	**2**	**17**	**13**	**19**	**16**

Notes:

1. All quantities include a 20 percent contingency
2. Quantities shown in cubic yards (cy) or linear feet (lf)
3. Durations assume a 22 day month, rounded up
4. Production rates assumed as follows:
    a. Armor Rock Removal - 600 cy/day
    b. Sheetpile Install/Remove - 20 lf/day
    c. Armor Rock Placement - 150 cy/day
    d. Perimeter Berm Install/Remove - 50 lf/day
    e. Solidification - 300 cy/day
    f. Dredging - 800 cy/day
    g. Residuals Cover/Backfill - 500 cy/day

Table 4-4
Summary of Construction Emissions Factors - Area North of I-10

	Alternative 1N Armored Cap and Ongoing OMM (No Further Action)	Alternative 2N Armored Cap, Institutional Controls (ICs) and Monitored Natural Recovery (MNR)	Alternative 3N Permanent Cap, ICs and MNR	Alternative 4N Partial Solidification/ Stabilization, Permanent Cap, ICs and MNR	Alternative 5N Partial Removal, Permanent Cap, ICs and MNR	Alternative 5aN Partial Removal of Materials Exceeding the PCL, Permanent Cap, ICs and MNR	Alternative 6N Full Removal of Materials Exceeding the PCL, ICs and MNR
Site Preparation							
Heavy Equipment Hours	N/A	N/A	0	2,100	350	4,150	2,000
Truck Trips	N/A	N/A	0	570	550	1,700	1,800
Construction of a Permanent Cap							
Heavy Equipment Hours	N/A	N/A	750	750	750	315	0
Truck Trips	N/A	N/A	260	260	260	105	0
Treatment							
Heavy Equipment Hours	N/A	N/A	0	1,800	0	0	0
Truck Trips	N/A	N/A	0	250	0	0	0
Removal							
Heavy Equipment Hours	N/A	N/A	0	0	5,050	11,200	13,500
Truck Trips	N/A	N/A	0	0	8,000	11,050	15,700
Armored Cap Restoration							
Heavy Equipment Hours	N/A	N/A	0	800	800	0	0
Truck Trips	N/A	N/A	0	520	520	0	0
TOTAL HEAVY EQUIPMENT HOURS	**N/A**	**N/A**	**750**	**5,450**	**6,950**	**15,665**	**15,500**
TOTAL TRUCK TRIPS	**N/A**	**N/A**	**260**	**1,600**	**9,330**	**12,855**	**17,500**
NORMALIZED EQUIPMENT HOURS			**1.0**	**7.3**	**9.3**	**20.9**	**20.7**
NORMALIZED TRUCK TRIPS			**1.0**	**6.2**	**35.9**	**49.4**	**67.3**

Notes:
1. Equipment hours and truck trips based on durations and quantities in Table 4-3.
2. Equipment hours assume 10 hour day and 80% up-time for each piece of equipment.
3. Truck trips assume a capacity of 20 tons per truck.
4. Site preparation includes TCRA cap rock removal and sheet pile/berm installation. Additional site preparation activities will occur, and would add to equipment hours and truck trips but were not included as a simplifying assumption.
5. Removal includes placement of backfill or residuals management cover.

Table 4-5
Summary of Worker Risk Factors - Area North of I-10

	Alternative 1N Armored Cap and Ongoing OMM (No Further Action)	Alternative 2N Armored Cap, Institutional Controls (ICs) and Monitored Natural Recovery (MNR)	Alternative 3N Permanent Cap, ICs, and MNR	Alternative 4N Partial Solidification/ Stabilization, Permanent Cap, ICs and MNR	Alternative 5N Partial Removal, Permanent Cap, ICs and MNR	Alternative 5aN Partial Removal of Materials Exceeding the PCL, Permanent Cap, ICs and MNR	Alternative 6N Full Removal of Materials Exceeding the PCL, ICs and MNR
Site Preparation							
Non Fatal Injuries	N/A	N/A	0.000	0.410	0.068	0.809	0.390
Fatal Injuries	N/A	N/A	0.0000	0.0016	0.0003	0.0033	0.0016
Construction of a Permanent Cap							
Non Fatal Injuries	N/A	N/A	0.146	0.146	0.146	0.061	0.000
Fatal Injuries	N/A	N/A	0.0006	0.0006	0.0006	0.0002	0.0000
Treatment							
Non Fatal Injuries	N/A	N/A	0.000	0.351	0.000	0.000	0.000
Fatal Injuries	N/A	N/A	0.0000	0.0014	0.0000	0.0000	0.0000
Removal							
Non Fatal Injuries	N/A	N/A	0.000	0.000	0.985	2.184	2.633
Fatal Injuries	N/A	N/A	0.0000	0.0000	0.0040	0.0088	0.0106
Armored Cap Restoration							
Non Fatal Injuries	N/A	N/A	0.000	0.156	0.156	0.000	0.000
Fatal Injuries	N/A	N/A	0.0000	0.0006	0.0006	0.0000	0.0000
TOTAL NON-FATAL INJURIES	**N/A**	**N/A**	**0.146**	**1.063**	**1.355**	**3.055**	**3.023**
TOTAL FATAL INJURIES	**N/A**	**N/A**	**0.0006**	**0.0043**	**0.0055**	**0.0123**	**0.0122**
NORMALIZED INJURY RATE			**1.0**	**7.3**	**9.3**	**20.9**	**20.7**

Notes:
1. Incident Rates based on data from U.S. Department of Labor (USDL), Bureau of Labor Statistics (USDL 2011).
2. Non-fatal injury estimate based on a rate of 3.9 per 200,000 work hours (NAICS code 23 - construction).
3. Fatal injury estimate based on a rate of 15.7 per 200,000,000 work hours (construction laborer).
4. Total employee work hours estimated based on equipment work hours (Table 4-4) and assuming a crew of 10: 5 workers at the staging area and 5 workers at the work site (3 operators + 2 support workers at each location).

USDL 2011. U.S. Department of Labor, Bureau of Labor Statistics, OSHA Recordable Case Rates and Census of Fatal Occupational Injuries, 2011

Table 4-6
Summary of Quantities and Durations - Area South of I-10

	Alternative 1S No Further Action	Alternative 2S Institutional Controls (ICs)	Alternative 3S Enhanced ICs	Alternative 4S Removal and Off-site Disposal
Site Preparation				
Stockpile/Loading Area Preparation	N/A	N/A		
Duration (days)	N/A	N/A	3	3
Construction				
Structure Removal (sf)	N/A	N/A	0	800
Duration (days)	N/A	N/A	0	5
Pad Removal (sf)	N/A	N/A	0	9,710
Duration (days)	N/A	N/A	0	4
Land-based Excavation (cy)	N/A	N/A	8,000	50,000
Duration (days)	N/A	N/A	5	50
House debris (ton)				20
Concrete Pad (ton)				364
Portland Cement (soil amendment, ton)				3,333
Marker Layer Placement (sy)	N/A	N/A	12,000	0
Duration (days)	N/A	N/A	2	0
Backfill (cy)	N/A	N/A	10,400	50,000
Duration (days)	N/A	N/A	10	50
Vegetative Cover (acre)	N/A	N/A	2	2
Duration (days)	N/A	N/A	1	1
Build Replacement Structure (sf)	N/A	N/A	0	800
Duration (days)	N/A	N/A	0	20
Replace Pad (sf)	N/A	N/A	0	9,710
Duration (days)	N/A	N/A	0	7
TOTAL DURATION (months)	**N/A**	**N/A**	**1**	**7**

Notes:

1. Durations assume a 22 day month, rounded up.
2. Production rates assumed as follows:
   a. Shallow Excavation/On-site Stockpiling - 1,500 cy/day
   b. Excavation/Soil Amendment - 1,000 cy/day
   c. Backfill - 1,000 cy/day
   d. Structure Removal - 150 sf/day
   e. Pad Removal - 2,500 sf/day
   f. Marker Layer Placement - 10,000 sy/day
   g. Vegetative Cover - 5 acre/day
   h. Replace Structure - 40 sf/day
   i. Replace Pad - 1,500 sf/day

Table 4-7
Summary of Construction Emissions Factors - Area South of I-10

	Alternative 1S No Further Action	Alternative 2S Institutional Controls (ICs)	Alternative 3S Enhanced ICs	Alternative 4S Removal and Off-site Disposal
Site Preparation				
Heavy Equipment Hours	N/A	N/A	24	24
Truck Trips	N/A	N/A	0	0
Construction				
Heavy Equipment Hours	N/A	N/A	134	882
Truck Trips	N/A	N/A	0	7,186
TOTAL HEAVY EQUIPMENT HOURS	**N/A**	**N/A**	**158**	**906**
TOTAL TRUCK TRIPS	**N/A**	**N/A**	**0**	**7,186**
NORMALIZED EQUIPMENT HOURS			**1.0**	**5.7**

Notes:
1. Equipment hours and truck trips based on durations and quantities in Table 4-6.
2. Equipment hours assume 10 hour day and 80% up-time for each piece of equipment.
3. Truck trips assume a capacity of 20 tons per truck.
4. Site preparation includes stockpile/loading area preparation. Additional site preparation activities will occur, and would add to equipment hours and truck trips but were not included as a simplifying assumption.

Table 4-8
Summary of Worker Risk Factors - Area South of I-10

	Alternative 1S No Further Action	Alternative 2S Institutional Controls (ICs)	Alternative 3S Enhanced ICs	Alternative 4S Removal and Off-site Disposal
Site Preparation				
Non Fatal Injuries	N/A	N/A	0.002	0.002
Fatal Injuries	N/A	N/A	0.0000	0.0000
Construction				
Non Fatal Injuries	N/A	N/A	0.013	0.086
Fatal Injuries	N/A	N/A	0.0001	0.0003
TOTAL NON-FATAL INJURIES	**N/A**	**N/A**	**0.015**	**0.088**
TOTAL FATAL INJURIES	**N/A**	**N/A**	**0.0001**	**0.0004**
NORMALIZED INJURY RATE			**1.0**	**5.7**

Notes:
1. Incident Rates based on data from U.S. Department of Labor (USDL), Bureau of Labor Statistics (USDL 2011).
2. Non-fatal injury estimate based on a rate of 3.9 per 200,000 work hours (NAICS code 23 - construction).
3. Fatal injury estimate based on a rate of 15.7 per 200,000,000 work hours (construction laborer).
4. Total employee work hours estimated based on equipment work hours (Table 4-7) and assuming a crew of 5 workers at the site (3 operators + 2 support workers).

USDL, 2011. U.S. Department of Labor, Bureau of Labor Statistics, OSHA Recordable Case Rates and Census of Fatal Occupational Injuries, 2011.

Table 5-1
Detailed Evaluation of Remedial Alternatives – Area North of I-10

	Alternative 1N **Armored Cap and No Further Action**	**Alternative 2N** **Armored Cap, Institutional Controls (ICs) and Monitored Natural Recovery (MNR)**	**Alternative 3N** **Permanent Cap, ICs and MNR**	**Alternative 4N** **Partial Solidification/ Stabilization, Permanent Cap, ICs and MNR**	**Alternative 5N** **Partial Removal, Permanent Cap, ICs and MNR**	**Alternative 5aN** **Partial Removal of Materials Exceeding the PCL, Permanent Cap, ICs and MNR**	**Alternative 6N** **Full Removal of Materials Exceeding PCLs, ICs and MNR**
Threshold Criteria							
Overall Protection	Meets[1]	Meets[1]	Meets	Meets	Meets	Meets	Meets
Compliance with ARARs	Meets	Meets	Meets	Meets	Meets	Meets	Meets
Balancing Criteria							
Long-Term Effectiveness	• Armored Cap has effectively prevented exposure of ecological and human receptors and requires long-term operations, monitoring and maintenance (OMM) • Natural recovery of sediments within the USEPA's Preliminary Site Perimeter will continue to provide additional reduction in exposure to dioxins and furans in surface sediments	• Same as Alternative 1N plus: • ICs protect the integrity of the Armored Cap, alert potential future property owners about subsurface risk in subsurface sediment	• Same as Alternative 2N plus: • Enhancement of the Armored Cap to create the Permanent Cap would provide additional reliability for the long-term performance of the remedy	• Same as Alternative 3N plus: • S/S of selected sediment would provide additional mobility controls (in addition to cap)	• Same as Alternative 3N plus: • Removal of selected sediment would eliminate the long-term potential of mobilizing COCs adsorbed to these sediments • Residuals cover would be required to manage sediment left behind as a result of dredging	• Same as Alternative 3N plus: • Removal of sediment from footprint of Armored Cap would eliminate the long-term potential of mobilizing COCs adsorbed to these sediments • Use of rigid engineering controls would reduce the potential for losses from dredging, lowering the long term impact of removal compared to Alternative 6N • Residuals cover would be required to manage sediment left behind as a result of dredging	• Same as Alternative 2N plus: • Removal of sediment from footprint of Armored Cap to the PCL for hypothetical recreational visitors would eliminate the long-term potential of mobilizing COCs adsorbed to these sediments • Residuals cover would be required to manage sediment left behind as a result of dredging
Reduction of TMV	• Mobility already reduced through treatment during the TCRA • No additional reduction proposed	• Same as Alternative 1N	• Mobility already reduced through treatment during TCRA • Additional potential mobility reduction achieved by constructing the Permanent Cap	• Same as Alternative 3N plus: • Additional mobility reduction through S/S of soils and sediments exceeding 13,000 ng/kg $TEQ_{DF,M}$	• Post-removal dewatering would reduce the mobility of COCs through the addition of amendments to facilitate transportation and disposal	• Same as Alternative 5N	• Same as Alternative 5N
Short-Term Effectiveness	• Achieve protection immediately • No water quality impacts associated with implementation • No sediment quality impacts associated with implementation • No tissue impacts associated with implementation • No potential loss of contained sediments	• Same as Alternative 1N	• Achieve protection upon completion of implementation • Minimal water quality impacts from turbidity during rock placement for Permanent Cap construction • No sediment quality impacts associated with implementation • No tissue impacts associated with	• Achieve protection upon completion of implementation • Water quality impacts during Armored Cap removal • Potential water quality impacts during sheetpile installation and removal • Potential for sheetpile to drive contamination deeper into subgrade • Potential water quality	• Achieve protection upon completion of implementation • Water quality impacts during Armored Cap removal • Potential water quality impacts from losses through turbidity barriers • Minimal water quality impacts from turbidity during backfilling and cap replacement	• Achieve protection upon completion of implementation • Water quality impacts during Armored Cap removal • Potential water quality impacts from losses through turbidity barriers • Minimal water quality impacts from turbidity during backfilling and cap replacement	• Achieve protection upon completion of implementation • Water quality impacts during Armored Cap removal • Potential water quality impacts from losses through turbidity barriers • Minimal water quality impacts from turbidity during backfilling and cap replacement

Table 5-1
Detailed Evaluation of Remedial Alternatives – Area North of I-10

	Alternative 1N Armored Cap and No Further Action	Alternative 2N Armored Cap, Institutional Controls (ICs) and Monitored Natural Recovery (MNR)	Alternative 3N Permanent Cap, ICs and MNR	Alternative 4N Partial Solidification/ Stabilization, Permanent Cap, ICs and MNR	Alternative 5N Partial Removal, Permanent Cap, ICs and MNR	Alternative 5aN Partial Removal of Materials Exceeding the PCL, Permanent Cap, ICs and MNR	Alternative 6N Full Removal of Materials Exceeding PCLs, ICs and MNR
	during storm events because Armored Cap remains in place • No worker safety risk • No air emissions from construction • No traffic impacts from construction		implementation • No potential loss of contained sediments during storm events because Armored Cap remains in place during construction • Minor potential neighborhood impacts from activities at the offsite staging area because construction duration is short • 0.15 estimated construction worker injuries • 0.0006 estimated construction worker fatalities • Air emissions from 750 hours of equipment operations • Air emissions and traffic impacts from 260 truck trips	impacts from losses through sheetpile gaps • Minimal water quality impacts from turbidity during backfilling and cap replacement • Minimal water quality impacts from turbidity during rock placement for Permanent Cap • Potential sediment quality impacts from losses through sheetpile gaps • Potential tissue impacts from water column releases during construction • Potential loss of currently contained sediments during storm events because Armored Cap must be removed to access sediments during construction • Moderate potential neighborhood impacts from activities at the offsite staging area because construction duration is long • 1.1 estimated construction worker injuries • 0.004 estimated construction worker fatalities • Air emissions from 5,450 hours of equipment operations • Air emissions and traffic impacts from 1,600 truck trips	• Minimal water quality impacts from turbidity during rock placement for Permanent Cap • Potential sediment quality impacts from dredging residuals • Potential tissue impacts from water column releases during construction • Potential loss of currently contained sediments during storm events because Armored Cap must be removed to access sediments during construction • Moderate to high potential neighborhood impacts from activities at the offsite staging area because construction duration is long and impacted material will be staged at the offsite staging area prior to disposal • 1.4 estimated construction worker injuries • 0.006 estimated construction worker fatalities • Air emissions from 6,950 hours of equipment operations • Air emissions and traffic impacts from 9,330 truck trips	• Minimal water quality impacts from turbidity during rock placement for Permanent Cap • Potential sediment quality impacts from dredging residuals • Potential tissue impacts from water column releases during construction • Potential loss of currently contained sediments during storm events because Armored Cap must be removed to access sediments during construction • Moderate to high potential neighborhood impacts from activities at the offsite staging area because construction duration is long and impacted material will be staged at the offsite staging area prior to disposal • 3.0 estimated construction worker injuries • 0.01 estimated construction worker fatalities • Air emissions from 15,665 hours of equipment operations • Air emissions and traffic impacts from 12,855 truck trips	• Potential sediment quality impacts from dredging residuals • Potential tissue impacts from water column releases during construction • Potential loss of currently contained sediments during storm events because Armored Cap must be removed to access sediments during construction • Moderate to high potential neighborhood impacts from activities at the offsite staging area because construction duration is long and impacted material will be staged at the offsite staging area prior to disposal • 3.0 estimated construction worker injuries • 0.01 estimated construction worker fatalities • Air emissions from 15,500 hours of equipment operations • Air emissions and traffic impacts from 17,500 truck trips
Implementability	• No implementability issues	• Property owners may object to land-use restrictions	• Same as Alternative 2N plus: • Access to work area	• Same as Alternative 3N plus: • Requires partial removal	• Same as Alternative 3N plus: • Locating suitable off-site	• Same as Alternative 5N plus: • Locating suitable off-site	• Same as Alternative 5N plus: • Volume of material is

Table 5-1
Detailed Evaluation of Remedial Alternatives – Area North of I-10

	Alternative 1N **Armored Cap and No Further Action**	**Alternative 2N** **Armored Cap, Institutional Controls (ICs) and Monitored Natural Recovery (MNR)**	**Alternative 3N** **Permanent Cap, ICs and MNR**	**Alternative 4N** **Partial Solidification/ Stabilization, Permanent Cap, ICs and MNR**	**Alternative 5N** **Partial Removal, Permanent Cap, ICs and MNR**	**Alternative 5aN** **Partial Removal of Materials Exceeding the PCL, Permanent Cap, ICs and MNR**	**Alternative 6N** **Full Removal of Materials Exceeding PCLs, ICs and MNR**
			limited as demonstrated during TCRA construction • Equipment size restricted by low bridge clearance on river • On-site staging area limited • Locating a suitable off-site location for material staging and barge loading could be a minor to moderate challenge, and could extend the length of the project depending on the location of the facility • Potential permitting issues if the off-site material staging area is located too far from the work area • Materials and equipment readily available for Permanent Cap construction • Construction techniques to create the Permanent Cap successfully demonstrated during TCRA construction	of Armored Cap, decontamination of those materials, and possible disposal • Isolation and dewatering of the treatment or removal area is a construction challenge, particularly if elevated water level occurs during construction • S/S treatment of materials with very high water content is more difficult to implement and less certain, particularly if work area is flooded during implementation	location for material staging and processing of dredged sediments could be a moderate challenge because of the nature of the dredged material, and could extend the length of the project depending on the location of the facility • Require partial removal of Armored Cap, decontamination of those materials, and possible disposal • Engineering controls such as silt curtains are difficult to implement and maintain in a flowing river, as demonstrated during TCRA construction	location for material staging and processing of dredged sediments could be a significant challenge because of the nature and volume of the dredged material to be processed at the off-site staging area, and could extend the length of the project depending on the location of the facility • Engineering controls such as sheet piles are difficult to implement and maintain in a flowing river • Volume of material is significantly greater, multiplying implementability challenges • Finding off-site disposal for high volume of dioxin/furan contaminated soil/sediment considered to be a challenge	significantly greater, multiplying implementability challenges • Finding off-site disposal for high volume of dioxin/furan contaminated soil/sediment considered to be a challenge • Permanent Cap considerations discussed for Alternative 3N are not applicable
TCRA Cost	$9M	$9M	$9M	$9M	$9M	$9M	$9M
Remedial Costs	$0.5M	$1.3M	$3.5M	$14.2M	$27.1M	$68.9M	$91.2M
Total Cost[2]	**$9.5M**	**$10.3M**	**$12.5M**	**$23.2M**	**$38.1M**	**$77.9M**	**$99.2M**
Modifying Criteria							
State Acceptance	T.B.D.	T.B.D.	T.B.D.	T.B.D.	T.B.D.	T.B.D.	T.B.D.
Community Acceptance	T.B.D.	T.B.D.	T.B.D.	T.B.D.	T.B.D.	T.B.D.	T.B.D.

Notes:
1. USEPA considers this alternative to meet Overall Protection of Human Health and the Environment for the short term, provided that enhancements to the TCRA cap suggested by USACE are conducted. Note that these enhancements were made by the Respondents in January 2014. See text for details.
2. Total Cost includes $9 million for Armored Cap design and construction that was conducted under the TCRA.

ARARs - Applicable or Relevant and Appropriate Requirements
COCs - chemicals of concern
IC - Institutional Controls
MNR - Monitored Natural Recovery
OMM - Operations, Monitoring, and Maintenance
PCL - Protective Concentration Level
S/S - solidification/stabilization
TBD – To Be Determined
TCRA – Time Critical Removal Action
TMV - toxicity, mobility or volume

Table 5-2

Detailed Evaluation of Remedial Alternatives – Area South of I-10

	Alternative 1S **No Further Action**	**Alternative 2S** **Institutional Controls (ICs)**	**Alternative 3S** **Enhanced ICs**	**Alternative 4S** **Removal and Off-site Disposal**
Threshold Criteria				
Overall Protection	Does Not Meet	Meets	Meets	Meets
Compliance with ARARs	Meets	Meets	Meets	Meets
Balancing Criteria				
Long-Term Effectiveness	• Hypothetical future construction workers performing excavation in affected areas could be exposed to impacted soil and could place impacted soil on the surface, resulting in an exposure pathway that is currently incomplete	• ICs would: – Alert potential future property owners about subsurface risk in subsurface soil – Educate hypothetical future construction workers about potential risks associated with subsurface soil – Control exposure to contaminated subsurface soils	• Same as Alternative 2S plus: • Physical warnings (marker layer and bollards) would provide additional warning to hypothetical future construction workers about the presence of contaminated subsurface soil	• Soil with $TEQ_{DF,M}$ concentrations exceeding the PCL would be removed from the remedial action areas and placed in a secure landfill to eliminate the potential for the hypothetical future construction worker exposure pathway or mismanagement of soil excavated in the future
Reduction of TMV	• No reduction of TMV through treatment	• Same as Alternative 1S	• Same as Alternative 1S	• Wet soil excavated would be amended to eliminate free liquid
Short-Term Effectiveness	• No worker safety risk • No air emissions from construction • No traffic impacts from construction	• Achieve protection immediately • No worker safety risk • No air emissions from construction • No traffic impacts from construction	• Achieve protection upon completion of implementation • Implementation does not involve exposure of contaminated soil • 0.015 estimated construction worker injuries • 0.0001 estimated construction worker fatalities • Air emissions from 160 hours of equipment operations	• Achieve protection upon completion of implementation • Implementation requires exposing contaminated soil, which is associated with potential exposure • 0.088 estimated construction worker injuries • 0.0004 estimated construction worker fatalities • Air emissions from 910 hours of equipment operations • Air emissions, traffic impacts, and potential releases from 7,200 truck trips
Implementability	• No implementability issues	• Property owners may object to land-use restrictions	• Same as Alternative 2S plus • No technical implementability issues as implementation entails the use of common construction practices	• Compliance of off-site disposal facility would be verified as required by the Off-site Rule • No technical implementability issues as implementation entails the use of common construction practices
Cost	$0.14M	$0.27M	$0.67M	$9.93M
Modifying Criteria				
State Acceptance	T.B.D.	T.B.D.	T.B.D.	T.B.D.
Community Acceptance	T.B.D.	T.B.D.	T.B.D.	T.B.D.

Notes:
ARARs - Applicable or Relevant and Appropriate Requirements
ICs - Institutional Controls
PCL - Protective Concentration Level
TBD – To Be Determined
TMV - toxicity, mobility or volume

Table 6-1a
Summary of Detailed Evaluation
Area North of I-10

Remedial Alternative		Evaluation Criterion						
		Overall Protection	Compliance with ARARs	Long-Term Effectiveness	Reduction of TMV Through Treatment	Short-Term Effectiveness	Implementability	Cost Effectiveness
1N	Armored Cap and No Further Action	Meet	Meet	Low-Med	Low	High	High	High
2N	Armored Cap, ICs and MNR	Meet	Meet	Medium	Low	High	High	High
3N	Permanent Cap, ICs and MNR	Meet	Meet	High	Low	High	High	Med-High
4N	Partial Solidification/ Stabilization, Permanent Cap, ICs and MNR	Meet	Meet	Med-High	High	Low-Med	Low	Medium
5N	Partial Removal, Permanent Cap, ICs and MNR	Meet	Meet	Med-High	Medium	Low-Med	Low	Low-Med
5aN	Partial Removal of Materials Exceeding the PCL, Permanent Cap, ICs and MNR	Meet	Meet	Low-Med	Medium	Low	Low	Low
6N	Full Removal of Materials Exceeding the PCL, ICs and MNR	Meet	Meet	Low-Med	Medium	Low	Low	Low

Notes:

Overall Protection and Compliance with ARARs are Threshold Criteria, for which the evaluation is that the remedial alternative does or does not meet the criterion. For all other criteria, remedial alternatives are evaluated to determine the degree to which the criterion is addressed.

ARAR - Applicable or relevant and appropriate requirements of environmental laws.

IC - Institutional controls

Med - Medium

MNR - Monitored natural recovery

PCL - Protective concentration level

TMV - Toxicity, mobility or volume

Table 6-1b
Summary of Detailed Evaluation
Area South of I-10

Remedial Alternative	Overall Protection	Compliance with ARARs	Long-Term Effectiveness	Reduction of TMV Through Treatment	Short-Term Effectiveness	Implementability	Cost Effectiveness
	Evaluation Criterion						
1S No Further Action	No	Meet	Low	Low	High	High	High
2S ICs	Meet	Meet	Medium	Low	High	High	High
3S Enhanced ICs	Meet	Meet	Med-High	Low	High	High	Med-High
4S Removal and Off-site Disposal	Meet	Meet	High	Medium	Low	Medium	Low

Notes:

Overall Protection and Compliance with ARARs are Threshold Criteria, for which the evaluation is that the remedial alternative does or does not meet the criterion. For all other criteria, remedial alternatives are evaluated to determine the degree to which the criterion is addressed.

ARAR - Applicable or relevant and appropriate requirements of environmental laws.

IC - Institutional controls

Med - Medium

MNR - Monitored natural recovery

PCL - Protective concentration level

TMV - Toxicity, mobility or volume

FIGURES

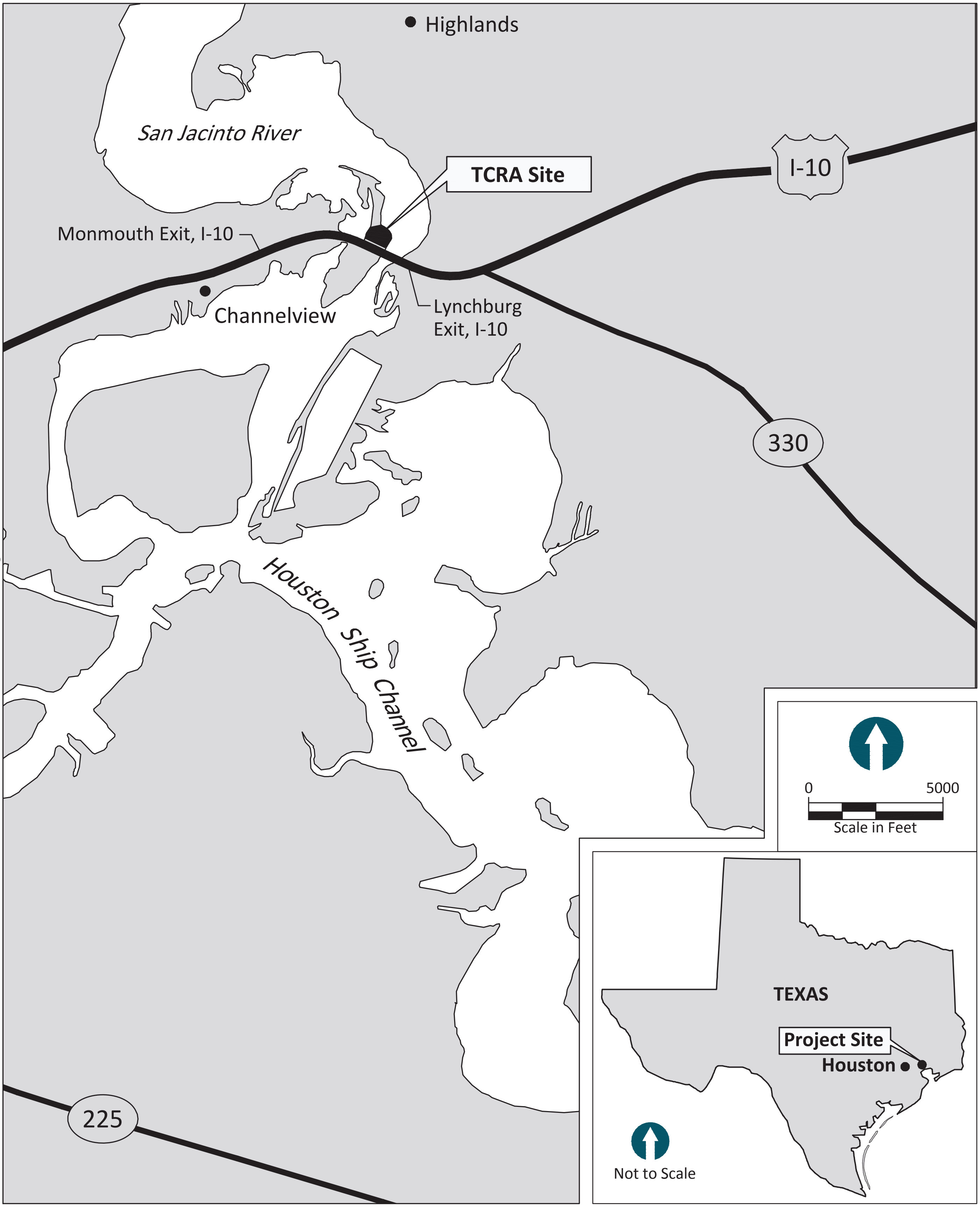

Figure 1-1
Vicinity Map
Feasibility Study
San Jacinto River Waste Pits Superfund Site

DRAFT

NOTES:
1. Designation of the Upland Sand Separation Area is intended to be a general reference to areas in which such activities are believed to have taken place based on a review of aerial photography from 1998 through 2002.
2. Aerial Imagery: Copyright Microsoft Bing Maps, 2010.
3. Hog Island location source: Google Earth, 2011.

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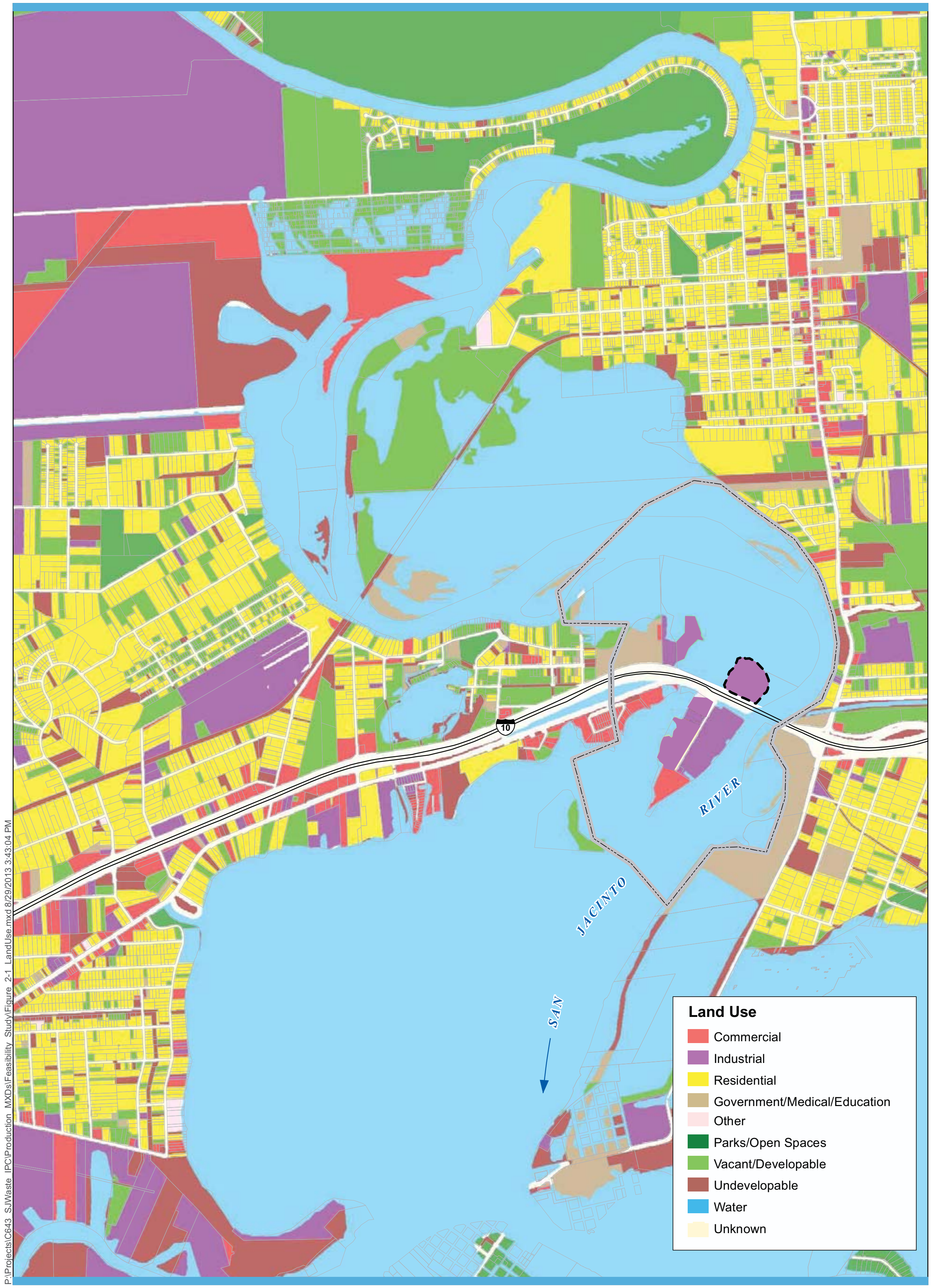
ANCHOR QEA
integral consulting inc

Figure 1-2
USEPA's Preliminary Site Perimeter and Surrounding Area
Feasibility Study
San Jacinto River Waste Pits Superfund Site

DRAFT



USEPA's Preliminary Site Perimeter
Limit of TCRA Cap
Tax Parcel Boundary

0 0.5
Scale in Miles

Figure 2-1
Land Use in the Vicinity of USEPA's Preliminary Site Perimeter
Feasibility Study
San Jacinto River Waste Pits Superfund Site

FEATURE SOURCES:
Land Use: Modified from Houston-Galveston Area Council*
Parcel Boundaries: Harris County Appraisal District

*Modifications to land use within USEPA's Preliminary Site Perimeter to show reasonably anticipated future land use where appropriate.

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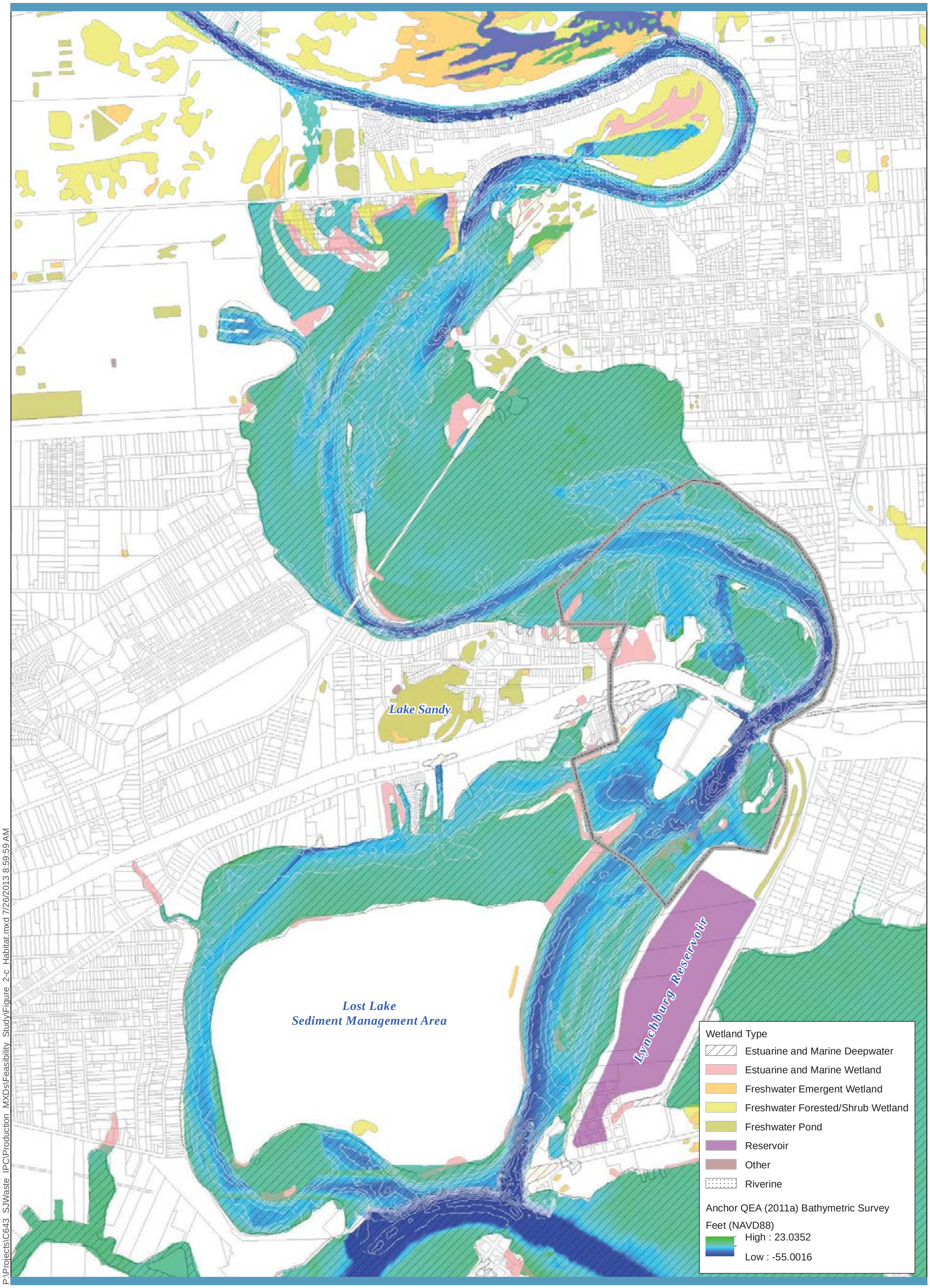

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ANCHOR QEA integral consulting inc

USEPA's Preliminary Site Perimeter

1-Meter 1995 Bathymetric Contour

Parcel Boundary

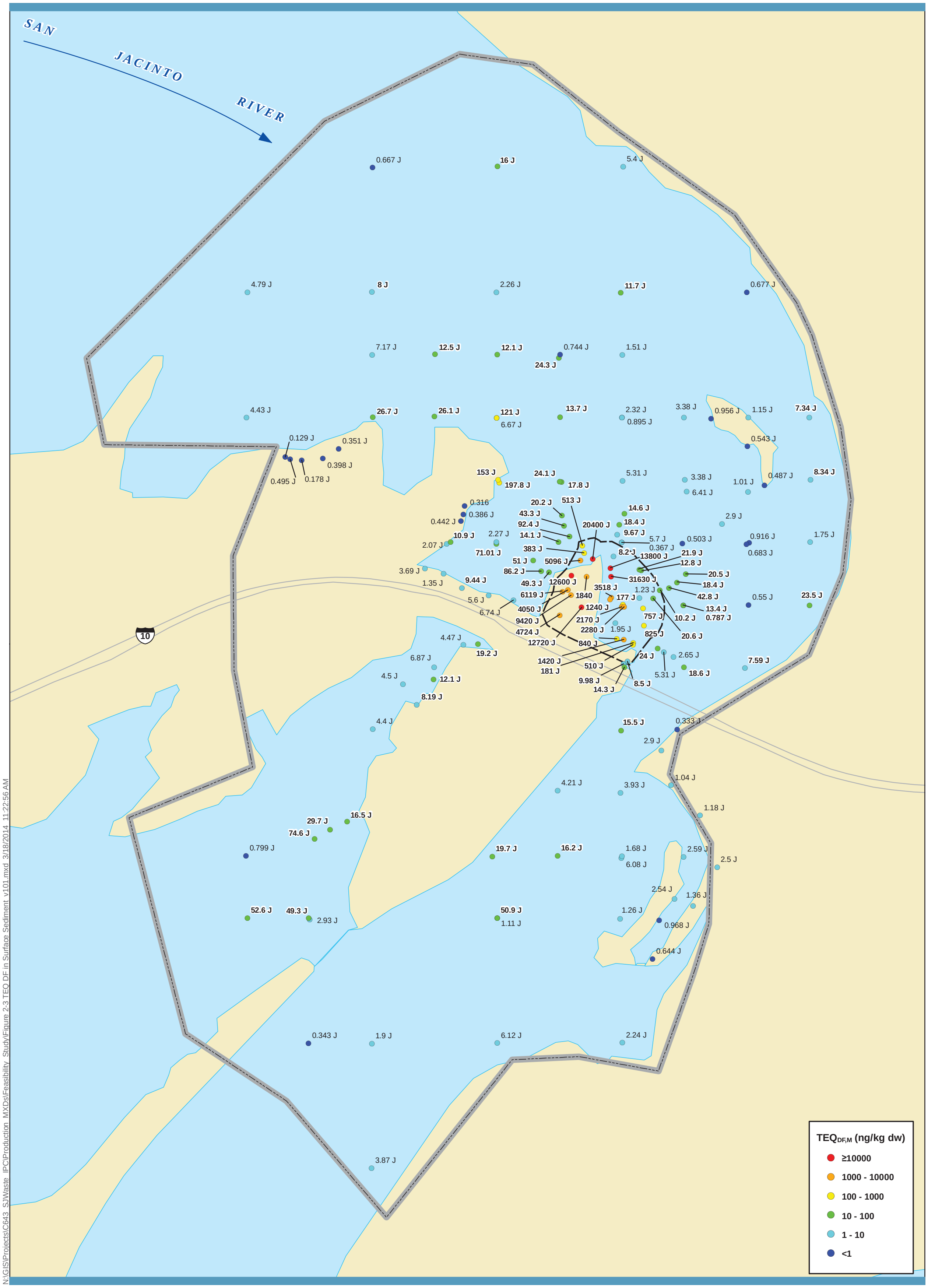
0 0.5

Miles

Figure 2-2
Habitats in the Vicinity of USEPA's Preliminary Site Perimeter
Feasibility Study
San Jacinto River Waste Pits Superfund Site

FEATURE SOURCES:
Bathymetry and Contours: Anchor QEA (2011a)
Wetlands: U.S. Fish and Wildlife Service.
Parcel Boundaries: Harris County Appraisal District.

DRAFT



N:\GIS\Projects\C643_SJ\Waste_IPC\Production_MXDs\Feasibility_Study\Figure 2-3 TEQ DF in Surface Sediment_v101.mxd 3/18/2014 11:22:56 AM

ANCHOR QEA | integral consulting inc.

0 800
Feet

USEPA's Preliminary Site Perimeter
Limit of Armored Cap
Surface Sediment Sample Location

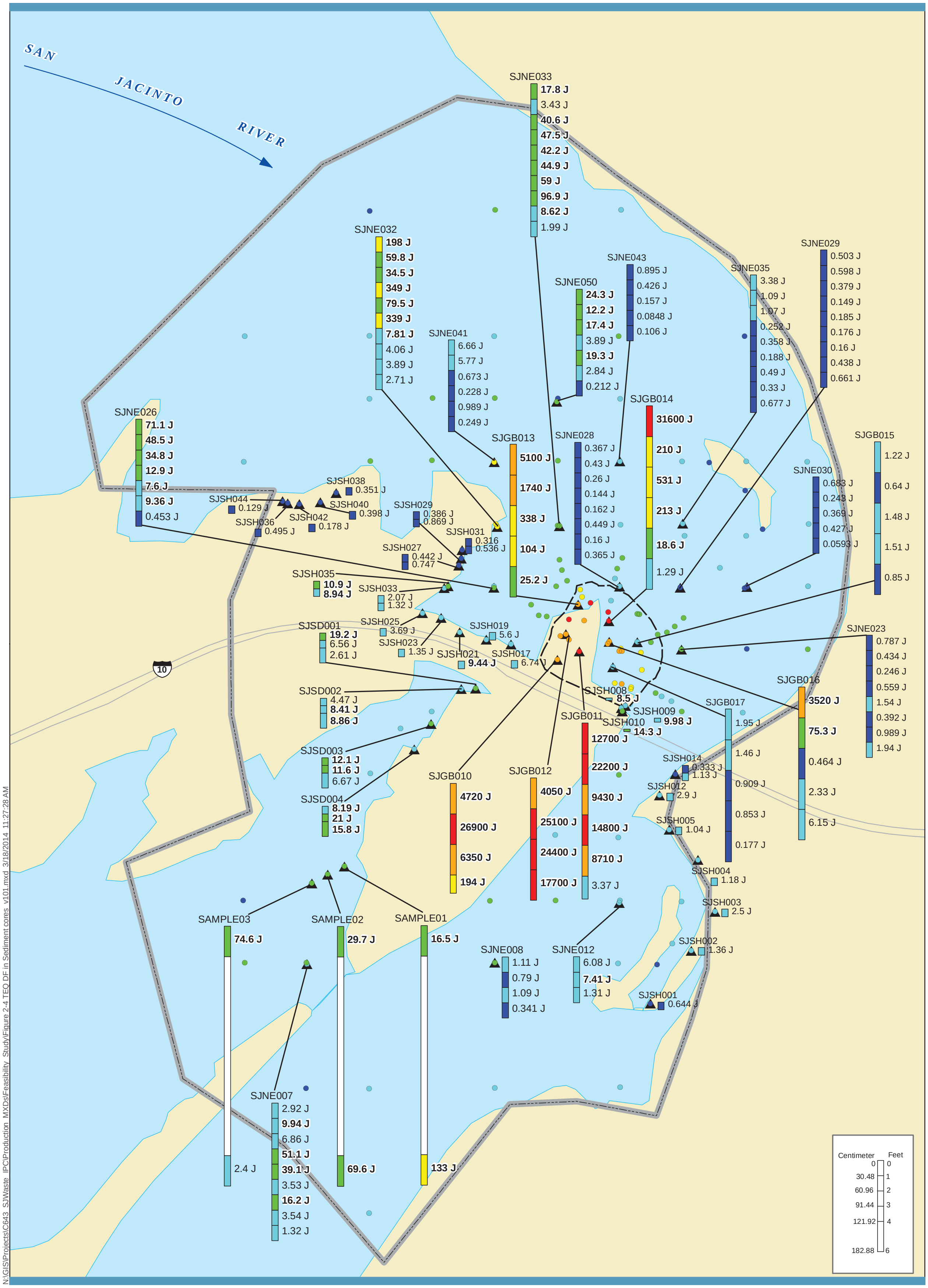
Notes:
$TEQ_{DF,M}$ = Toxicity equivalent for 2,3,7,8-TCDD calculated for dioxins and furans using mammalian TEFs from van den Berg et al. (2006) (nondetect = 1/2 detection limit)

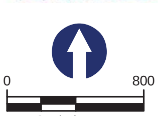
J = Estimated. One or more congeners used to calculate the $TEQ_{DF,M}$ was not detected.

Concentrations in bold indicate values above reference envelope value (REV); REV = 7.2 ng/kg dw

Figure 2-3
$TEQ_{DF,M}$ Concentrations in Surface Sediment
Feasibility Study
San Jacinto River Waste Pits Superfund Site

DRAFT





USEPA's Preliminary Site Perimeter
Limit of Armored Cap

Core Location
Surface Sediment Sample Location

$TEQ_{DF,M}$ (ng/kg dw)

Cores

- ≥10000
- 1000 - 10000
- 100 - 1000
- 10 - 100
- 1 - 10
- <1
- No analysis

Notes:

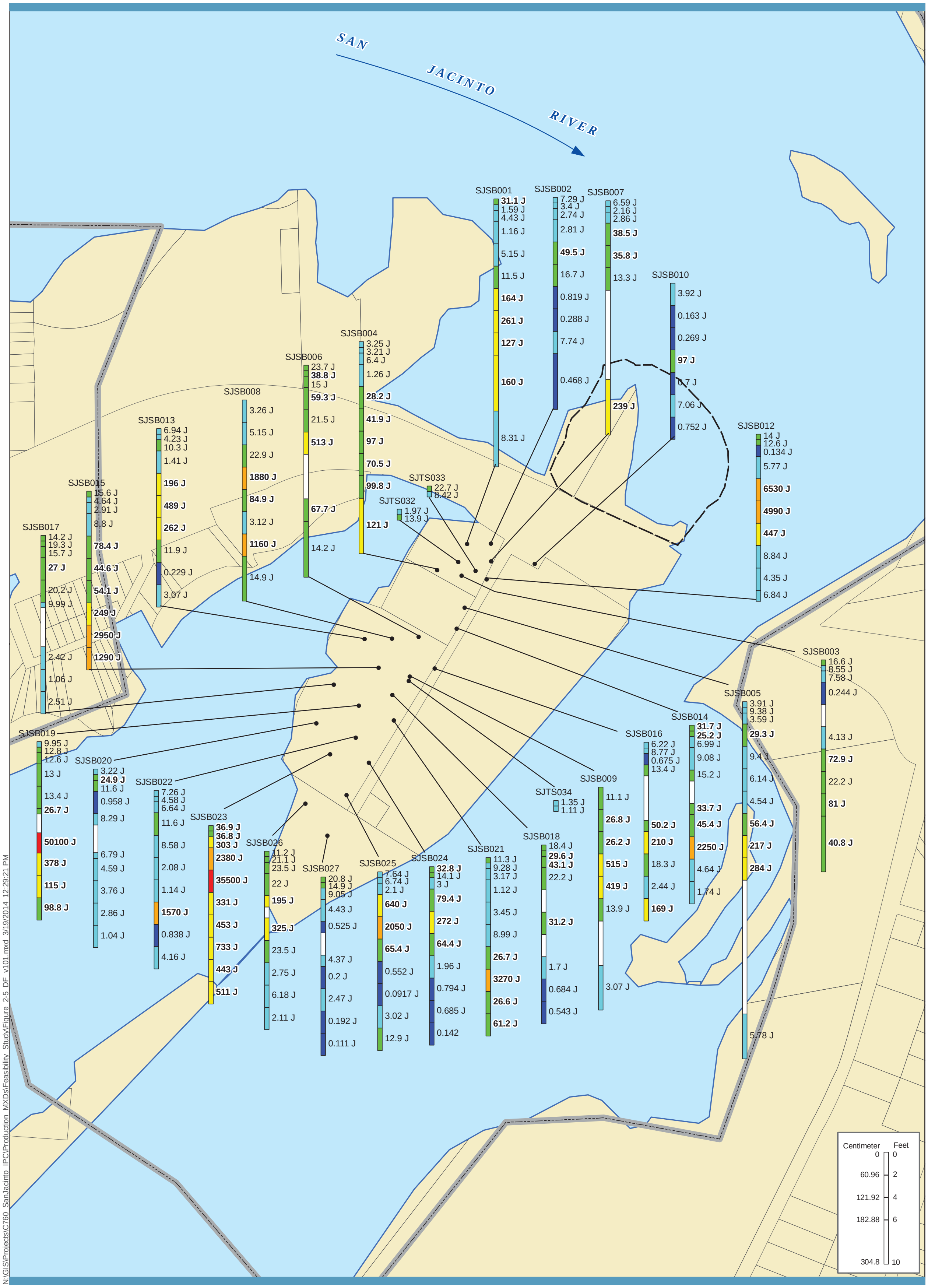
$TEQ_{DF,M}$ = Toxicity equivalent for 2,3,7,8-TCDD calculated for dioxins and furans using mammalian TEFs from van den Berg et al. (2006) (nondetect = 1/2 detection limit)

J = Estimated. One or more congeners used to calculate the $TEQ_{DF,M}$ was not detected.

Concentrations in bold indicate values above reference envelope value (REV); REV= 7.2 ng/kg dw

Figure 2-4
$TEQ_{DF,M}$ Concentrations in Sediment Cores
Feasibility Study
San Jacinto River Waste Pits Superfund Site

DRAFT



N:\GIS\Projects\C760_SanJacinto_IPC\Production_MXDs\Feasibility_Study\Figure_2-5_DF_v101.mxd 3/19/2014 12:29:21 PM

USEPA's Preliminary Site Perimeter
Limit of Armored Cap
Soil Boring Location

Notes:
$TEQ_{DF,M}$ = Toxicity equivalent for dioxins and furans using mammalian TEFs from van den Berg et al. (2006) (nondetect =1/2 detection limit)

J = Estimated, One or more congeners used to calculate the $TEQ_{DF,M}$ was not detected

Concentrations in bold indicate values above reference envelope value (REV); REV= 24.3 ng/kg dw

FEATURE SOURCES:
Parcel Boundaries: Harris County Appraisal District
Hydrology: Harris County Flood Control District

$TEQ_{DF,M}$ (ng/kg dw)
Cores
- ≥10000
- 1000 - 10000
- 100 - 1000
- 10 - 100
- 1 - 10
- <1
- No analysis

0 800
Feet

Figure 2-5
$TEQ_{DF,M}$ Concentrations in Soil South of I-10
Feasibility Study
San Jacinto River Waste Pits Superfund Site

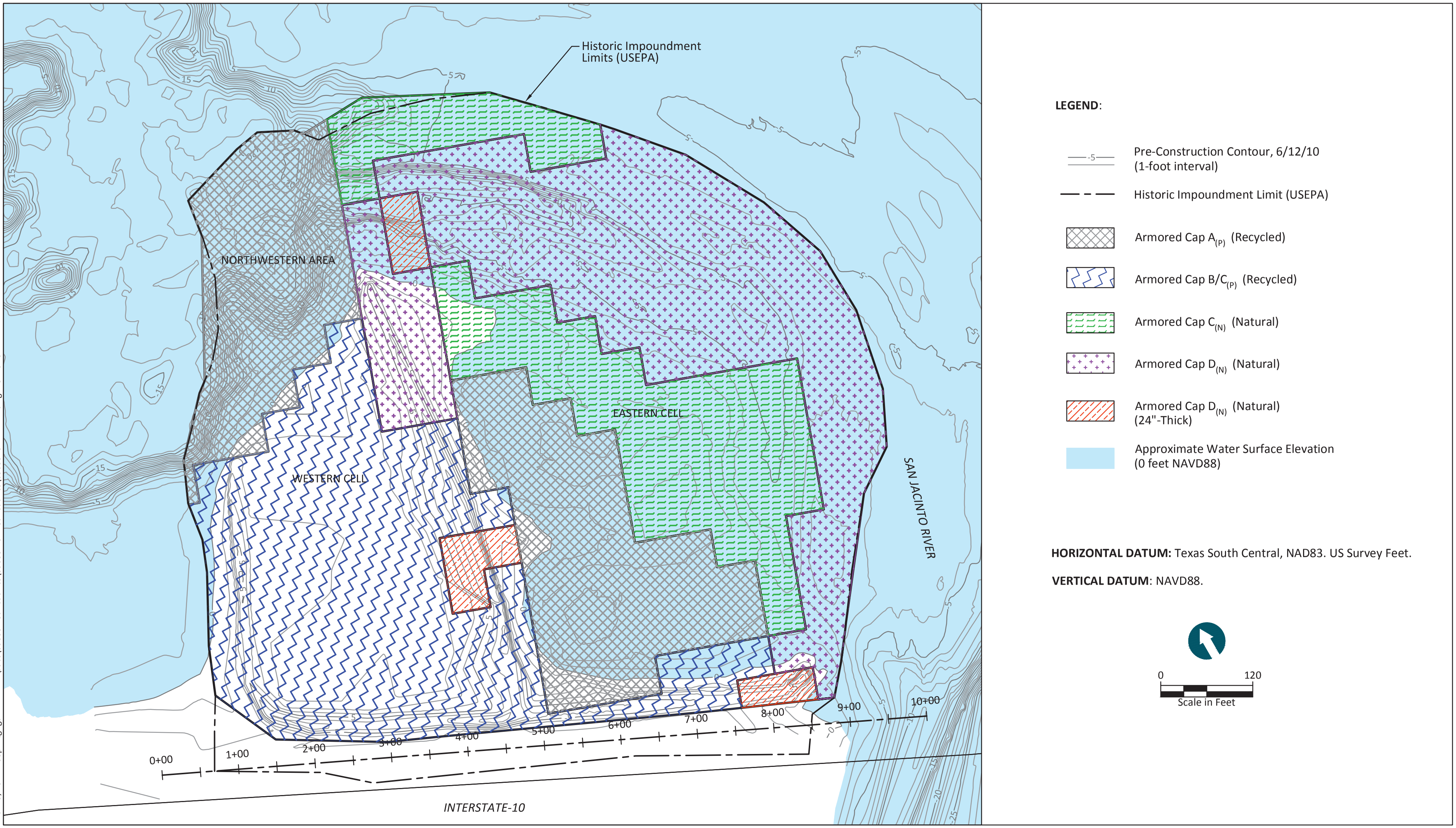
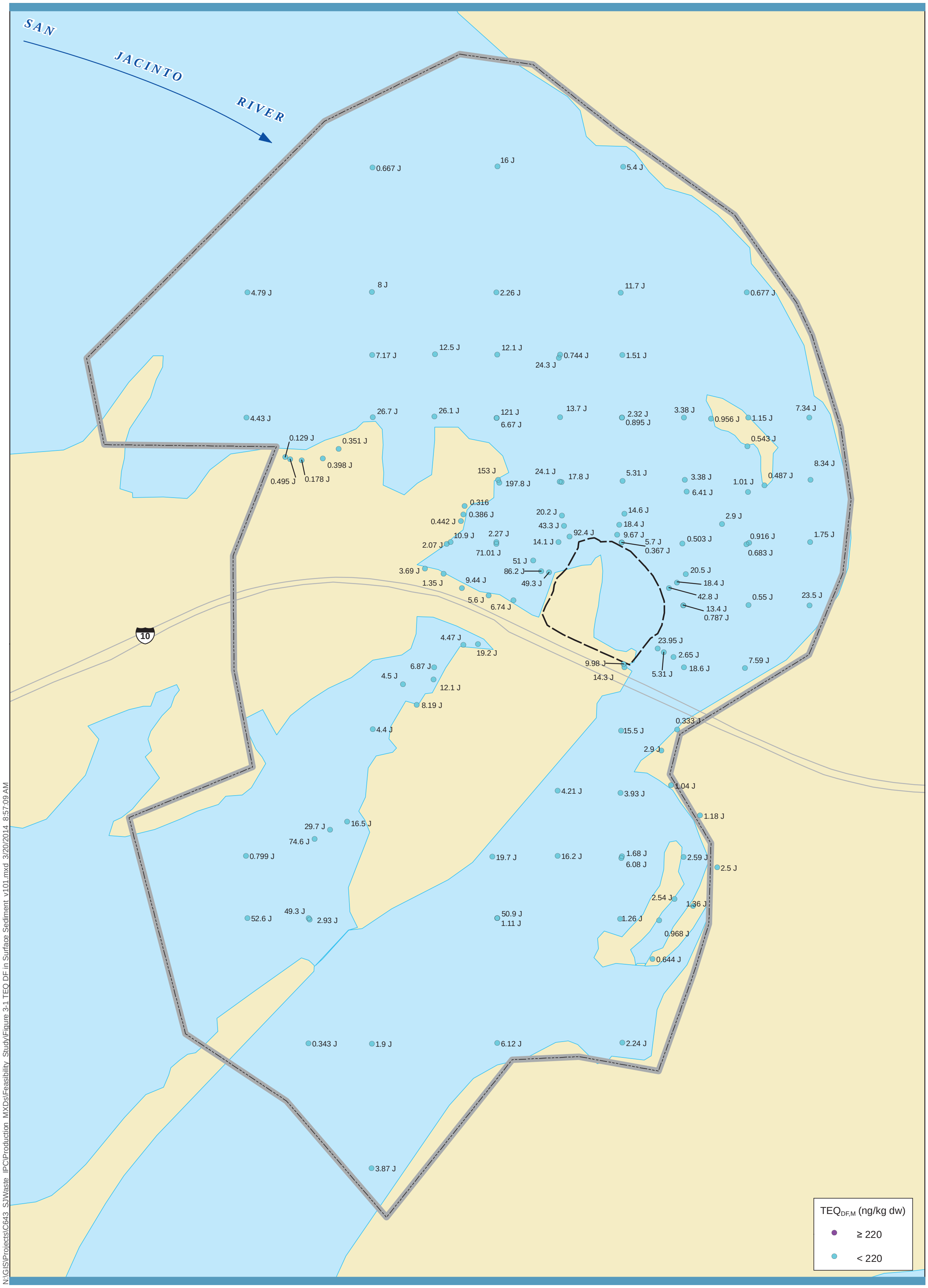


Figure 2-6
TCRA Cap As-Built Drawing
Feasibility Study
San Jacinto River Waste Pits Superfund Site

DRAFT



ANCHOR QEA integral consulting inc.

USEPA's Preliminary Site Perimeter
Limit of Armored Cap
Surface Sediment Sample Location

0 800
Feet

Figure 3-1
$TEQ_{DF,M}$ Concentrations in Surface Sediment Outside Armored Cap
Compared to Hypothetical Recreational Visitor PCL
Feasibility Study
San Jacinto River Waste Pits Superfund Site

Notes:
$TEQ_{DF,M}$ = Toxicity equivalent for 2,3,7,8-TCDD calculated for dioxins and furans using mammalian TEFs from van den Berg et al. (2006) (nondetect = 1/2 detection limit)

J = Estimated. One or more congeners used to calculate the $TEQ_{DF,M}$ was not detected.

The sediment Protective Concentration Level for a hypothetical recreational visitor for $TEQ_{DF,M}$ is 220 ng/kg dry weight.

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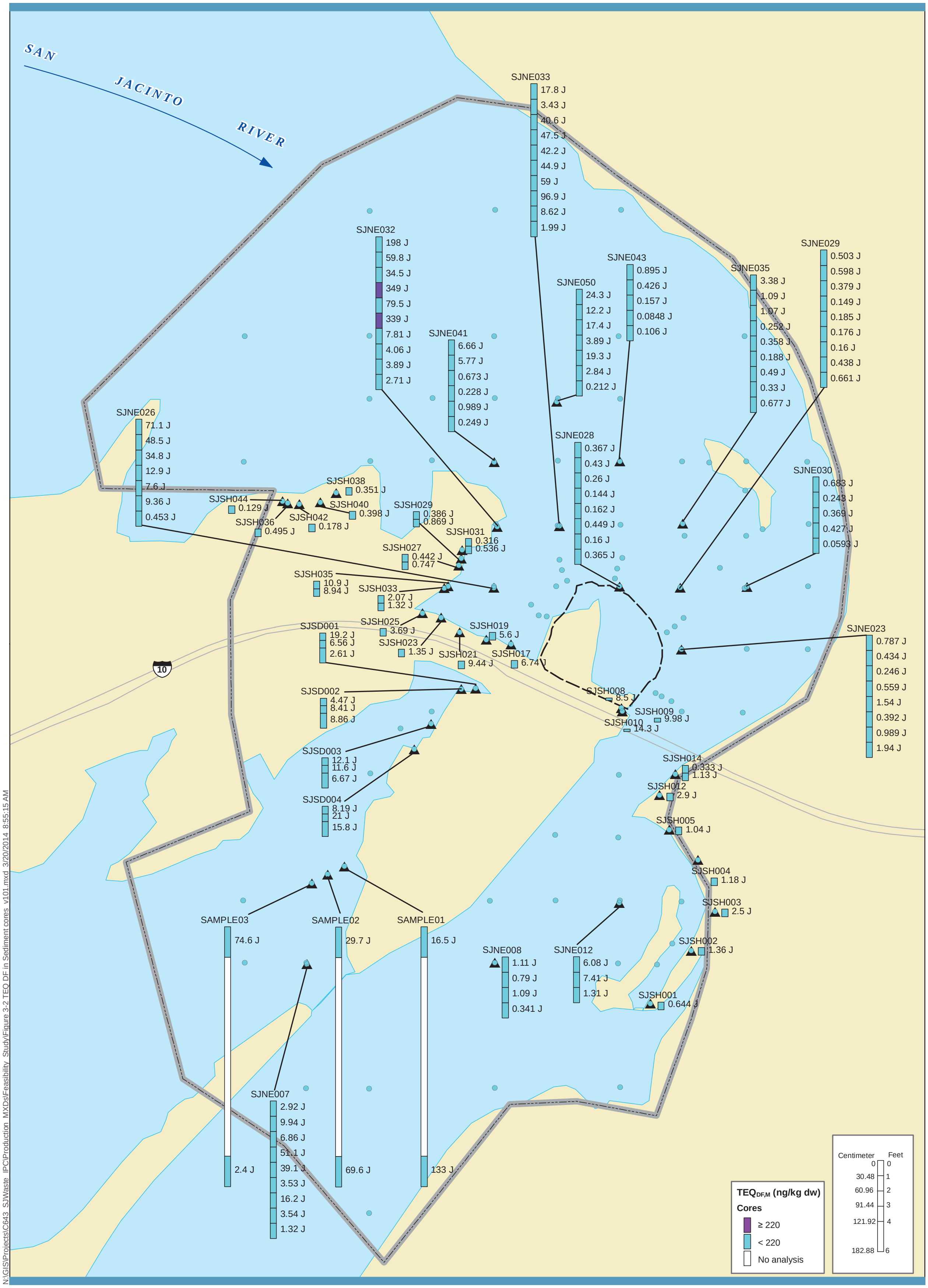


ANCHOR QEA integral consulting inc

USEPA's Preliminary Site Perimeter
Limit of Armored Cap
Core Location
Surface Sediment Sample Location

0 800
Scale in Feet

Notes:
$TEQ_{DF,M}$ = Toxicity equivalent for 2,3,7,8-TCDD calculated for dioxins and furans using mammalian TEFs from van den Berg et al. (2006) (nondetect = 1/2 detection limit)

J = Estimated. One or more congeners used to calculate the $TEQ_{DF,M}$ was not detected.

The sediment Protective Concentration Level for a hypothetical recreational visitor for $TEQ_{DF,M}$ is 220 ng/kg dry weight.

Figure 3-2
$TEQ_{DF,M}$ Concentrations in Sediment Cores Outside Armored Cap Compared to Hypothetical Recreational Visitor PCL
Feasibility Study
San Jacinto River Waste Pits Superfund Site

DRAFT

ANCHOR QEA integral consulting inc

0 800

Feet

USEPA's Preliminary Site Perimeter

Limit of Armored Cap

Soil Investigation Area 4

Surface Soil/Sediment Sample Location

Notes:

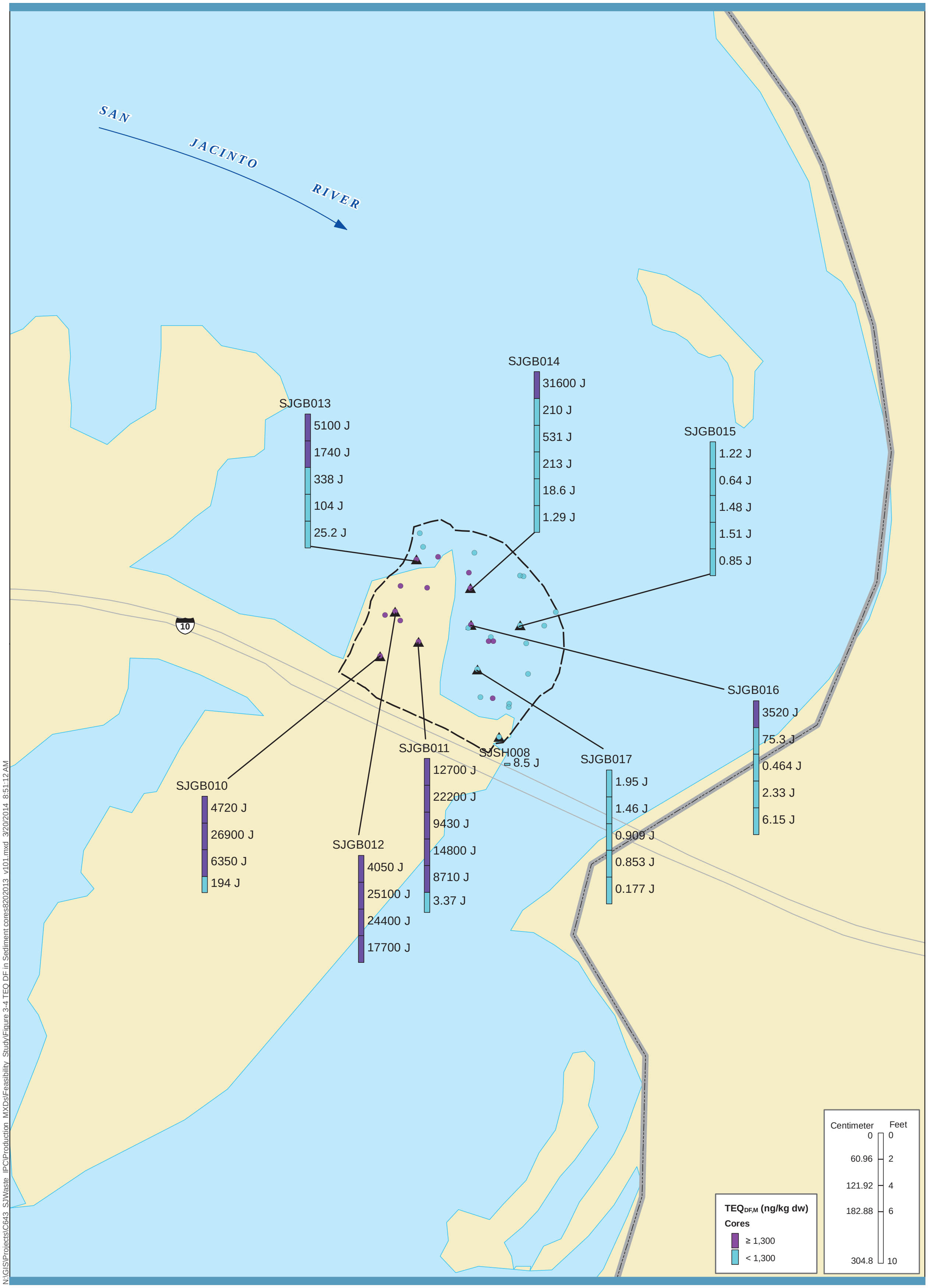
TEQ$_{DF,M}$ = Toxicity equivalent for 2,3,7,8-TCDD calculated for dioxins and furans using mammalian TEFs from van den Berg et al. (2006) (nondetect = 1/2 detection limit)

J = Estimated. One or more congeners used to calculate the TEQ$_{DF,M}$ was not detected.

The soil/sediment Protective Concentration Level for a hypothetical future outdoor commercial worker for TEQ$_{DF,M}$ is 1,300 ng/kg dry weight (May 14, 2013, letter to USEPA).

Figure 3-3

TEQ$_{DF,M}$ Concentrations in Surface Soil/Sediment
Inside Armored Cap and the Area of Investigation South of I-10
Compared to Hypothetical Future Outdoor Commercial Worker PCL
Feasibility Study
San Jacinto River Waste Pits Superfund Site



N:\GIS\Projects\C643_SJWaste_JPC\Production_MXDs\Feasibility_Study\Figure 3-4 TEQ DF in Sediment cores8202013_v101.mxd 3/20/2014 8:51:12 AM

ANCHOR QEA integral consulting inc.

0 800
Scale in Feet

USEPA's Preliminary Site Perimeter
Limit of Armored Cap
Core Location
Surface Soil/Sediment Sample Location

Notes:
$TEQ_{DF,M}$ = Toxicity equivalent for 2,3,7,8-TCDD calculated for dioxins and furans using mammalian TEFs from van den Berg et al. (2006) (nondetect = 1/2 detection limit)

J = Estimated. One or more congeners used to calculate the $TEQ_{DF,M}$ was not detected.

The soil/sediment Protective Concentration Level for a hypothetical future outdoor commercial worker for $TEQ_{DF,M}$ is 1,300 ng/kg dry weight (May 14, 2013, letter to USEPA).

Figure 3-4
$TEQ_{DF,M}$ Concentrations in Soil/Sediment Cores Inside Armored Cap Compared to Hypothetical Future Outdoor Commercial Worker PCL
Feasibility Study
San Jacinto River Waste Pits Superfund Site

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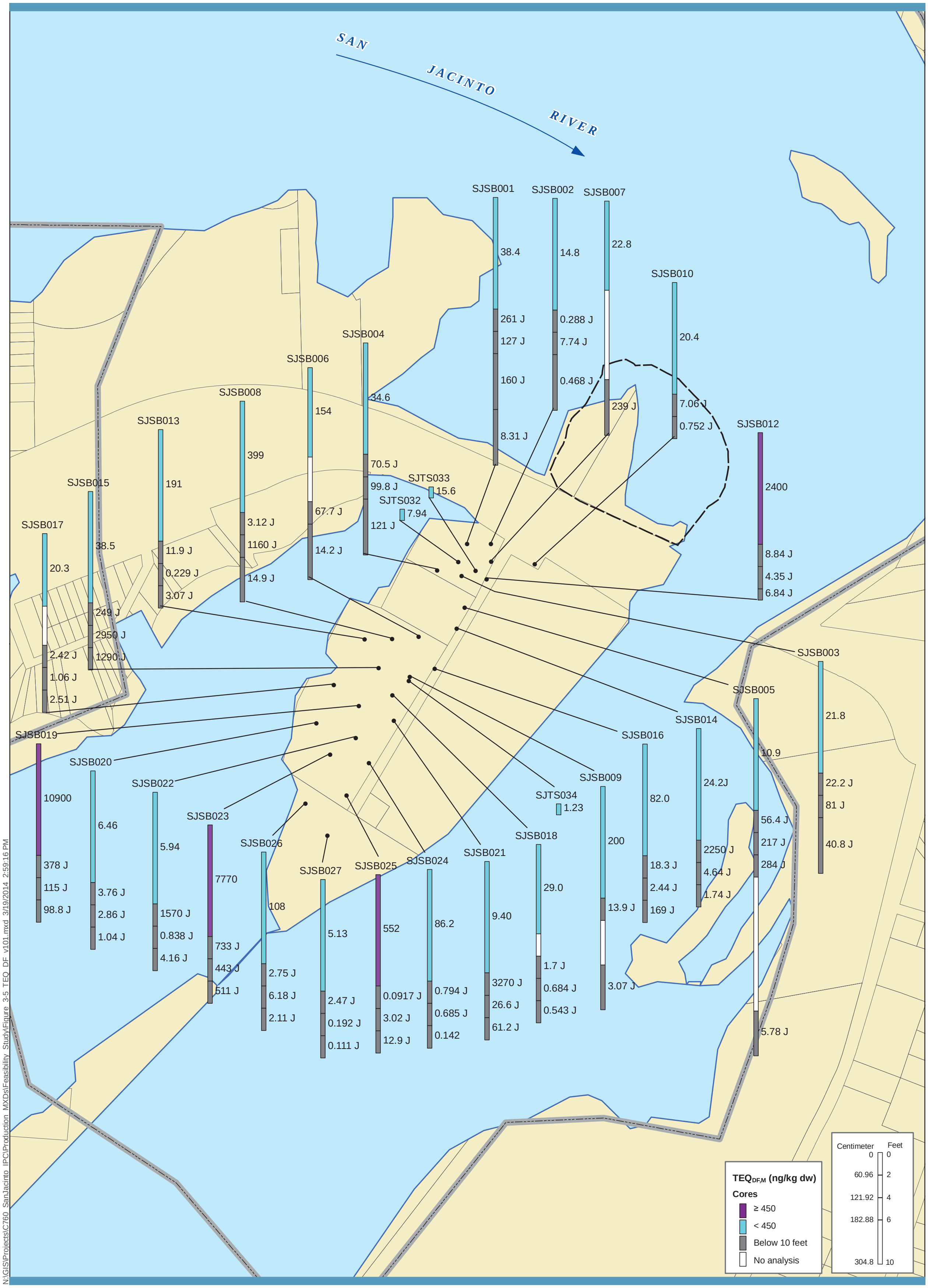

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ANCHOR QEA
integral consulting inc

0 400
Feet

USEPA's Preliminary Site Perimeter
Limit of Armored Cap
● Soil Boring Location

Notes:
$TEQ_{DF,M}$ = Toxicity equivalent for dioxins and furans using mammalian TEFs from van den Berg et al. (2006) (nondetect =1/2 detection limit)

J = Estimated, One or more congeners used to calculate the $TEQ_{DF,M}$ was not detected.

The soil Protective Concentration Level for a hypothetical future construction worker for $TEQ_{DF,M}$ is 450 ng/kg dry weight. Concentrations are averaged in the top 10 feet, consistent with risk assessment assumption.

FEATURE SOURCES:
Parcel Boundaries: Harris County Appraisal District
Hydrology: Harris County Flood Control District

Figure 3-5
$TEQ_{DF,M}$ Concentrations in Soil in the Area of Investigation South of I-10
Compared to Hypothetical Future Construction Worker PCL
Feasibility Study
San Jacinto River Waste Pits Superfund Site

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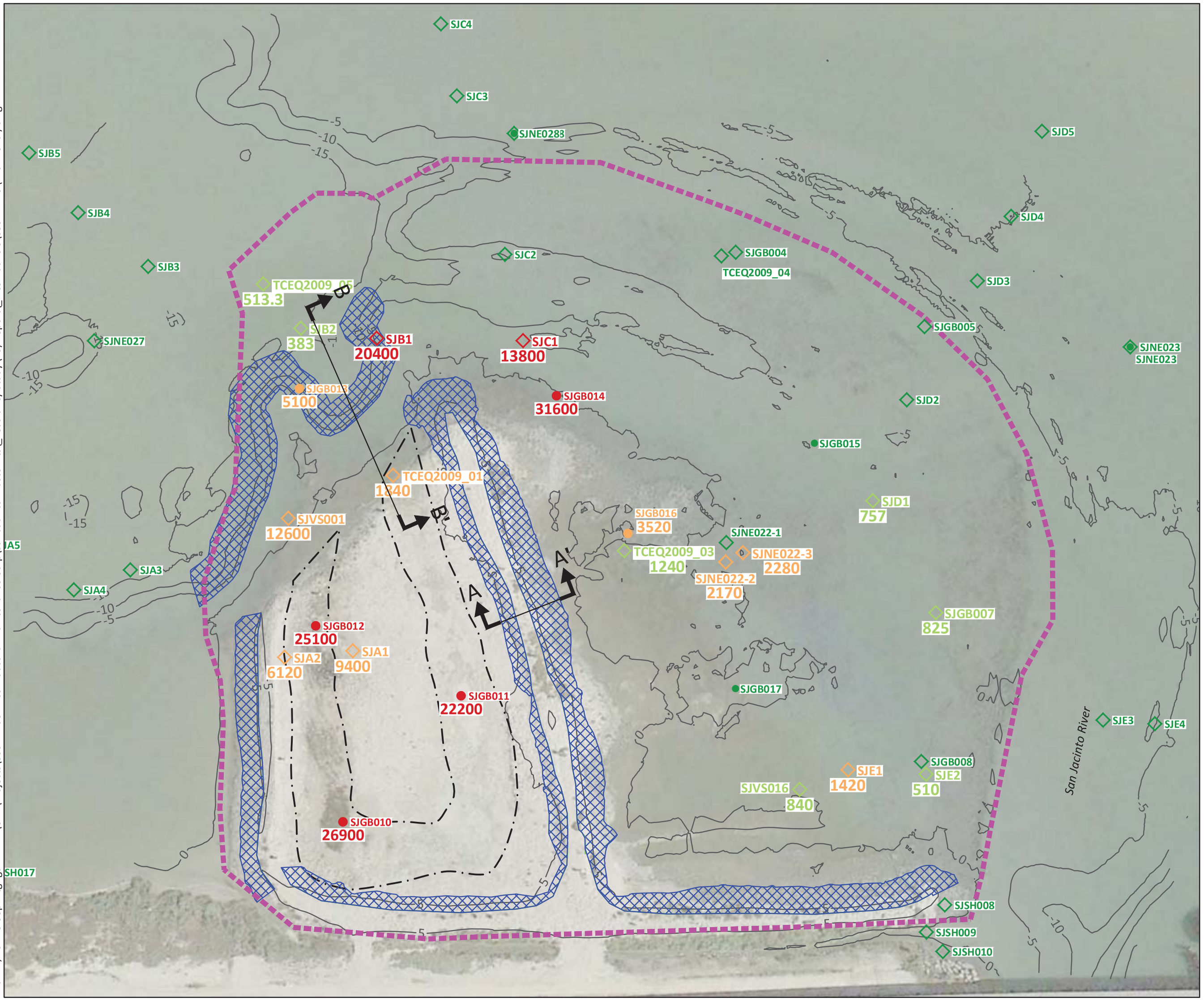

LEGEND:

- Existing Contour (5 Foot Interval)
- Armored Cap Limit
- Area of Additional Rock Placement for Flattening Slopes to 5H:1V on berms and 3H:1V in the Northwest Area
- TCRA Footprint of Stabilization
- SJGB014● Core location: TEQ ≥ 13,000 ng/kg
- SJGB013● Core location: 1,300 ≤ TEQ < 13,000 ng/kg
- SJGB016● Core location: 220 ≤ TEQ < 1,300 ng/kg
- SJGB017● Core location: TEQ < 220 ng/kg
- SJB1◇ Grab location: TEQ ≥ 13,000 ng/kg
- SJA1◇ Grab location: 1,300 ≤ TEQ < 13,000 ng/kg
- SJB2◇ Grab location: 220 ≤ TEQ < 1,300 ng/kg
- SJC3◇ Grab location: TEQ < 220 ng/kg
- **825** Concentration TEQ_{DF} (ng/kg dw) (See Note 1)
- A A' Cross Section Location (See Figure 4-2)

NOTE:

1. Concentration shown at each sample location represents the highest concentration calculated at any depth interval at that location.

AERIAL SOURCE: Google Earth Pro, dated October 2012.
SOURCE: Drawing prepared from surveys provided by Hydrographic Consultants dated October 2012 and January/February 2013.
HORIZONTAL DATUM: Texas State Plane South Central, NAD83, U.S. Feet.
VERTICAL DATUM: NAVD 88.

0 120
Scale in Feet

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Figure 4-1
Plan View - Alternative 3N, Permanent Cap
Feasibility Study
San Jacinto River Waste Pits Superfund Site

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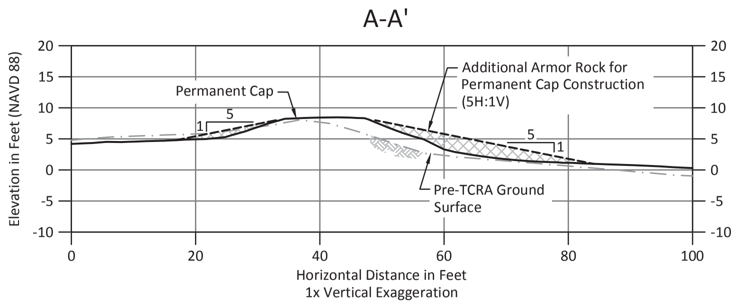

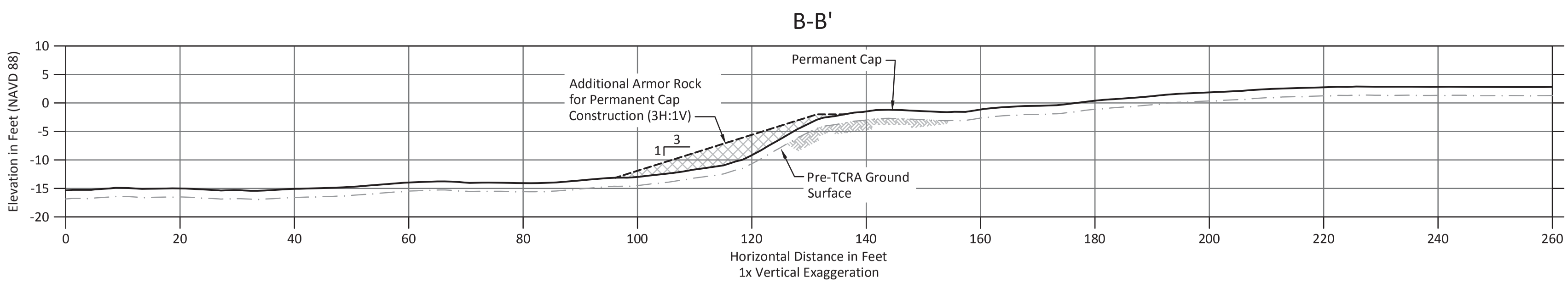

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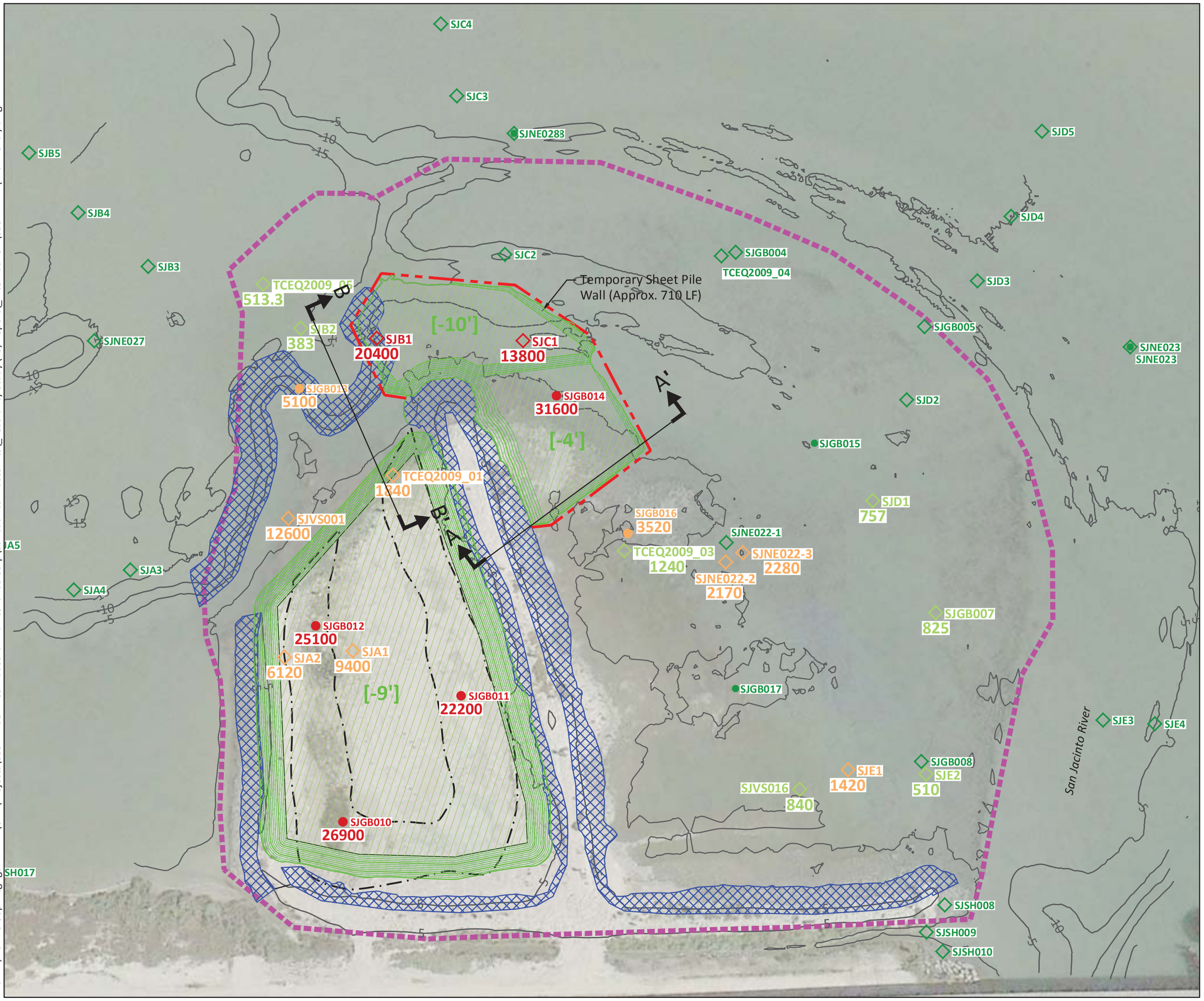
ANCHOR QEA

Figure 4-2
Cross Section A-A' - Alternative 3N
Feasibility Study
San Jacinto River Waste Pits Superfund Site

DRAFT



LEGEND:

- Existing Contour (5 Foot Interval)
- [-4'] Target Solidification Elevation (NAVD 88)
- Solidification Area
- Temporary Sheet Pile Wall
- Armored Cap Limit
- Area of Additional Rock Placement for Flattening Slopes to 5H:1V on berms and 3H:1V in the Northwest Area
- TCRA Footprint of Stabilization
- SJGB014 ● Core location: TEQ ≥ 13,000 ng/kg
- SJGB013 ● Core location: 1,300 ≤ TEQ < 13,000 ng/kg
- SJGB016 ● Core location: 220 ≤ TEQ < 1,300 ng/kg
- SJGB017 ● Core location: TEQ < 220 ng/kg
- SJB1 ◇ Grab location: TEQ ≥ 13,000 ng/kg
- SJA1 ◇ Grab location: 1,300 ≤ TEQ < 13,000 ng/kg
- SJB2 ◇ Grab location: 220 ≤ TEQ < 1,300 ng/kg
- SJC3 ◇ Grab location: TEQ < 220 ng/kg
- 825 Concentration TEQ^{DF} (ng/kg dw) (See Note 1)
- A A' Cross Section Location (See Figure 4-4)

NOTE:
1. Concentration shown at each sample location represents the highest concentration calculated at any depth interval at that location.

AERIAL SOURCE: Google Earth Pro, dated October 2012.
SOURCE: Drawing prepared from surveys provided by Hydrographic Consultants dated October 2012 and January/February 2013.
HORIZONTAL DATUM: Texas State Plane South Central, NAD83, U.S. Feet.
VERTICAL DATUM: NAVD 88.

0 120
Scale in Feet

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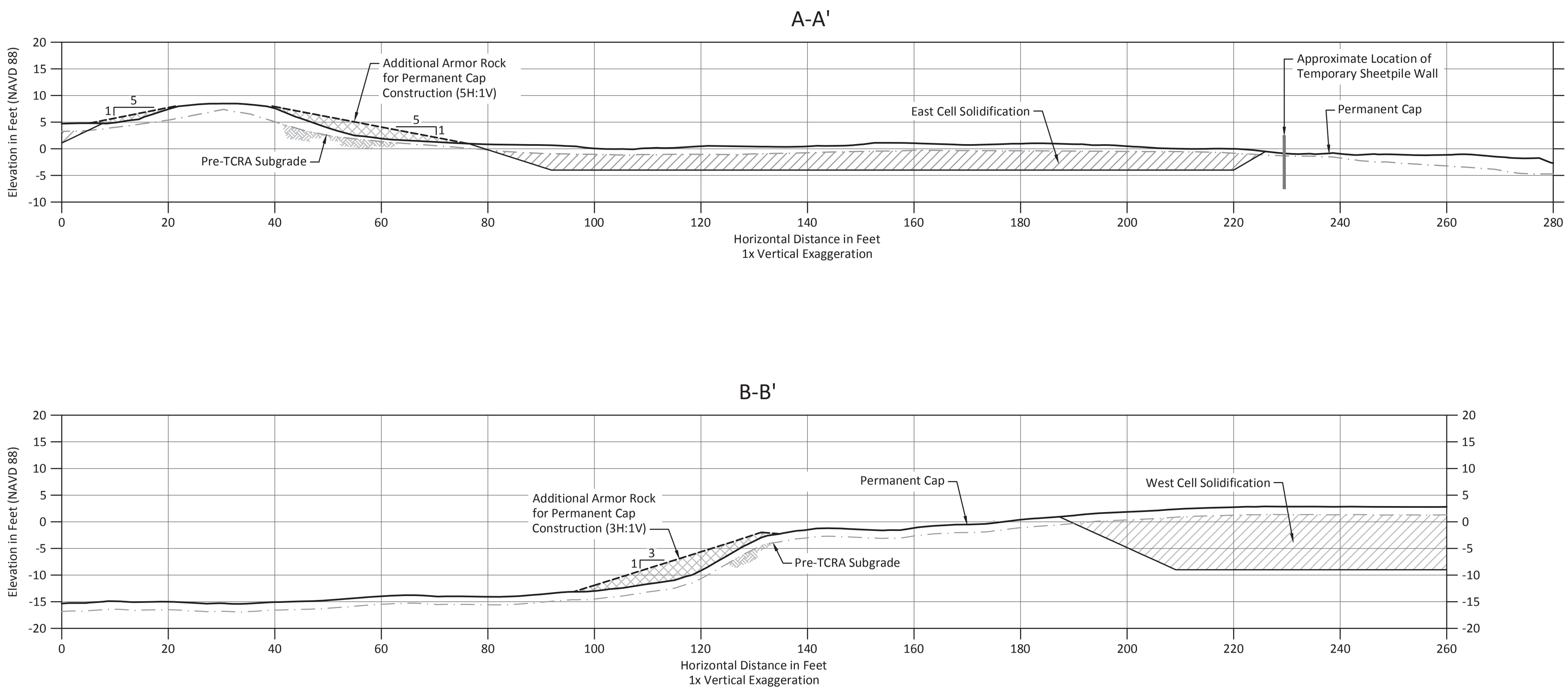
ANCHOR QEA

Figure 4-3
Plan View - Alternative 4N
Feasibility Study
San Jacinto River Waste Pits Superfund Site

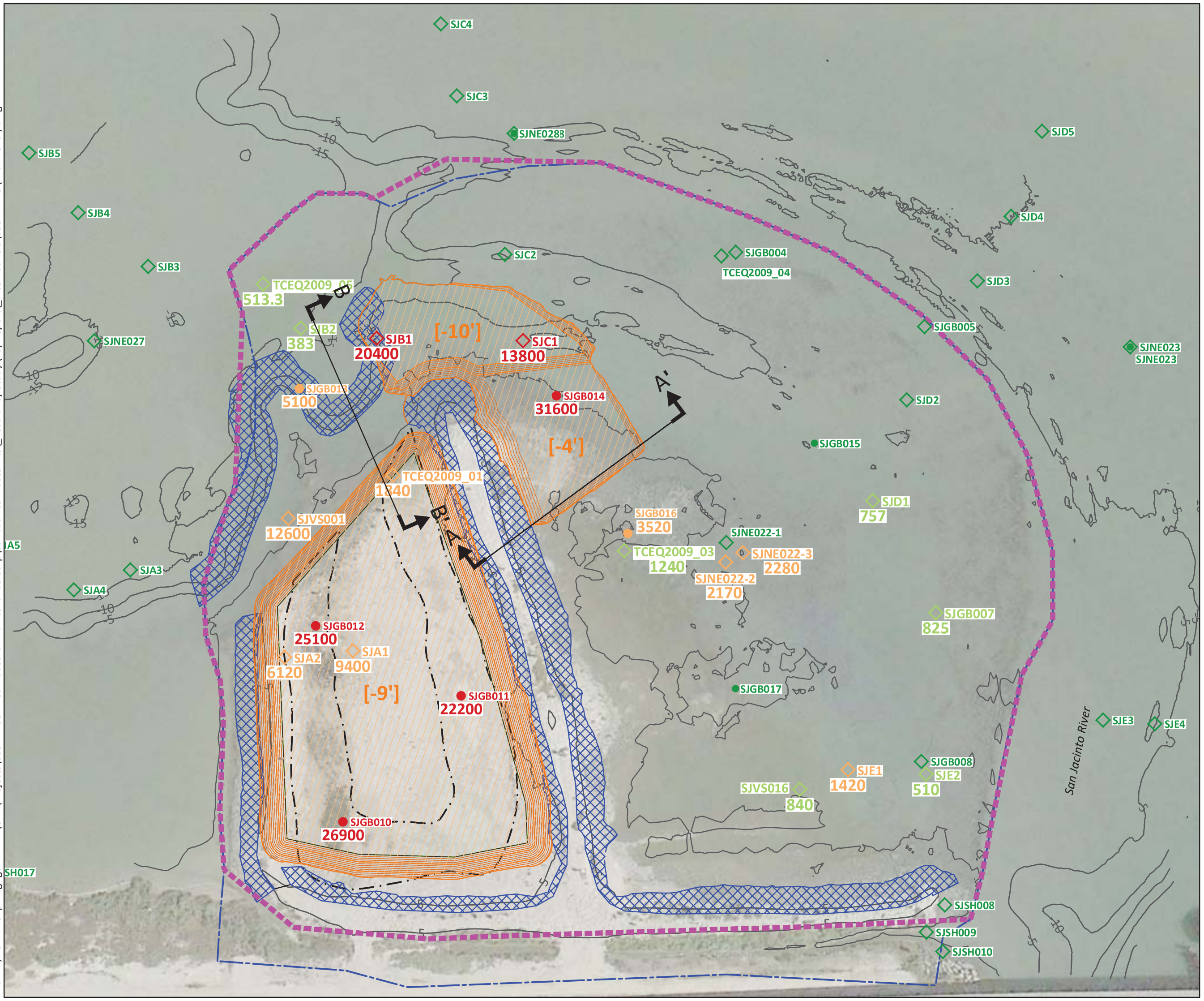
DRAFT



ANCHOR QEA

Figure 4-4
Cross Sections A-A' and B-B' - Alternative 4N
Feasibility Study
San Jacinto River Waste Pits Superfund Site

DRAFT



LEGEND:

- Existing Contour (5 Foot Interval)
- [-4'] Target Cut Elevation (NAVD 88)
- Removal Area
- Armored Cap Limit
- Area of Additional Rock Placement for Flattening Slopes to 5H:1V on berms and 3H:1V in the Northwest Area
- TCRA Footprint of Stabilization
- SJGB014● Core location: TEQ ≥ 13,000 ng/kg
- SJGB013● Core location: 1,300 ≤ TEQ < 13,000 ng/kg
- SJGB016● Core location: 220 ≤ TEQ < 1,300 ng/kg
- SJGB017● Core location: TEQ < 220 ng/kg
- SJB1◇ Grab location: TEQ ≥ 13,000 ng/kg
- SJA1◇ Grab location: 1,300 ≤ TEQ < 13,000 ng/kg
- SJB2◇ Grab location: 220 ≤ TEQ < 1,300 ng/kg
- SJC3◇ Grab location: TEQ < 220 ng/kg
- 825 Concentration TEQ_{DF} (ng/kg dw) (See Note 1)
- A A' Cross Section Location (See Figure 4-6)

NOTE:

1. Concentration shown at each sample location represents the highest concentration calculated at any depth interval at that location.

AERIAL SOURCE: Google Earth Pro, dated October 2012.
SOURCE: Drawing prepared from surveys provided by Hydrographic Consultants dated October 2012 and January/February 2013.
HORIZONTAL DATUM: Texas State Plane South Central, NAD83, U.S. Feet.
VERTICAL DATUM: NAVD 88.

0 120
Scale in Feet

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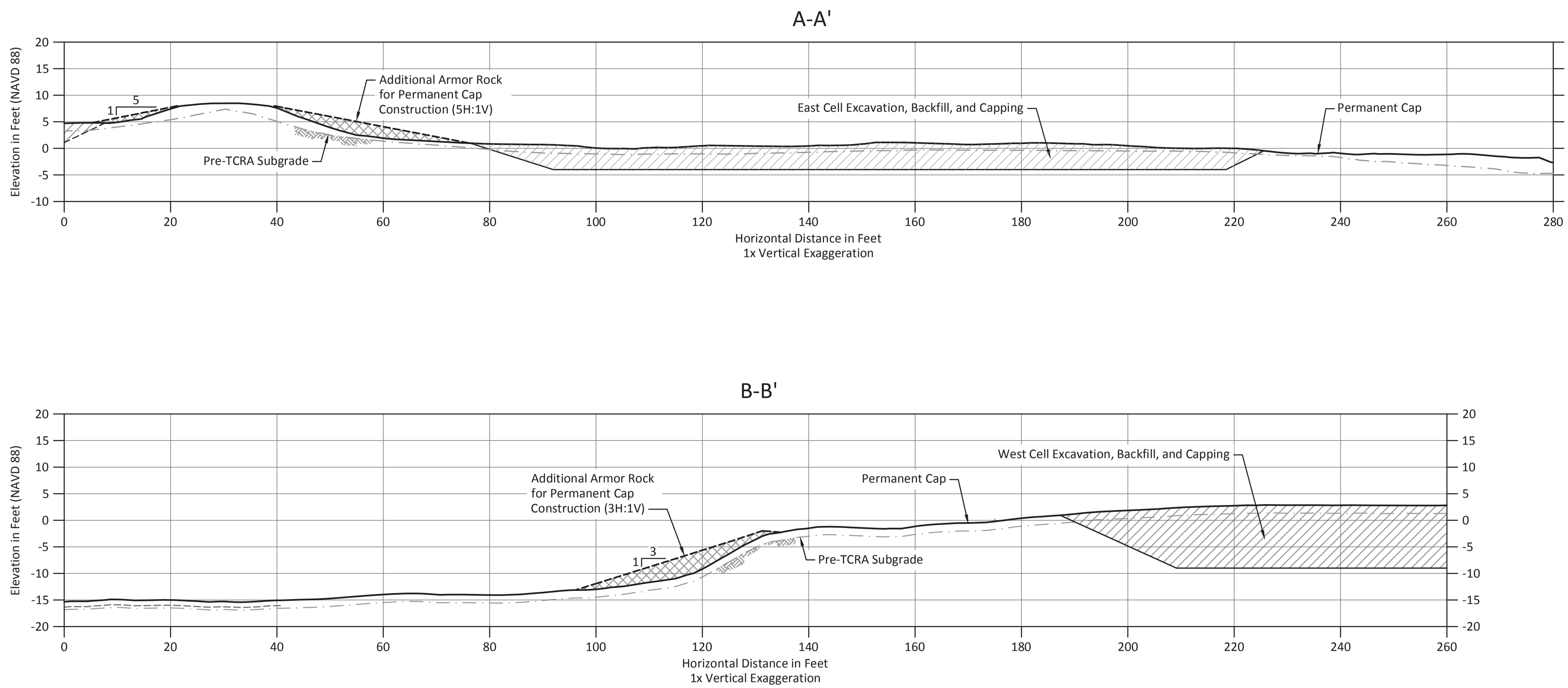
ANCHOR QEA

Figure 4-5
Plan View - Alternative 5N
Feasibility Study
San Jacinto River Waste Pits Superfund Site



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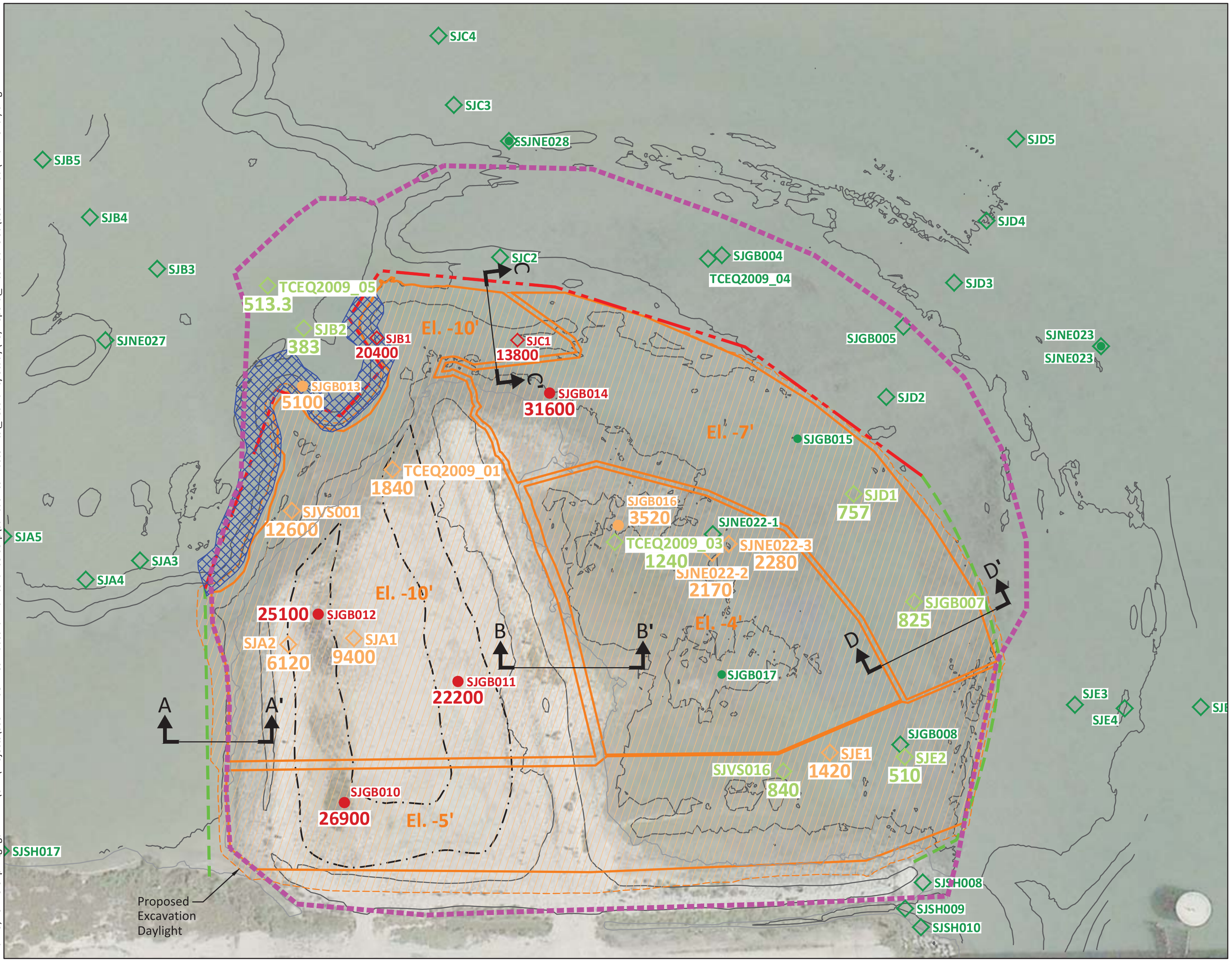
ANCHOR QEA

Figure 4-6
Cross Sections A-A' and B-B' - Alternative 5N
Feasibility Study
San Jacinto River Waste Pits Superfund Site

DRAFT



LEGEND:

- Existing Contour (5 Foot Interval)
- [-4'] Target Cut Elevation (NAVD 88)
- Removal Area
- Area of Additional Rock Placement for Flattening Slopes to 3H:1V in the Northwest Area
- Armored Cap Limit
- Sheet Pile Wall
- Containment Berm
- TCRA Footprint of Stabilization
- SJGB014 Core location: TEQ ≥ 13,000 ng/kg
- SJGB013 Core location: 1,300 ≤ TEQ < 13,000 ng/kg
- SJGB016 Core location: 220 ≤ TEQ < 1,300 ng/kg
- SJGB017 Core location: TEQ < 220 ng/kg
- SJB1 Grab location: TEQ ≥ 13,000 ng/kg
- SJA1 Grab location: 1,300 ≤ TEQ < 13,000 ng/kg
- SJB2 Grab location: 220 ≤ TEQ < 1,300 ng/kg
- SJC3 Grab location: TEQ < 220 ng/kg
- 825 Concentration TEQ_{DF} (ng/kg dw) (See Note 1)
- A A' Cross Section Location (See Figure 4-8)

NOTE:

1. Concentration shown at each sample location represents the highest concentration calculated at any depth interval at that location.

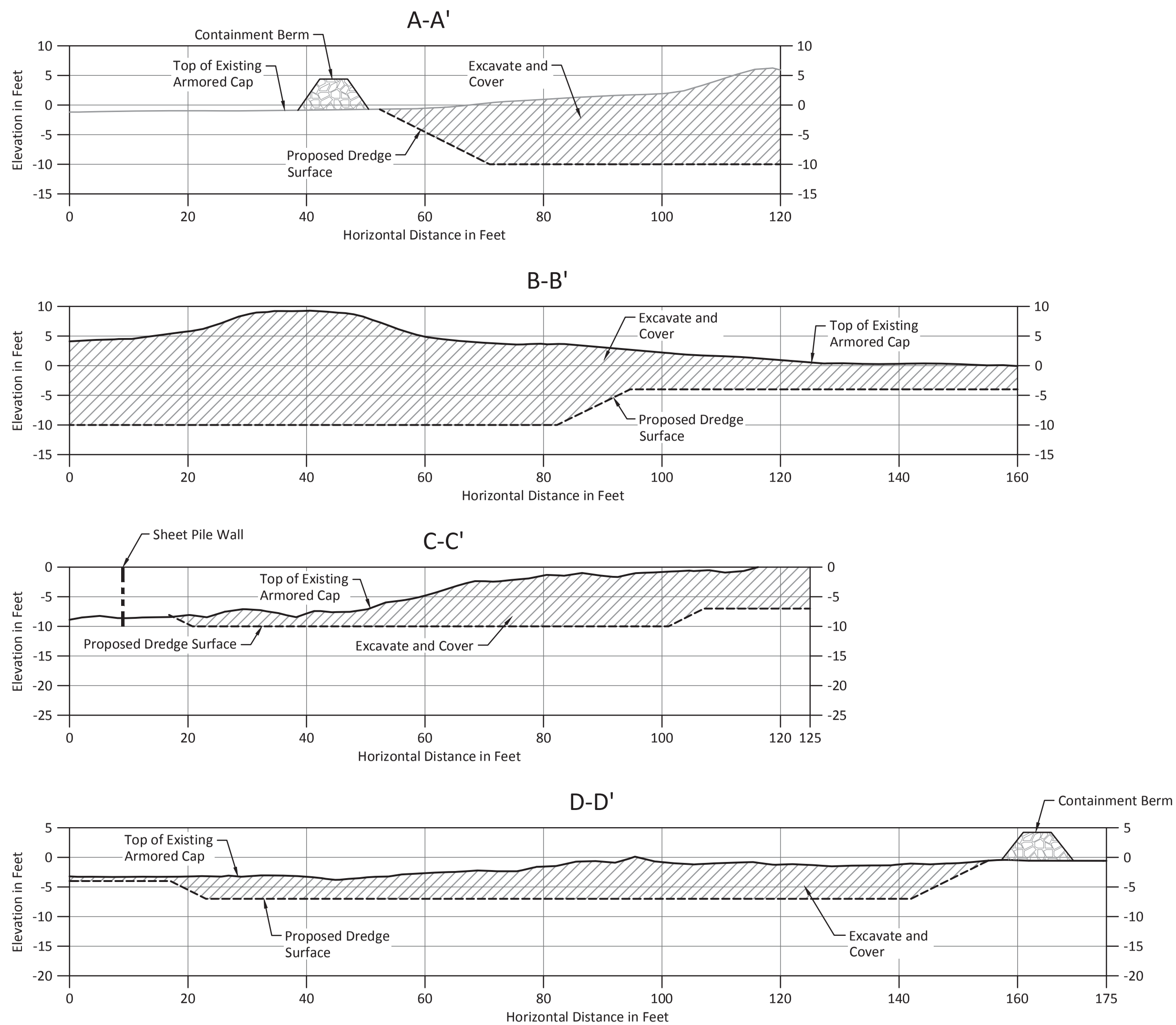
AERIAL SOURCE: Google Earth Pro, dated October 2012.
SOURCE: Drawing prepared from surveys provided by Hydrographic Consultants dated October 2012 and January/February 2013.
HORIZONTAL DATUM: Texas State Plane South Central, NAD83, U.S. Feet.
VERTICAL DATUM: NAVD 88.

0 120
Scale in Feet

ANCHOR QEA

Figure 4-7
Plan View - Alternative 5aN
Feasibility Study
San Jacinto River Waste Pits Superfund Site

DRAFT



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ANCHOR QEA

Figure 4-8
Cross Sections A-A' through D-D' - Alternative 5aN
Feasibility Study
San Jacinto River Waste Pits Superfund Site

DRAFT

LEGEND:

- Existing Contour (5 Foot Interval)
- [-4'] Target Cut Elevation (NAVD 88)
- Removal Area
- Armored Cap Limit
- TCRA Footprint of Stabilization
- SJGB014 Core location: TEQ ≥ 13,000 ng/kg
- SJGB013 Core location: 1,300 ≤ TEQ < 13,000 ng/kg
- SJGB016 Core location: 220 ≤ TEQ < 1,300 ng/kg
- SJGB017 Core location: TEQ < 220 ng/kg
- SJB1 Grab location: TEQ ≥ 13,000 ng/kg
- SJA1 Grab location: 1,300 ≤ TEQ < 13,000 ng/kg
- SJB2 Grab location: 220 ≤ TEQ < 1,300 ng/kg
- SJC3 Grab location: TEQ < 220 ng/kg
- 825 Concentration TEQ_{DF} (ng/kg dw) (See Note 1)
- A A' Cross Section Location (See Figure 4-8)

NOTE:
1. Concentration shown at each sample location represents the highest concentration calculated at any depth interval at that location.

AERIAL SOURCE: Google Earth Pro, dated October 2012.
SOURCE: Drawing prepared from surveys provided by Hydrographic Consultants dated October 2012 and January/February 2013.
HORIZONTAL DATUM: Texas State Plane South Central, NAD83, U.S. Feet.
VERTICAL DATUM: NAVD 88.

0 200
Scale in Feet

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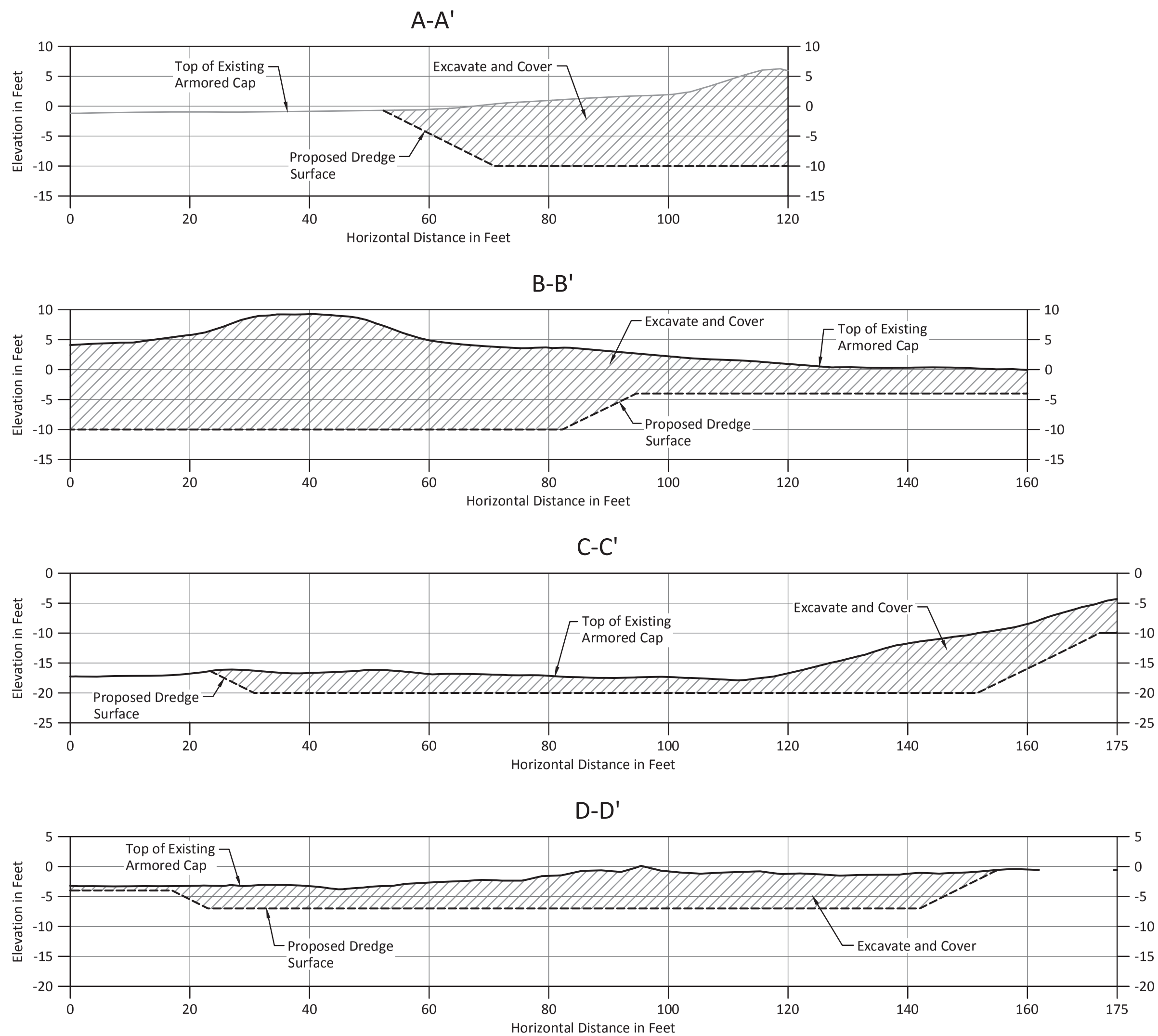
ANCHOR QEA

Figure 4-9
Plan View - Alternative 6N
Feasibility Study
San Jacinto River Waste Pits Superfund Site

DRAFT



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ANCHOR QEA

Figure 4-10
Cross Sections A-A', B-B', C-C', and D-D' - Alternative 6N
Feasibility Study
San Jacinto River Waste Pits Superfund Site

DRAFT

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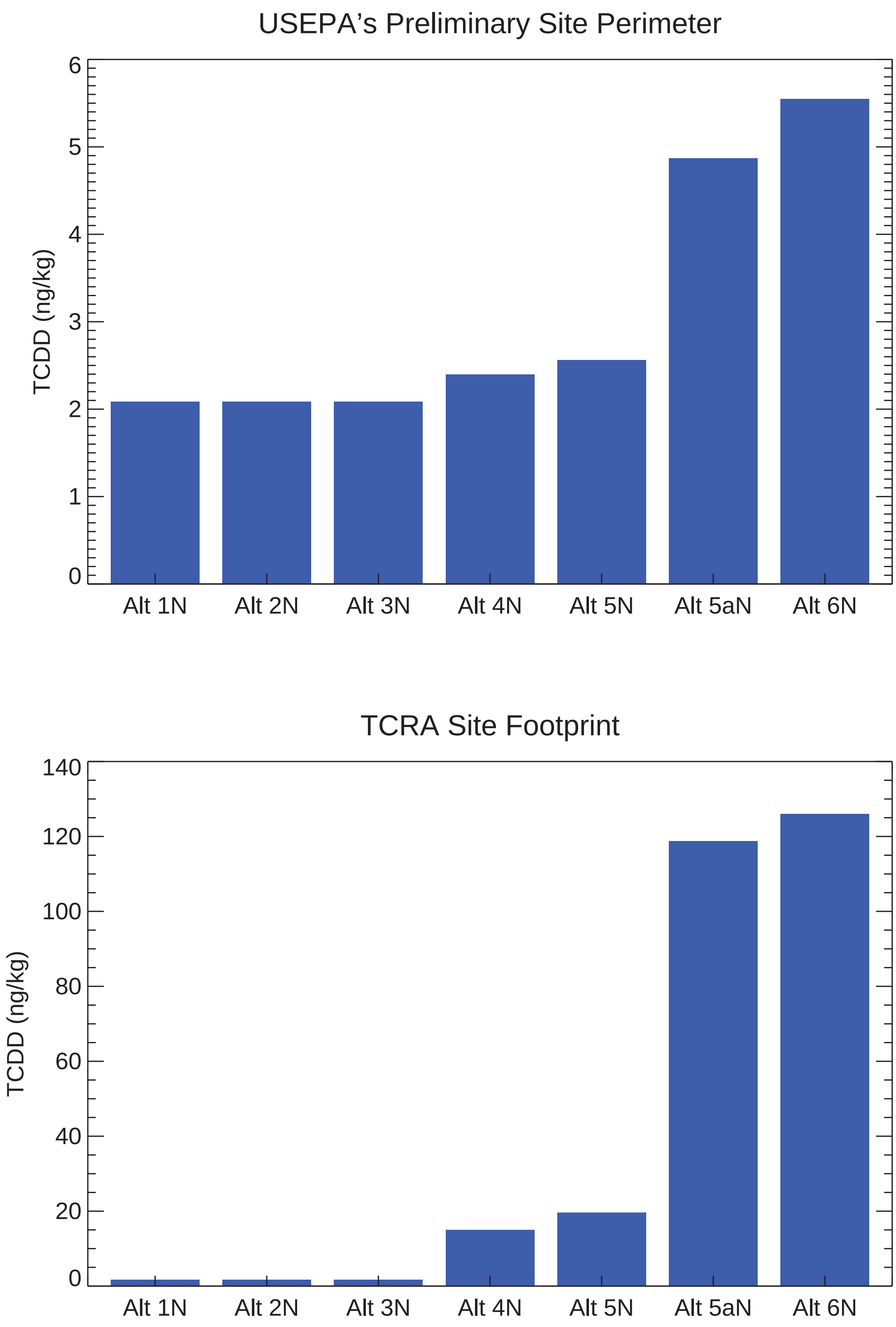
Preliminary Remedial Action Area
USEPA's Preliminary Site Perimeter
Limit of Armored Cap
Soil Boring Location

ANCHOR QEA integral consulting inc.

0 400
Feet

FEATURE SOURCES:
Parcel Boundaries: Harris County Appraisal District
Hydrology: Harris County Flood Control District

Figure 4-11
Preliminary Remedial Action Areas South of I-10
Feasibility Study
San Jacinto River Waste Pits Superfund Site



Model Run: SJR_PROJ2_BC_TCDD_1301-06, SJR_PROJ2_BC_TCDD_1301-06, SJR_PROJ2_BC_TCDD_1301-06, SJR_PROJ3_BC_TCDD_1307-01, SJR_PROJ3_BC_TCDD_1307-02, SJR_PROJ3_BC_TCDD_1402-01, SJR_PROJ3_BC_TCDD_1307-03

Figure 6-1a

Comparison of Model-Predicted Surface Sediment (top 6 inches) TCDD Concentrations in Year 21, Averaged over USEPA's Preliminary Site Perimeter and TCRA Site Footprint

Feasibility Study

San Jacinto River Waste Pits Superfund Site

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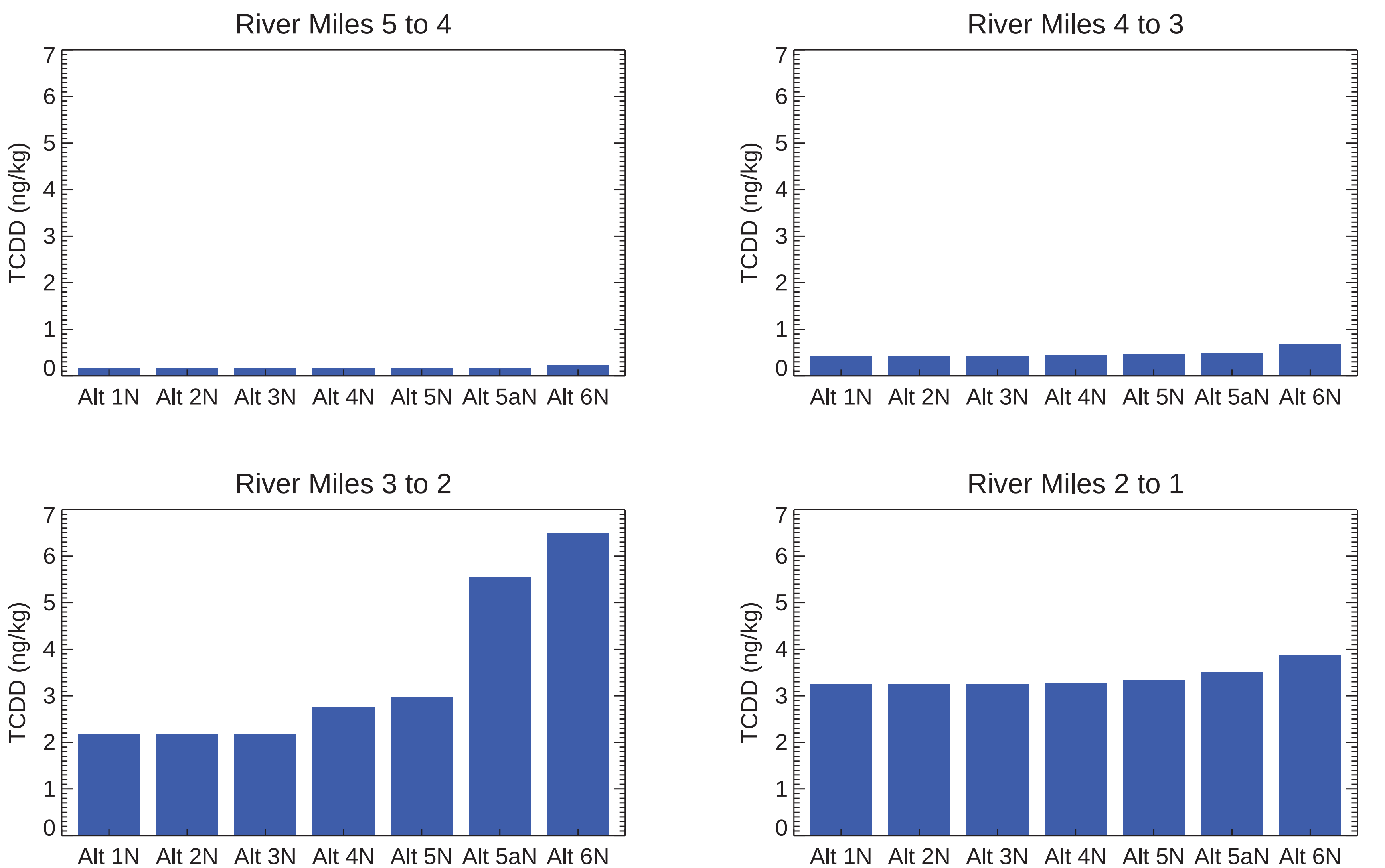

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SJR_PROJ3_BC_TCDD_1307-01, SJR_PROJ3_BC_TCDD_1307-02, SJR_PROJ3_BC_TCDD_1402-01, SJR_PROJ3_BC_TCDD_1307-03

Figure 6-1b

Comparison of Model-Predicted Surface Sediment (top 6 inches) TCDD Concentrations in Year 21, Averaged by River Mile

Feasibility Study

San Jacinto River Waste Pits Superfund Site

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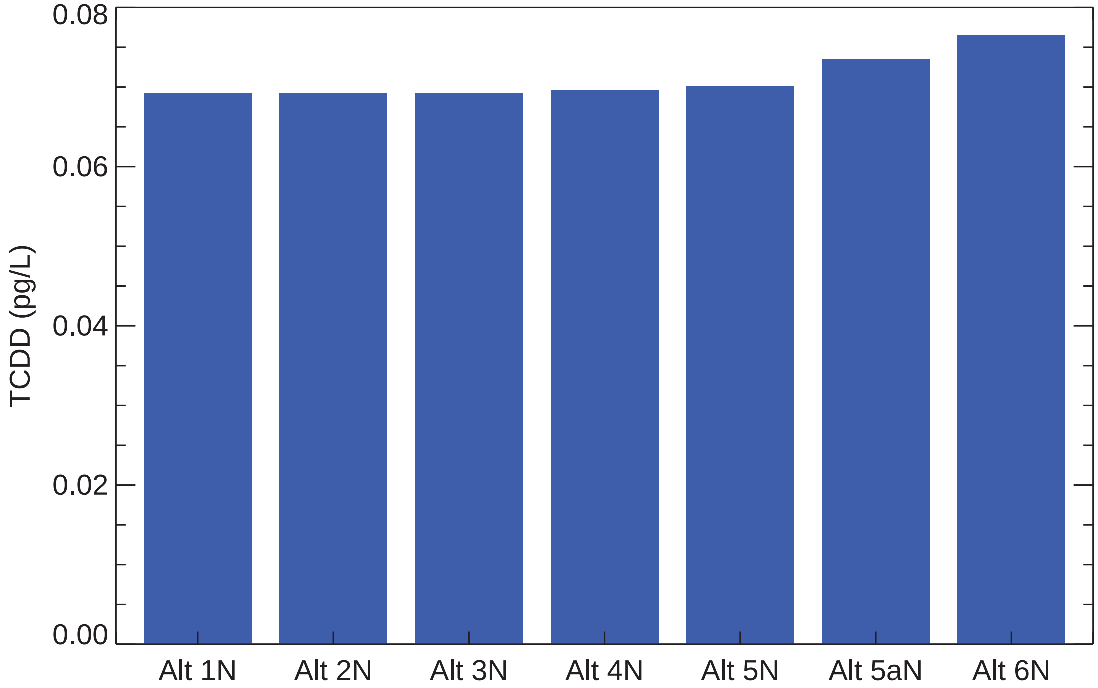
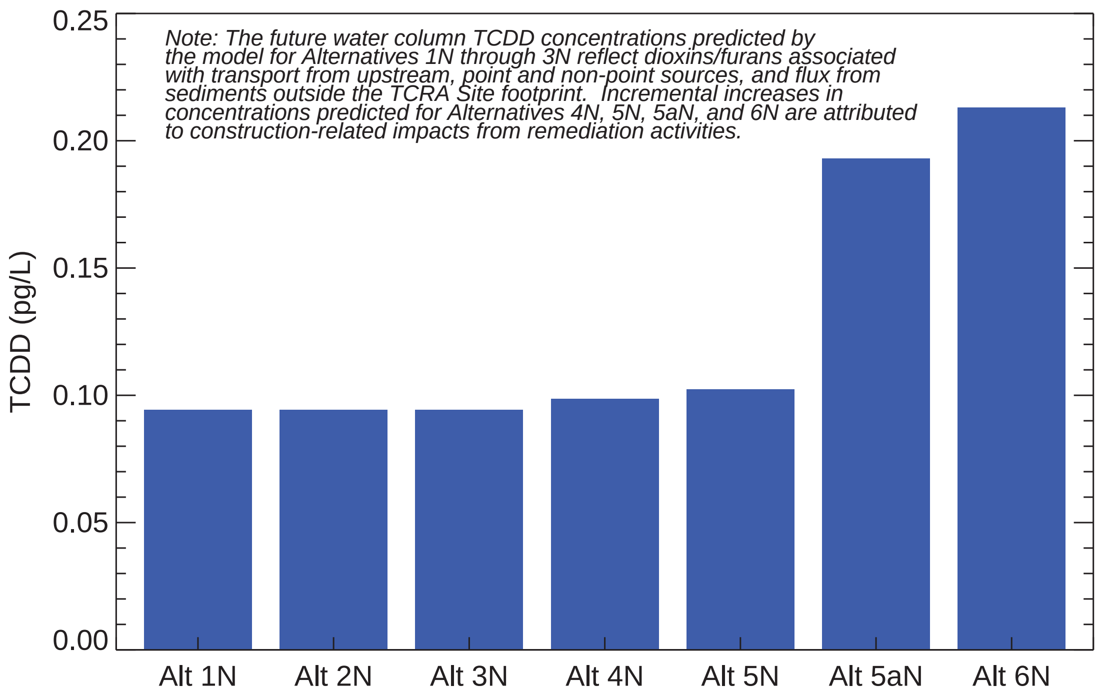
USEPA's Preliminary Site Perimeter



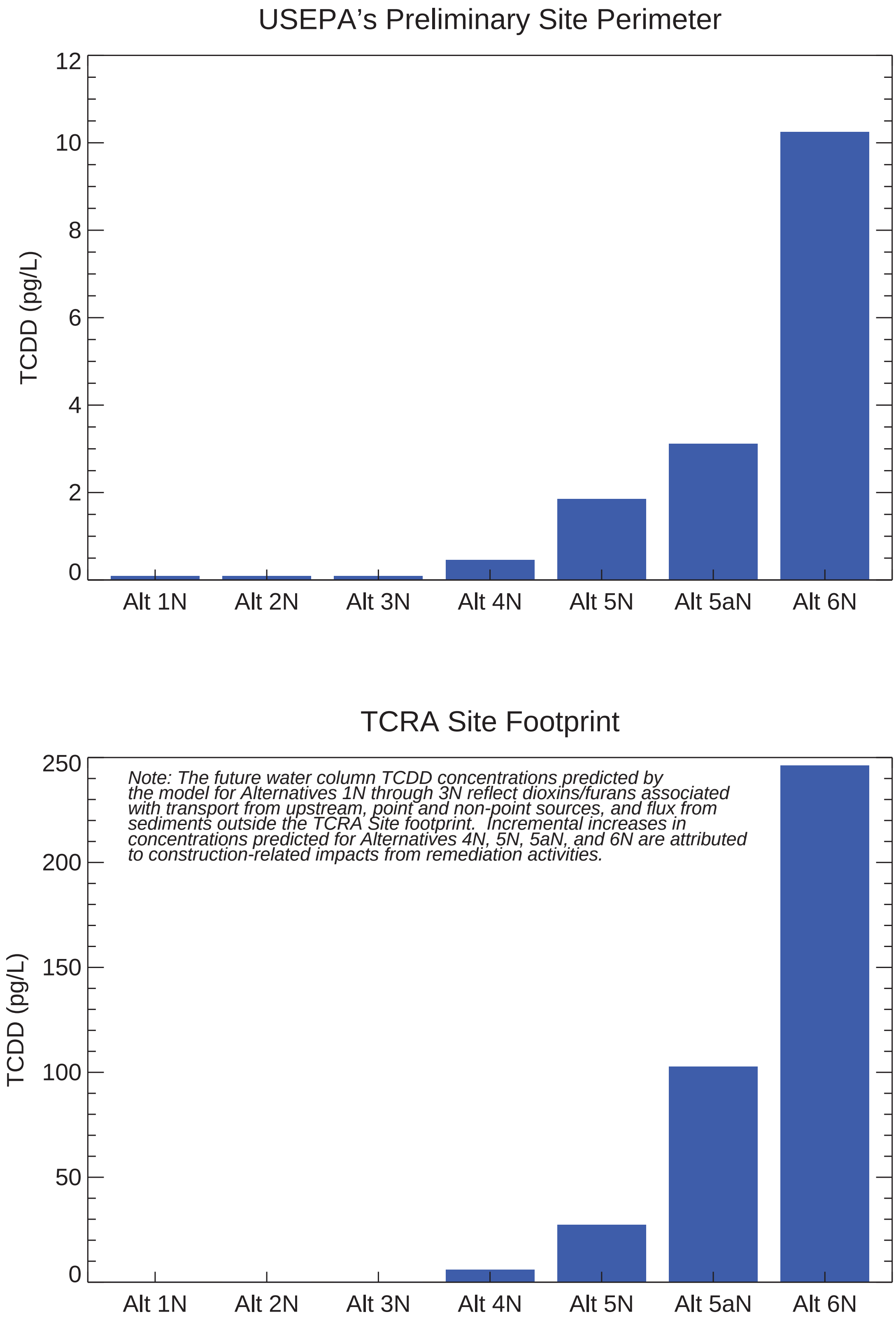
TCRA Site Footprint



Model Run: SJR_PROJ2_BC_TCDD_1301-06, SJR_PROJ2_BC_TCDD_1301-06, SJR_PROJ2_BC_TCDD_1301-06, SJR_PROJ3_BC_TCDD_1307-01, SJR_PROJ3_BC_TCDD_1307-02, SJR_PROJ3_BC_TCDD_1402-01, SJR_PROJ3_BC_TCDD_1307-03

Figure 6-2

Comparison of Model-Predicted Annual Average Water Column TCDD Concentrations (Year 21) over USEPA's Preliminary Site Perimeter and TCRA Site Footprint
Feasibility Study
San Jacinto River Waste Pits Superfund Site



Model Run: SJR_PROJ2_BC_TCDD_1301-06, SJR_PROJ2_BC_TCDD_1301-06, SJR_PROJ2_BC_TCDD_1301-06, SJR_PROJ3_BC_TCDD_1307-01, SJR_PROJ3_BC_TCDD_1307-02, SJR_PROJ3_BC_TCDD_1402-01, SJR_PROJ3_BC_TCDD_1307-03

Figure 6-3

Comparison of Model-Predicted Annual Average Water Column TCDD Concentrations (Year 1) over USEPA's Preliminary Site Perimeter and TCRA Site Footprint
Feasibility Study
San Jacinto River Waste Pits Superfund Site

ANCHOR QEA

DRAFT FINAL INTERIM FEASIBILITY STUDY REPORT

APPENDIX A: CHEMICAL FATE AND TRANSPORT MODELING

SAN JACINTO RIVER WASTE PITS SUPERFUND SITE

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LIST OF ACRONYMS AND ABBREVIATIONS

Anchor Environmental	Anchor Environmental, LLC
Anchor QEA	Anchor QEA, LLC
cfs	cubic feet per second
cm	centimeter
D_{50}	median particle diameter
FS	Feasibility Study
HSC	Houston Ship Channel
IC	institutional control
Integral	Integral Consulting Inc.
MNR	monitored natural recovery
MT	metric tons
ng/kg	nanograms per kilogram
NOAA	National Oceanic and Atmospheric Administration
NSR	net sedimentation rate
OCDD	octachlorodibenzo-p-dioxin
PCL	Protective Concentration Level
RI	Remedial Investigation
Site	San Jacinto River Waste Pits Superfund Site
SJRF	San Jacinto River Fleet
S/S	solidification/stabilization
TCDD	2,3,7,8-tetrachlorodibenzo-p-dioxin
TCDF	2,3,7,8-tetrachlorodibenzofuran
TCEQ	Texas Commission on Environmental Quality
TCRA	Time Critical Removal Action
TEQ	toxicity equivalent
TMDL	total maximum daily load
TOC	total organic carbon
USEPA	U.S. Environmental Protection Agency
WSE	water surface elevation

1 INTRODUCTION

This appendix to the Draft Final Interim Feasibility Study (FS) Report for the San Jacinto River Waste Pits Superfund Site (Site) describes chemical fate and transport modeling that was performed in support of the FS. The models used in this effort are summarized in Section 1.1, and the specific evaluations conducted for the FS are introduced in Section 1.2.

1.1 Background on the Chemical Fate and Transport Modeling Study

The Chemical Fate and Transport Modeling Study report (Anchor QEA 2012a) was submitted for U.S. Environmental Protection Agency (USEPA) review in February 2012, and USEPA comments were addressed in a draft final report submitted on July 18, 2012. USEPA approved the report with certain modifications in a letter dated September 12, 2012 (Miller 2012, pers. comm.).[1] The document was modified accordingly, and the final report was submitted to USEPA on October 11, 2012 (Anchor QEA 2012a).

1.1.1 Study Objectives

The primary goal of the Chemical Fate and Transport Modeling Study (Anchor QEA 2012a) was to simulate physical and chemical processes governing chemical fate and transport of selected dioxins and furans in the aquatic environment within the USEPA's Preliminary Site Perimeter[2], which is shown on Figure 1-1. The primary objectives of the chemical fate and transport analysis were three-fold, as follows:

- Develop conceptual site models for sediment transport and chemical fate and transport
- Develop and apply quantitative methods (i.e., computer models) that can be used to evaluate the effectiveness of various remedial alternatives during the FS
- Address specific questions about sediment transport and chemical fate and transport processes within the USEPA's Preliminary Site Perimeter

[1] In that letter, USEPA also required that additional model sensitivity analyses be performed as part of the FS. Those sensitivity analyses were conducted and are described in Section 2 of this Appendix.

[2] The term "USEPA's Preliminary Site Perimeter" refers to the area shown within the "preliminary perimeter" in Appendix B of the Unilateral Administrative Order (USEPA 2009).

Any model has some amount of uncertainty associated with its predictions due to various assumptions that need to be made during its development and/or data limitations; because of this uncertainty, results from the chemical fate and transport modeling are used in the FS to provide relative comparisons between the outcomes of the various remedial alternatives being evaluated (models are best used on a relative basis, because most sources of uncertainty are common to all scenarios). Specific predictions of chemical concentrations in sediment and water do not represent actual measures of sediment or water quality during the time period being modeled.

1.1.2 Model Framework and Model Study Area

The fate and transport modeling is based on three linked models that simulate hydrodynamics, sediment transport, and chemical fate and transport (Figure 1-2). The hydrodynamic model simulates temporal and spatial changes in water depth, current velocity, and bed shear stress in the San Jacinto River. This information is transferred from the hydrodynamic model to the sediment transport model, which is used to simulate the erosion, deposition, and transport of sediment in the San Jacinto River. The sediment transport model is used to simulate temporal and spatial changes in suspended sediment concentrations in the water column and bed elevation changes (i.e., bed scour depth and net sedimentation rate [NSR]). The results from the hydrodynamic and sediment transport models are transferred to the chemical fate and transport model, which calculates spatial and temporal variations of dioxin and furan concentrations in the water column and sediment bed. Specifically, the chemical fate processes represented by the model include the following:

- *Sediment-water interactions* – Particulate-associated dioxins and furans within the sediment bed enter the water column in cases where erosion of the surface layer occurs, and chemicals being transported in the water column can likewise deposit on the bed.
- *Partitioning and dissolved phase flux* – Dioxins and furans within the surface layer of the sediment bed are also present in the dissolved phase due to partitioning processes. In some cases, the resulting porewater concentrations can be greater than those in the overlying water column. Such a concentration gradient, through the process of surface exchange flux (due to diffusion, bioturbation, and tidal pumping), can result in

a transfer of dissolved-phase mass to the water column that in turn can affect concentrations in the river under low-flow conditions.

- *Transport in the water column* – Dissolved and particulate phase dioxins and furans that are present in the water column from a variety of sources, including atmospheric deposition, upstream sources, point sources such as waste water treatment outfalls, and sediments within the area, are transported with the currents, which are affected by freshwater flow in addition to more complex circulation patterns associated with the tides.
- *Inputs from external sources* – As described above, dioxins and furans can enter the aquatic environment from the sediment bed and external sources. The Texas Commission on Environmental Quality's dioxin Total Maximum Daily Load (TMDL) study[3] (University of Houston and Parsons 2006) detected dioxins and furans in samples of outfalls and surface runoff, and in dry and wet atmospheric deposition samples that were collected adjacent to the San Jacinto River and in areas within the USEPA's Preliminary Site Perimeter. These inputs represent external sources to the area, referred to below as the Model Study Area, and are accounted for and reflected in the results of the fate and transport modeling presented below.

The model's predictions reflect the processes described above using a mass balance approach; as such, its predictions of surface water concentrations reflect sources from upstream, point and non-point sources, flux from sediments, and transport throughout the Model Study Area.

For the purposes of chemical fate and transport modeling, the Model Study Area is defined as the San Jacinto River from the Lake Houston Dam to the Houston Ship Channel (HSC; Figure 1-1). This Model Study Area was selected so that appropriate boundary conditions are utilized in the numerical models, which was needed to produce reliable predictions within the USEPA's Preliminary Site Perimeter.[4] The resolution of model grid cells is spatially variable, with high resolution (i.e., smaller grid cells) in the region near the impoundments north of Interstate 10 (Northern Impoundments), which is the area that underwent a Time Critical Removal Action (TCRA) and is hereafter referred to as the TCRA Site.

[3] http://www.tceq.texas.gov/waterquality/tmdl/26-hscdioxin.html

[4] The hydrodynamic model also simulates a portion of the HSC in order to properly represent tidal exchange at the confluence with the San Jacinto River (see Anchor QEA 2012a for details).

1.1.3 Model Development and Calibration

Model development and calibration was described in the Chemical Fate and Transport Modeling Study report (Anchor QEA 2012a). A brief summary is provided below.

Development of the hydrodynamic model consisted of specifying the following inputs: 1) bathymetry and geometry; 2) freshwater inflow at the upstream boundary at the Lake Houston Dam; 3) freshwater inflow at the various bayous discharging into the simulated portion of the HSC; and 4) water surface elevation (WSE) at the downstream boundary (i.e., near the confluence of the San Jacinto River and the HSC). Data obtained from historical sources or collected as part of this study were used to determine these model inputs. The hydrodynamic model was calibrated using current velocity and WSE data collected at two locations in the Model Study Area during 2010 and 2011. Daily average WSE data collected at the U.S. 90 Bridge during a 14-year period (1997 to 2010) were used for additional validation of model performance over a wide range of flow conditions in the river. Overall, the calibration and validation results demonstrate that the model is able to sufficiently simulate the hydrodynamics within the Model Study Area to meet the objectives of this study.

The sediment transport model was developed based on Model Study Area-specific information on sediment properties (e.g., grain size distribution, bulk density), bed properties (e.g., mapping of cohesive and non-cohesive bed areas), and boundary conditions (e.g., sediment load passing Lake Houston Dam and incoming load during flood tide at the downstream boundary near the confluence of the San Jacinto River and the HSC). The calibration period for the sediment transport model was the 21-year period from 1990 through 2010. The sediment transport model was calibrated to measurements of long-term NSR estimated from radioisotope cores collected at ten locations within the Model Study Area. Overall, the report concluded that the model predicted NSRs with reasonable accuracy. The general pattern of net sedimentation predicted by the model is qualitatively consistent with known characteristics of the Model Study Area. At small spatial scales (e.g., single grid cell), the model uncertainty is higher; however, as the spatial scale increases, the uncertainty in the model's predictive capability decreases. This trend (i.e., decreasing uncertainty in model reliability with increasing spatial scale) is consistent with sediment transport models developed at other sites that have been successfully calibrated and used as a management tool.

The chemical fate and transport model was developed for three dioxin and furan congeners (2,3,7,8-tetrachlorodibenzo-p-dioxin [TCDD], 2,3,7,8-tetrachlorodibenzofuran [TCDF], and octachlorodibenzo-p-dioxin [OCDD]). Parameters describing the various processes simulated by the fate model (described above) were developed based on available Model Study Area data (e.g., dioxin and furan concentrations in sediment and surface water), information generated as part of the TMDL study (e.g., loads associated with permitted outfalls, atmospheric deposition, and surface runoff), and literature (e.g., depth and rate of sediment bioturbation and surface porewater exchange coefficients). The chemical fate model was developed and calibrated using surface water and sediment bed data collected between 2002 and 2010 prior to the TCRA; the number of samples is summarized in Table 1-1 below.

Table 1-1
Summary of Water Column and Sediment Data Used to Develop and Calibrate Fate and Transport Model

Program	Years	Number of Locations	Number of Samples
TMDL surface water[1]	2002 – 2004	6[2]	34[2]
TCEQ surface water	2009	2[2]	3[2]
TMDL sediment	2002 – 2005	70	70
TCEQ et al. sediment[3]	2009	18	19
RI sediment	2010	162	170

Notes:
[1] Each TMDL water column sample was analyzed separately for dissolved- and particulate-phase dioxins/furans.
[2] Only one of the TMDL surface water sample locations (nine total samples) was located within the USEPA's Preliminary Site Perimeter (but from a location outside the perimeter of the Northern Impoundments). The 2009 TCEQ surface water samples were all collected from within the perimeter of the Northern Impoundments. As shown in the table above, the data available for surface water were more limited than those for sediment, especially post-2004.
[3] 2009 sediment data were collected by TCEQ and others
RI – Remedial Investigation
TCEQ – Texas Commission on Environmental Quality
TMDL – total maximum daily load

The chemical fate model was shown to provide a good representation of spatial gradients in water column dioxin and furan concentrations (on a whole-water basis) across the Model Study Area.[5] The model also simulated the spatial patterns and differences between particulate- and dissolved-phase water column concentrations within the Model Study Area. With respect to surface sediment concentrations, for which much more empirical data are available for comparison (Table 1-1), the chemical fate model predicted a decline in surface sediment concentrations within the area surrounding the USEPA's Preliminary Site Perimeter over the period from 2005 to 2010 that is within a factor of 2.5 of the decline estimated from data-based evaluations presented in the *Chemicals of Potential Concern Technical Memorandum* (Integral 2011); these results are considered consistent when uncertainties associated with both the data and model are taken into account.

Overall, the modeling framework summarized above provides a useful management tool for evaluating remedial alternatives in the FS. It integrates the large body of Model Study Area data into a quantitative, objective framework. The models were calibrated to several datasets covering varying spatial and temporal scales, and were shown to provide a good representation of hydrodynamics, sediment transport, and chemical fate and transport within the Model Study Area, subject to the above-described data limitations.

It should be noted that the model summarized above was developed and calibrated based on data collected prior to implementation of the TCRA in 2010 and 2011. The TCRA was implemented to stabilize soils/sediments within the original 1966 perimeter berm of the TCRA Site to prevent the release of dioxins and furans and other chemicals of potential concern to the environment (Anchor QEA 2011a) by installation of an armor rock cap that in most areas was placed atop a geotextile bedding layer (as well as a geomembrane cover layer in certain portions of the area). The effect of the TCRA on fate and transport of dioxins and furans in the Model Study Area was evaluated by the modeling presented in this appendix.

[5] Model predictions of water concentrations are not equivalent to actual measurements, and verification of model predictions is limited by data availability as noted above.

1.2 Application of the Model in the Feasibility Study

As part of the FS, the model was used to develop estimates of future dioxin and furan concentrations in sediment and surface water within the Model Study Area. The specific FS model applications presented in this appendix include the following:

- Long-term future simulations were first conducted for current (post-TCRA) conditions (i.e., starting from contemporary sediment concentrations within the USEPA's Preliminary Site Perimeter, and reflecting the presence of the Armored Cap [as described in the FS] at the TCRA Site). These simulations served two purposes for the FS. First, the model was used to provide estimates of the effects of the TCRA on surface water concentrations of select dioxin and furan congeners within the Model Study Area. Second, these simulations also provide estimates of rates of natural recovery (i.e., reductions in surface sediment dioxin and furan concentrations over time) in various portions of the Model Study Area in the absence of any remedial action beyond the current Armored Cap. These simulations, therefore, apply to the No Further Action alternative (Alternative 1N), as well as two other alternatives evaluated in the FS: i) Alternative 2N (institutional controls [ICs] and monitored natural recovery [MNR]); and ii) Alternative 3N (ICs and MNR plus construction of enhancements to the Armored Cap [as described in the FS] to create the Permanent Cap [Permanent Cap]). For both of these evaluations (i.e., predictions of the effects of the TCRA on surface water concentrations and predictions of natural recovery rates), simulations were also conducted with alternate sets of model input parameters to develop uncertainty bounds on the predictions.
- Simulations were also conducted of Alternatives 4N, 5N, 5aN, and 6N, which include active remediation of soil/sediments within the TCRA Site, as well as sediments exceeding Protective Concentration Levels (PCLs) from another area within the USEPA's Preliminary Site Perimeter in the case of Alternative 6N. In addition to evaluating general long-term trends for these alternatives, the model's predictions of relative future sediment and water column dioxin and furan concentrations from these simulations were also used to quantify potential short- and long-term impacts associated with the construction activities (i.e., sediment resuspension and release during remediation and effects of dredge residuals).

1.3 Appendix Organization

The remainder of this appendix is organized as follows. Section 2 describes sensitivity analyses that were performed with the hydrodynamic and sediment transport models at the request of USEPA in its letter approving the draft final Chemical Fate and Transport Modeling Study report (Miller 2012, pers. comm.). Section 3 presents long-term simulations of post-TCRA future conditions conducted with the model, including a discussion of the model setup, model results, and uncertainty analyses associated with use of the model to: 1) evaluate the impacts of the TCRA on estimated surface water concentrations; and 2) predict future surface sediment concentrations and estimated rates of natural recovery. Section 4 documents the model simulations used to evaluate the remedial alternatives; it compares the estimated rates of natural recovery from the post-TCRA future simulation, which is representative of Alternatives 1N through 3N, with results from model simulations of the active soil/sediment remediation alternatives (Alternatives 4N through 6N). A summary of this appendix is presented in Section 5, and reference citations are contained in Section 6.

2 HYDRODYNAMIC AND SEDIMENT TRANSPORT MODEL SENSITIVITY ANALYSES

In response to USEPA's request for additional hydrodynamic and sediment transport model sensitivity analyses in its conditional approval letter for the draft final Chemical Fate and Transport Modeling Study report (Miller 2012, pers. comm.), a series of simulations was conducted to evaluate: 1) sediment deposition and erosion during high-flow events; and 2) the sensitivity of model predictions to WSE at the downstream boundary.

2.1 Evaluation of Deposition and Erosion During High-Flow Events

The calibrated hydrodynamic and sediment transport models (Anchor QEA 2012a) were used to simulate sediment transport processes in the San Jacinto River during high-flow events. A range of high-flow conditions, from 2- to 100-year events, were investigated, with the objective of answering the following questions:

- What portions of the Model Study Area are depositional and what areas experience erosion during a given high-flow event?
- What are the depths of net deposition and erosion during a given high-flow event?

High-flow events with return periods of 2, 10, and 100 years were evaluated during this analysis. The probability of a high-flow event occurring in any given year is 50 percent, 10 percent, and 1 percent for return periods of 2, 10, and 100 years, respectively. Peak flow rates at Lake Houston Dam for the three high-flow events evaluated in this analysis are listed in Table 2-1. The peak flow rates for these flood simulations were determined from a flood frequency analysis that was performed using historical flow rate data collected at Lake Houston Dam (see Section 3.3.1 of Anchor QEA 2012a). Incoming sediment loads to the San Jacinto River at the dam during the flood simulations were estimated using the methodology described in Section 4.2.3 of Anchor QEA (2012a).

Table 2-1
Peak Flow Rates and Sediment Loads at Lake Houston Dam for High-Flow Event Simulations

Return Period (years)	Peak Flow Rate (cfs)	Total Sediment Load (MT)
2	38,400	56,600
10	126,000	324,000
100	372,000	1,620,000

Notes:
cfs – cubic feet per second
MT – metric tons

Simulating sediment transport in the San Jacinto River during a high-flow event requires specifying time-variable inflow at both the Lake Houston Dam and the HSC boundary tributaries (i.e., high-flow hydrographs). At the Lake Houston Dam inflow boundary, the hydrograph that occurred during the high-flow event in October 1994 was chosen. This flood had a peak flow rate of approximately 356,000 cubic feet per second (cfs) measured in the San Jacinto River at the U.S. Geological Survey gauging station located at the U.S. 90 Bridge near Sheldon, Texas, representing a return period of between 50 and 100 years. The October 1994 event was selected for this analysis, as opposed to other high flow events that occurred in the area, because this event was: 1) the highest flow rate during the 21-year period used for sediment transport model calibration (1990 through 2010); and 2) similar in magnitude (i.e., only 4.5 percent lower) to the flow rate for the 100-year flood (372,000 cfs). The hydrographs for the specific high-flow events evaluated in this analysis (i.e., 2-, 10-, and 100-year events) were developed by linearly scaling the October 1994 hydrograph so that the peak flow rate corresponded to the appropriate value for each event (i.e., those listed in Table 2-1). For example, the hydrograph for the 100-year event was generated by increasing the peak flow rate during the October 1994 event by 4.5 percent. For the hydrographs of the HSC tributaries, observed time-variable flow rates during the October 1994 flood period were used as model input. This assumption was evaluated in a sensitivity analysis by comparing the results to those using the average flow rates for each of the tributaries.

Temporal variation in WSE at the downstream boundary for these simulations was specified using data collected during the October 1994 high-flow event at the National Oceanic and Atmospheric Administration (NOAA) tidal gauge station at Morgan's Point. Time histories of flow rate at Lake Houston Dam (top panel) and WSE at the downstream boundary (bottom panel) during the high-flow event simulations are shown on Figure 2-1. The WSE shown on this figure represents the WSE corresponding to the 100-year event (i.e., measured at Morgan's Point during the October 1994 event); this same WSE was used for the downstream boundary for the 2- and 10-year event simulations, because flow rate has more of an effect on predicted velocities and net sedimentation within the USEPA's Preliminary Site Perimeter than the downstream boundary WSE.

Spatial distributions of predicted net erosion and deposition at the end of the 2-year high-flow simulation are shown on Figures 2-2 and 2-3, respectively. During the 2-year high-flow event, net erosion was predicted to occur only in 6 percent of the total bed area in the Model Study Area and over just 8 percent of the area within the USEPA's Preliminary Site Perimeter,[6] with bed scour being predicted to occur primarily in the sub-tidal zone. Predicted net erosion depths in these limited areas were all less than -3 centimeters (cm), with average and maximum predicted net erosion depths of -0.5 and -2.3 cm, respectively, within the USEPA's Preliminary Site Perimeter during the 2-year flood. Within the USEPA's Preliminary Site Perimeter, the average and maximum net deposition values were predicted to be 0.1 and 1.9 cm, respectively, during the 2-year high-flow event (Table 2-2).

During the 10-year high-flow event, net erosion was predicted over a larger area, although most of the net erosion depths were predicted to be less than -5 cm; there were a few isolated areas with erosion depths predicted to range between -5 and -8 cm. Spatial distributions of predicted net erosion and deposition for the 10-year flood simulation are presented on Figures 2-4 and 2-5, respectively. Average values of predicted net erosion and deposition within the corresponding portions of the USEPA's Preliminary Site Perimeter were -2.1 and 0.7 cm, respectively, during the 10-year flood (Table 2-2). Maximum values of bed scour and deposition were -7.7 and 9.9 cm, respectively, within that area. Over the entire Model Study Area, net deposition was predicted to occur in 73 percent of the bed area, with net erosion predicted in 27 percent of the area. The fractions of bed area predicted to experience net deposition and net erosion within the USEPA's Preliminary Site Perimeter during the 10-year event were 54 percent and 46 percent, respectively.

[6] Total area for the Model Study Area and USEPA's Preliminary Site Perimeter is 4,023 acres and 900 acres, respectively.

Spatial distributions of predicted net erosion and deposition at the end of the 100-year high-flow simulation are shown on Figures 2-6 and 2-7, respectively. Net erosion was predicted in 45 percent of the bed area in the Model Study Area (with the remaining 55 percent being net depositional) and 56 percent of the area within the USEPA's Preliminary Site Perimeter. During the simulated 100-year flood, the average and maximum values of predicted net deposition within the USEPA's Preliminary Site Perimeter were 2.6 and 26 cm, respectively (Table 2-2). The average and maximum predicted scour depths were -4.5 and -29 cm, respectively, within the USEPA's Preliminary Site Perimeter; scour depths greater than 10 cm were predicted to occur in less than 5 percent of that area.

Table 2-2
Predicted Bed Elevation Change within the USEPA's Preliminary Site Perimeter for High-Flow Event Simulations

Return Period (years)	Average Net Deposition (cm)	Maximum Net Deposition (cm)	Average Net Erosion (cm)	Maximum Net Erosion (cm)
2	0.1	1.9	-0.5	-2.3
10	0.7	9.9	-2.1	-7.7
100	2.6	26	-4.5	-29

Notes:
cm – centimeters

Results of the high-flow event simulations described above are representative of conditions immediately after the occurrence of those floods. The post-flood conditions will change with time as sediment is transported into the Model Study Area during lower flow conditions (i.e., deposition will occur in areas that experience bed scour during floods). This type of recovery process after a major flood was incorporated into the long-term 21-year sediment transport calibration simulation (Anchor QEA 2012a). The results from those simulations indicated that the area within the USEPA's Preliminary Site Perimeter is net depositional on a long-term basis (i.e., throughout the 21-year simulation presented in Anchor QEA [2012a]).

2.2 Sensitivity Analysis: Water Surface Elevation at Downstream Boundary

Data collected at the Morgan's Point tidal gauge station were used to specify WSE at the downstream boundary of the hydrodynamic model because of gaps in the data records of the

Battleship Texas State Park and Lynchburg gauge stations. An analysis of differences between WSE data collected at the Battleship Texas State Park/Lynchburg and Morgan's Point gauge stations was presented in Anchor QEA (2012a). The effects of data source for specifying WSE at the downstream boundary of the model were evaluated by simulating hydrodynamic conditions from 2002 using data collected at the Lynchburg gauge station (Anchor QEA 2012a). USEPA requested that a similar analysis be conducted using WSE data collected during 2001 (Miller 2012, pers. comm.). Comparisons of WSE data collected at the Morgan's Point and Lynchburg tidal gauge stations during 2001 are shown on Figure 2-8. These data show WSE was very consistent between the two stations in 2001. The only significant differences in WSE between the two locations occurred in early June 2001, during a flood on the San Jacinto River; this flood had a peak flow rate that corresponded to a return period between 2 and 10 years. The WSE measured at Morgan's Point during that event were lower than those measured at the Lynchburg station.

The models were used to simulate hydrodynamics and sediment transport during 2001, with the downstream boundary condition specified using WSE data collected at the Lynchburg tidal gauge station. These results were compared to the original (base case) simulation for 2001, for which the downstream boundary condition was specified using WSE data collected at the Morgan's Point tidal gauge station. Cumulative frequency distributions of predicted bed elevation changes for grid cells within the USEPA's Preliminary Site Perimeter for the base case (Morgan's Point) and sensitivity (Lynchburg) simulations are compared on Figure 2-9. Differences in bed elevation change between the two simulations range between -2 and +1 cm for the grid cells within the USEPA's Preliminary Site Perimeter (Figure 2-9, bottom panel). These results are similar to the previous analysis conducted for 2002 (Anchor QEA 2012a). A one-to-one comparison of bed elevation changes for each model grid cell within the USEPA's Preliminary Site Perimeter is presented on Figure 2-10; this figure also demonstrates the minimal difference between the base case and sensitivity simulations. Overall, the data source for specifying WSE at the downstream boundary of the hydrodynamic model has minimal effect on sediment transport within the USEPA's Preliminary Site Perimeter.

3 SIMULATION OF POST-TCRA FUTURE CONDITIONS

As noted in Section 1.1.3, the calibrated model described in Anchor QEA (2012a) was developed based on data collected prior to placement of the Armored Cap in 2010 and 2011. As such, the model was first updated to reflect current conditions, which include the presence of the Armored Cap over the TCRA Site. Long-term future simulations under these post-TCRA conditions were then conducted using the updated model. These simulations were used to provide estimates of future rates of natural recovery (i.e., reductions in water column and surface sediment dioxin and furan concentrations over time) in various portions of the Model Study Area. The subsections below describe the methods used to develop these long-term simulations, and the results from the model evaluations of TCRA impacts on relative surface water concentrations and model-predicted rates of natural recovery in sediments.

Because any model has some amount of uncertainty associated with its predictions (due to uncertainty in certain model inputs and assumptions, as well as data limitations), it is often desirable to quantify that uncertainty so that it can be factored into the interpretation of model predictions, as well as any decisions that may be made based on the results. Therefore, this section also describes an analysis of uncertainty that involved conducting simulations based on alternate sets of input parameters, for both sediment transport and chemical fate. Specifically, the uncertainty analysis results associated with the sediment transport model, and the chemical fate model's predictions of the effects of the TCRA on surface water dioxin/furan concentrations and future natural recovery rates in sediments are described. In some cases, the uncertainty associated with certain model assumptions may be difficult to quantify. While these uncertainties exist, they do not hinder the model's ability to evaluate scenarios on a comparative (relative) basis, because such sources of uncertainty are common to all scenarios.

3.1 Hydrodynamic and Sediment Transport Models

3.1.1 Model Setup

3.1.1.1 General Setup of Long-Term Simulation

The long-term, 21-year hydrodynamic and sediment transport simulations used for calibration of the sediment transport model (Anchor QEA 2012a) were updated to represent conditions present in the TCRA Site after implementation of the TCRA for the purposes of future simulations; this period is referred to hereafter as the Future Projection Period. The basis of design for the Armored Cap was the construction of a cap designed to withstand a flow event with a return period of 100 years. The area that was affected is shown on Figure 3-1. Model inputs were revised to reflect physical conditions after construction of the Armored Cap, with the following changes made within the TCRA Site:

- Bed elevations were updated to reflect the increase in elevation due to the Armored Cap.
- The sediment bed map was revised to reflect the placement of the Armored Cap, which is composed of armor stone, and, therefore, represented as non-cohesive sediment in the model.
- The median particle diameter (D_{50}) was updated to represent the armor stone size of the Armored Cap.

Updated bed elevation inputs were based on an interpolated surface map created from data collected during October 2012 by Hydrographic Consultants Limited, which was representative of post-TCRA construction conditions. Pre- and post-TCRA bathymetry and topography data are compared on Figure 3-1. Increases in bed elevation due to the Armored Cap placement (i.e., post-TCRA construction) are evident within the TCRA Site on this figure.

The sediment bed map for the model grid cells within the TCRA Site was converted from cohesive to non-cohesive sediment, as shown on Figure 3-2. The model's median particle diameter in the TCRA Site was also updated using cover material gradation data provided in the Final Removal Action Work Plan (Anchor QEA 2011b). Each zone within the TCRA Site received a specific cap material type; a summary of those zones is shown in Table 3-1, and a comparison of the changes to the median particle diameter used in the model to reflect these cap types is shown on Figure 3-3.

Table 3-1
Cover Material Gradation of the Armored Cap

Material Designation Zone	Material Type	Median Particle Diameter: D_{50} (inches)
Cap A	Recycled concrete	3
Cap B/C	Recycled concrete	6
Cap C	Natural stone	6
Cap D	Natural stone	8

3.1.1.2 Uncertainty Analysis

Uncertainty exists in the predictions of the sediment transport model because of uncertainty in model inputs and assumptions. Although some uncertainties are difficult to quantify, the effects of uncertainty in key model inputs on the long-term sediment transport model calibration were previously evaluated through a quantitative sensitivity analysis, as documented in Section 4.4.1 of Anchor QEA (2012a). Specifically, the effects of varying the following model inputs were evaluated: 1) erosion rate parameters; 2) incoming sediment load at the Lake Houston Dam;[7] and 3) effective bed roughness. To evaluate the effects of possible interactions between the three inputs, a factorial analysis was conducted, which resulted in eight simulations to account for all of the possible combinations of the bounding limits of the three inputs. The parameter sets used in the eight sensitivity simulations are provided in Table 3-2, where "lower" refers to lower-bound value and "upper" refers to upper-bound value. The effects of each sensitivity simulation were evaluated through comparison to the base case simulation results. A more detailed description of this sensitivity analysis is provided in Section 4.4.1 of Anchor QEA (2012a). These same sensitivity analysis simulations were repeated for the post-TCRA conditions model setup.

[7] As described in Anchor QEA (2012a), the incoming sediment load was varied by ± a factor of 2 with respect to that used for the base model calibration. A factor of 2 was selected for the sensitivity analysis to understand the model response to changes in the upstream load, while also maintaining fidelity to the model calibration (i.e., increases beyond a factor of 2 would result in the model being out of calibration with respect to the NSR data).

Table 3-2
Bounding Limits for Sediment Transport Model Sensitivity Analysis

Sensitivity Simulation	Upstream Sediment Load	Effective Bed Roughness	Erosion Rate Parameters
1	Lower	Lower	Lower
2	Lower	Lower	Upper
3	Lower	Upper	Lower
4	Lower	Upper	Upper
5	Upper	Lower	Lower
6	Upper	Lower	Upper
7	Upper	Upper	Lower
8	Upper	Upper	Upper

3.1.2 Results

Spatial distributions of predicted NSRs for the long-term simulation period for pre- (i.e., the sediment transport model calibration) and post-TCRA conditions are shown on Figures 3-4 and 3-5, respectively. Generally, the model predicted slightly more deposition to occur within the TCRA Site for the post-TCRA case; otherwise, differences in NSR between the two cases are minimal. Spatial distributions of predicted net erosion rate for pre- and post-TCRA conditions are presented on Figures 3-6 and 3-7, respectively. Areas of net erosion are similar for the two cases.

To evaluate the uncertainty of these sediment transport model predictions, comparisons of model-predicted and empirically estimated NSR values are shown on Figure 3-8. On that figure, each cross-hatched box represents the range of NSR values based on lower- and upper-bound estimates of the data, and the whisker bars correspond to the uncertainty range in NSR due to uncertainty in laboratory analytical results. The model-predicted NSR values (shown as different colored circles representing the base case post-TCRA future simulation and the various sensitivity simulations) represent average values during the Future Projection Period. This Future Projection Period included a rare flood (i.e., approximately 100-year return period, as discussed in Section 2.1) that was predicted to have a significant effect on the Model Study Area, which may bias the model predictions of NSR to some extent due to its inclusion in the simulation period (i.e., unrealistic decrease of NSR; see Anchor QEA [2012a]). Thus, model predictions for the 16-year period corresponding to flows from 1995 through 2010 are also compared to the empirically estimated NSR values. Similar comparisons of predicted and estimated NSR for the 16-year period from 1995 through 2010 are shown on Figure 3-9. Overall, these figures show that the range of sensitivity simulations result in predicted values for NSR that are within approximately a factor of 2 of the base case calibration, which in many cases is consistent with the range of uncertainty in the empirical data.

Results of the sensitivity simulations for post-TCRA conditions were also evaluated using a sediment mass balance for the Model Study Area as a metric for quantitative comparison. The sensitivity of the predicted trapping efficiency for the Model Study Area to varying the three model inputs is shown on Figure 3-10. The base case trapping efficiency predicted by the model was 17 percent, with the range of trapping efficiencies for the sensitivity simulations being 6 percent to 24 percent.[8] These results are very similar to the sensitivity analysis results for the pre-TCRA condition (Anchor QEA 2012a).

Rates of gross erosion, gross deposition, and net deposition and erosion for the base case and each of the sensitivity simulations predicted within the USEPA's Preliminary Site Perimeter are compared on Figure 3-11. Gross erosion rate was the total sediment mass eroded from all grid cells that were predicted to be erosional (i.e., bed scour) during the Future Projection Period within the USEPA's Preliminary Site Perimeter. Similarly, gross deposition rate was the total sediment mass deposited in all grid cells that were predicted to be depositional during the Future Projection Period. Rate of net change (i.e., either net deposition or erosion) was the difference between gross deposition and gross erosion (i.e., rate of change equals gross deposition minus gross erosion, with positive values being net deposition and negative values being net erosion). Overall, the sensitivity analyses result in a range in gross erosion and deposition rates that are within a factor of 2 to 3 of the base case.

Based on the results described above, sediment transport Sensitivity Simulations 2 and 7 were selected as lower- and upper-bound parameter sets to be carried forward to the evaluation of fate and transport model uncertainty (described below). The lower-bound parameter set produced the minimum trapping efficiency within the Model Study Area

[8] Simulation 4 was net erosional, so no trapping efficiency was calculated for that simulation.

(Figure 3-10), as well as the minimum net deposition rate within the USEPA's Preliminary Site Perimeter (Figure 3-11). In contrast, the upper-bound parameter set produced the second highest values of trapping efficiency within the Model Study Area (Figure 3-10) and net deposition rate within the USEPA's Preliminary Site Perimeter (Figure 3-11). Predicted NSRs within the USEPA's Preliminary Site Perimeter for these lower- and upper-bound parameter sets were in reasonable agreement with the range of measured values (Figures 3-8 and 3-9).

3.2 Chemical Fate and Transport Model

3.2.1 Model Setup

3.2.1.1 General Setup of Long-Term Simulations

As described in Anchor QEA (2012a), the chemical fate and transport model was calibrated over the 6-year period between 2005 and 2010. For the long-term future simulations conducted for the FS, the fate and transport model also used the Future Projection Period (i.e., this forecast was based on the 21-year flow and tide history used for the hydrodynamic and sediment transport models described above). These simulations were developed to predict future dioxin/furan concentrations to support relative comparisons of remedial alternatives; the historical hydrodynamic information used to project conditions during the Future Projection Period was only used as a means of estimating future flow and tide conditions in the river (i.e., this makes the reasonable assumption that flows in the future will be statistically similar to those observed in the past).

In addition, the sediment dioxin/furan concentrations in the model were revised for the simulations of post-TCRA future conditions. As described in Anchor QEA (2012a), the initial sediment concentrations specified in the model for calibration were based on concentrations of dioxins and furans in sediment collected within the Model Study Area in 2002 to 2005. For the future simulations described in this section, the sediment dioxin/furan initial concentrations in the model were updated using the 2010 to 2012 Remedial Investigation (RI) Report sediment dataset (Integral and Anchor QEA 2013). This dataset provides a more detailed characterization of contemporary dioxin/furan sediment concentrations within the USEPA's Preliminary Site Perimeter. The methodology used to develop surface sediment dioxin/furan initial conditions was generally the same as that described in Section 5.2.5.2 of Anchor QEA (2012a)—i.e., Thiessen polygons were generated for all sediment sample locations and mapped onto the model grid. However, in the area of the TCRA Site, the Thiessen polygons were generated consistent with the methodology used in the Remedial Alternatives Memorandum (Anchor QEA 2012b), whereby the polygons were generated separately for the areas within and outside the TCRA Site boundary. To simulate future (i.e., post-placement of the Armored Cap) conditions, the sediment dioxin/furan concentrations were set to zero in the grid cells corresponding to the TCRA Site. This setting in the model corresponds to the assumption of no release of dioxins/furans from that area to the overlying water column, consistent with the data collected during the Armored Cap Porewater Assessment (see Section 5.3 of the RI Report). However, the post-TCRA model simulation results (described below) show that the surface of the Armored Cap equilibrates with sediments from the surrounding area over time because of transport and deposition of dioxin-bearing sediments from upstream areas. As discussed above, to evaluate the impacts of the TCRA on relative surface water conditions, a second comparison simulation was conducted based on pre-TCRA sediment conditions; for this simulation, the surface sediment concentrations within the TCRA Site were based on RI samples collected from that area. Figures 3-12a and 3-12b present the Thiessen polygons within the USEPA's Preliminary Site Perimeter developed based on the 2010 to 2012 RI data used for these two simulations for TCDD and TCDF, respectively.

Similar to the sediment initial conditions, sediment total organic carbon (TOC) in the model was updated based on the 2010 to 2012 RI dataset. A map showing the updated model TOC is provided on Figure 3-13. All other chemical fate model inputs (i.e., boundary conditions, external loads, partition coefficients, mass transfer coefficients) used in the post-TCRA future simulations were the same as those from the calibrated model (Anchor QEA 2012a).

3.2.1.2 Uncertainty Analysis

Similar to the sediment transport model uncertainty analysis described above, the effects of input uncertainty on chemical fate model predictions were previously evaluated through sensitivity analyses conducted as part of the Chemical Fate and Transport Modeling Study (Anchor QEA 2012a). To develop uncertainty analyses for the long-term future modeling for the FS, the two bounding sediment transport simulations described in Section 3.1.1.2 above (i.e., sediment transport Sensitivity Simulations 2 and 7) were propagated through the fate model uncertainty simulations and combined with two bounding chemical fate and transport input parameter sets. The sets of bounding parameters for the fate and transport model used in this uncertainty analysis were those from the combined parameter sensitivity analysis described in Section 5.3.3.2.7 of Anchor QEA (2012a). For that sensitivity analysis, values related to bed mixing (i.e., depth and rate of bioturbation), the downstream boundary condition (i.e., estimated dioxin/furan concentrations in surface water at HSC), and partition coefficients were modified (Anchor QEA 2012a). The goal of these simulations was to produce upper-bound and lower-bound results to quantify the uncertainty range associated with the model's base case future predictions. Because different combinations of chemical fate model parameters, when coupled with the two bounding sediment transport model simulations, could produce differing responses in water column and sediment concentrations, all four possible combinations were simulated (i.e., the two bounding sediment transport simulations and two alternate sets of chemical fate parameters).

Table 3-3 lists the combinations of sediment transport and chemical fate model input sets that were used in the uncertainty analysis, and how they are referred to in the discussion of results below.

Table 3-3
Fate Model Uncertainty Simulations

		Fate Model Parameters		
Fate Run Name	**Sediment Transport Sensitivity Simulation**	**Bed Mixing**	**Downstream Boundary**	**Partition Coefficient**
Fate Uncertainty 1	Simulation 7	None	Decreased	Increased
Fate Uncertainty 2	Simulation 7	Increased	Increased	Decreased
Fate Uncertainty 3	Simulation 2	None	Decreased	Increased
Fate Uncertainty 4	Simulation 2	Increased	Increased	Decreased

3.2.2 Results

3.2.2.1 Water Column

The predicted effects of placement of the Armored Cap on surface water concentrations, including model uncertainty, were evaluated based on a review of pre- and post-TCRA water column concentration estimates for the four fate model uncertainty simulations described above. It was determined that Fate Uncertainty Simulations 1 and 4 produced the largest upper and lower bounds for the water column predictions, respectively. Therefore, all figures discussed in this section include results for six simulations: the base case (shown as solid lines) and Fate Uncertainty Simulations 1 and 4 (shown as dashed lines), each for both pre- and post-TCRA conditions. These model predictions of water quality are useful for relative comparisons of pre- and post-TCRA conditions, as well as conditions under various remedial alternatives (see Section 4) but are not equivalent to empirical measurements. This is why model uncertainty has been characterized and carried through the discussion of results below and model predictions are most appropriately used for comparative purposes on a relative basis.

As described in Section 1.1.3, the chemical fate and transport model was developed for three dioxin and furan congeners (TCDD, TCDF, and OCDD). Pre- and post-TCRA simulations were conducted for TCDD and TCDF but not OCDD; furthermore, to simplify the discussion presented in this appendix, results below are only discussed for TCDD.[9]

A longitudinal profile of annual average, model-predicted water column TCDD concentration estimates, including the model uncertainty bounds (i.e., annual averages for the two uncertainty simulations), is presented on Figures 3-14a and 3-14b. For these figures, model results were averaged using the same methodology as described in Section 5.3.2.1.1 of Anchor QEA (2012a) and are summarized as follows:

- Model results were averaged only for low-flow days, which was defined as flow less than 4,000 cfs over the Lake Houston Dam.[10]

[9] Graphics of model results for TCDF have been included in Attachment 1 to this appendix; TCDF results are not included in the discussion of this appendix because: 1) model results for TCDF were consistent with those for TCDD in all cases; 2) as noted in Anchor QEA (2012a), the fate and transport behavior of TCDF is similar to that of TCDD due to similarities in their chemical characteristics; and 3) TCDF generally contributes to TEQ in smaller proportions than TCDD (Integral and Anchor QEA 2013). Results for OCDD are not presented in this appendix because OCDD was included in the model only to provide added robustness to the calibration (i.e., because OCDD has different chemical characteristics and it exhibits a different spatial pattern across the Model Study Area as compared to TCDD/TCDF [Anchor QEA 2012a]); it is indicative of background dioxin/furan sources within the Model Study Area (Integral and Anchor QEA 2013).

[10] This also only included days in which flow over the Lake Houston Dam was greater than zero; there are often many days throughout each year where there is no freshwater flow over the dam. These zero-flow conditions were excluded from the averaging to be consistent with conditions, during which the sampling data used for model calibration were collected (Anchor QEA 2012a).

- In order to be shown on a one-dimensional longitudinal profile, the model results from the two-dimensional model grid used in the San Jacinto River were averaged laterally (i.e., across the channel), as well as longitudinally at increments ranging generally from 0.1 to 0.5 mile.
- The annual average results shown on Figures 3-14a and 3-14b are for 2 example years of the simulation. Year 11, which is shown on Figure 3-14a, represents a typical low-flow (having a relatively high frequency of days with zero freshwater inflow upstream of Lake Houston Dam) year near the middle of the model simulation. Year 7, which is shown on Figure 3-14b, represents a year exhibiting a relatively higher frequency of days with non-zero freshwater inflow upstream of Lake Houston Dam. Annual average longitudinal profiles of TCDD (and TCDF) for all years of the Future Projection Period have been included in Attachment 1.

As noted by USEPA in its comments on the draft FS, the model-predicted spatial profiles of pre-TCRA TCDD concentrations shown on Figures 3-14a and 3-14b are somewhat different from those shown for the calibrated model and data shown on Figure 5-19 in Anchor QEA (2012a). Reasons for the apparent differences include the following:

- Model results vary considerably over time and space. As noted above, the results shown on Figure 3-14a represent an annual average of a laterally averaged longitudinal profile for 1 year of the simulation (Year 11). Likewise, Figure 3-14b shows a somewhat different annual average longitudinal profile for a different year of the simulation (Year 7). (Annual average longitudinal profiles for all 21 years of the simulation are shown on Figures 1.1-1a through 1.1-1u in Attachment 1 and show considerable year-to-year variability). Much of the variability observed in the model-predicted annual average longitudinal profiles can be attributed to differences in the amount and frequency of days with zero freshwater inflow from Lake Houston Dam in a particular year.
- Figures 3-14a and 3-14b do not show the variability of daily model predictions over time (they only show annual averages for the base case and upper/lower bound uncertainty simulations), nor do they show the spatial variability among the model grid cells included in the lateral averages. To better understand the range of TCDD concentrations predicted by the model within a given year, a longitudinal profile of model-predicted annual average concentrations (including the range of predictions

associated with the base case simulation) in Year 11 is shown on Figure 3-15. Near the TCRA Site, pre-TCRA TCDD concentrations range from 0.03 to 1 ng/L TCDD, which is generally consistent with water column data collected pre-TCRA in this area.

Therefore, the apparent differences in longitudinal profiles between these simulations and the model calibration simulations (Anchor QEA 2012a) are primarily a result of year-to-year differences in flow and spatial variations that are masked by averaging. Nonetheless, these factors do not affect the use of these simulations, since the primary purpose (as stated previously) is to make relative comparisons between the various scenarios (i.e., between pre- and post-TCRA simulations in the case of Figure 3-14).

The base case and uncertainty simulations all show that the largest differences in predicted water column TCDD concentrations between pre- and post-TCRA conditions are generally within the immediate vicinity of the TCRA Site. For a given set of starting sediment concentrations (i.e., pre- or post-TCRA), the uncertainty simulations produce bounds that are within a factor of 2 to 3 of the base case results. Also, when comparing water column concentration estimates in this area between the two cases, the upper-bound (pre- versus post-TCRA) and lower-bound (pre- versus post-TCRA) simulations both show that the post-TCRA results are lower than the pre-TCRA results (similar to the base case results), with differences up to a factor of 2 to 3. Thus, these results show that although there is uncertainty in the exact magnitude of model-predicted concentrations (e.g., a factor of 2 to 3), there is relatively less uncertainty in the predicted relative reductions achieved by the TCRA (i.e., the upper and lower bounds from the uncertainty simulations show reductions in water column concentration estimates as a result of the TCRA that are both consistent with the base case).

To further illustrate differences in model-predicted pre- and post-TCRA water column concentrations, time-series plots of laterally averaged concentration estimates were developed. Figure 3-16 shows model-calculated concentration estimates of TCDD (averaged monthly) over the Future Projection Period at the following five locations:

- Lake Houston Dam

- River Mile[11] 12, which is near the U.S. 90 Bridge
- River Mile 4.5, which is just upstream of the northern limit of the USEPA's Preliminary Site Perimeter
- River Mile 2.5, which transects the TCRA Site
- River Mile -0.5, which is at the confluence between the San Jacinto River and HSC

Time-series plots were also developed to show spatially averaged model results within the USEPA's Preliminary Site Perimeter and within the footprint of the TCRA Site (Figure 3-17). The flow rate over the Lake Houston Dam is shown on the top panel of both figures.[12] Similar to the spatial profiles, these figures show that the relative differences between pre- and post-TCRA water column concentration estimates for both the upper-bound and lower-bound simulations are similar to the base case. When comparing the overall uncertainty ranges for the six simulations, these figures show that at some of the larger spatial scales, the differences between the pre- and post-TCRA simulations are likely within the range of model uncertainty, although at smaller spatial scales, the effects of the TCRA are clearly evident because there is little to no overlap of the uncertainty bounds (e.g., bottom panel of Figure 3-17).[13] These results indicate there is a relatively localized effect of the TCRA on model-predicted water column concentrations.

[11] River mile locations are shown on Figure 1-1.

[12] The hydrographs shown on Figures 3-16 and 3-17 show a notable change in flow variability starting in Year 7 (model Year 7 corresponds to hydrologic conditions in calendar year 1996 from the Future Project Period). The observed change in the flow variability at this time is related to the availability of Lake Houston Dam lake level data; specifically, lake level data post-July 1996 were used to calculate flow rate based on a rating curve of the dam spillway. When the lake water level dropped below the spillway elevation, there was no recorded flow over the Dam (resulting in flows going to zero). To estimate flow rates prior to July 1996 (when lake level data were not available), flow rate data from six USGS gauging stations located on tributaries to Lake Houston were summed and prorated based on the ratio of the drainage areas of the six tributary watersheds and the drainage area of the watershed that drains into Lake Houston. The effect of reservoir storage on flow rate at the dam was not taken into account using this method, so base flow rates were always modeled as greater than zero for the period prior to July 1996. The methodology used for this analysis is described in Section 3.3.1 of Anchor QEA (2012a).

[13] It should be recognized that model uncertainty is generally higher at smaller spatial scales than it is at larger spatial scales (as discussed in Section 1.1.3). Specifically, water column (and sediment results described later) averaged over relatively small scales, such as the TCRA Site, tend to be somewhat more uncertain than results averaged over larger areas, such as USEPA's Preliminary Site Perimeter. That said, results at these smaller scales are presented for relative comparison purposes only.

To summarize the effects of the TCRA on water column concentration estimates, average percent reductions in model-predicted, pre- and post-TCRA water column TCDD concentration estimates were calculated. Percent reductions in model-predicted water column TCDD concentrations were averaged over two timescales: 1) during the first year of the model simulation, and 2) over the entire Future Projection Period. The calculations were made on various spatial scales, consistent with those shown on Figures 3-16 and 3-17 (i.e., spatially averaged over the USEPA's Preliminary Site Perimeter, laterally averaged over the transect at River Mile 2.5 that runs directly through the TCRA Site, spatially averaged over the TCRA Site, and for the grid cell with the peak estimated concentration within the footprint of the TCRA Site). A summary of the predicted improvement in water column concentration (quantified as an estimated percent reduction between the pre- and post-TCRA model simulations) averaged over these various temporal and spatial scales is provided for the base case and Fate Uncertainty Simulations 1 and 4 in Table 3-4 below.

Table 3-4
Summary of Percent Reduction in Water Column TCDD Concentration Estimates

Run	Time Averaging Period	Percent Reduction			
		USEPA's Preliminary Site Perimeter	River Mile 2.5	TCRA Site	Peak Concentration
Base Case	Year 1	38	74	88	87
Fate Uncertainty 1		43	78	89	87
Fate Uncertainty 4		39	73	87	86
Base Case	Long-term	26	63	86	87
Fate Uncertainty 1		19	49	84	91
Fate Uncertainty 4		38	73	88	89

The base case and uncertainty simulation results all indicate that the model predicts the TCRA achieves significant relative reductions in water column TCDD concentration estimates. When looking at Year 1 of the simulation, the calculated percent reductions are relatively similar between the base case and the uncertainty bounds for all of the various averaging areas, with the uncertainty of the various percent reductions ranging from less than 1 percent to 5 percent. The following are the model's predicted results over the long term:

- When averaged over the USEPA's Preliminary Site Perimeter, the uncertainty range on the base case-predicted reduction in concentration of 26 percent is from 19 percent to 38 percent.
- Within the model grid cells corresponding to the lateral transect at River Mile 2.5, the long-term average percent reduction predicted by the model is 63 percent, with an uncertainty range of 49 percent to 73 percent.
- Within the footprint of the TCRA Site, long-term average estimated concentration reductions are similar between the base case and the uncertainty simulations (i.e., between 84 percent and 88 percent).
- Finally, at the smallest localized scale (i.e., a single model grid cell corresponding to the maximum predicted concentration in the vicinity of the TCRA Site), the base case model prediction and the uncertainty simulations all resulted in a nearly 90-percent reduction in peak TCDD concentration over the long term.

Overall, the results from these uncertainty analyses show that although there is uncertainty in the exact magnitude of model-predicted water column concentrations, there is relatively less uncertainty in the predicted relative reductions achieved by the TCRA, which average in the range of 30 percent within the USEPA's Preliminary Site Perimeter (uncertainty range of approximately 20 to 40 percent) to 90 percent in the localized areas of the TCRA Site (with uncertainty range of less than 5 percent). Water column concentrations in the immediate vicinity of the Armored Cap are not reduced completely due to various background sources, flux from sediments outside the limits of the TCRA Site, and transport associated with river currents and tidal circulation.

3.2.2.2 Surface Sediment

Model-predicted future rates of natural recovery in surface sediments, including the range of model uncertainty, were evaluated at various spatial scales over the Model Study Area using the long-term future simulation described above (i.e., starting from post-TCRA sediment concentrations and forecasting over the Future Projection Period). With regard to model uncertainty, in some cases, the four fate model sensitivity simulations described in Table 3-3 had differing effects on predicted long-term surface sediment concentrations in different portions of the Model Study Area; therefore, the figures described below contain results for all four sensitivity simulations compared with the base case predictions.

Figure 3-18 shows a time series of model-predicted surface (0- to 6-inch) sediment TCDD concentrations averaged over the USEPA's Preliminary Site Perimeter. This figure shows a base case predicted decrease in TCDD concentration of approximately 75 percent over the Future Projection Period (decreasing from an initial TCDD concentration of approximately 8 nanograms per kilogram [ng/kg] to 2 ng/kg by Year 21). To quantify the rate of decline, an exponential decay curve was fit through the model results, and the rate of decline was calculated (see example for the base case simulation shown as a dotted line on Figure 3-18); the model-predicted decline of TCDD in surface sediment concentrations within the USEPA's Preliminary Site Perimeter corresponds to a half-life of 11 years. Although the model results vary year-to-year due to differences in flow conditions (which drive differences in sediment transport), the nature of the predicted recovery curve (i.e., an exponential decline) exhibits an asymptotic behavior, which is expected because concentrations of dioxins/furans would be expected to approach regional background concentrations associated with remaining sources of dioxins/furans (i.e., point and non-point sources, transport from upstream) in the area. For the uncertainty simulations, this predicted decline ranges from more than 85 percent (Fate Uncertainty 1) to 40 percent (Fate Uncertainty 4), corresponding to half-lives that vary by about a factor of 2 from the base case, ranging from 7 years to 24 years (Figure 3-18). The faster rates of recovery predicted for the Fate Uncertainty 1 simulation are a result of a combination of increased sedimentation rates and decreased mixing within the bed for this simulation. Conversely, the slower rates of recovery predicted for the Fate Uncertainty 4 simulation are a result of lower sedimentation and increased mixing within the bed.

Figure 3-19 shows time-series plots of model-predicted surface (0- to 6-inch) sediment TCDD concentrations averaged over 1-mile reaches in the vicinity of the TCRA Site. Similar to the spatial averages calculated for the USEPA's Preliminary Site Perimeter, the 1-mile reach averages show a trend of decreasing surface sediment concentrations over the model simulation period. The predicted natural recovery in this area can be attributed to ongoing deposition of lower concentration sediments derived from upstream areas of the river. The 1-mile reach that includes the TCRA Site (River Miles 3 to 2) shows a predicted decrease in concentration consistent with that for the USEPA's Preliminary Site Perimeter (i.e., 75-percent decrease corresponding to an 11-year half-life, with an uncertainty range that varies by about a factor of 2 to 3 from the base case). These results also show year-to-year variability, which is a result of varying flow and sediment transport conditions. For example, the model predicts an increase in concentration during Year 5 within River Miles 3 to 2, which is a result of predicted erosion during the highest flow event included in the simulation (corresponding to a return period between 50 and 100 years, as discussed in Section 2.1), but that increase only has a temporary effect on the long-term average trend predicted within that 1-mile area. Predicted rates of natural recovery in the other 1-mile reaches are similar to that in the reach containing the TCRA Site (i.e., half-lives of approximately 10 years), with estimated uncertainty ranges of approximately a factor of 2 to 3 (i.e., half-life values ranging from approximately 5 to 35 years). In some cases, the year-to-year variability in surface sediment concentrations is greater than others; however, an important finding from these simulations is that, despite the relatively wide ranges in parameter values included in these various uncertainty simulations, the model predicts decreases in concentration in all cases and spatial scales over the long term.

Lastly, as described in Section 3.2.1, the Armored Cap was simulated by setting the sediment bed TCDD/TCDF concentrations to zero within the corresponding model grid cells (which eliminated flux of dioxins/furans from this area to the overlying water column). Figure 3-20 shows a time-series plot of the base case model-predicted surface sediment TCDD concentrations averaged over this area (i.e., the capped area). Because concentrations were initially set to zero in this area, Figure 3-20 can be used to evaluate the model's prediction of sediment re-equilibration levels within the surface of the Armored Cap. This figure shows predicted surface sediment TCDD concentrations increasing to approximately 2 ng/kg over the Future Projection Period. This predicted increase is a result of deposition of sediments from the surrounding areas of the river on the surface of the Armored Cap, and the concentration is generally consistent with regional background levels in surface sediment (e.g., Table 4-5 of the RI Report indicates TCDD background concentrations range from 0.01 to 5 ng/kg; Integral and Anchor QEA 2013).

4 MODELING TO SUPPORT EVALUATION OF REMEDIAL ALTERNATIVES

As described in Section 3.2.2.2 above, the post-TCRA future chemical fate model simulation was used to evaluate relative changes in surface sediment dioxin/furan concentrations over time (i.e., rates of natural recovery) in the Model Study Area. The results from this simulation apply to Alternatives 1N through 3N evaluated in the FS (as discussed in Section 4.1). Section 4.2 provides a description of additional model simulations that were conducted for FS Alternatives 4N, 5N, 5aN, and 6N, which include active remediation of sediments within the TCRA Site, as well as one other area within the USEPA's Preliminary Site Perimeter in the case of Alternative 6N. In addition to evaluating general long-term trends for these alternatives, the model's predictions of future sediment and water column dioxin/furan concentrations from these simulations were used to quantify potential short- and long-term impacts associated with the construction activities (i.e., sediment resuspension and release during remediation and effects of dredge residuals).[14]

4.1 Simulation of Natural Recovery for FS Alternatives

The predicted rates of natural recovery presented in Section 3.2.2.2 apply to Alternatives 1N through 3N for the FS. For the purposes of chemical fate and transport modeling, these alternatives can all be characterized by the post-TCRA future simulation because Alternatives 1N (No Further Action) and 2N (ICs and MNR) have no additional remedial activities, and Alternative 3N only includes construction of the Permanent Cap, which would not be expected to create any significant potential for construction-related releases of dioxins/furans. Therefore, there would be no significant differences in future surface water or sediment concentrations among Alternatives 1N through 3N; thus, the long-term chemical fate model predictions described in Section 3.2.2 would be the same for all three of these alternatives.

4.2 Simulation of Remediation Alternatives 4N, 5N, 5aN, and 6N

Additional simulations were conducted using the calibrated fate and transport model for FS Alternatives 4N, 5N, 5aN, and 6N, because these alternatives include active remediation of

[14] As noted previously, despite there being various sources of uncertainty associated with the model, they do not hinder the model's ability to evaluate remedial alternatives on a comparative (relative) basis, because most sources of uncertainty are common to all alternatives.

sediments that could affect long-term chemical fate and transport within the Model Study Area (due to resuspension and release during remediation and dredge residuals). The remediation components of these alternatives are as follows:

- Alternatives 4N and 5N include the same Permanent Cap as Alternative 3N, as well as partial remediation of sediments from portions of the TCRA Site. For Alternative 4N, this would consist of solidification/stabilization (S/S) of soils/sediments beneath the Armored Cap that have concentrations exceeding 13,000 ng/kg on a toxicity equivalent (TEQ) basis whereas for Alternative 5N, it would involve removal of those same materials, after which the remediated area would be backfilled and the Armored Cap would be replaced/reconstructed and then enhanced to create a Permanent Cap.
- Alternative 5aN includes partial removal of sediments exceeding the PCL for protection of the hypothetical recreational visitor (220 ng/kg TEQ) for the area within the Armored Cap with water depth shallower than 10 feet. Under this alternative, portions of the Armored Cap would remain in place and would be enhanced to create a Permanent Cap. A sand cover would be placed in the dredged areas following removal to address dredge residuals.
- Alternative 6N includes full removal of soils/sediments from the TCRA Site, as well as removal of sediments exceeding the PCL in one other area of the USEPA's Preliminary Site Perimeter. A sand cover would be placed following removal to address dredge residuals.

The simulations of these alternatives utilized the same 21-year future simulation length, hydrologic conditions, and boundary loads as described for the simulations of post-TCRA future conditions in Section 3.2.1. However, unlike the simulation of post-TCRA conditions, these simulations account for the effects of sediment remediation on dioxins/furans within the Model Study Area, and as such, required the following:

- "Mapping" of the remediation footprints onto the chemical fate model grid
- Specification of dioxin/furan releases during in-water construction activities associated with the sediment remediation
- Specification of post-remediation concentrations, including simulation of the effects of dredge residuals on sediment concentrations for certain cases

Details regarding the additional model setup required for simulation of these alternatives are provided in the subsection that follows.

4.2.1 Model Setup

4.2.1.1 Mapping of Remediation Areas onto the Model Grid

In order to simulate Alternatives 4N, 5N, 5aN, and 6N in the fate model, the footprint of the remediation area for each alternative was first "mapped" onto the fate model grid. As discussed in Section 4 of the FS, the remediation footprints are defined as follows:

- For Alternatives 4N and 5N, the footprint was based on the limited portion of the TCRA Site containing dioxin/furan concentrations in excess of 13,000 ng/kg on a TEQ basis. The resulting remediation footprint consists of two areas, which are termed the Eastern Cell and Western Cell (as defined in the FS; Figure 4-1). Because remediation of the Western Cell would be performed from land, releases during remediation would be expected to be minimal from that area; therefore, only the Eastern Cell was represented in the model simulations for these two alternatives.
- The Alternative 5aN dredging footprint was delineated to encompass the portion of the TCRA Site containing sediment samples with concentrations exceeding a PCL of 220 ng/kg TEQ and water depths shallower than 10 feet. Note that this area also includes all sample locations that exceed 13,000 ng/kg TEQ, as required by USEPA when they developed this alternative.
- The Alternative 6N dredging footprint was delineated to encompass all areas containing sediment samples with concentrations exceeding a PCL of 220 ng/kg TEQ. These areas included a large portion of the TCRA Site, as well as one sample polygon offshore of the San Jacinto River Fleet (SJRF) property (Figure 4-1).

These remediation areas were mapped onto the chemical fate model grid as shown on Figure 4-1.

4.2.1.2 Releases during Sediment Remediation

The model's simulation of sediment remediation accounts for releases of dioxins/furans during construction by specifying a fraction of the chemical mass present in the remediated sediment (i.e., sediment that is removed in the case of Alternatives 5N, 5aN, and 6N, or that which undergoes S/S in the case of Alternative 4N) that could be released to the water column under the simulated conditions. Details on how this potential release was represented in the model are discussed below.

Potential releases of chemical mass during remediation activities were simulated in the fate model as a dissolved phase flux of dioxins/furans to the water column within each remediated grid cell. The magnitude of that release flux was determined based on the average concentration and depth of sediments removed (or subject to S/S in the case of Alternative 4N), an assumed fraction of dioxin/furan mass released, and the construction schedule associated with the removal or S/S activities (i.e., time it takes to remediate that grid cell based on the specified production rate for the alternative). For each remediation footprint, an average depth of remediation and volume-weighted average concentration within the remediation prism were calculated. These values were used in conjunction with each grid cell's surface area and bulk density to calculate the mass of dioxins/furans remediated for the purposes of the model's release calculation. The depths and concentrations used in these calculations are listed in Table 4-1.

Table 4-1
Average Remediation Depth and Volume-Weighted Average Sediment Concentration Used for Calculating Potential Releases During Construction

Alternative / Remediation Area	Average Depth of Remediated Sediment (feet)	Volume-Weighted Average Concentration in Remediation Prism	
		TCDD (ng/kg)	TCDF (ng/kg)
Alternatives 4N and 5N (Eastern Cell of footprint within TCRA Site)	7	5,600	23,800
Alternative 5aN (portion of TCRA Site with water depth < 10 feet)	6.75	5,100	15,800
Alternative 6N (TCRA Site)	6.75	4,300	13,100
Alternative 6N (polygon adjacent to SJRF property)	6	120	500

The dioxin/furan mass release fractions applied in the calculations are as follows:

- For simulation of S/S under Alternative 4N (Eastern Cell only) and sediment removal under Alternative 5aN (which would include the construction of an earthen berm and sheetpile wall as an engineered barrier to manage water quality during construction), a release rate of 0.85 percent was assumed. This value was based on the midpoint of the range of release values estimated from areas of the Hudson River in which sediment removal was performed within sheet pile walls (Anchor QEA and Arcadis 2010). This value is in the low end of the range observed from sites where dredge release has been measured. It was assumed for the purposes of these model simulations to be representative of releases that could occur when engineered barriers are utilized to manage water quality during construction (under Alternative 5aN) or due to disturbance of the sediments during S/S activities (under Alternative 4N).
- Simulation of release during sediment removal under Alternatives 5N (Eastern Cell only) and 6N assumed the fraction of dioxins/furans released during removal was 3 percent of the chemical mass removed. This value is based on case studies of dredging release at various contaminated sediment sites across the country, as summarized in Section 5.4.2 of the FS Report (see FS Table 5-2).

The mass of dioxin/furan released (calculated in each grid cell based on the average depth and concentration of remediated sediment and the assumed release rates as described above) was specified in the model to occur uniformly over the time needed to complete the in-water remediation activities of a given alternative. These times were estimated to be 1.5 months and 0.5 month for Alternatives 4N and 5N, respectively (Eastern Cell only), 8.5 months for Alternative 5aN, and 13 months for Alternative 6N; the start of remediation was specified to begin in the first year of the projection period for each alternative.

4.2.1.3 Sediment Bed Concentrations Following Remediation

Because the remediation activities for Alternatives 4N and 5N would include backfilling followed by replacement/reconstruction of the Armored Cap, it was assumed for the purposes of modeling that the surface sediment concentration within the remediated grid cells would be zero following construction, consistent with the method used to simulate the Armored Cap in the post-TCRA future simulation. However, due to the extensive removal under Alternatives 5aN and 6N, the remediation would be conducted through in-water construction techniques (dredging), followed by placement of a sand cover to manage residuals. Thus, an analysis of post-remediation sediment concentrations was needed for accurate simulation of that alternative in the model. The methods used for specifying post-remediation bed concentrations in the model to account for the Alternatives 5aN and 6N dredging are described below.

Sediment removal under Alternatives 5aN and 6N was simulated in the fate model by resetting the simulated sediment bed to reflect post-dredging conditions within the removal areas. The corresponding post-remediation sediment concentrations were specified to account for three factors: 1) sediment residuals that would be generated following dredging; 2) the observed concentration of the (un-dredged) sediment present beneath the neatline elevation of the last dredge pass; and 3) the placement of a sand cover following dredging to manage residuals.

The potential for generating residuals during dredging is well documented (e.g., Patmont and Palermo 2007; U.S. Army Corps of Engineers 2008a, 2008b; Bridges et al. 2010). Based on information regarding residuals generated at other sites where environmental dredging has been performed (e.g., Patmont and Palermo 2007; Bridges et al. 2010; Anchor Environmental 2007; Alcoa 2006), post-remediation sediment bed concentrations in areas subject to dredging were specified in the model as follows:

- Deep sediments (i.e., the bottom 39 inches of the simulated 48-inch sediment bed) were set to un-dredged sediment concentrations that were specified based on sampling data. Note that Alternative 6N includes two separate dredge areas (i.e., the TCRA Site and the polygon adjacent to the SJRF property); given the relatively small size of these two dredge areas (relative to the size of the overall model grid), the deep sediment concentration was defined as a single average concentration over each of these two areas.

- A 3-inch layer of dredge residuals was assumed to be generated above the deeper un-dredged sediments;[15] dioxin/furan concentrations in the residual layer were assumed to be equal to sediment concentrations in the deepest samples above the specified dredge depths, which were considered representative of the last dredge pass (Patmont and Palermo 2007; Bridges et al. 2010). In other words, because Alternatives 5aN and 6N include removal of sediments exceeding the PCL (220 ng/kg TEQ), the residual layer concentration was defined based on sampling data collected immediately above the 220 ng/kg TEQ depth horizon (which in many cases was greater than 220 ng/kg TEQ). As with the deep concentrations, the residual layer concentrations were defined as a single average concentration over the footprint of each dredge area.
- The top 6 inches of the simulated bed sediment in each dredge area was assumed to consist of a residual cover (e.g., sand); dioxin/furan concentrations in this cover material were assumed to be 5 percent of the dredge residual concentrations (due to mixing when the cover is placed). This value was specified based on experience from other dredging projects (e.g., Alcoa 2006; Anchor Environmental 2007).

Table 4-2 provides a summary of the concentrations of TCDD and TCDF specified for the various model bed layers described above under Alternatives 5aN and 6N. These concentrations were calculated based on the same surface and subsurface sediment core data used to determine the horizontal and vertical extents of removal as described in Section 4 of the FS.

[15] The 3-inch residual layer thickness was specified based on an assumed average 6-foot dredge cut plus 1-foot over-dredge, with 5-percent sediment loss (i.e., [6 feet + 1 foot] * 0.05 = 4.2 inches); this thickness was rounded down to 3 inches, which is the thickness of a single model sediment bed layer.

Table 4-2
Summary of Post-Remediation Sediment Bed Concentrations for Alternatives 5aN and 6N

Alternative / Remediation Area	Model Bed Layer	TCDD (ng/kg)	TCDF (ng/kg)
Alternative 5aN (portion of TCRA Site with water depth < 10 feet)	Top 6 inches (residual cover)	*(3,956 × 0.05)* = 198	*(9,979 × 0.05)* = 499
	Next 3 inches (residual layer)	3,956	9,979
	Bottom-most 39 inches (un-dredged sediment)	37	107
Alternative 6N (TCRA Site)	Top 6 inches (residual cover)	*(3,956 * 0.05)* = 198	*(9,979 * 0.05)* = 499
	Next 3 inches (residual layer)	3,956	9,979
	Bottom-most 39 inches (un-dredged sediment)	37	107
Alternative 6N (polygon adjacent to SJRF property)	Top 6 inches (residual cover)	*(224 * 0.05)* = 11	*(1,050 * 0.05)* = 53
	Next 3 inches (residual layer)	224	1,050
	Bottom-most 39 inches (un-dredged sediment)	6	17

4.2.2 Results

This subsection presents the results from the fate and transport model long-term (21-year) simulations of Alternatives 4N, 5N, 5aN, and 6N for TCDD (results for TCDF are contained in Attachment 1). For comparison purposes, the water column and sediment TCDD concentration estimates predicted for these three alternatives are presented together on overlay plots, along with those from the simulation of post-TCRA future conditions (representative of Alternatives 1N through 3N) described in Section 3.2.2. Hereafter in this appendix, the post-TCRA future simulation is referred to as “Alternatives 1N through 3N.”

4.2.2.1 Water Column

Longitudinal profiles of predicted water column TCDD concentration estimates during the first year of the simulation are shown on Figure 4-2a. As shown on this figure, predicted lateral average water column concentration estimates for Alternatives 4N, 5N, 5aN, and 6N all exhibit substantial increases in the vicinity of the TCRA Site relative to the simulation for Alternatives 1N through 3N. These predicted increases are a result of simulated releases of TCDD during remediation within the TCRA Site for these alternatives (which is simulated to occur over the first month or two for Alternatives 4N and 5N, the first 8.5 months for

Alternative 5aN, and the first 13 months of the simulation for Alternative 6N). The magnitude of these predicted increases is proportional to the volume of remediated sediment and the assumed release rate associated with the construction techniques (discussed in Section 4.2.1.2 above). Relative to Alternatives 1N through 3N, the Year 1 average concentrations in the area of the TCRA Site are predicted to increase by approximately 10-, 50-, 90- and more than 100-fold for Alternatives 4N, 5N, 5aN, and 6N, respectively, as a result of the simulated TCDD releases during remediation. Several years following the simulated remediation, as represented by model results from simulation Year 11 (Figure 4-2b), differences in predicted water column concentration estimates between the Alternatives 1N through 3N simulation and results for Alternatives 4N, 5N, 5aN, and 6N are much smaller. Concentration estimates throughout the USEPA's Preliminary Site Perimeter predicted for Alternatives 4N and 5N in Year 11 are indistinguishable from those predicted for Alternatives 1N through 3N, and those for Alternatives 5aN and 6N are only slightly higher than Alternatives 1N through 3N (i.e., increases of 50 percent or less for Alternative 5aN and 70 percent or less for Alternative 6N), due to elevated flux from sediments (discussed more below).

Figure 4-3 shows time-series plots of model-predicted monthly average water column TCDD concentration estimates averaged over the USEPA's Preliminary Site Perimeter and within the footprint of the TCRA Site for the various alternatives (i.e., Alternatives 4N, 5N, 5aN, 6N, and Alternatives 1N through 3N). This figure also shows the large predicted increases in water column concentration estimates during Year 1 of the simulations for Alternatives 4N, 5N, 5aN, and 6N (relative to Alternatives 1N through 3N), within both averaging areas; the timing of these increases corresponds directly to the simulated remediation durations associated with these alternatives. After the simulated remediation is complete, the results for Alternatives 4N/5N and 5aN/6N exhibit differing behavior, as follows:

- Average water column concentration estimates within the USEPA's Preliminary Site Perimeter for Alternatives 4N and 5N are predicted to decrease to levels consistent with those predicted under Alternatives 1N through 3N following the simulated remediation (Figure 4-3, middle panel). Similar results are predicted for average water column concentrations within the footprint of the TCRA Site (Figure 4-3, bottom panel), although the Alternative 4N/5N results are predicted to be slightly elevated as compared to Alternatives 1N through 3N.

- For Alternatives 5aN and 6N, the average water column concentration estimates predicted within the USEPA's Preliminary Site Perimeter generally track those predicted for the Alternatives 1N through 3N simulation following remediation (i.e., after Year 1); however, the Alternatives 5aN and 6N results are generally higher than those of Alternatives 1N through 3N. Results for Alternative 6N are approximately double those of Alternatives 1N through 3N for approximately 5 years after completion of the simulated dredging (and results for Alternative 5aN are somewhat lower than those of Alternative 6N but still higher than those for Alternatives 1N through 3N). The predicted increases under these two alternatives are indicative of potential for long-term impacts in some areas. Longer term, water column concentration estimates within the USEPA's Preliminary Site Perimeter predicted for Alternative 5aN and 6N approach those of Alternatives 1N through 3N (i.e., approximately 11 years after remediation), as lower concentration sediments are deposited in that area. Average concentrations within the TCRA Site for Alternative 5aN and 6N are also predicted to decrease after the simulated dredging. Ten years after remediation, the results for Alternatives 5aN and 6N are approximately two to four times higher than those predicted under Alternatives 1N through 3N (with results for Alternative 6N being somewhat higher than those predicted for Alternative 5aN). By the end of the Future Projection Period, the difference between Alternatives 1N through 3N and Alternatives 5aN and 6N decreases to about a factor of two. This predicted difference between Alternatives 5aN/6N relative to Alternatives 1N through 3N is due to a combination of sediment residuals generated during dredging within the TCRA Site (i.e., higher concentration sediments at depth are brought to the surface as residuals during removal and subsequently simulated to be entrained within the residual cover) and TCDD that is redistributed following release during dredging; these two factors are discussed further below.

4.2.2.2 Surface Sediment

Time series of model-predicted surface sediment TCDD concentrations averaged over the USEPA's Preliminary Site Perimeter for Alternatives 1N through 3N and Alternatives 4N, 5N, 5aN, and 6N are shown on Figure 4-4. This figure shows that the average surface sediment concentrations within this area are predicted to increase in Year 1 under

Alternatives 4N, 5N, 5aN, and 6N, as compared to Alternatives 1N through 3N. The magnitudes of these increases differ for each alternative, with those for Alternatives 4N and 5N being 1 and 2 ng/kg (approximate increases of 12 percent and 25 percent), respectively, whereas the concentrations predicted for Alternatives 5aN and 6N at the end of Year 1 represent an approximate two- and three-fold increase, respectively, relative to Alternatives 1N through 3N. The large predicted increases for Alternatives 5aN and 6N are due in part to high concentration sediment residuals that are generated during the simulated dredging within the TCRA Site. The predicted increases for Alternatives 4N and 5N, as well as a majority of those predicted for Alternatives 5aN and 6N, are due to fluxes of dissolved dioxins/furans simulated to be released during remediation that partition onto suspended sediments and are subsequently re-deposited both within and outside of the TCRA Site. Following these initial increases, the surface sediment concentrations predicted for Alternatives 4N, 5N, 5aN, and 6N generally track those of the Alternatives 1N through 3N simulations, declining at an average half-life of about 10 years (albeit at higher concentrations, especially for Alternatives 5aN and 6N).

Figure 4-5 shows time-series plots of surface sediment TCDD concentrations averaged over 1-mile reaches within the vicinity of the TCRA Site. The river mile that includes the TCRA Site (River Miles 3 to 2) shows initial increases in sediment concentration for Alternatives 4N, 5N, 5aN, and 6N that are similar to those shown on Figure 4-4 (i.e., approximately 20 to 30 percent for Alternatives 4N and 5N, two-fold for Alternative 5aN, and almost three-fold for Alternative 6N). For the remaining three 1-mile reaches, the predicted sediment concentrations under Alternatives 4N and 5N are similar to or slightly higher in some cases (e.g., Alternative 5N in River Miles 4 to 3) than those predicted under Alternatives 1N through 3N. The predicted sediment concentrations for Alternative 5aN are somewhat higher than those for Alternatives 1N through 3N, 4N, and 5N; however, the results for Alternative 6N show noticeable predicted increases in concentration relative to Alternatives 1N through 3N, 4N, 5N, and 5aN in all three one-mile reaches (although the absolute magnitude of these increases is small in some cases; e.g., 1 to 2 ng/kg in River Miles 5 to 4). The larger increase observed under Alternative 6N are due to dissolved TCDD that was simulated to be released during remediation within the TCRA Site, and was predicted to partition onto suspended sediments that were being transported in the area and subsequently deposited outside of the TCRA Site. The larger increase predicted for River Miles 3 to 2 under Alternatives 5aN and 6N is also due in part to the simulated sediment residuals generated during dredging within the TCRA Site. The effects of dredge release and subsequent redistribution for Alternative 5aN and 6N are further explored through the graphics described below.

The effects of redistribution of TCDD following release during remediation, as predicted by the model, are further evident when surface sediment concentrations are viewed on a model grid cell basis. Figures 4-6a, 4-6b, 4-6c, and 4-6d present maps of model-predicted surface sediment concentrations at the end of simulation Year 1 for Alternatives 4N, 5N, 5aN, and 6N, respectively. Each figure shows the results from the Alternatives 1N through 3N simulation on the left panel (for comparison), the results for the given alternative on the center panel, and the difference between concentrations predicted for the given alternative and Alternatives 1N through 3N on the right panel (positive values on these panels indicate a predicted increase in concentration relative to Alternatives 1N through 3N). These figures illustrate the predicted spatial patterns of TCDD redistribution following release during remediation for Alternatives 4N, 5N, 5aN, and 6N, as indicated by the areas of increased concentrations surrounding the TCRA Site. The magnitude of these increases and spatial extent over which they occur differs by alternative, according to the magnitude of TCDD mass simulated to be released during remediation. For example, for Alternative 4N, a relatively small zone of increases in the range of 1 to 3 ng/kg is predicted (Figure 4-6a), with larger increases of 3 to 10 ng/kg predicted within the TCRA Site. The corresponding areas of similar increases are larger for Alternative 5N (Figure 4-6b), with increases of 3 to 10 ng/kg extending beyond the TCRA Site and downstream of the I-10 Bridge, and increases of 1 to 3 ng/kg occurring over half of the USEPA's Preliminary Site Perimeter. Alternative 5aN shows a larger area of redistribution, with increases of 1 to 3 ng/kg predicted throughout most of the USEPA's Preliminary Site Perimeter, increases of 3 to 10 ng/kg throughout a large fraction of that area, and increases of 10 to 30 ng/kg in a small area near the TCRA Site. The redistribution following the simulated Alternative 6N dredge release is even more extensive; it is predicted to result in increases in 3 to 10 ng/kg over most of the USEPA's Preliminary Site Perimeter, with increases of over 30 ng/kg immediately adjacent to the TCRA Site.

Model results averaged over the TCRA Site are shown on Figure 4-7. As described in Section 3.2.2.2, the results for Alternatives 1N through 3N shown on this plot represent the average

TCDD concentration in sediments that deposit on the surface of the Armored Cap (which approach 2 ng/kg at the end of the Future Projection Period). The results for Alternatives 4N, 5N, 5aN, and 6N show differences relative to Alternatives 1N through 3N that reflect the effects of simulated release/redistribution and dredge residuals in the case of Alternatives 5aN and 6N. For Alternatives 4N and 5N, the effects of simulated release during remediation within the TCRA Site and subsequent redeposition causes predicted TCDD concentrations to increase to 30 and 40 ng/kg, respectively. The model's representation of dredging conducted under Alternatives 5aN and 6N results in an average surface sediment concentration in this area that is more than two orders of magnitude higher than Alternatives 1N through 3N (i.e., over 200 ng/kg). This value is consistent with the concentrations of the residual covers specified in this area (see Table 4-1) but higher as a result of TCDD that was predicted to be released during dredging and subsequently redeposited in that area. Following these initial increases associated with remediation, the concentrations within the TCRA Site are predicted to decrease by approximately a factor of two over the remainder of the simulations of Alternatives 4N, 5N, 5aN, and 6N, as a result of deposition of sediments derived from upstream areas.

Overall, the simulations of Alternatives 4N, 5N, 5aN, and 6N indicate that short- and long-term impacts associated with simulated releases during sediment remediation and dredge residuals in the case of Alternative 5aN and 6N are predicted to result in increases in estimated surface water and surface sediment concentrations when compared to the Alternatives 1N through 3N simulation. The magnitudes of these increases differ by alternative and the spatial scale over which model results are averaged, with those associated with Alternative 6N and the small scale of the TCRA Site area being the largest.

5 SUMMARY

The modeling framework developed in the Chemical Fate and Transport Modeling Study was used as a tool for evaluating remedial alternatives in the FS.

As directed by USEPA (Miller 2012, pers. comm.), additional hydrodynamic and sediment transport model sensitivity analyses were first conducted. Analyses using an alternate data source to specify WSE at the downstream hydrodynamic model boundary indicated minimal effect on sediment transport within the USEPA's Preliminary Site Perimeter. Model simulations were conducted to evaluate high-flow events with return periods of 2, 10, and 100 years. Within the USEPA's Preliminary Site Perimeter, the model predicted areas of both net deposition and net erosion for these flood event simulations, with increases in the area and depth of erosion with increasing return period flows. In general, depths of erosion and deposition within the corresponding areas during these events were predicted to average a few cm or less, with bed scour greater than 10 cm only being predicted in a limited area for the 100-year event. Longer-term simulations that include the effects of an approximate 100-year flood event indicate that following such erosion during flood events, the system recovers, consistent with its state of long-term net deposition.

The chemical fate model was then used to develop future predictions of dioxin and furan concentrations in sediment and surface water within the Model Study Area. Simulations were first conducted for post-TCRA future conditions by configuring the model to represent the Armored Cap at the TCRA Site. This included changing sediment transport model inputs to reflect the characteristics of the Armored Cap and setting the chemical concentration of the corresponding grid cells to zero in the chemical fate and transport model (to represent the Armored Cap's elimination of dioxin/furan flux to the surface water). The model was run for a 21-year future period based on the hydrologic record from 1990 through 2011 that included wide variations in flows and tidal conditions, including an approximate 100-year event. These post-TCRA future simulations were also conducted with alternate sets of model input parameters, for both sediment transport and chemical fate, to develop uncertainty bounds on the model predictions.

By comparing results from the post-TCRA simulations to those from similar simulations conducted based on pre-TCRA sediment concentrations, the model was used to evaluate the effects of the TCRA on surface water dioxin and furan concentration estimates within the Model Study Area. The chemical fate model predicted significant improvements in surface water concentrations as a result of the TCRA; reductions were predicted over several spatial scales. Within the USEPA's Preliminary Site Perimeter, surface water concentration estimates were predicted to be reduced by a factor of 2 to 3 (with the post-TCRA concentrations being driven by sources of dioxins/furans from upstream transport and point and non-point sources in the Model Study Area). These findings were not significantly affected by the model uncertainty analysis, which provided quantitative bounds on these reductions. However, it should be noted that the underlying water column dataset used to develop and calibrate the fate and transport model was smaller than the sediment data, imparting some uncertainty in the predictions of absolute concentrations.

The long-term post-TCRA simulations were also used to predict rates of natural recovery in surface sediments; these predictions are representative of FS Alternatives 1N, 2N, and 3N. The model predicted long-term declines in average surface sediment concentrations throughout the USEPA's Preliminary Site Perimeter consistent with an approximate 10-year half-life. Although there are periods of variability in the predicted surface sediment concentration trends that coincide with variations in flow and sediment transport conditions (e.g., periodic erosion), the longer-term predicted trends are characterized by declines throughout the simulation. Uncertainty analyses conducted for these simulations did not produce significantly differing results—despite the relatively wide ranges in parameter values evaluated, the model predicted long-term declines in surface sediment concentration in all cases and spatial scales. The model also predicted average surface sediment concentrations in the Armored Cap, which initially were set to zero, to increase to a level that approaches regional background concentrations.

Finally, simulations were conducted for the active sediment remediation alternatives (i.e., partial S/S and removal within the TCRA Site for FS Alternatives 4N and 5N, respectively, extensive sediment removal within the TCRA Site for Alternative 5aN, and extensive sediment removal within the TCRA Site and one other area for Alternative 6N). In addition to evaluating general long-term trends for these alternatives, the model was used to quantify potential short- and long-term impacts associated with the sediment remediation activities (i.e., sediment resuspension and release during remediation and the effects of dredge residuals). Within and outside the TCRA Site, the model predicted large increases in surface water concentrations during Year 1 of the simulations of Alternatives 4N, 5N, 5aN, and 6N (relative to the simulation of Alternatives 1N through 3N). These short-term increases in predicted surface water concentrations ranged from approximately an order of magnitude for Alternative 4N to greater than two orders of magnitude for Alternative 6N, and were due to simulated releases during remediation. Following the initial simulated remediation period, model results for Alternatives 4N and 5N showed little to no increase in surface water concentration estimates relative to Alternatives 1N through 3N, whereas predicted concentrations for Alternatives 5aN and 6N remained higher than the Alternatives 1N through 3N simulation by a factor of 2 or more within the footprint of the TCRA Site throughout the duration of the long-term simulation. Increases in surface sediment concentration in and around the TCRA Site (relative to Alternatives 1N through 3N) were also predicted for Alternatives 4N, 5N, 5aN, and 6N. These increases were a result of simulated dissolved phase releases during remediation that partition onto suspended sediments as they are transported in the area and subsequently deposit on the sediment bed, as well as dredge residuals in the case of Alternative 5aN and 6N. The magnitude of these increases differed by alternative and also by the spatial scale over which the model results were averaged, with those associated with Alternatives 5aN and 6N and the small scale of the TCRA Site area being the largest. The spatial extent of these predicted increases was also greatest for Alternatives 5aN and 6N, for which increases were predicted to occur over large portions of the USEPA's Preliminary Site Perimeter.

Overall, the results from the post-TCRA simulations of natural recovery (i.e., Alternatives 1N, 2N, and 3N) and the simulations of the active sediment remediation alternatives (i.e., Alternatives 4N, 5N, 5aN, and 6N) provide predictions of long-term relative changes in surface water and sediment dioxin/furan concentrations, as well as quantitative estimates of the potential short- and long-term effects of sediment remediation, that were used to support the comparative evaluation of alternatives conducted in the FS.

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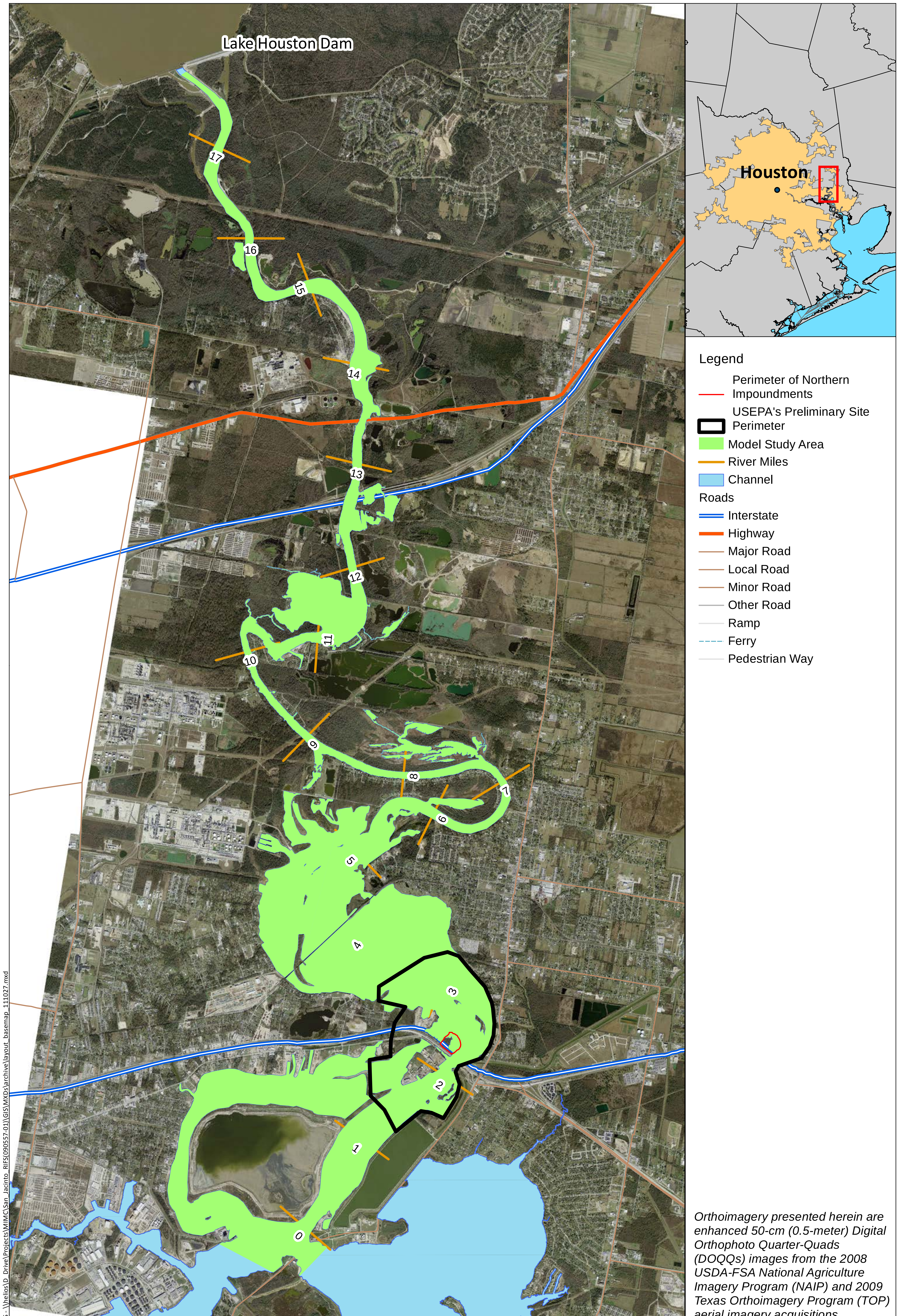

Legend

- Perimeter of Northern Impoundments
- USEPA's Preliminary Site Perimeter
- Model Study Area
- River Miles
- Channel

Roads

- Interstate
- Highway
- Major Road
- Local Road
- Minor Road
- Other Road
- Ramp
- Ferry
- Pedestrian Way

Orthoimagery presented herein are enhanced 50-cm (0.5-meter) Digital Orthophoto Quarter-Quads (DOQQs) images from the 2008 USDA-FSA National Agriculture Imagery Program (NAIP) and 2009 Texas Orthoimagery Program (TOP) aerial imagery acquisitions.

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Miles: 0 0.5 1 1.5 2

Figure1-1
Model Study Area
Feasibility Study
San Jacinto River Waste Pits Superfund Site

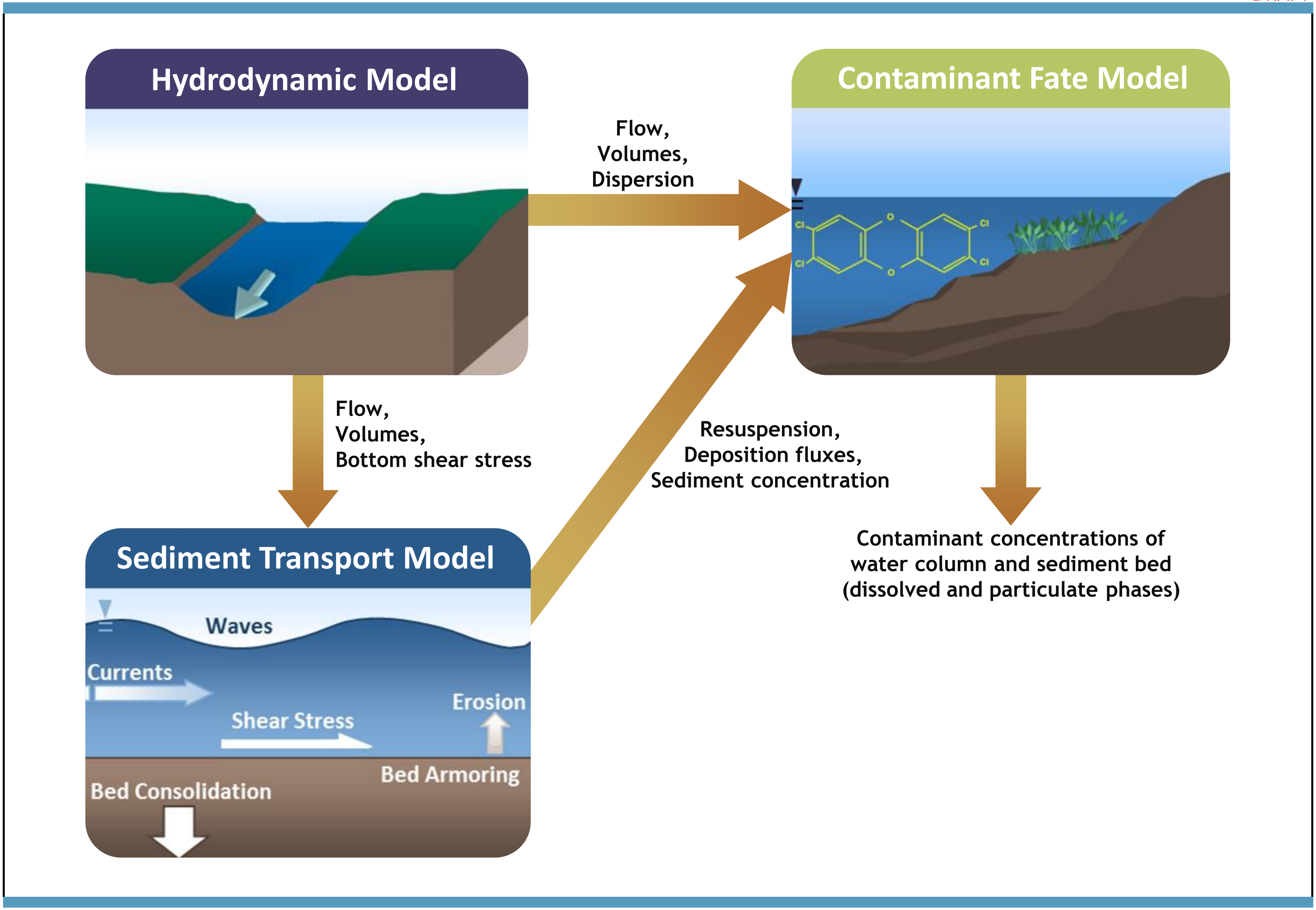

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Figure 1-2
Fate Model Linkages
Feasibility Study
San Jacinto River Waste Pits Superfund Site

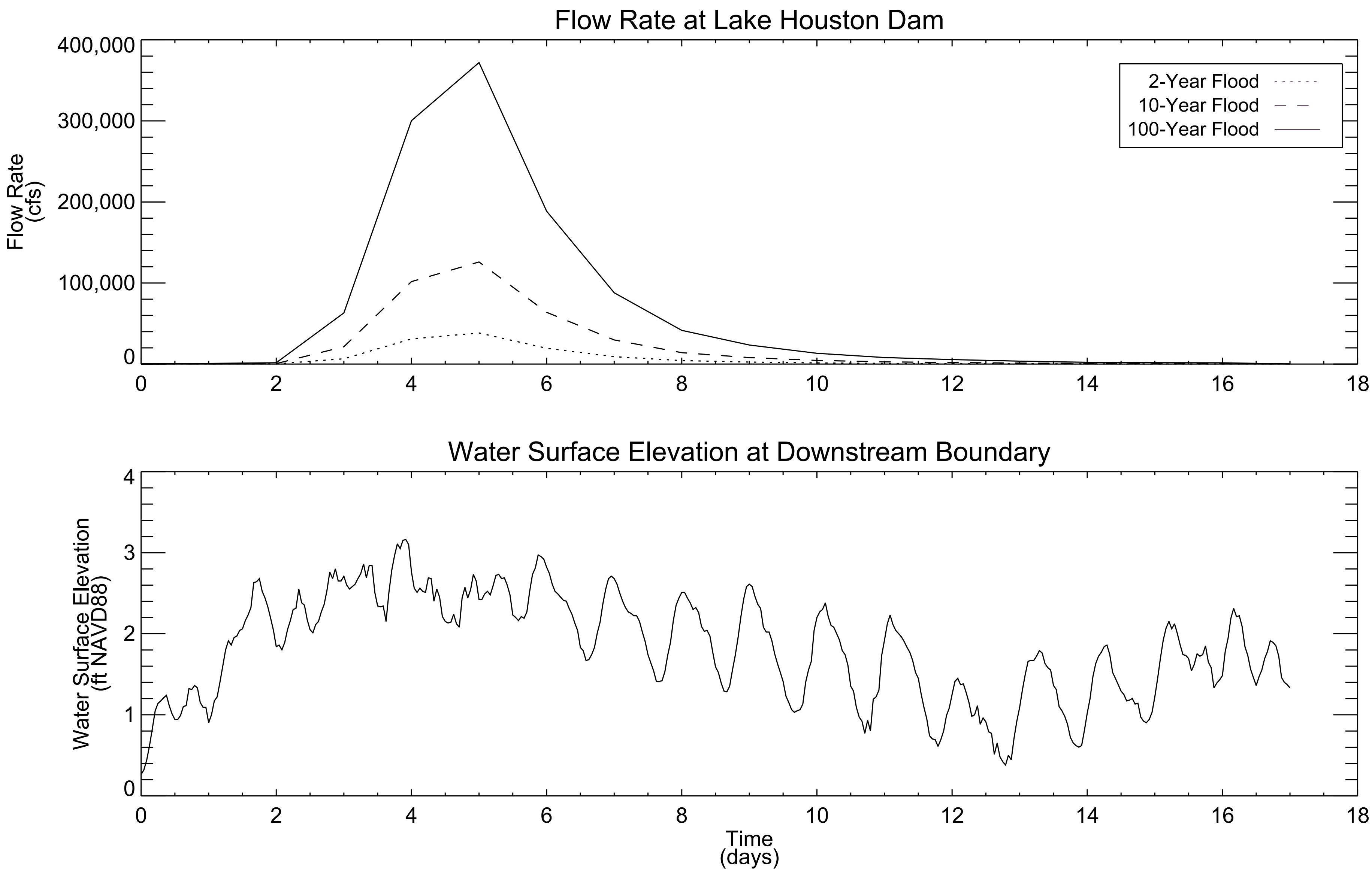

Figure 2-1
Time Variable Hydrodynamic Boundary Conditions for High-Flow Event Simulations
Feasibility Study
San Jacinto River Waste Pits Superfund Site

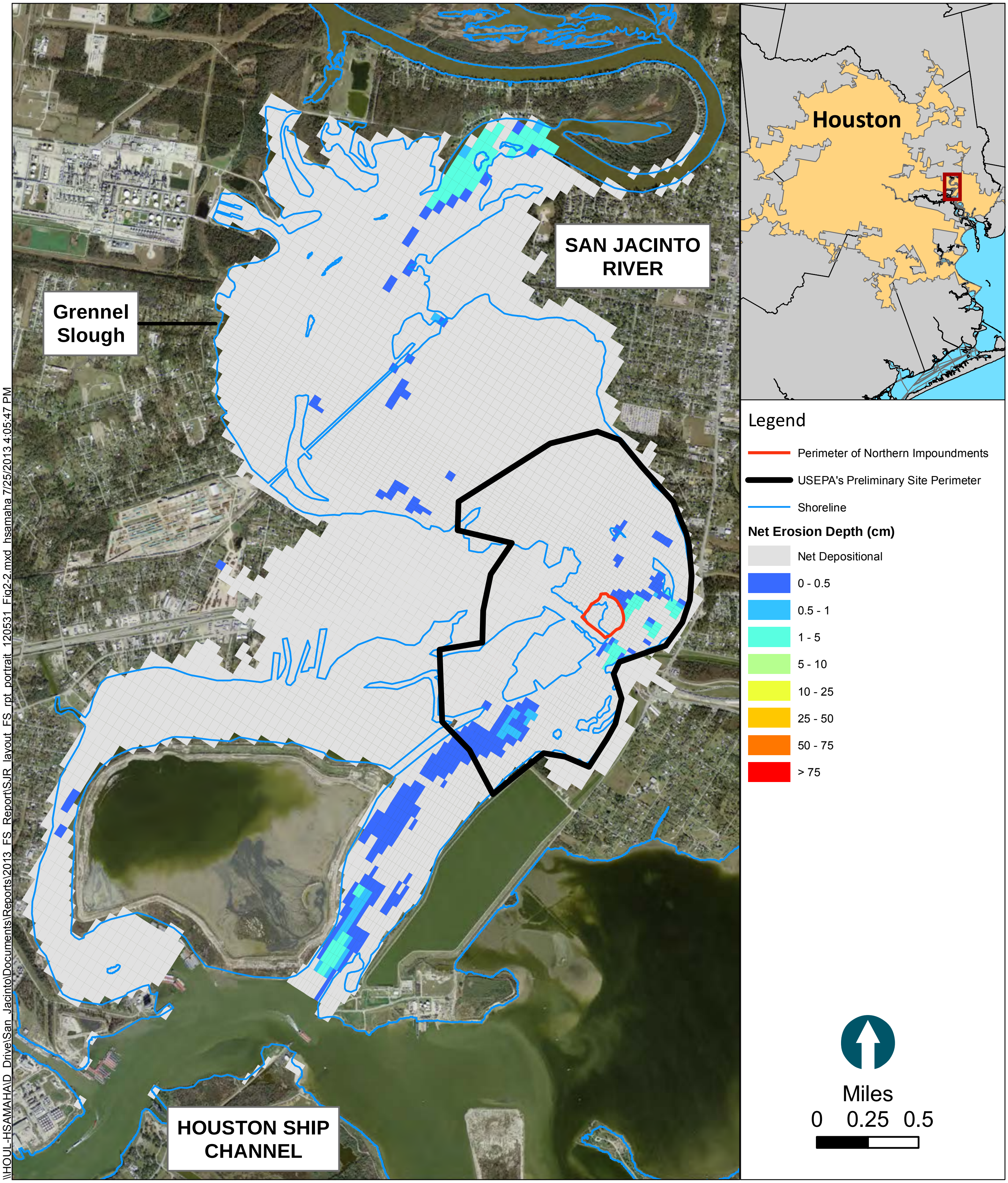

Figure 2-2
Spatial Distribution of Predicted Net Erosion During 2-Year Flood
Feasibility Study
San Jacinto River Waste Pits Superfund Site

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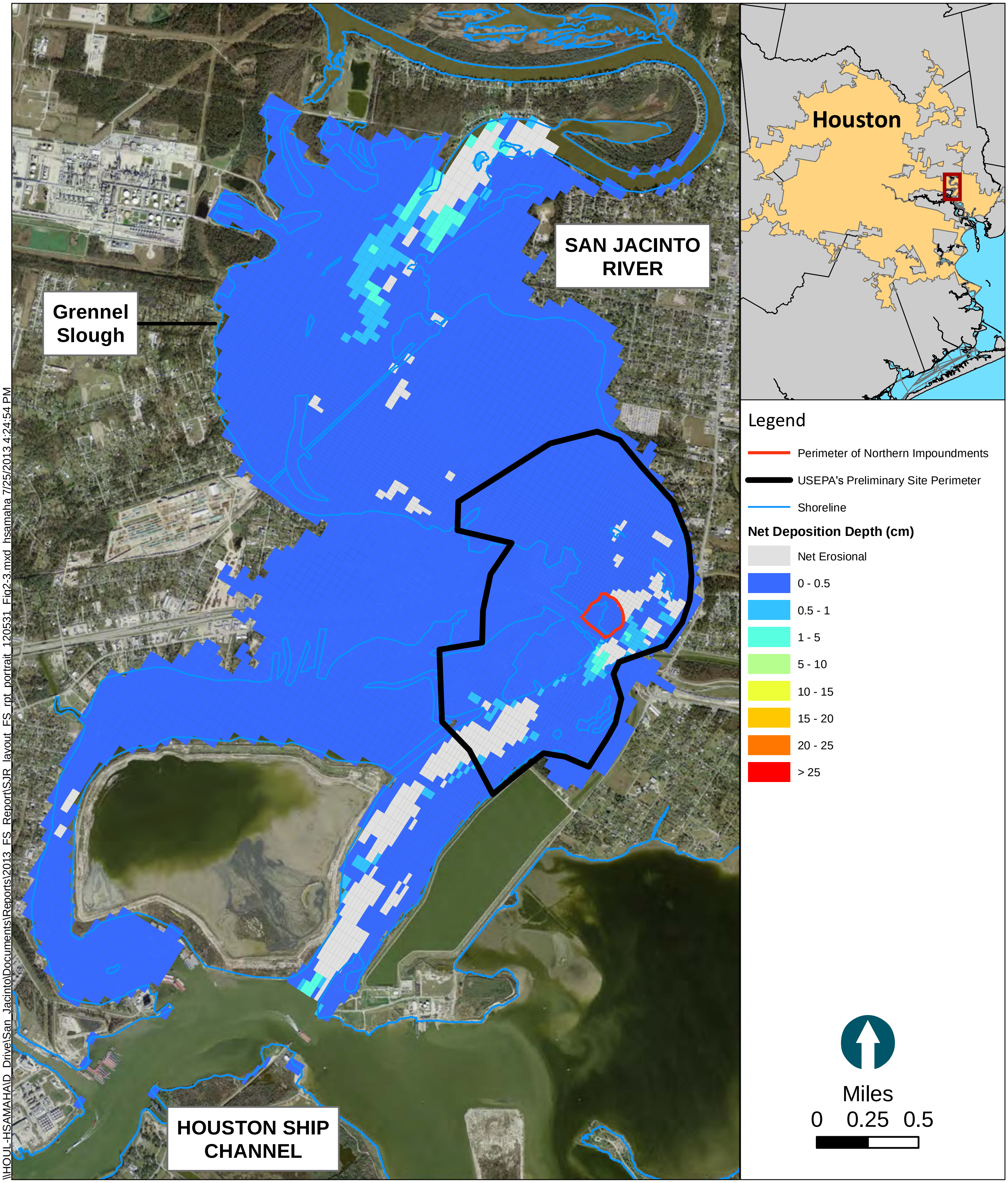

Figure 2-3
Spatial Distribution of Predicted Net Deposition During 2-Year Flood
Feasibility Study
San Jacinto River Waste Pits Superfund Site

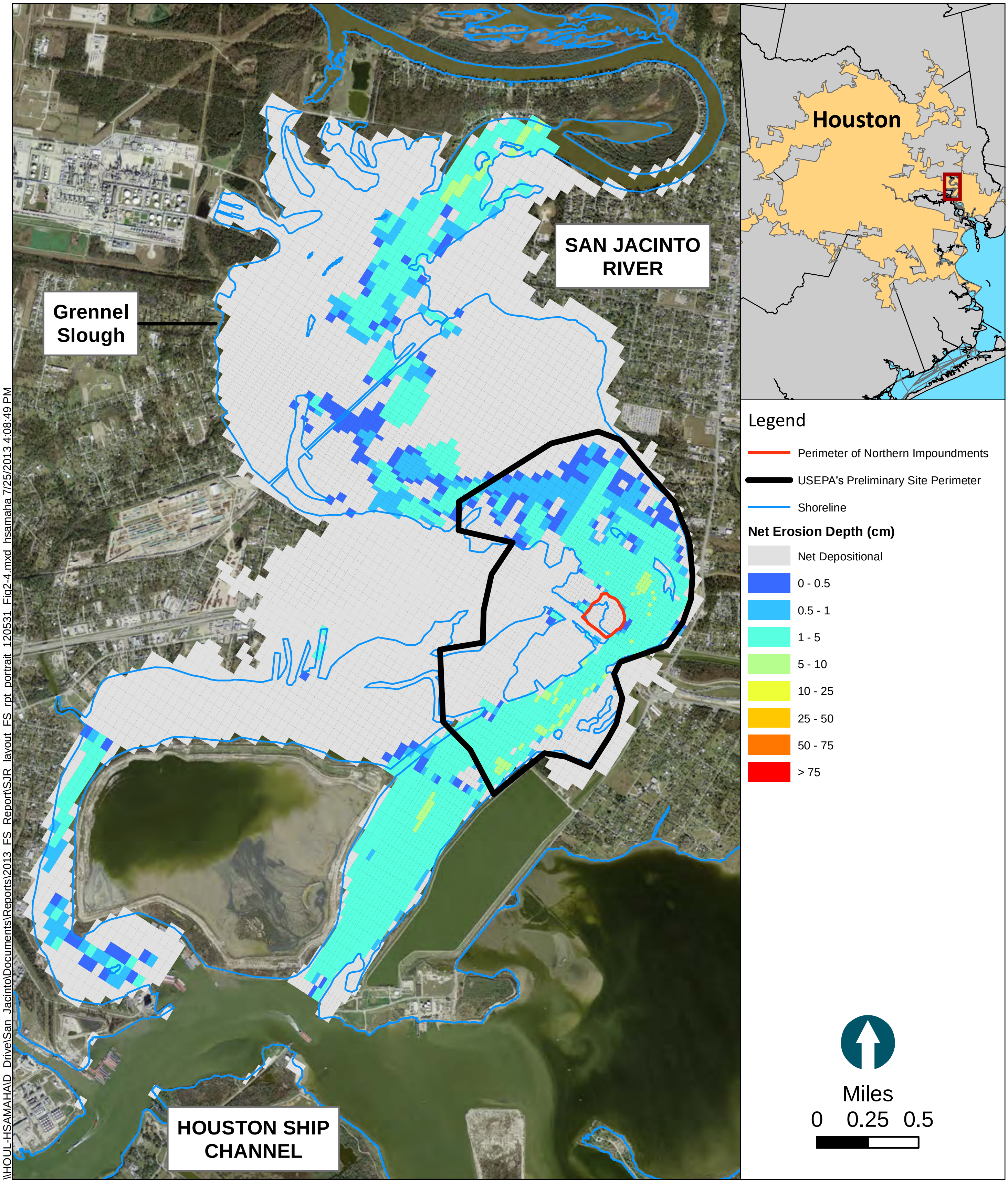

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Figure 2-4
Spatial Distribution of Predicted Net Erosion During 10-Year Flood
Feasibility Study
San Jacinto River Waste Pits Superfund Site

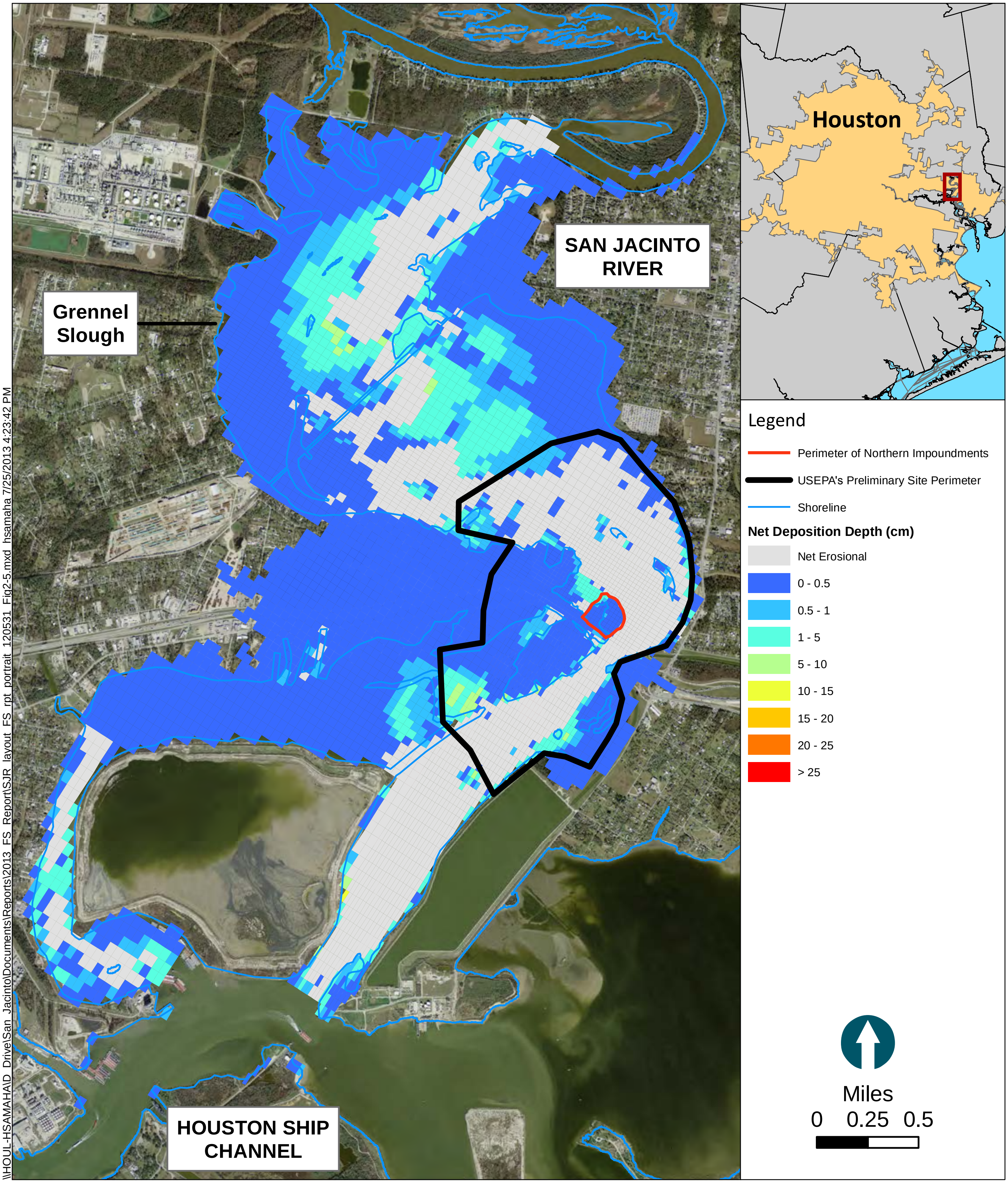

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Figure 2-5
Spatial Distribution of Predicted Net Deposition During 10-Year Flood
Feasibility Study
San Jacinto River Waste Pits Superfund Site

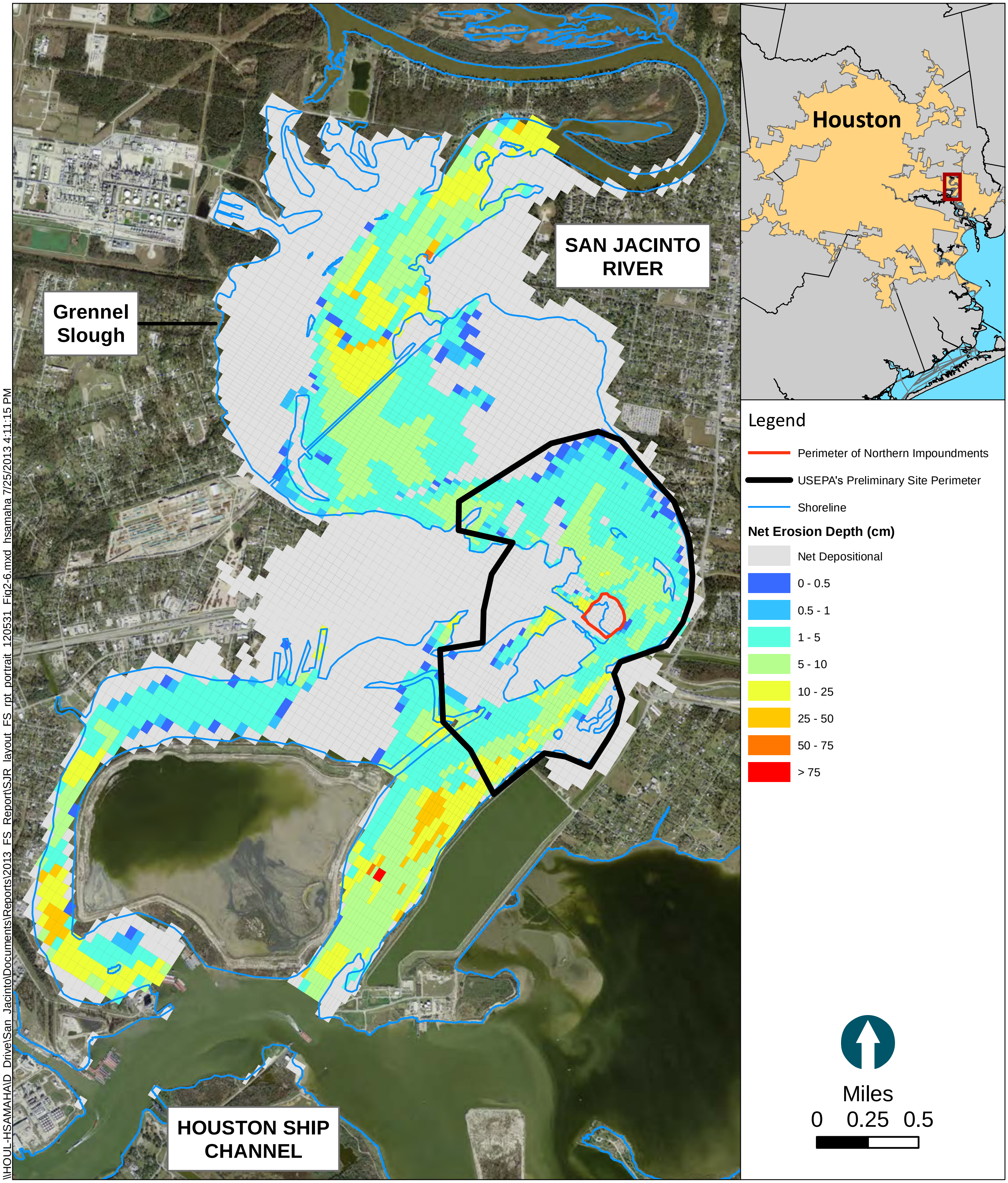

Figure 2-6
Spatial Distribution of Predicted Net Erosion During 100-Year Flood
Feasibility Study
San Jacinto River Waste Pits Superfund Site

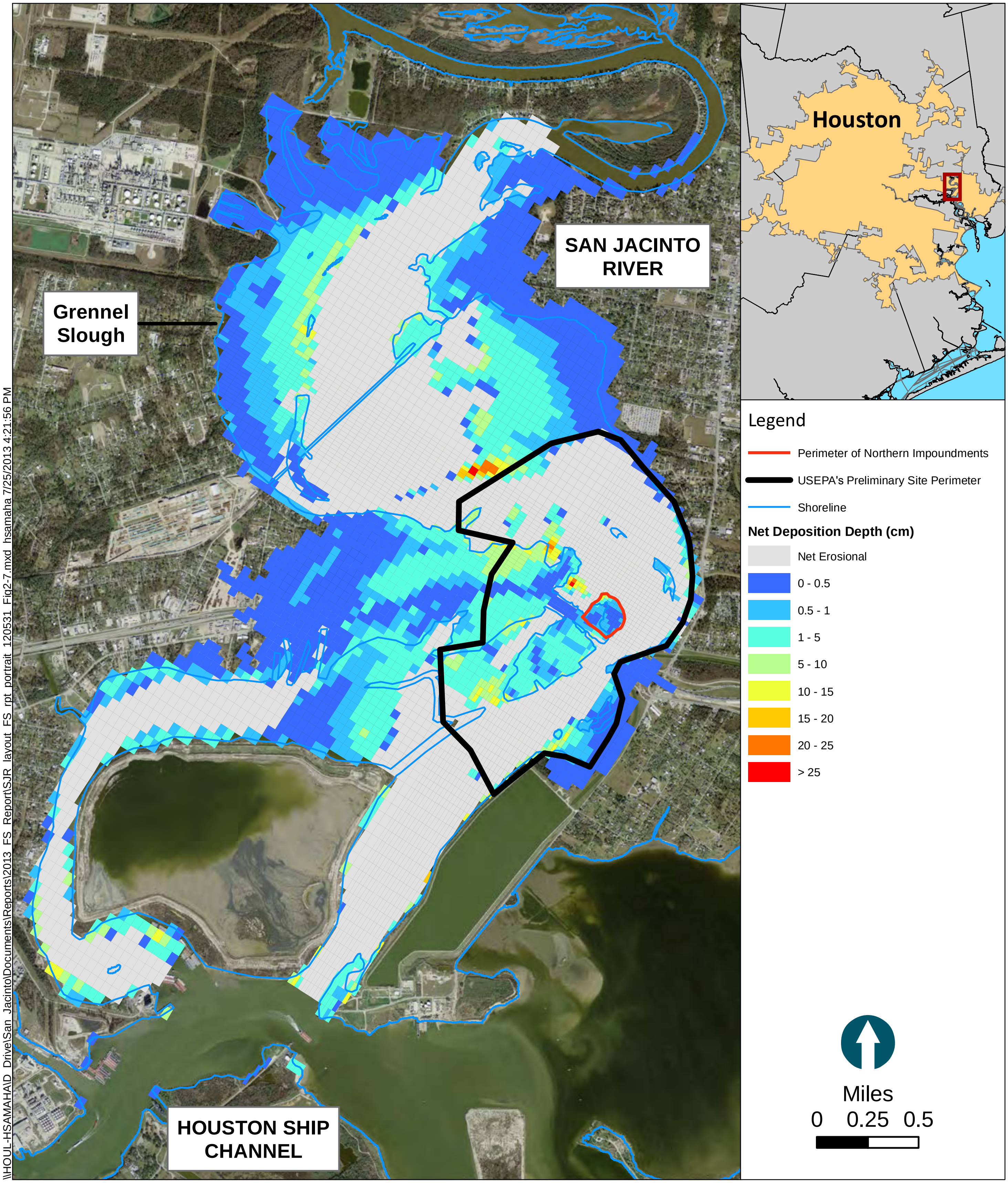

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Figure 2-7
Spatial Distribution of Predicted Net Deposition During 100-Year Flood
Feasibility Study
San Jacinto River Waste Pits Superfund Site

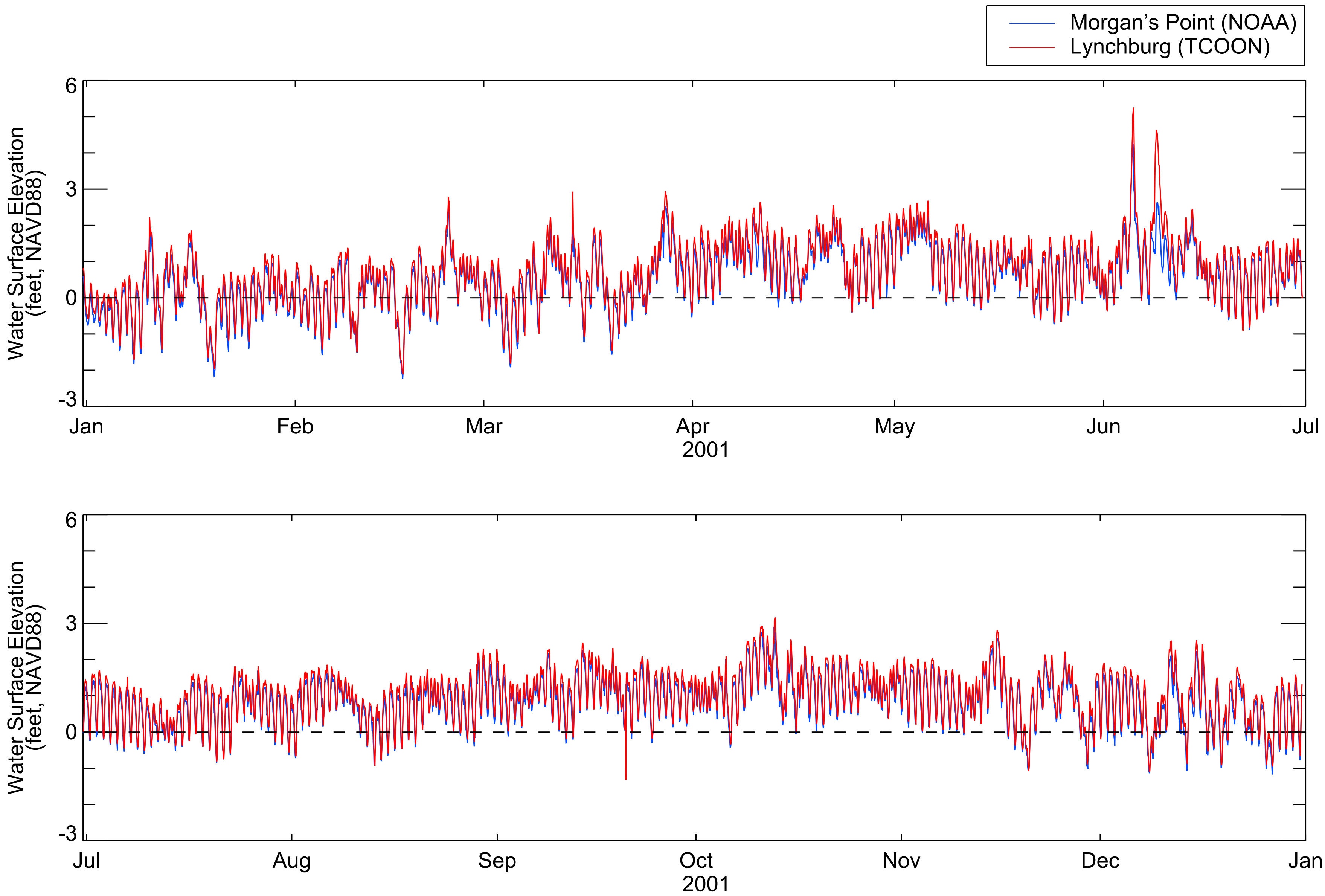

Figure 2-8

Comparison of Water Surface Elevations Measured at Morgan's Point and Lynchburg Gauge Stations During 2001

Feasibility Study

San Jacinto River Waste Pits Superfund Site

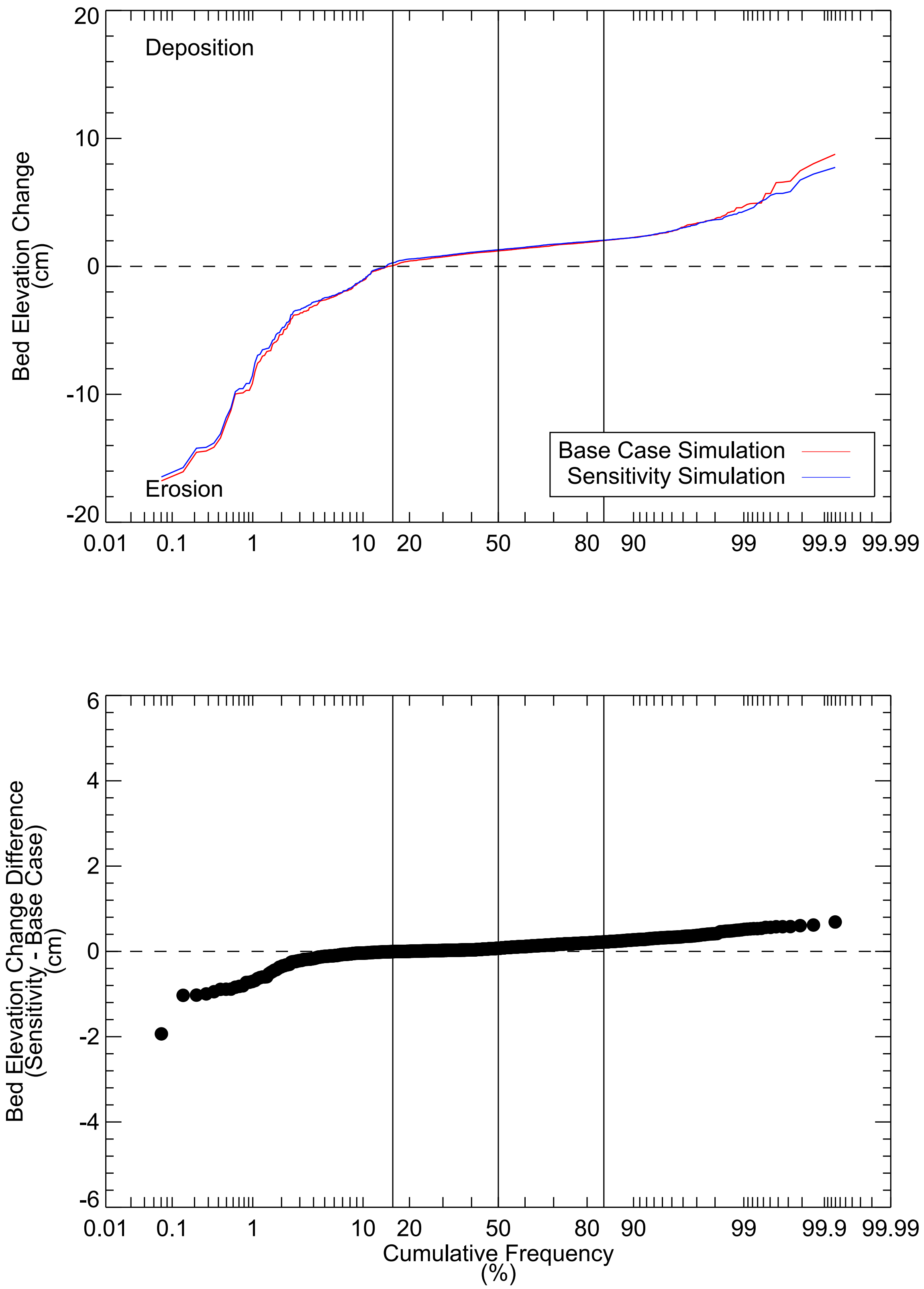

Figure 2-9

WSE Boundary Condition Sensitivity Analysis: Comparison of Cumulative Frequency Distributions of Bed Elevation Change for Base Case and Sensitivity Simulations
Feasibility Study
San Jacinto River Waste Pits Superfund Site

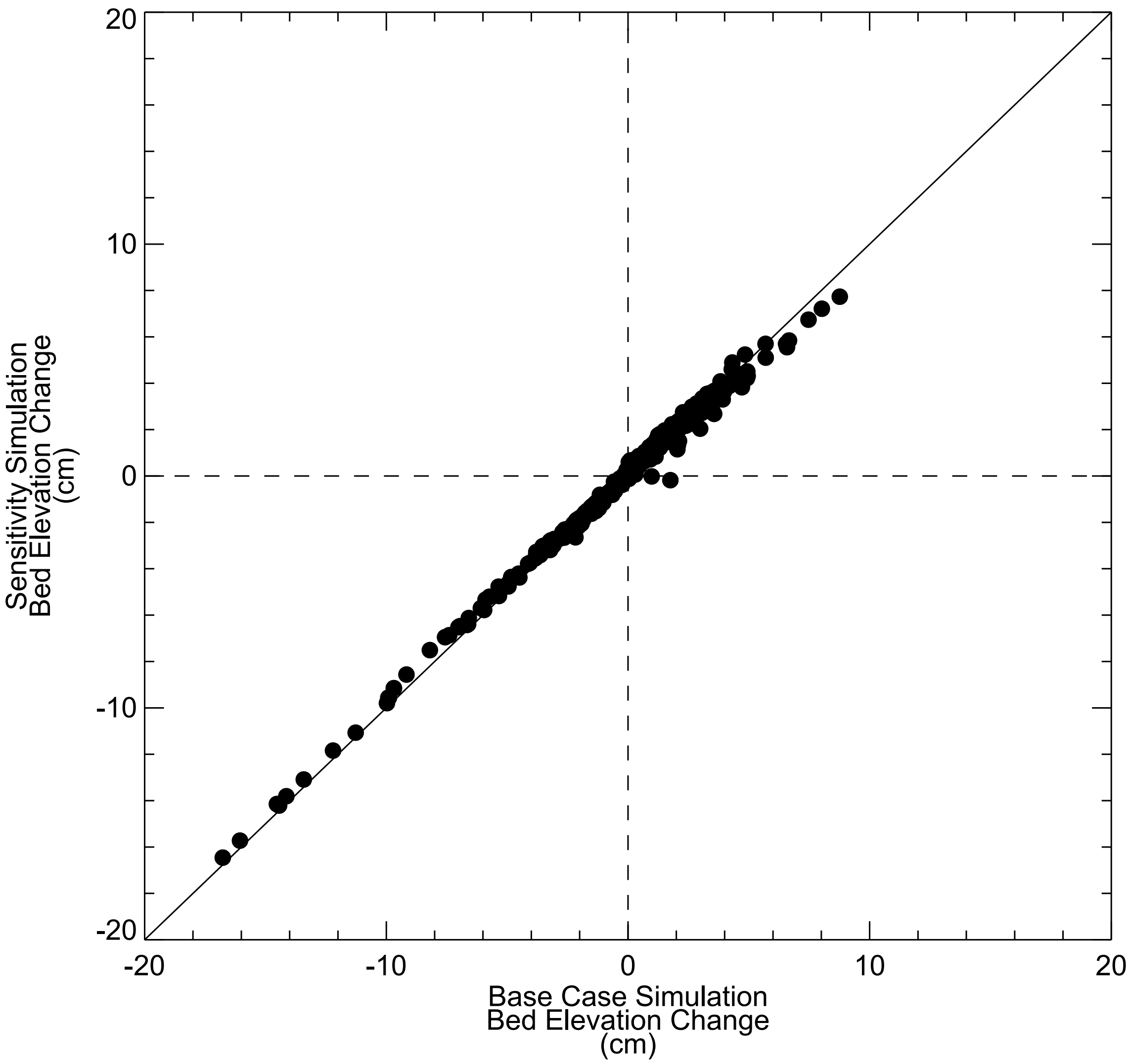

Figure 2-10

WSE Boundary Condition Sensitivity Analysis: One-to-One Comparisons of Bed Elevation Change for Base Case and Sensitivity Simulations
Feasibility Study
San Jacinto River Waste Pits Superfund Site

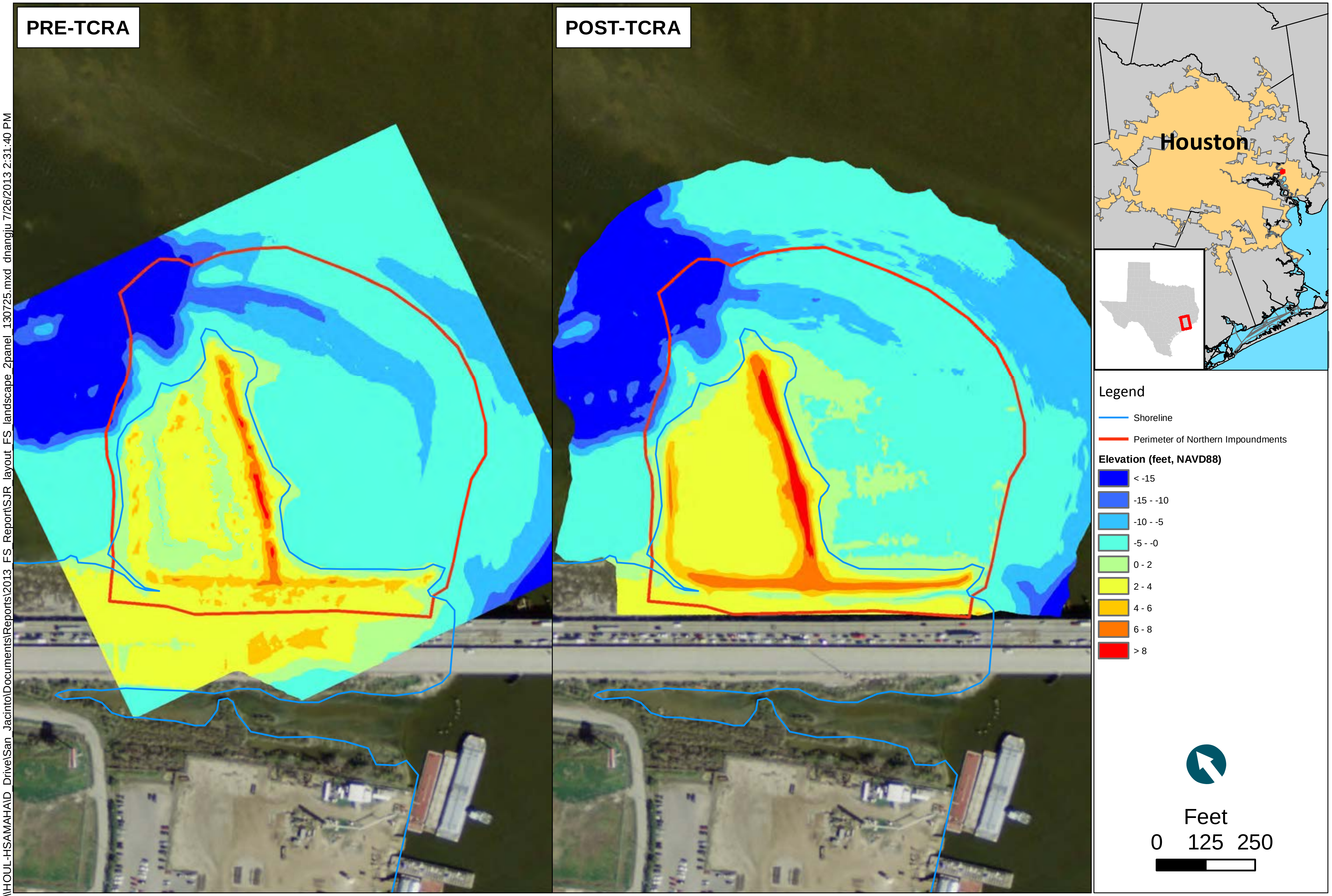

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Figure 3-1
Comparison of Bathymetry and Topography near the TCRA Site: Pre- and Post-TCRA
Feasibility Study
San Jacinto River Waste Pits Superfund Site

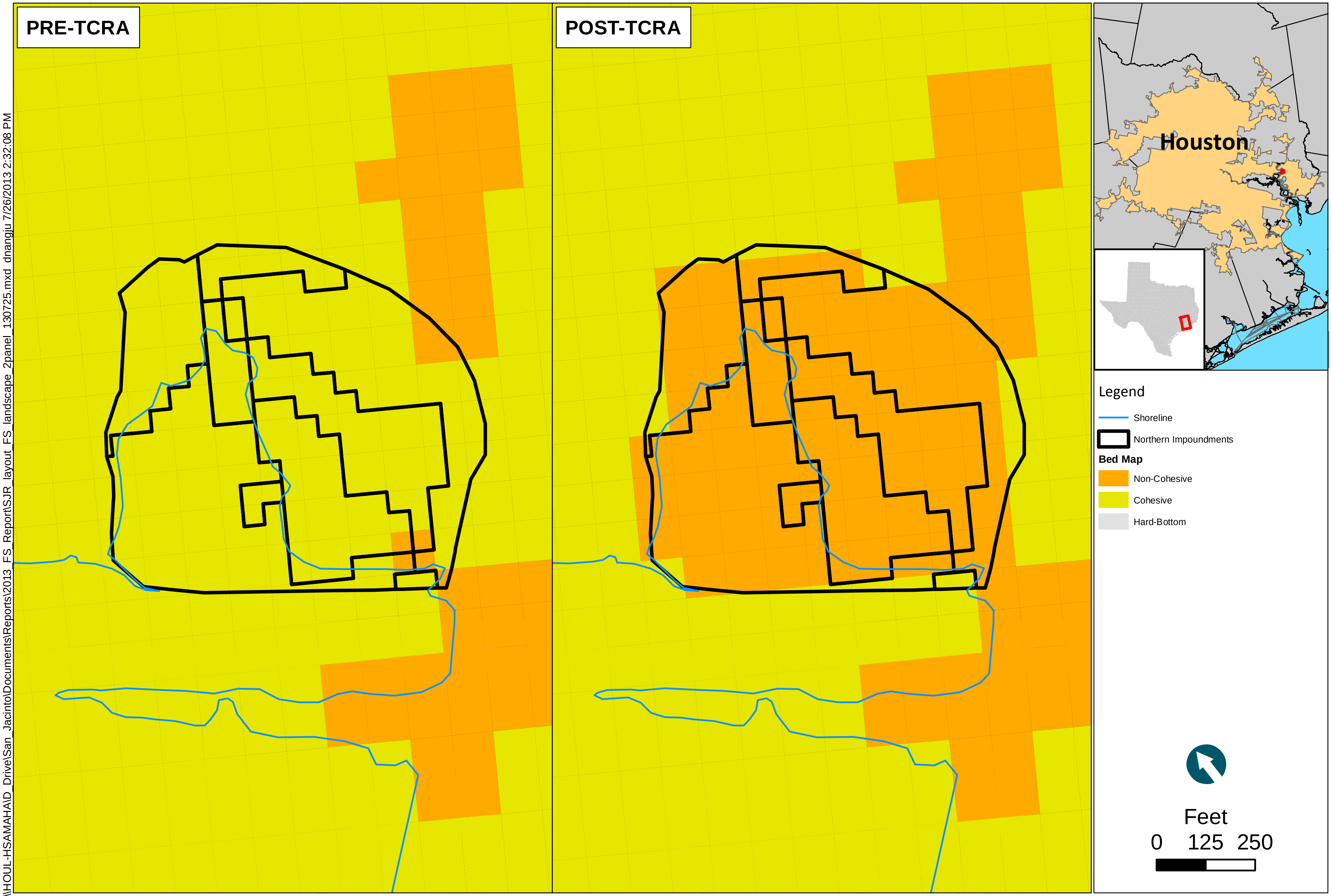

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Figure 3-2
Comparison of Sediment Bed Map in the TCRA Site
Used for Model Input: Pre- and Post-TCRA
Feasibility Study
San Jacinto River Waste Pits Superfund Site

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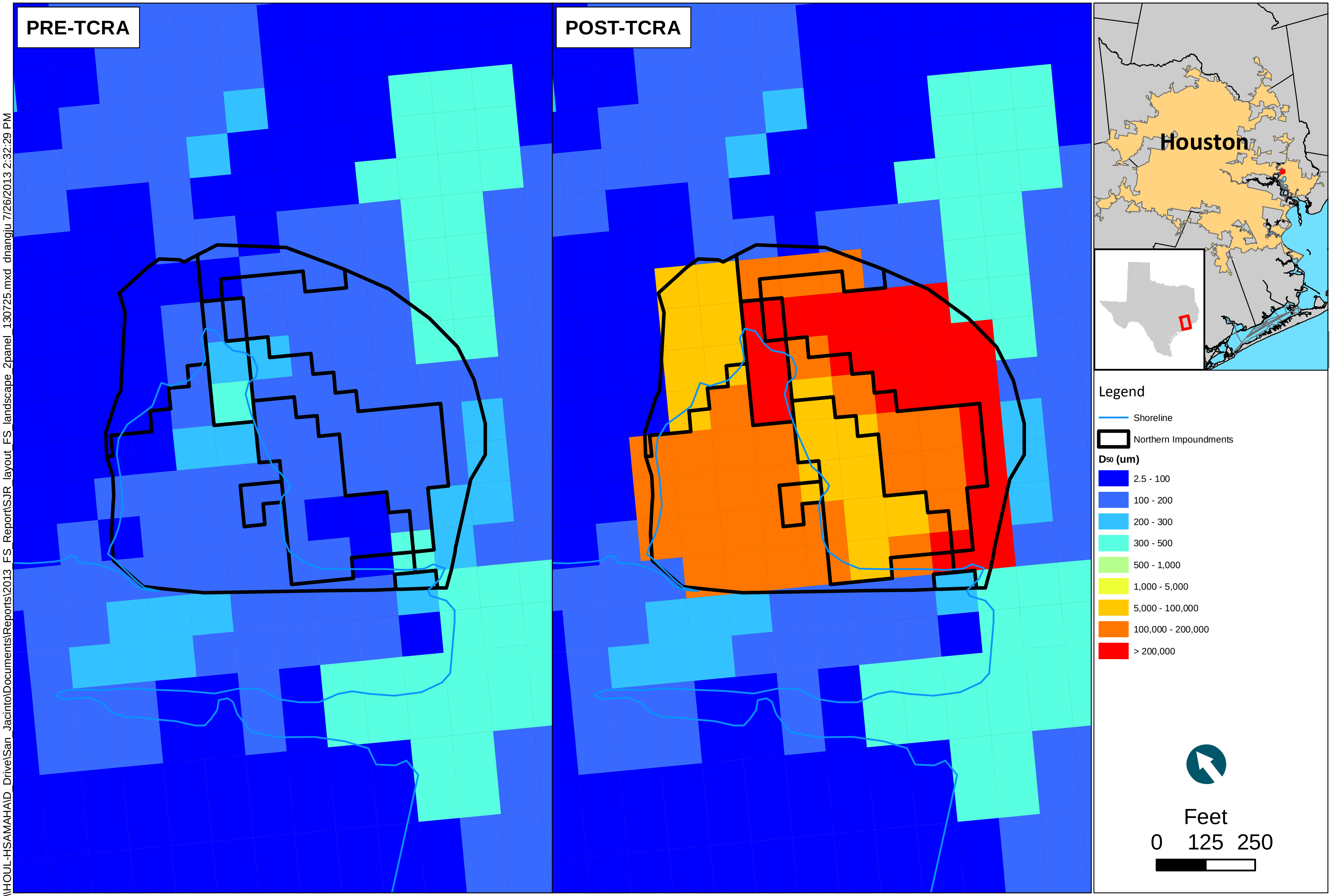

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Figure 3-3
Comparison of D_{50} in the TCRA Site Used to Specify Initial Conditions: Pre- and Post-TCRA
Feasibility Study
San Jacinto River Waste Pits Superfund Site

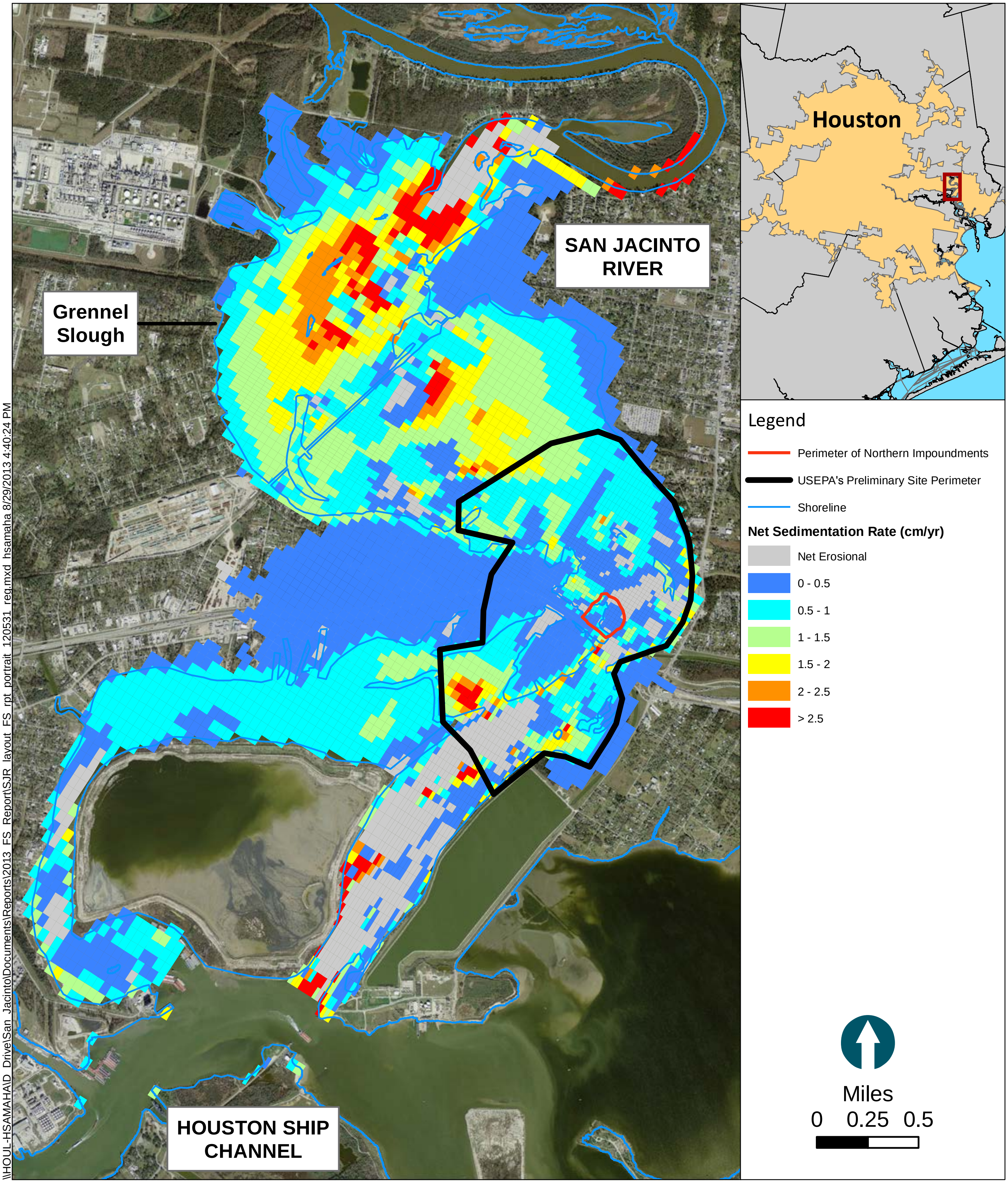

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Figure 3-4
Spatial Distribution of Predicted Net Sedimentation Rate for 21-Year Period: Pre-TCRA Base Case Simulation
Feasibility Study
San Jacinto River Waste Pits Superfund Site

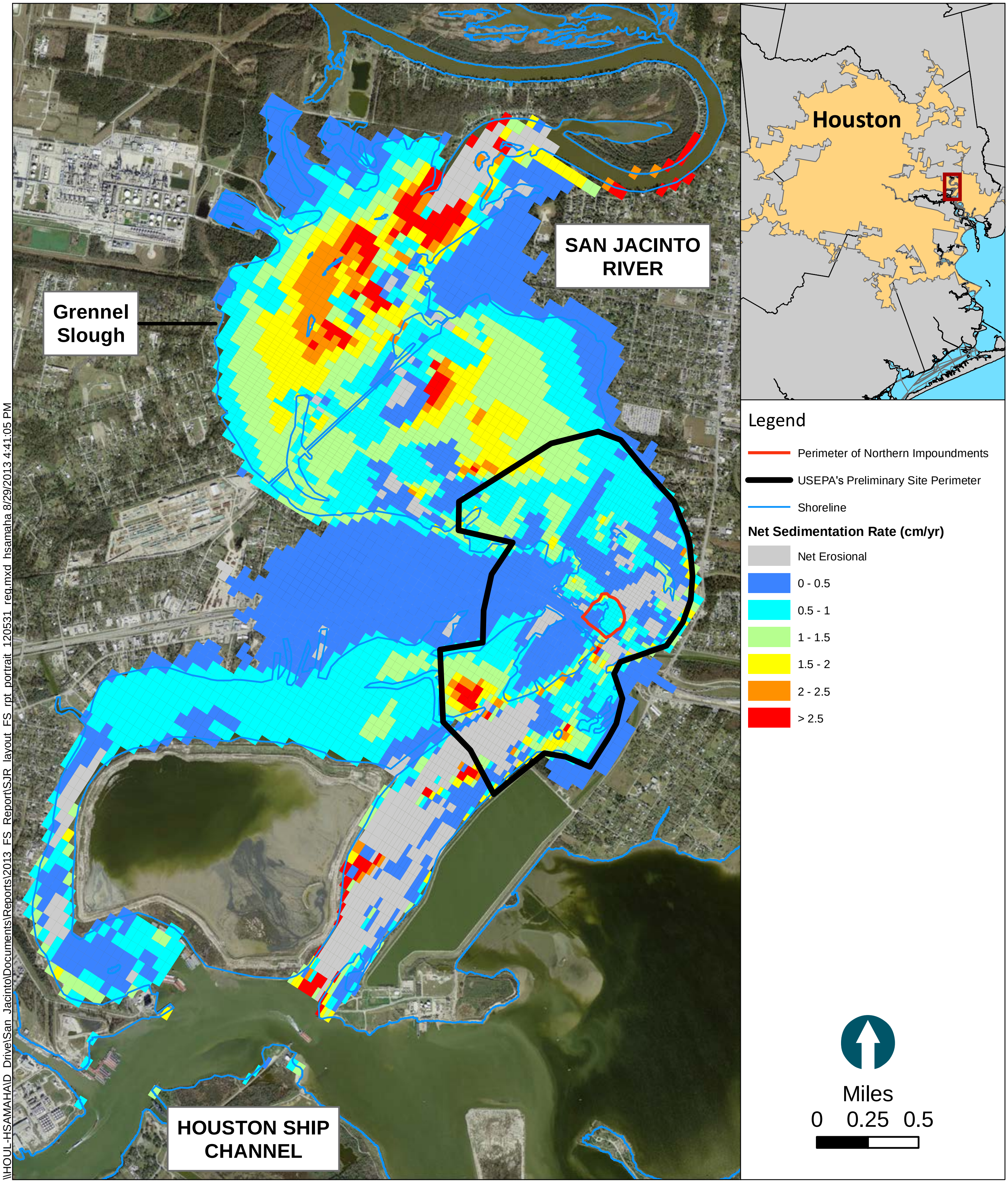

Figure 3-5
Spatial Distribution of Predicted Net Sedimentation Rate for 21-Year Period: Post-TCRA Base Case Simulation
Feasibility Study
San Jacinto River Waste Pits Superfund Site

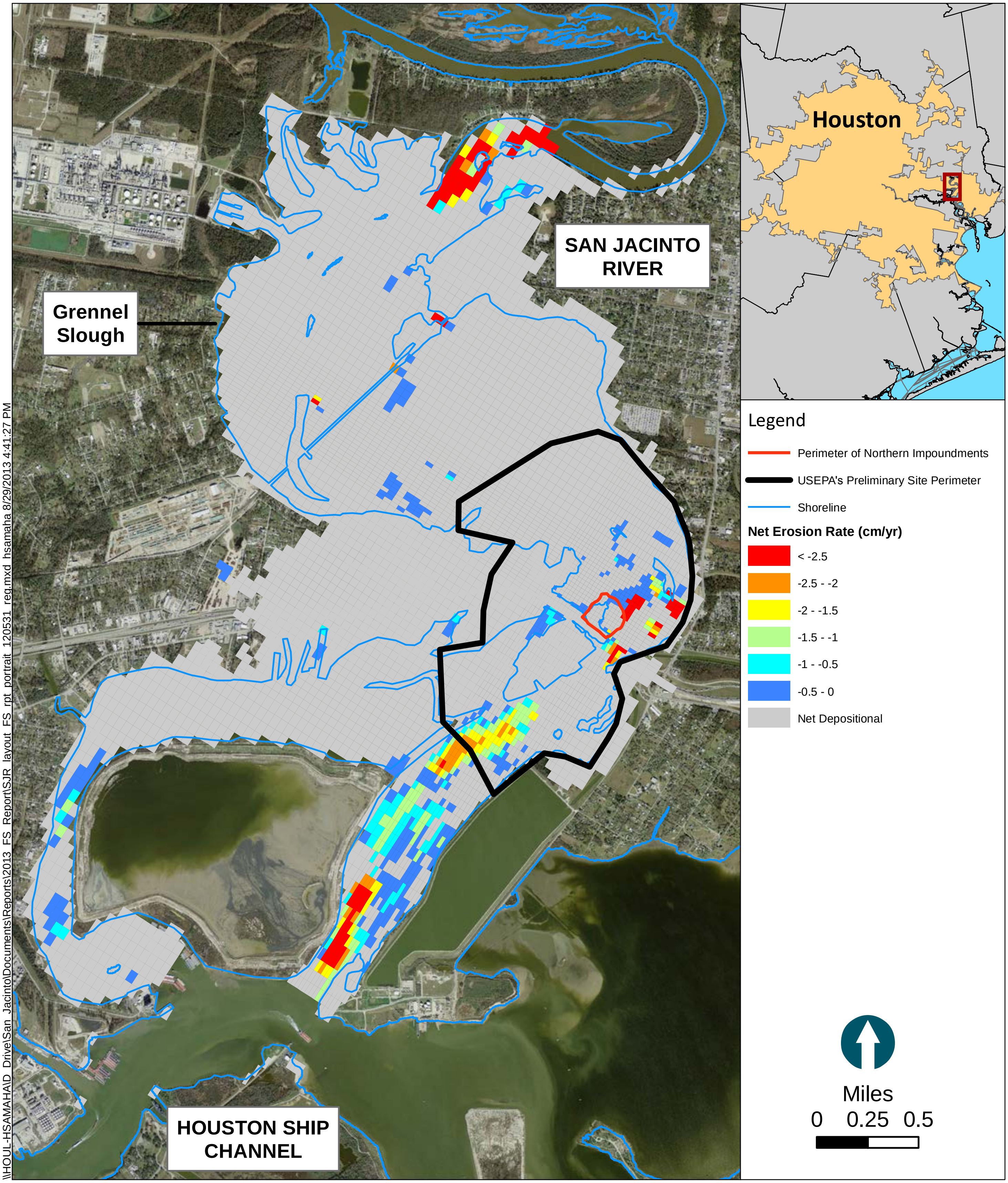

Figure 3-6
Spatial Distribution of Predicted Net Erosion Rate for 21-Year Period: Pre-TCRA Base Case Simulation
Feasibility Study
San Jacinto River Waste Pits Superfund Site

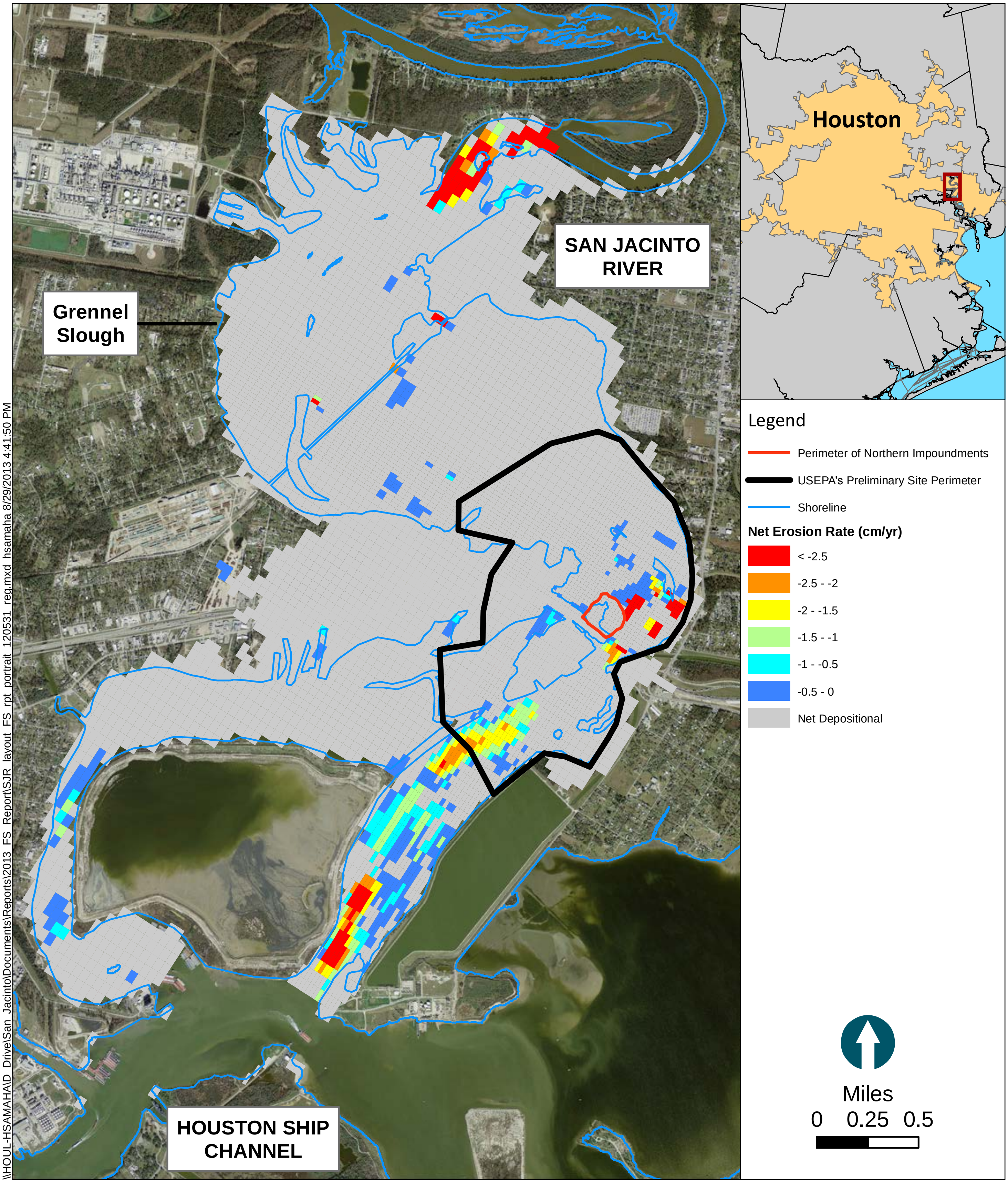

Figure 3-7
Spatial Distribution of Predicted Net Erosion Rate for 21-Year Period: Post-TCRA Base Case Simulation
Feasibility Study
San Jacinto River Waste Pits Superfund Site

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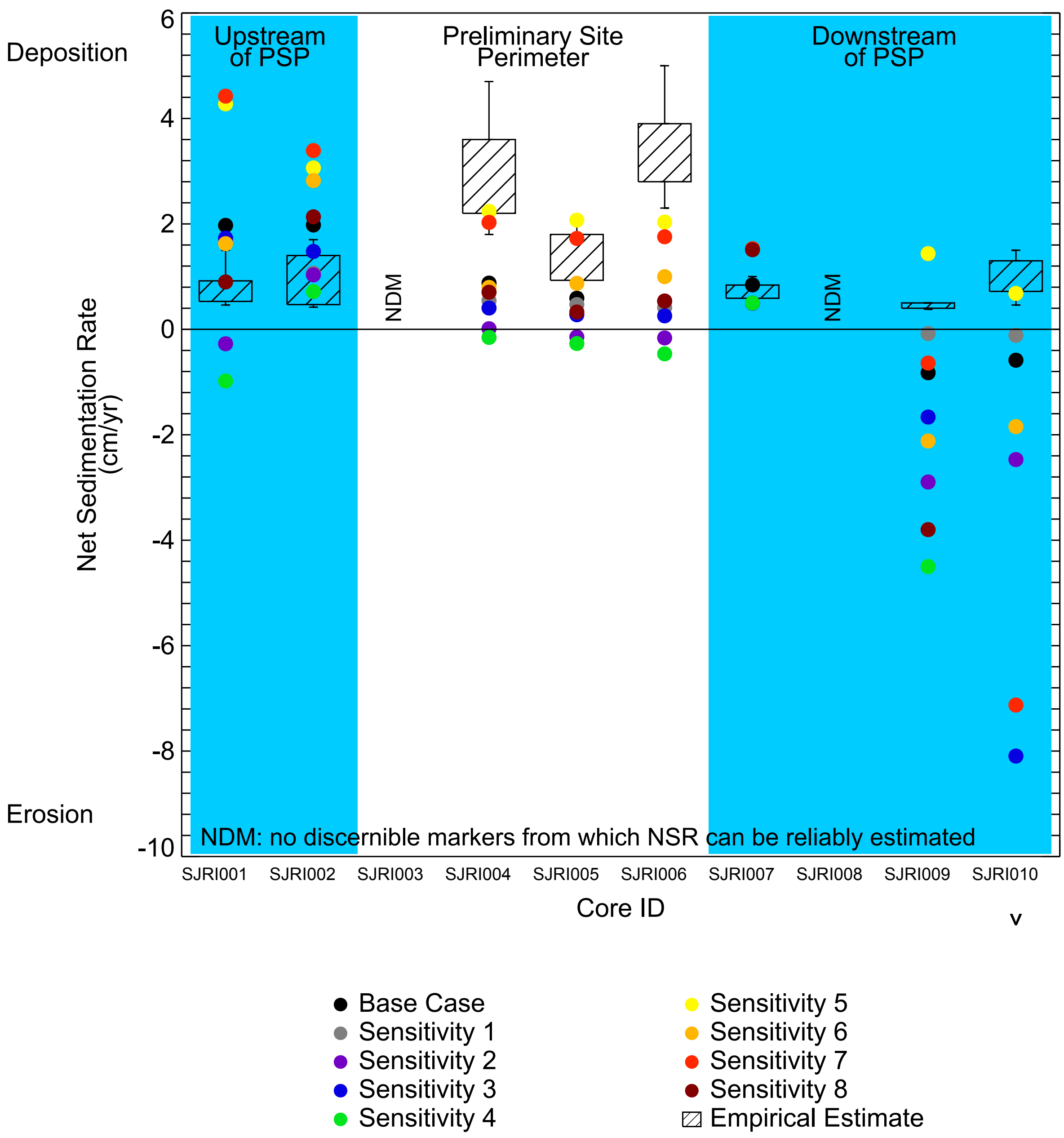

Figure 3-8

Comparison of Empirically Estimated and Predicted Net Sedimentation Rates for 21-Year Period: Post-TCRA Conditions

Feasibility Study

San Jacinto River Waste Pits Superfund Site

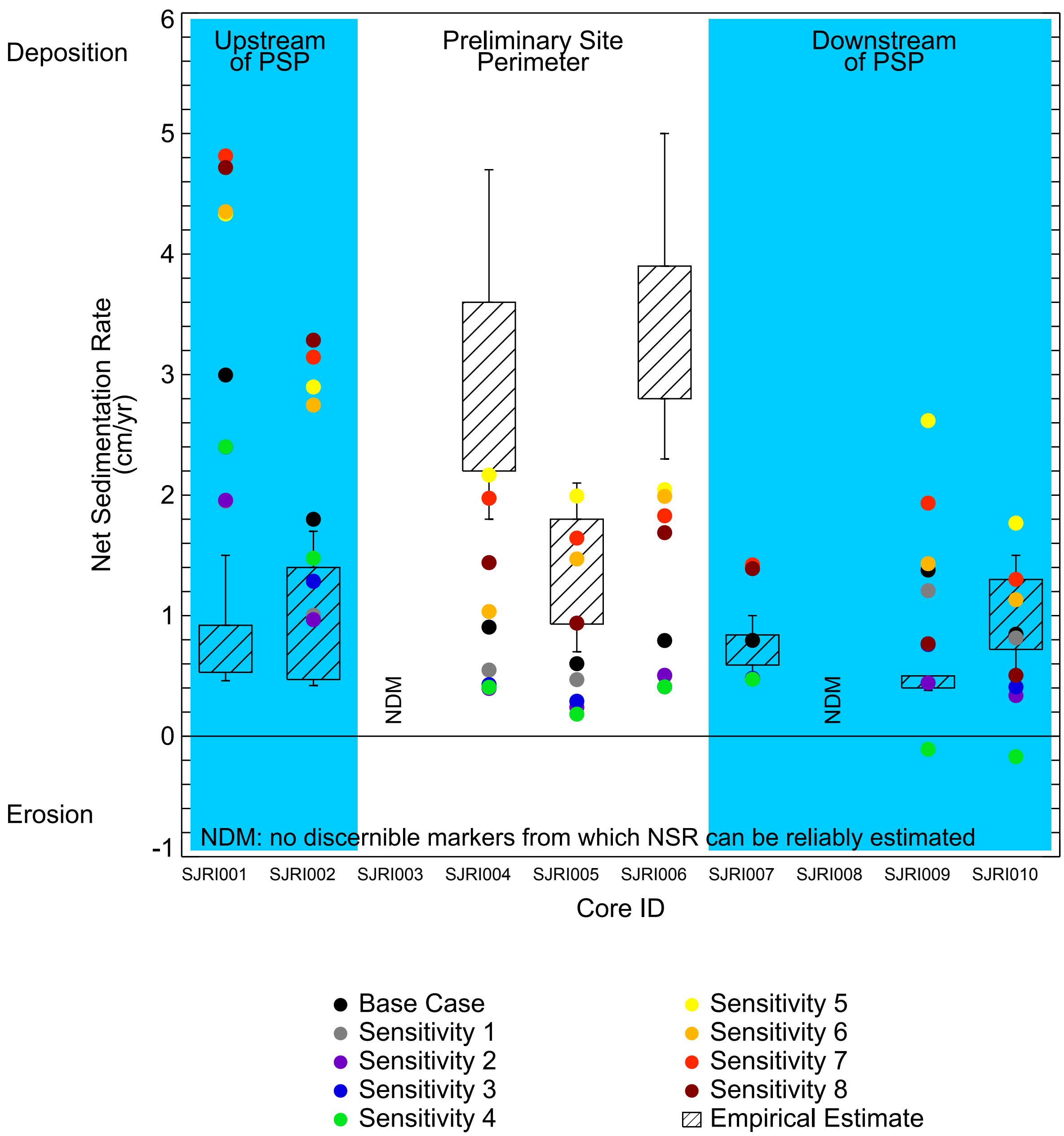

Figure 3-9

Comparison of Empirically Estimated and Predicted Net Sedimentation Rates for 16-Year Period: Post-TCRA Conditions

Feasibility Study

San Jacinto River Waste Pits Superfund Site

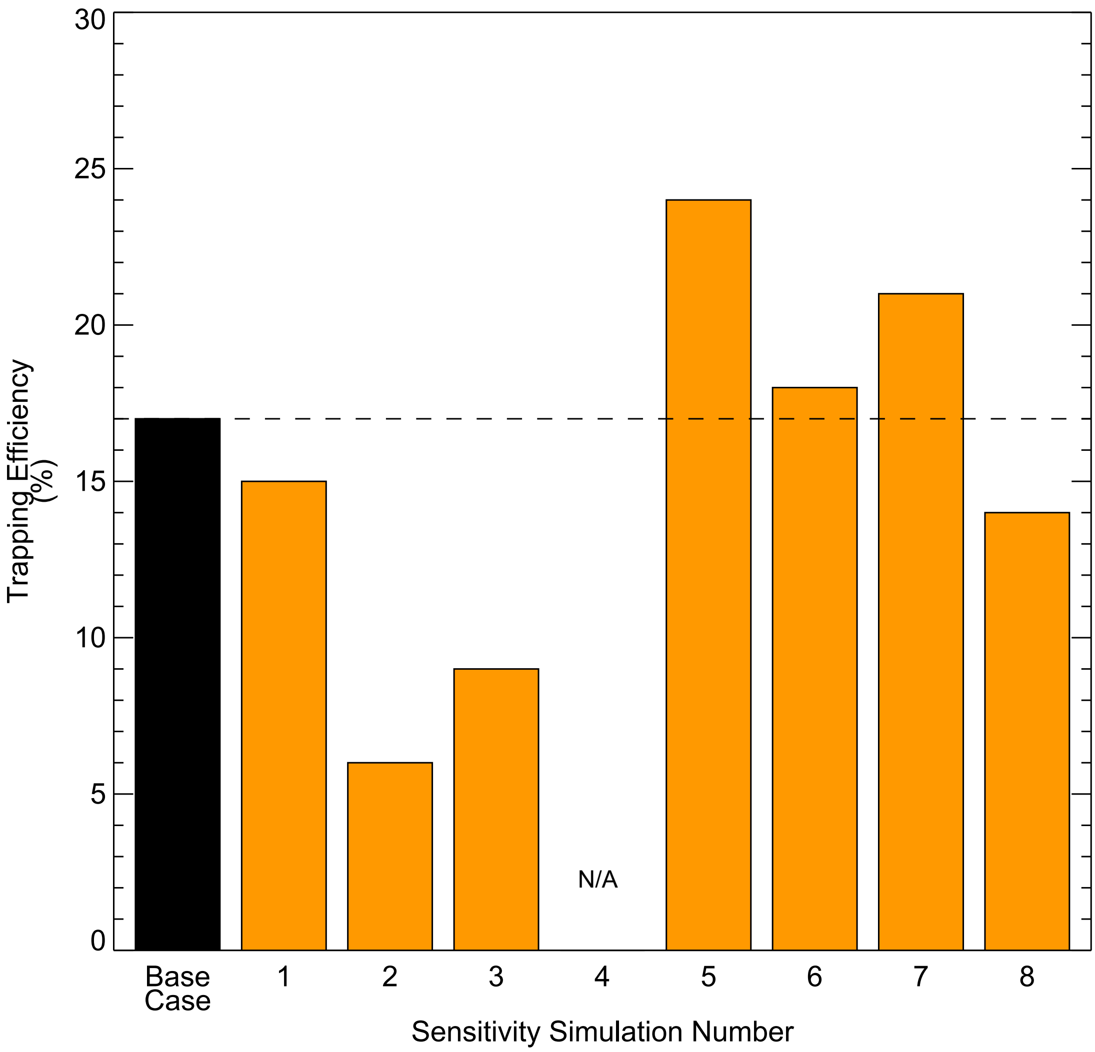

Figure 3-10

Comparison of Trapping Efficiency for Post-TCRA Sensitivity Simulations: Model Study Area
Feasibility Study
San Jacinto River Waste Pits Superfund Site

N/A: trapping efficiency could not be calculated because simulation was net erosional

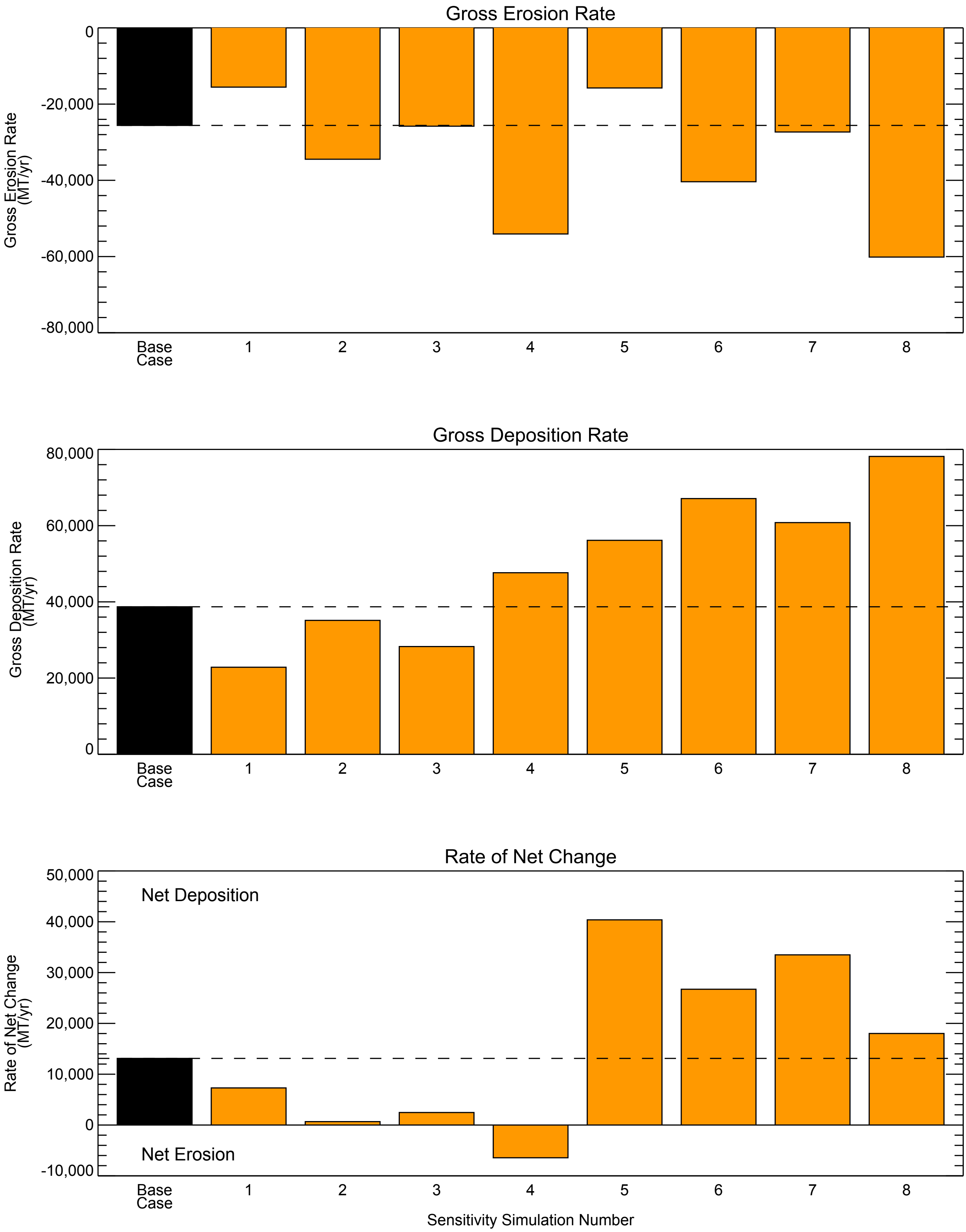

Figure 3-11

Comparison of Gross Erosion Rate, Gross Deposition Rate, and Rate of Net Change for Post-TCRA Sensitivity Simulations: USEPA's Preliminary Site Perimeter Feasibility Study
San Jacinto River Waste Pits Superfund Site

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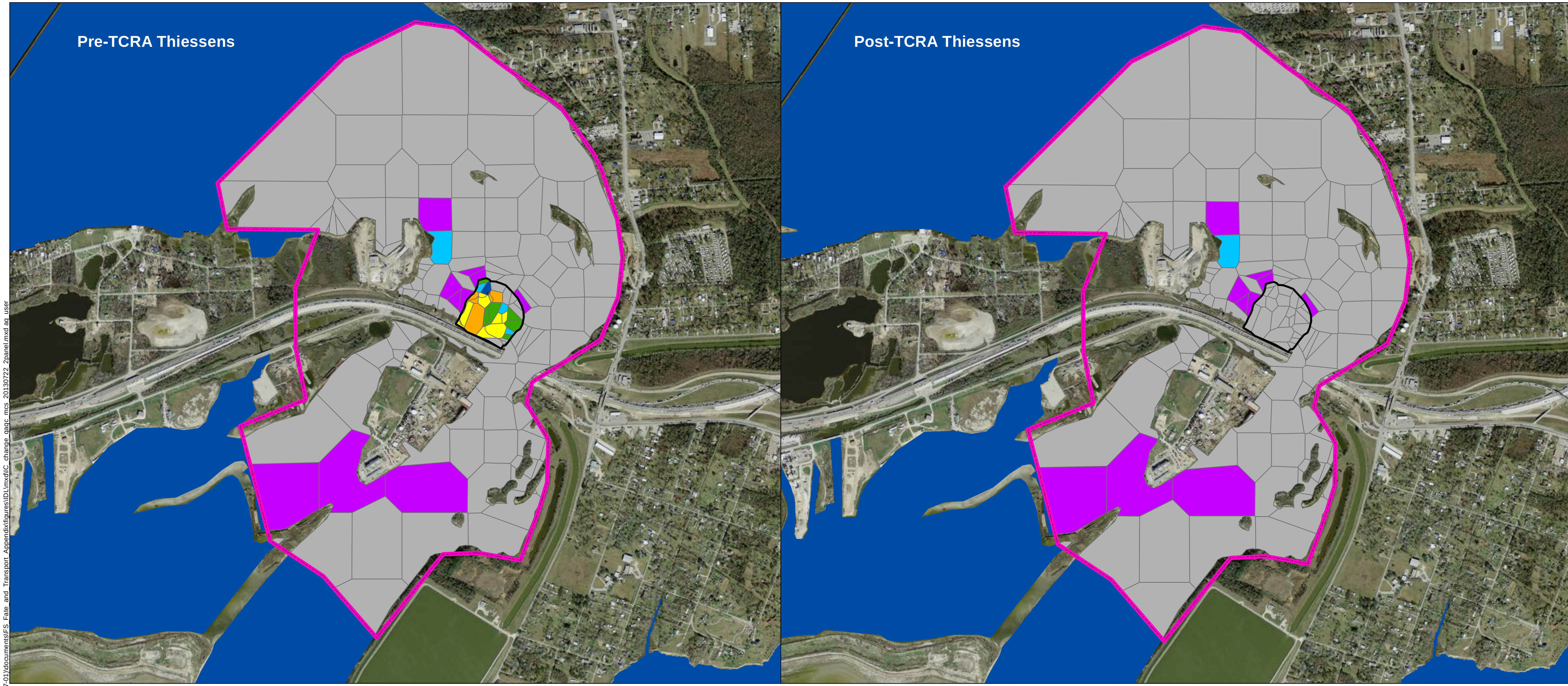

LEGEND

- Perimeter of Northern Impoundments
- USEPA's Preliminary Site Perimeter

TCDD Surface Sediment Concentration (ng/kg)

- < 30
- 30 - 100
- 100 - 300
- 300 - 1000
- 1000 - 3000
- 3000 - 10000
- > 10000
- Channel

NOTES:
Orthoimagery presented herein are enhanced 50-cm (0.5-meter) Digital Orthophoto Quarter-Quads (DOQQs) images from the 2008 USDA-FSA National Agriculture Imagery Program (NAIP) and 2009 Texas Orthoimagery Program (TOP) aerial imagery acquisitions.

0 0.5 1 Miles

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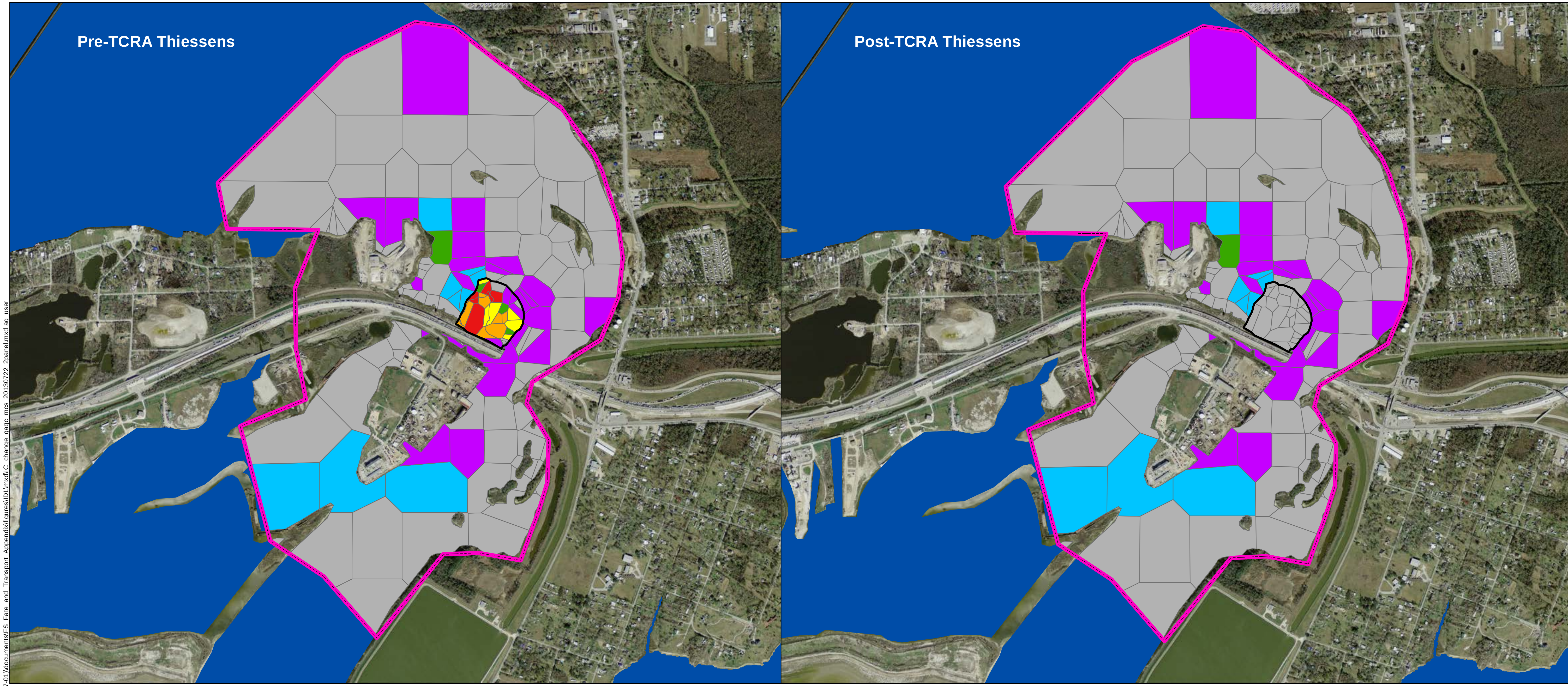
Figure 3-12a
Surface Sediment Thiessen Polygons Used for Fate Model Initial Conditions (TCDD)
Feasibility Study
San Jacinto River Waste Pits Superfund Site



LEGEND

- Perimeter of Northern Impoundments
- USEPA's Preliminary Site Perimeter

TCDF Surface Sediment Concentration (ng/kg)

- < 30
- 30 - 100
- 100 - 300
- 300 - 1000
- 1000 - 3000
- 3000 - 10000
- > 10000
- Channel

NOTES:
Orthoimagery presented herein are enhanced 50-cm (0.5-meter) Digital Orthophoto Quarter-Quads (DOQQs) images from the 2008 USDA-FSA National Agriculture Imagery Program (NAIP) and 2009 Texas Orthoimagery Program (TOP) aerial imagery acquisitions.

0 0.5 1 Miles

Figure 3-12b
Surface Sediment Thiessen Polygons Used for Fate Model Initial Conditions (TCDF)
Feasibility Study
San Jacinto River Waste Pits Superfund Site

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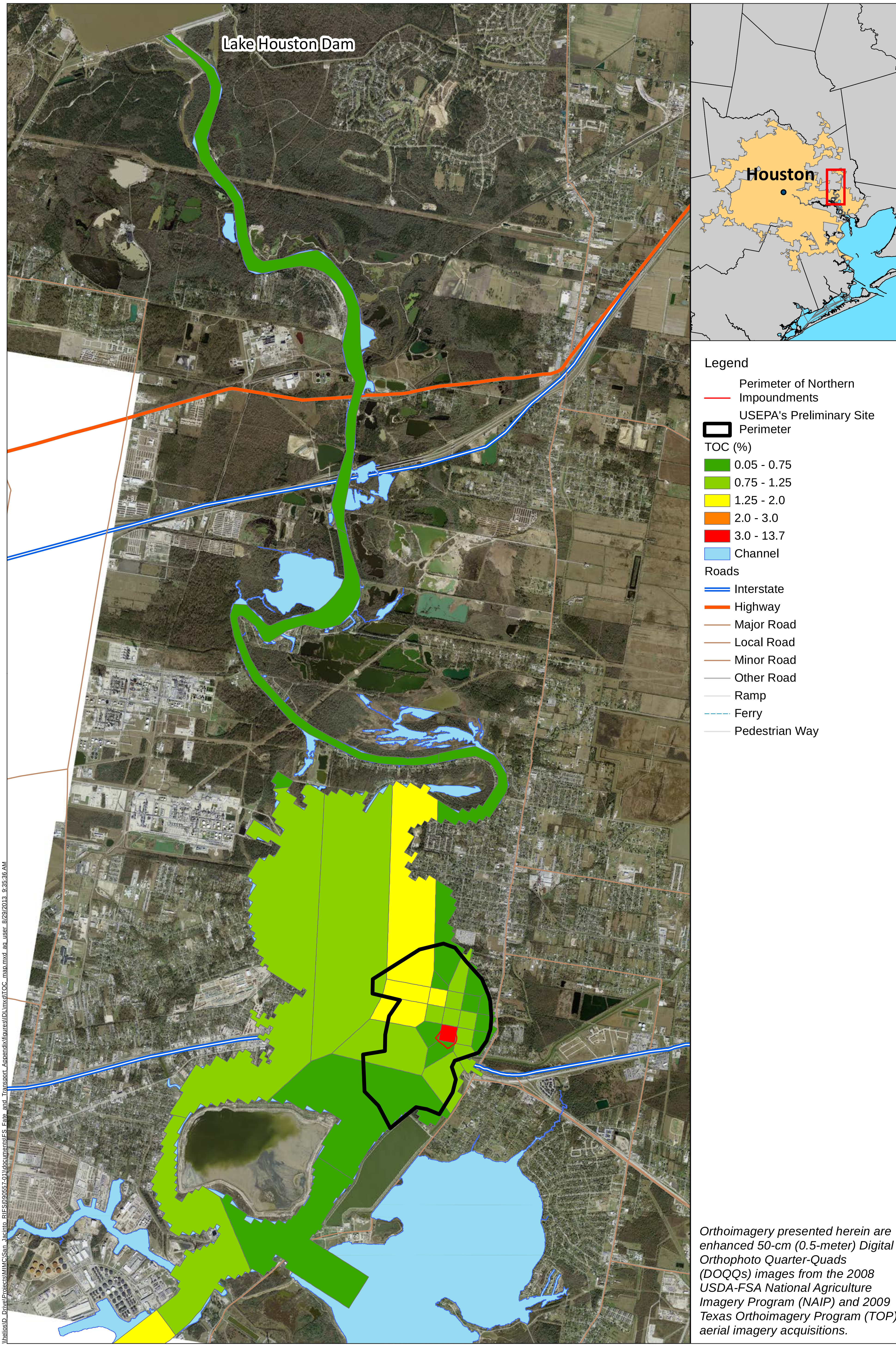
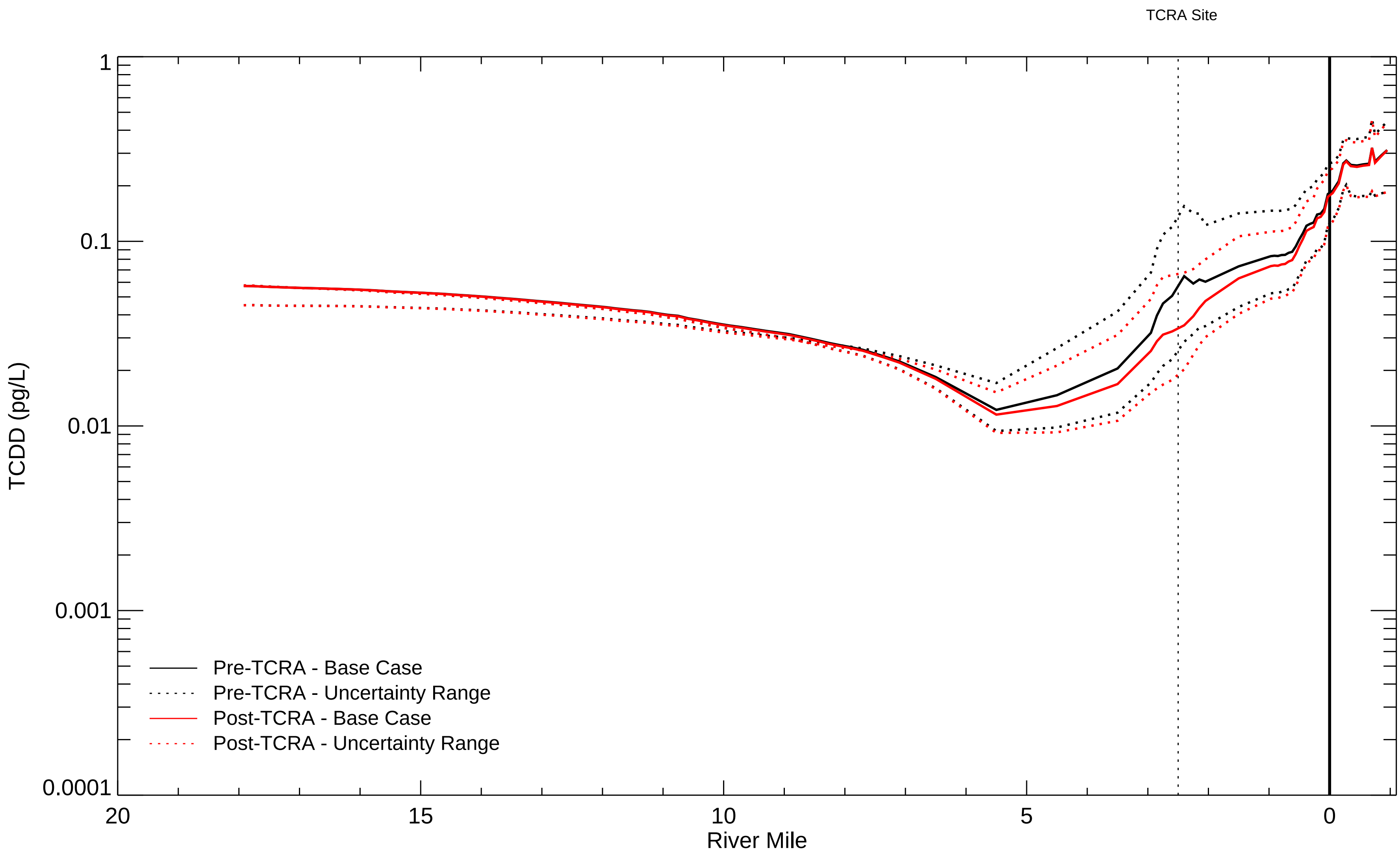


ANCHOR QEA

Miles
0 0.5 1 1.5 2

Figure 3-13
Thiessen Polygons of Total Organic Carbon
Feasibility Study
San Jacinto River Waste Pits Superfund Site



Model Run: SJR_PROJ1_BC_TCDD_1301-03, SJR_PROJ1_SENS1_TCDD_1305-41, SJR_PROJ1_SENS2_TCDD_1305-38, SJR_PROJ2_BC_TCDD_1301-06, SJR_PROJ2_SENS1_TCDD_1305-29, SJR_PROJ2_SENS2_TCDD_1305-26

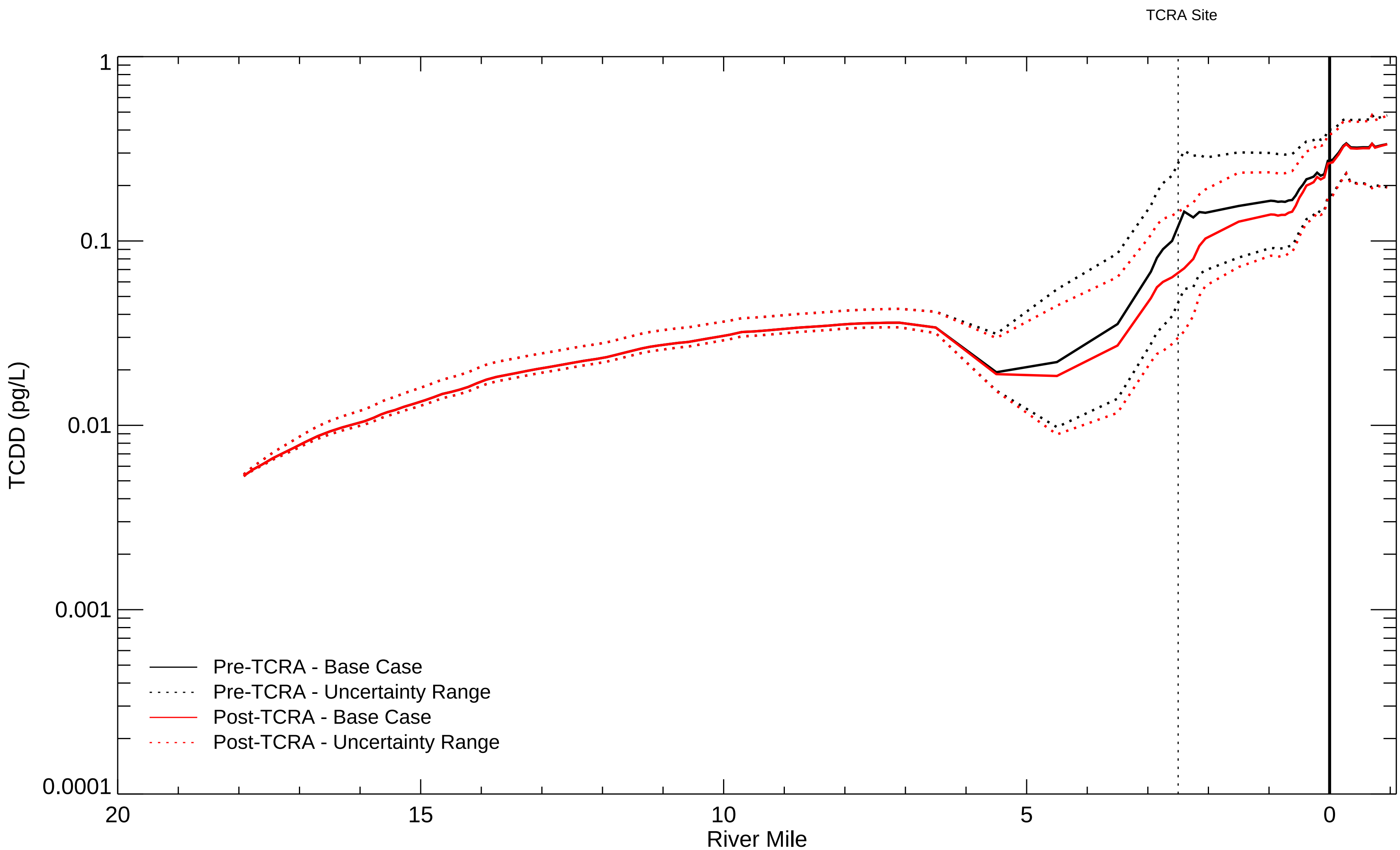
Figure 3-14a

Spatial Profiles of Model-Predicted Annual Average Water Column TCDD Concentrations (Model Year 11)

Feasibility Study

San Jacinto River Waste Pits Superfund Site

ANCHOR QEA



Model Run: SJR_PROJ1_BC_TCDD_1301-03, SJR_PROJ1_SENS1_TCDD_1305-41, SJR_PROJ1_SENS2_TCDD_1305-38, SJR_PROJ2_BC_TCDD_1301-06, SJR_PROJ2_SENS1_TCDD_1305-29, SJR_PROJ2_SENS2_TCDD_1305-26

Figure 3-14b

Spatial Profiles of Model-Predicted Annual Average Water Column TCDD Concentrations (Model Year 7)
Feasibility Study
San Jacinto River Waste Pits Superfund Site

ANCHOR QEA

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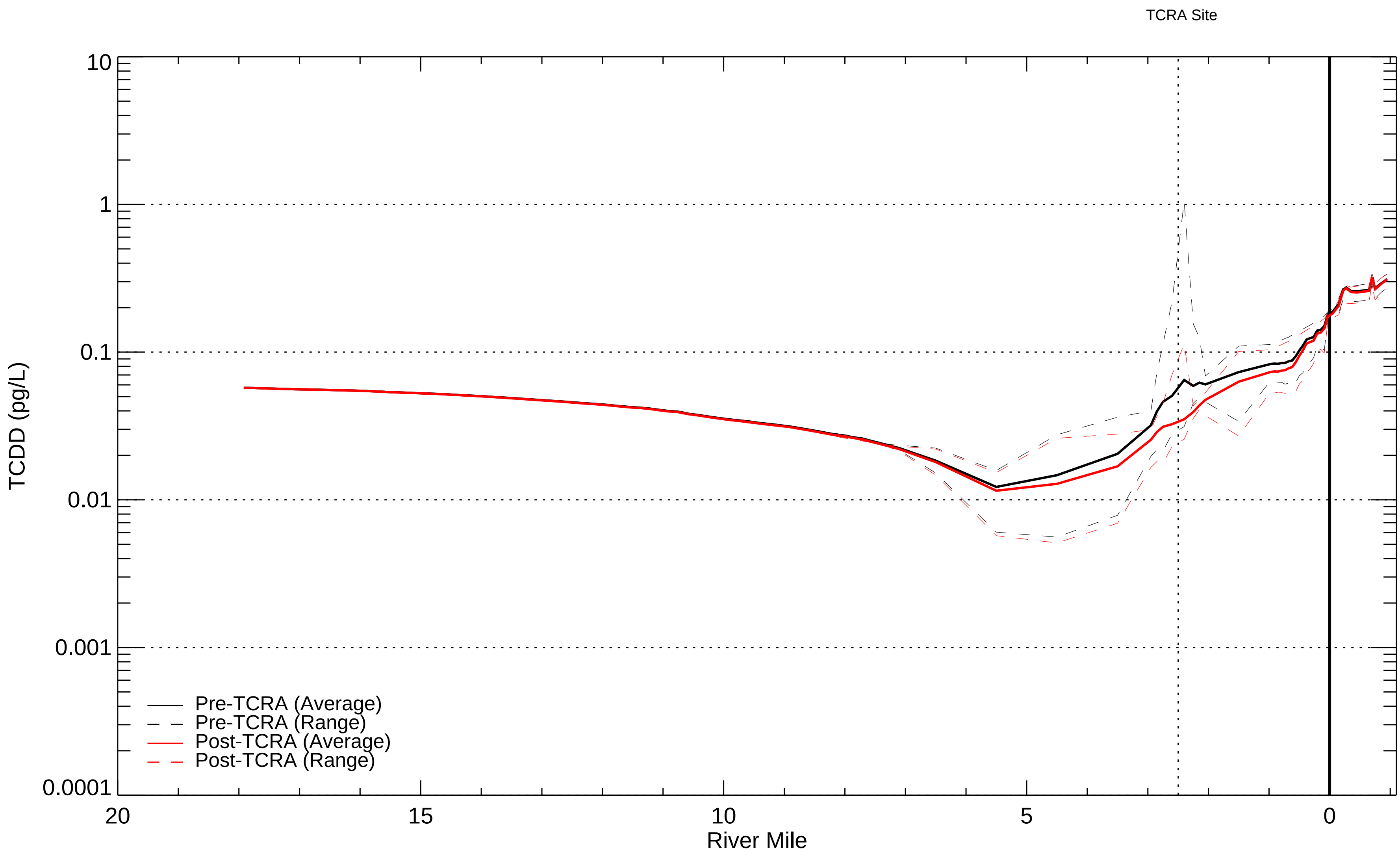
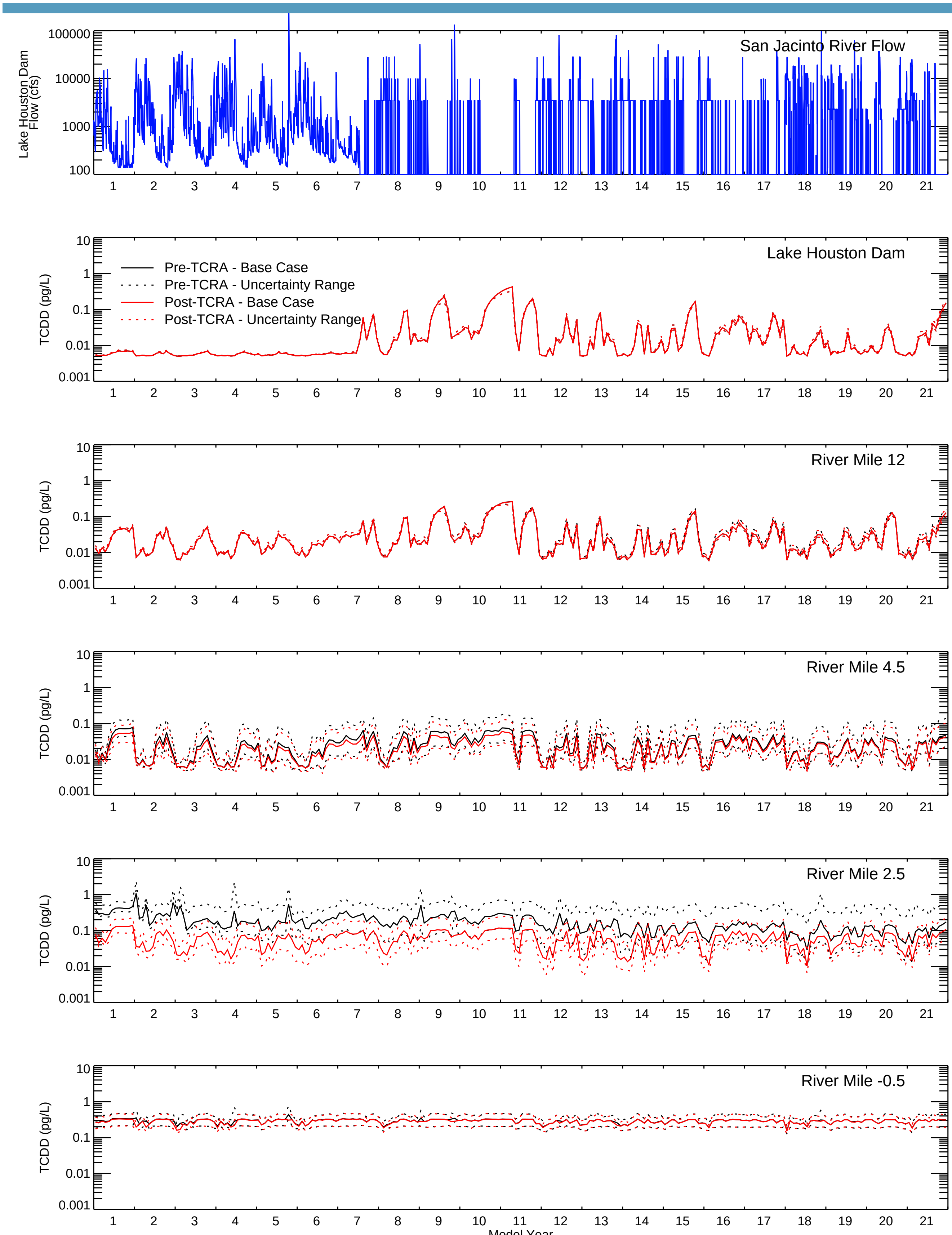


Model Run: SJR_PROJ1_BC_TCDD_1301-03, SJR_PROJ2_BC_TCDD_1301-06

Figure 3-15

Spatial Profiles of Model-Predicted Annual Average Pre- and Post-TCRA Water Column TCDD Concentrations Including Range (Model Year 11)
Feasibility Study
San Jacinto River Waste Pits Superfund Site

ANCHOR QEA



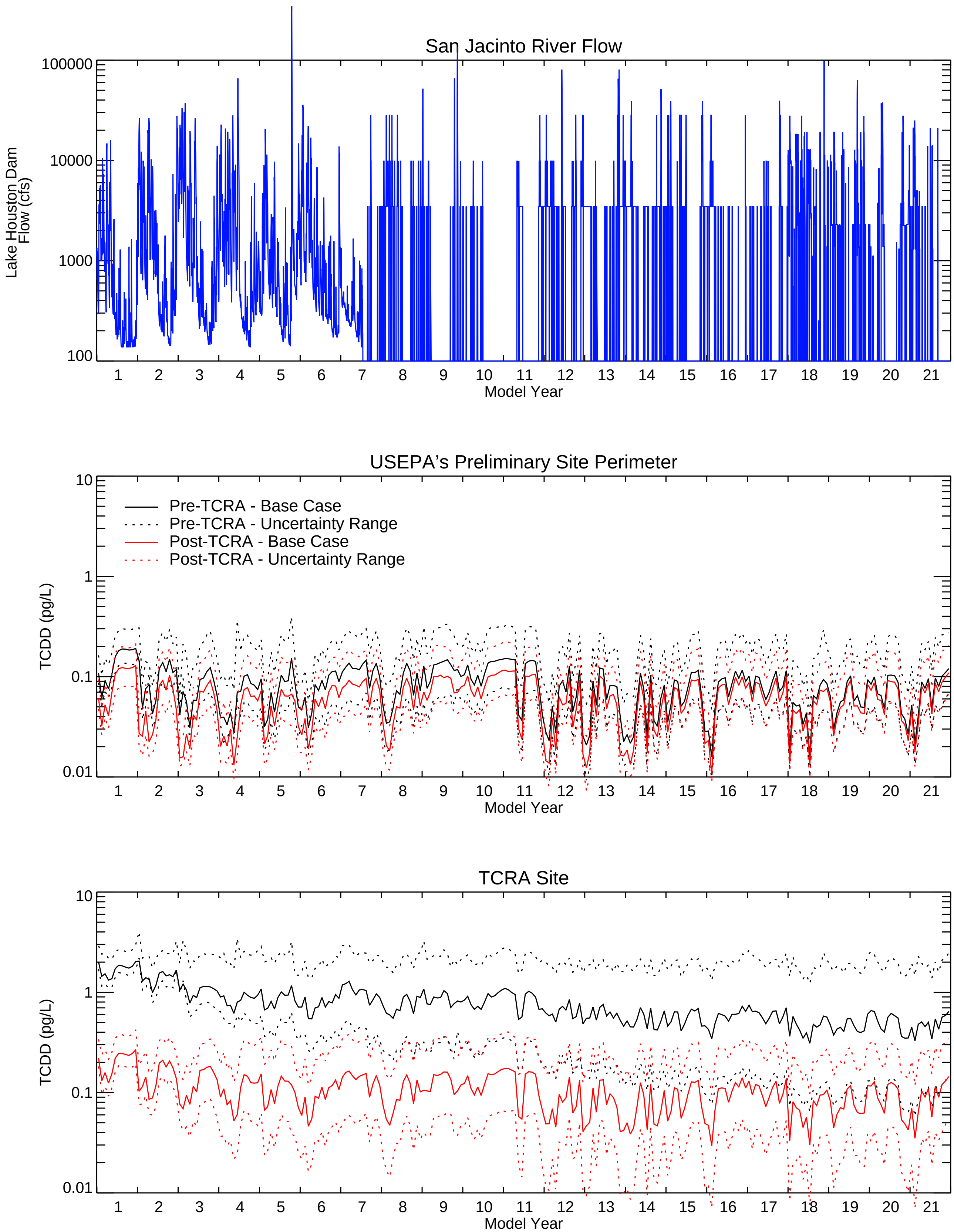
Model Run: SJR_PROJ1_BC_TCDD_1301-03, SJR_PROJ1_SENS1_TCDD_1305-41,
SJR_PROJ1_SENS2_TCDD_1305-38, SJR_PROJ2_BC_TCDD_1301-06,
SJR_PROJ2_SENS1_TCDD_1305-29, SJR_PROJ2_SENS2_TCDD_1305-26

Figure 3-16

Time Series of Model-Predicted Water Column TCDD Concentrations at Select Transects
Feasibility Study
San Jacinto River Waste Pits Superfund Site

Note: Flow less than 100 cfs plotted at 100 cfs.

ANCHOR QEA



Model Run: SJR_PROJ1_BC_TCDD_1301-03, SJR_PROJ1_SENS1_TCDD_1305-41, SJR_PROJ1_SENS2_TCDD_1305-38, SJR_PROJ2_BC_TCDD_1301-06, SJR_PROJ2_SENS1_TCDD_1305-29, SJR_PROJ2_SENS2_TCDD_1305-26

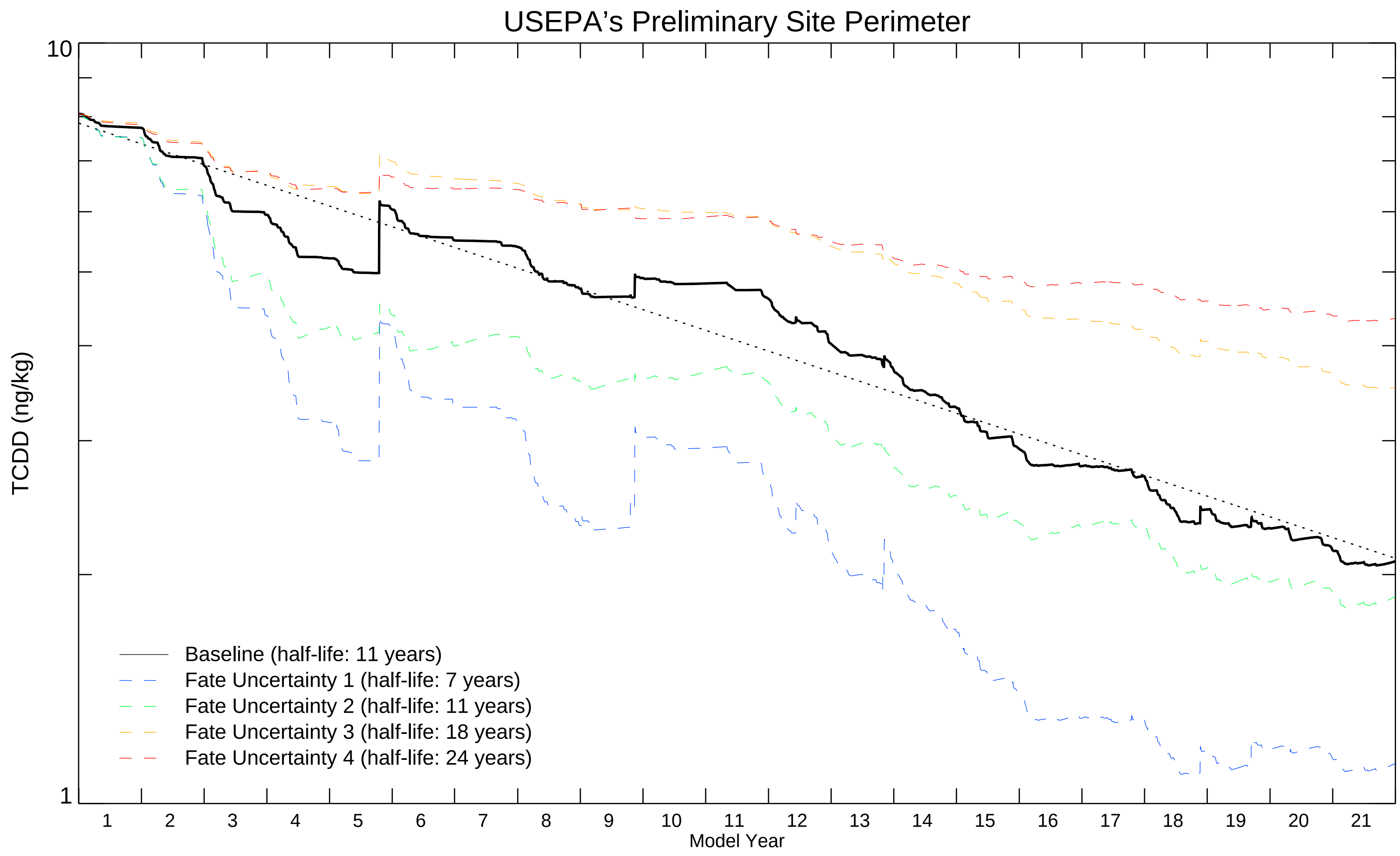
Figure 3-17

Time Series of Model-Predicted Water Column TCDD Concentrations within the USEPA's Preliminary Site Perimeter and TCRA Site

Feasibility Study

San Jacinto River Waste Pits Superfund Site

Note: Flow less than 100 cfs plotted at 100 cfs.



Model Run: SJR_PROJ2_BC_TCDD_1301-06, SJR_PROJ2_SENS1_TCDD_1305-29, SJR_PROJ2_SENS4_TCDD_1305-21, SJR_PROJ2_SENS3_TCDD_1305-22, SJR_PROJ2_SENS2_TCDD_1305-26

Figure 3-18

Time Series of Model-Predicted Post-TCRA Surface Sediment (top 6 inches) TCDD Concentrations
Averaged within the USEPA's Preliminary Site Perimeter
Feasibility Study
San Jacinto River Waste Pits Superfund Site

ANCHOR QEA

Note: Dotted line represents an exponential decay curve fit to the model results.

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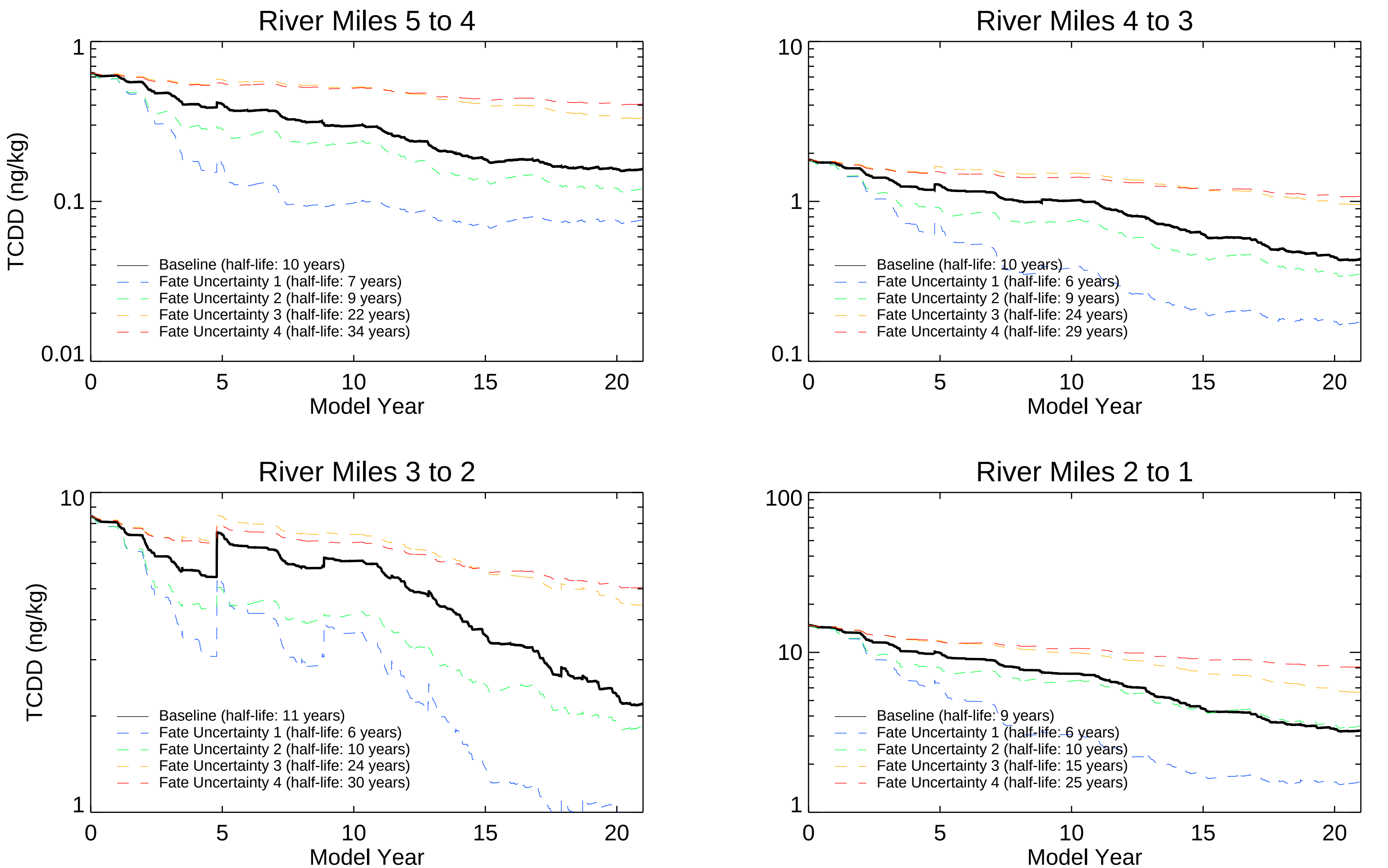
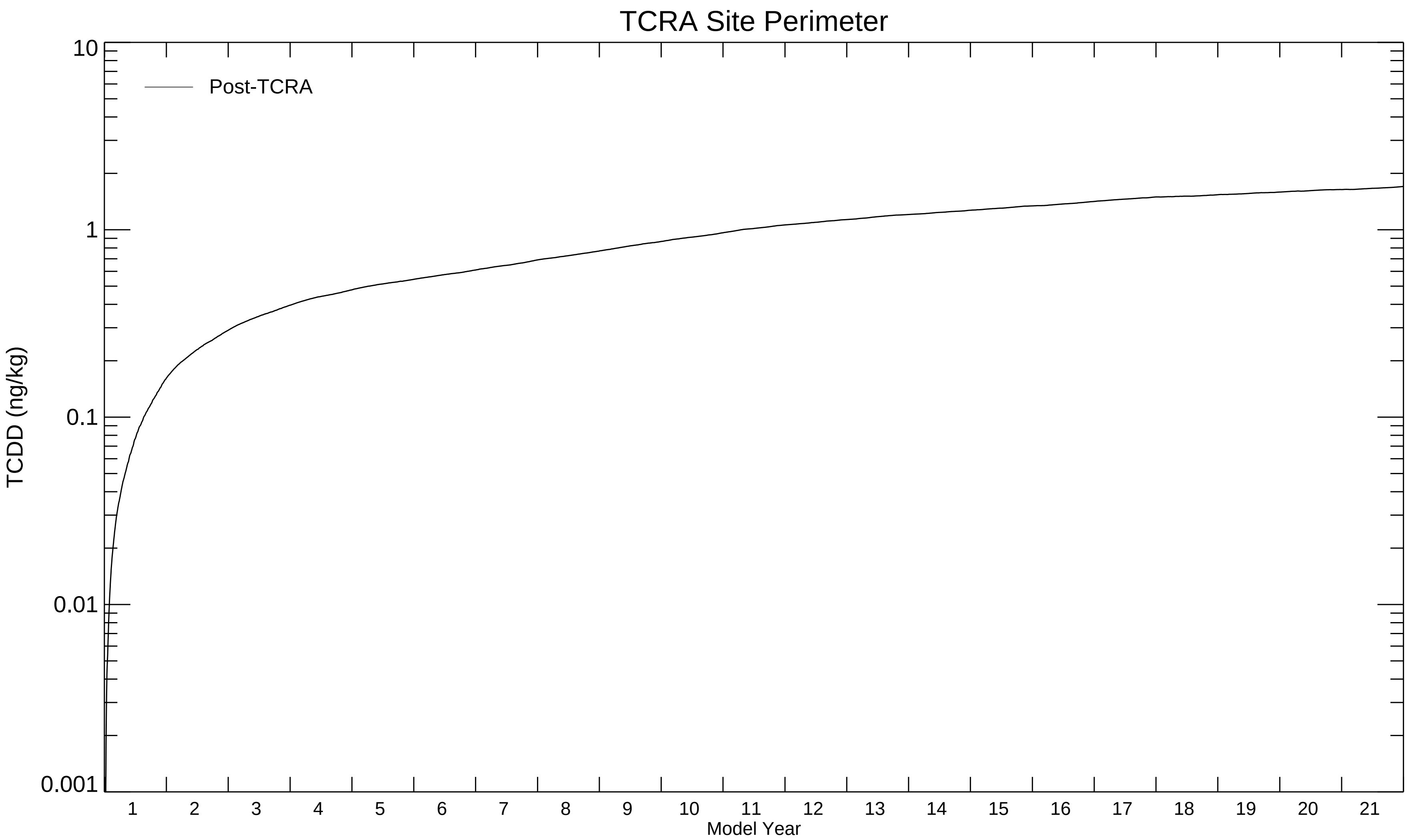


Model Run: SJR_PROJ2_BC_TCDD_1301-06, SJR_PROJ2_SENS1_TCDD_1305-29, SJR_PROJ2_SENS4_TCDD_1305-21, SJR_PROJ2_SENS3_TCDD_1305-22, SJR_PROJ2_SENS2_TCDD_1305-26

Figure 3-19

Time Series of Model-Predicted Post-TCRA Surface Sediment (top 6 inches) TCDD Concentrations Averaged by River Mile
Feasibility Study
San Jacinto River Waste Pits Superfund Site

ANCHOR QEA



Model Run: SJR_PROJ2_BC_TCDD_1301-06

Figure 3-20

Time Series of Model-Predicted Post-TCRA Sediment TCDD Concentration on the Surface of the Armored Cap
Feasibility Study
San Jacinto River Waste Pits Superfund Site

ANCHOR QEA

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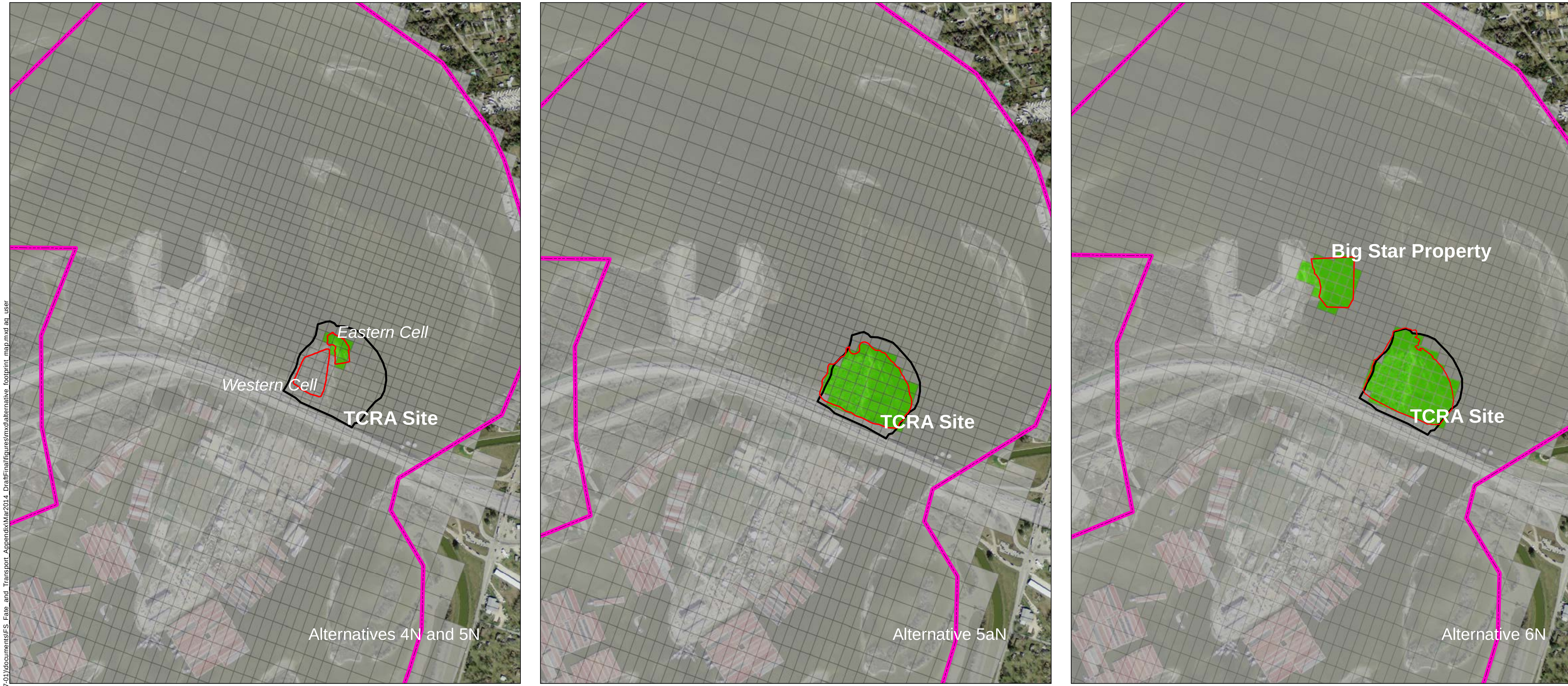

LEGEND

- USEPA's Preliminary Site Perimeter
- Perimeter of Northern Impoundments
- Remediation Footprint
- Model Grid
- Remediation Footprint Represented in Model

NOTES:
Orthoimagery presented herein are enhanced 50-cm (0.5-meter) Digital Orthophoto Quarter-Quads (DOQQs) images from the 2008 USDA-FSA National Agriculture Imagery Program (NAIP) and 2009 Texas Orthoimagery Program (TOP) aerial imagery acquisitions.

0 0.5 1 Miles

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ANCHOR QEA

Figure 4-1
Alternatives 4N, 5N, 5aN, and 6N Remediation Footprints
Feasibility Study
San Jacinto River Waste Pits Superfund Site

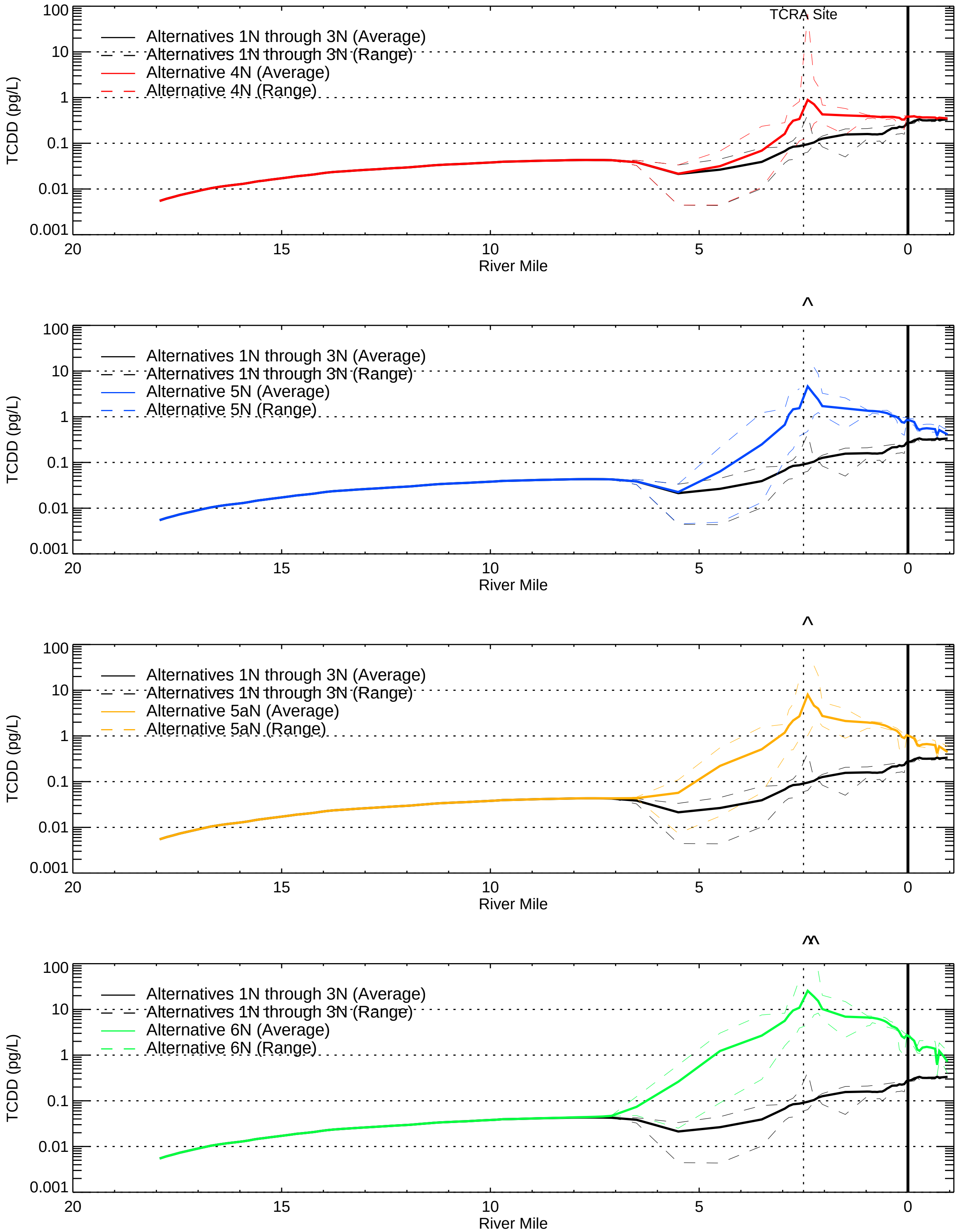

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Figure 4-2a

Spatial Profiles of Model-Predicted Annual Average Water Column TCDD Concentrations for Alternatives 1N through 3N and Alternatives 4N, 5N, 5aN, and 6N Simulations (Model Year 1)

Feasibility Study

San Jacinto River Waste Pits Superfund Site

ANCHOR QEA

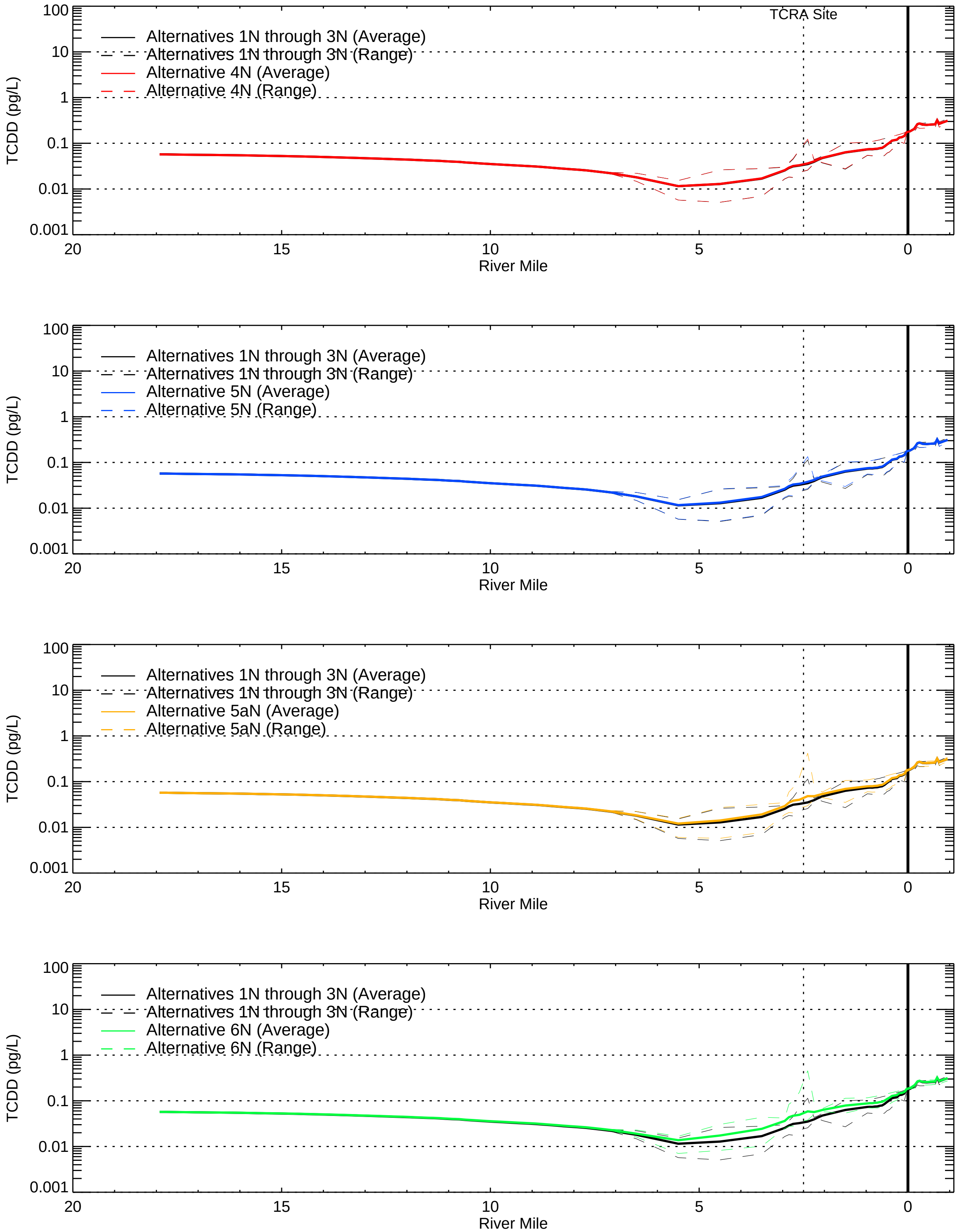

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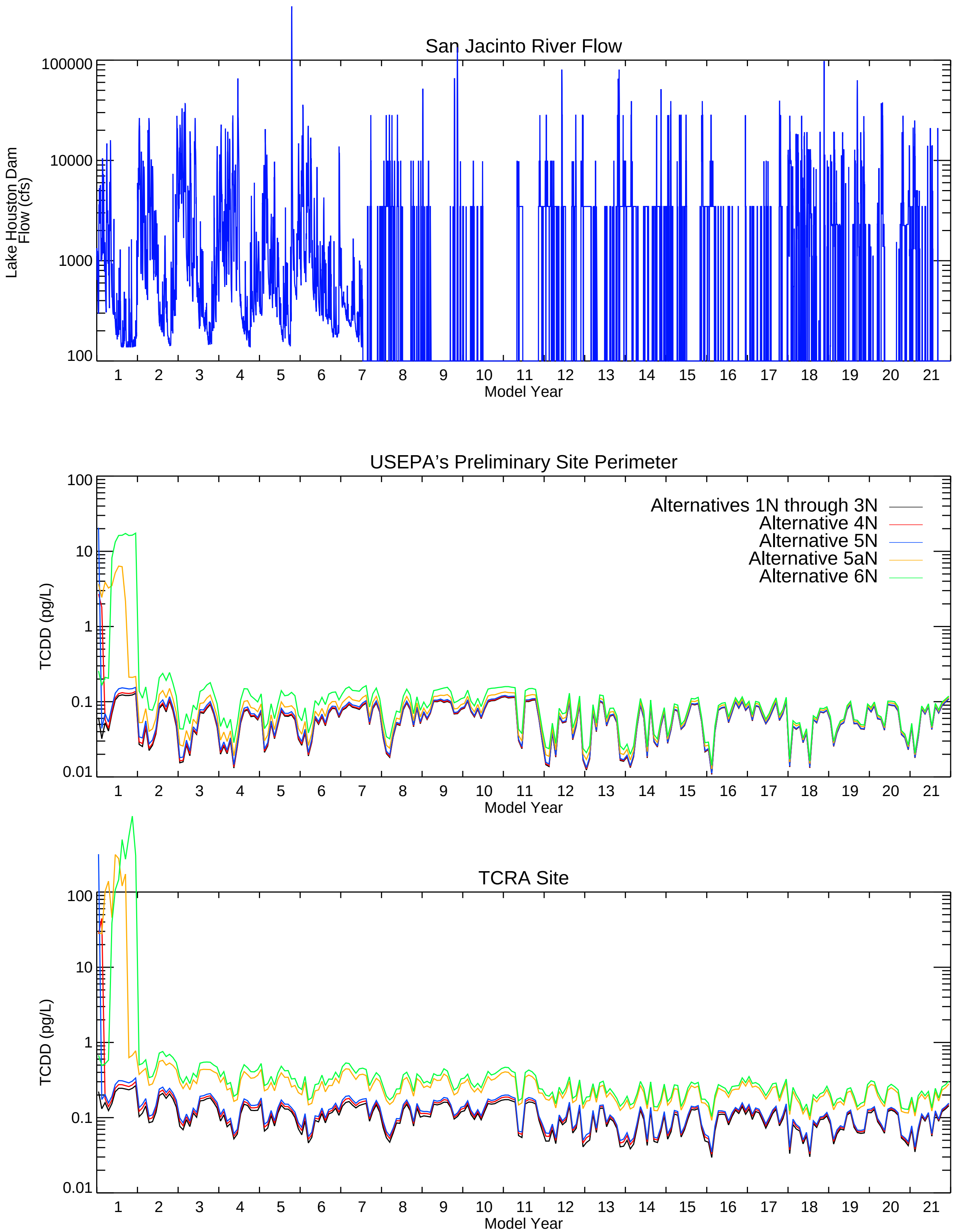
Figure 4-2b

Spatial Profiles of Model-Predicted Annual Average Water Column TCDD Concentrations for Alternatives 1N through 3N and Alternatives 4N, 5N, 5aN, and 6N Simulations (Model Year 11)

Feasibility Study

San Jacinto River Waste Pits Superfund Site

ANCHOR QEA



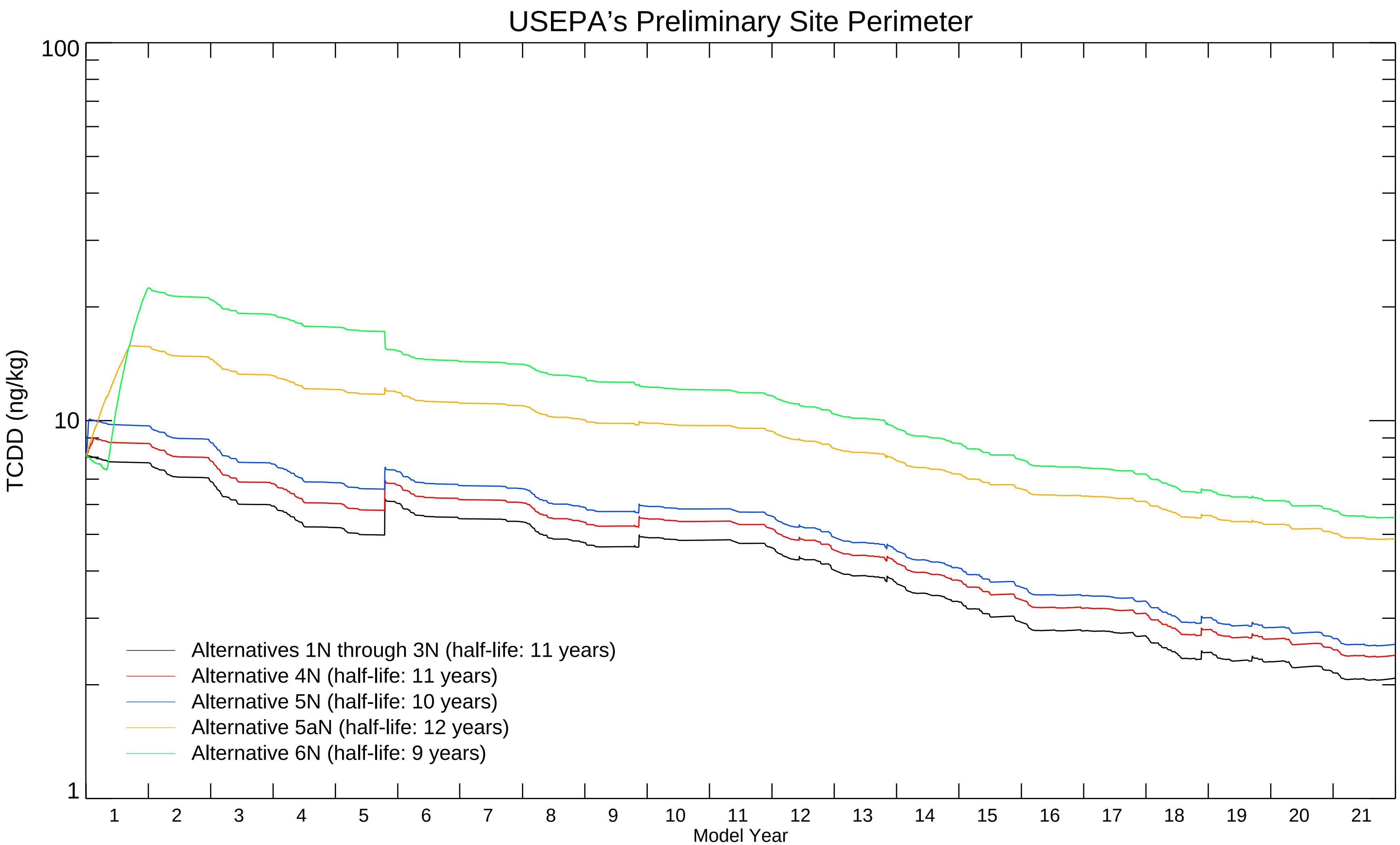
Model Run: SJR_PROJ2_BC_TCDD_1301-06, SJR_PROJ3_BC_TCDD_1307-01,
SJR_PROJ3_BC_TCDD_1307-02, SJR_PROJ3_BC_TCDD_1402-01,
SJR_PROJ3_BC_TCDD_1307-03

Figure 4-3

Time Series of Model-Predicted Water Column TCDD Concentrations Averaged within the USEPA's Preliminary Site Perimeter and TCRA Site for Alternatives 1N through 3N and Alternatives 4N, 5N, 5aN, and 6N Simulations
Feasibility Study
San Jacinto River Waste Pits Superfund Site

ANCHOR QEA

Note: Flow less than 100 cfs plotted at 100 cfs.



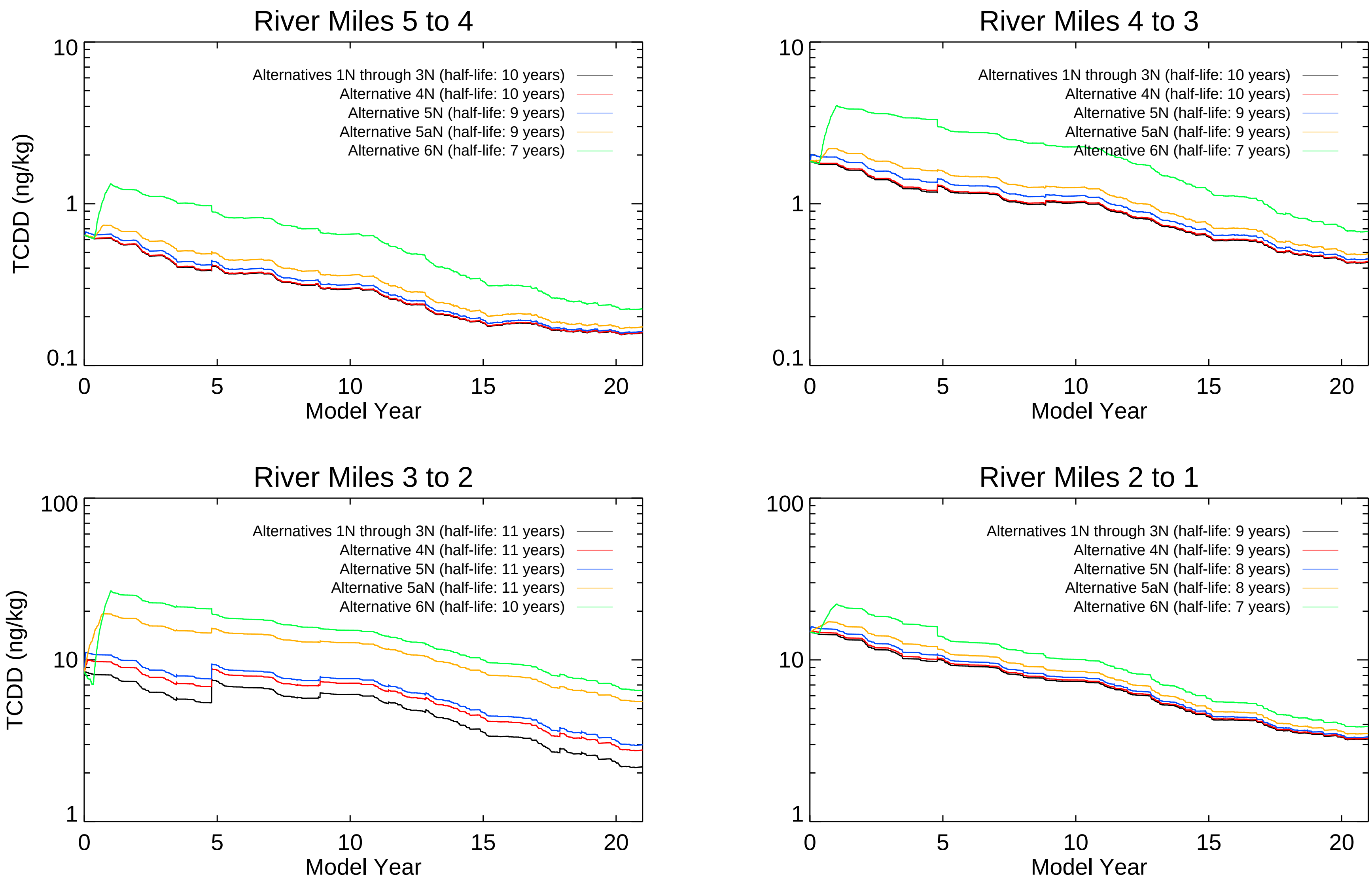
* The remediation year (year 1) is excluded from the half-life calculation for all the simulations on this plot.

Model Run: SJR_PROJ2_BC_TCDD_1301-06, SJR_PROJ3_BC_TCDD_1307-01, SJR_PROJ3_BC_TCDD_1307-02, SJR_PROJ3_BC_TCDD_1402-01, SJR_PROJ3_BC_TCDD_1307-03

Figure 4-4

Time Series of Model-Predicted Surface Sediment (top 6 inches) TCDD Concentrations Averaged within the USEPA's Preliminary Site Perimeter for Alternatives 1N through 3N and Alternatives 4N, 5N, 5aN, and 6N Simulations
Feasibility Study
San Jacinto River Waste Pits Superfund Site

ANCHOR QEA

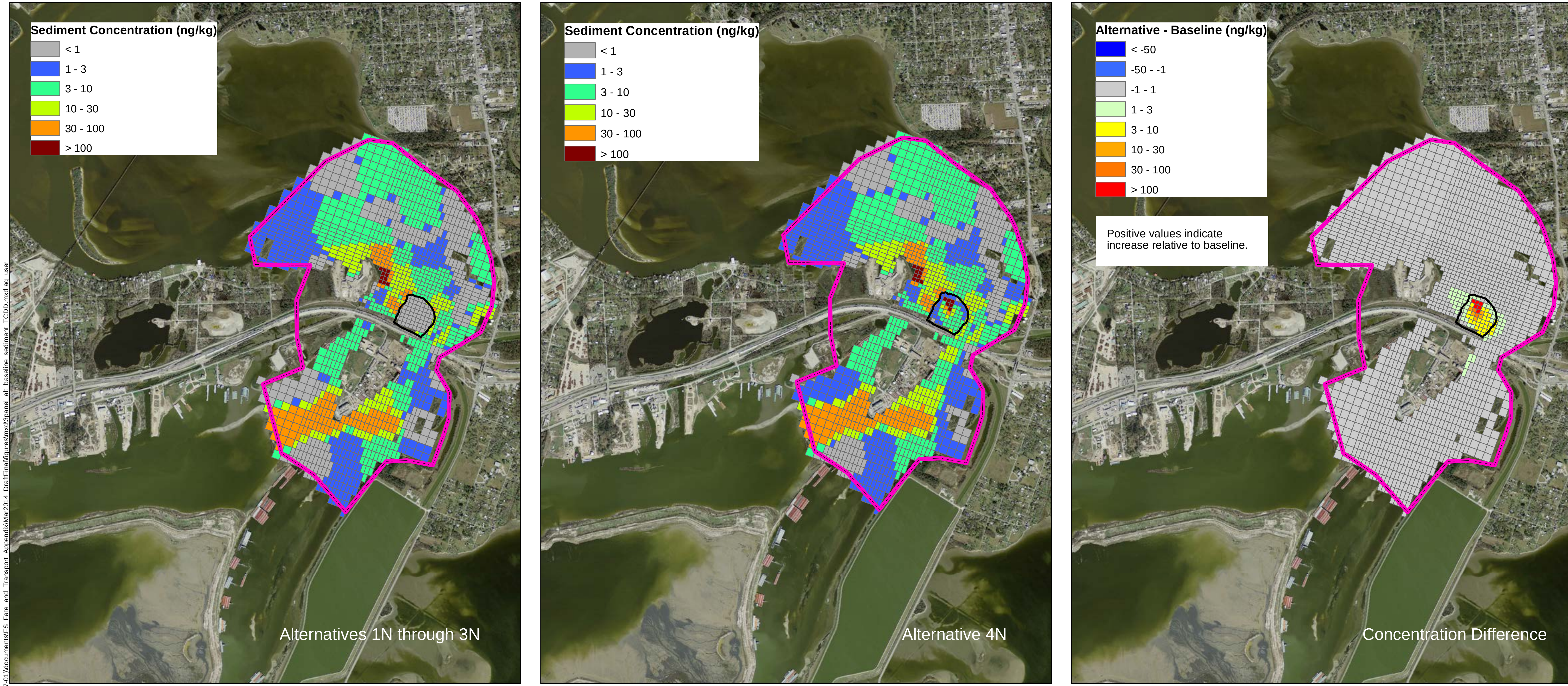


* The remediation year (year 1) is excluded from the half-life calculation for all the simulations on this plot.

Model Run: SJR_PROJ2_BC_TCDD_1301-06, SJR_PROJ3_BC_TCDD_1307-01, SJR_PROJ3_BC_TCDD_1307-02, SJR_PROJ3_BC_TCDD_1402-01, SJR_PROJ3_BC_TCDD_1307-03

Figure 4-5

Time Series of Model-Predicted Surface Sediment (top 6 inches) TCDD Concentrations Averaged by River Mile for Alternatives 1N through 3N and Alternatives 4N, 5N, 5aN, and 6N Simulations
Feasibility Study
San Jacinto River Waste Pits Superfund Site



LEGEND

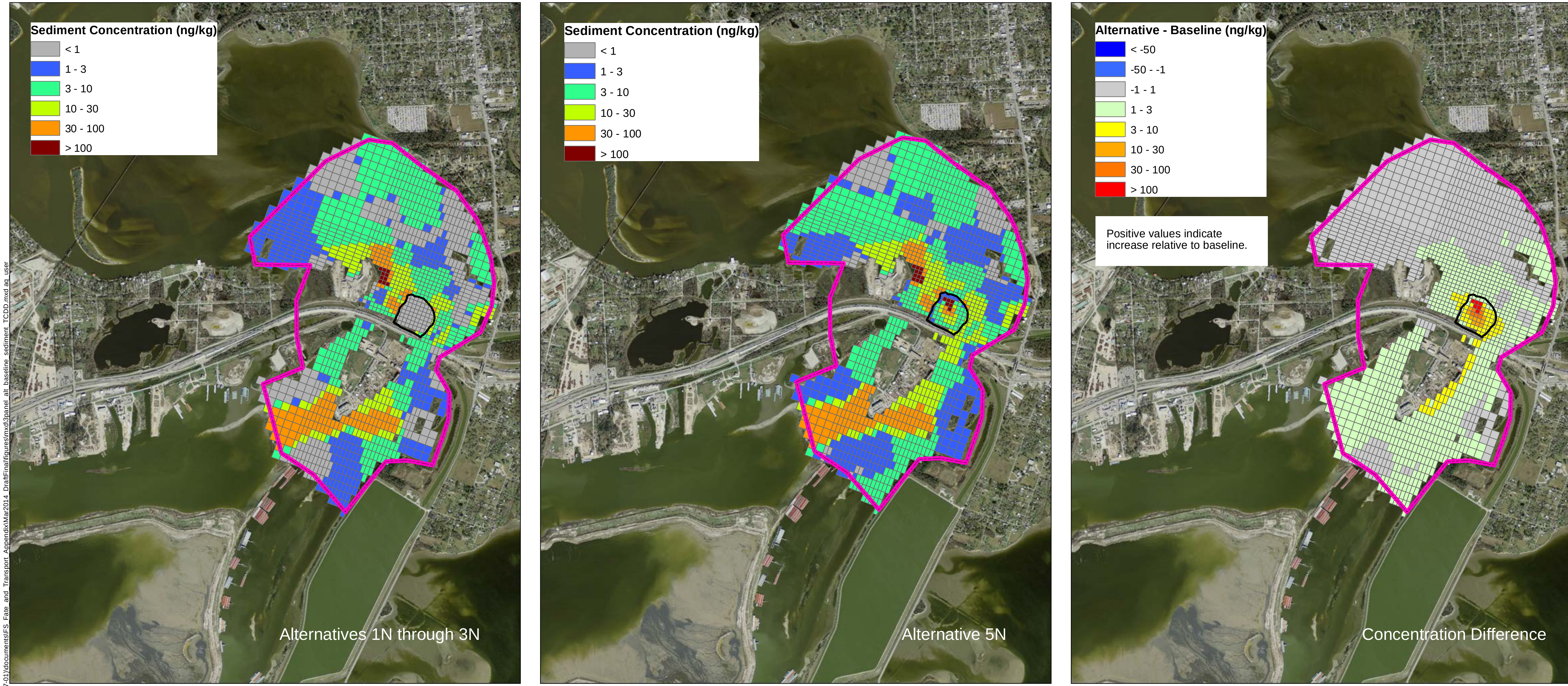
Perimeter of Northern Impoundments

USEPA's Preliminary Site Perimeter

NOTES:
Orthoimagery presented herein are enhanced 50-cm (0.5-meter) Digital Orthophoto Quarter-Quads (DOQQs) images from the 2008 USDA-FSA National Agriculture Imagery Program (NAIP) and 2009 Texas Orthoimagery Program (TOP) aerial imagery acquisitions.

0 1 2 Miles

Figure 4-6a
Model-Predicted Surface Sediment (top 6 inches) TCDD Concentrations at the End of the First Model Year for Alternatives 1N through 3N and Alternative 4N Simulations
Feasibility Study
San Jacinto River Waste Pits Superfund Site



LEGEND

- Perimeter of Northern Impoundments
- USEPA's Preliminary Site Perimeter

NOTES:
Orthoimagery presented herein are enhanced 50-cm (0.5-meter) Digital Orthophoto Quarter-Quads (DOQQs) images from the 2008 USDA-FSA National Agriculture Imagery Program (NAIP) and 2009 Texas Orthoimagery Program (TOP) aerial imagery acquisitions.

0 1 2 Miles

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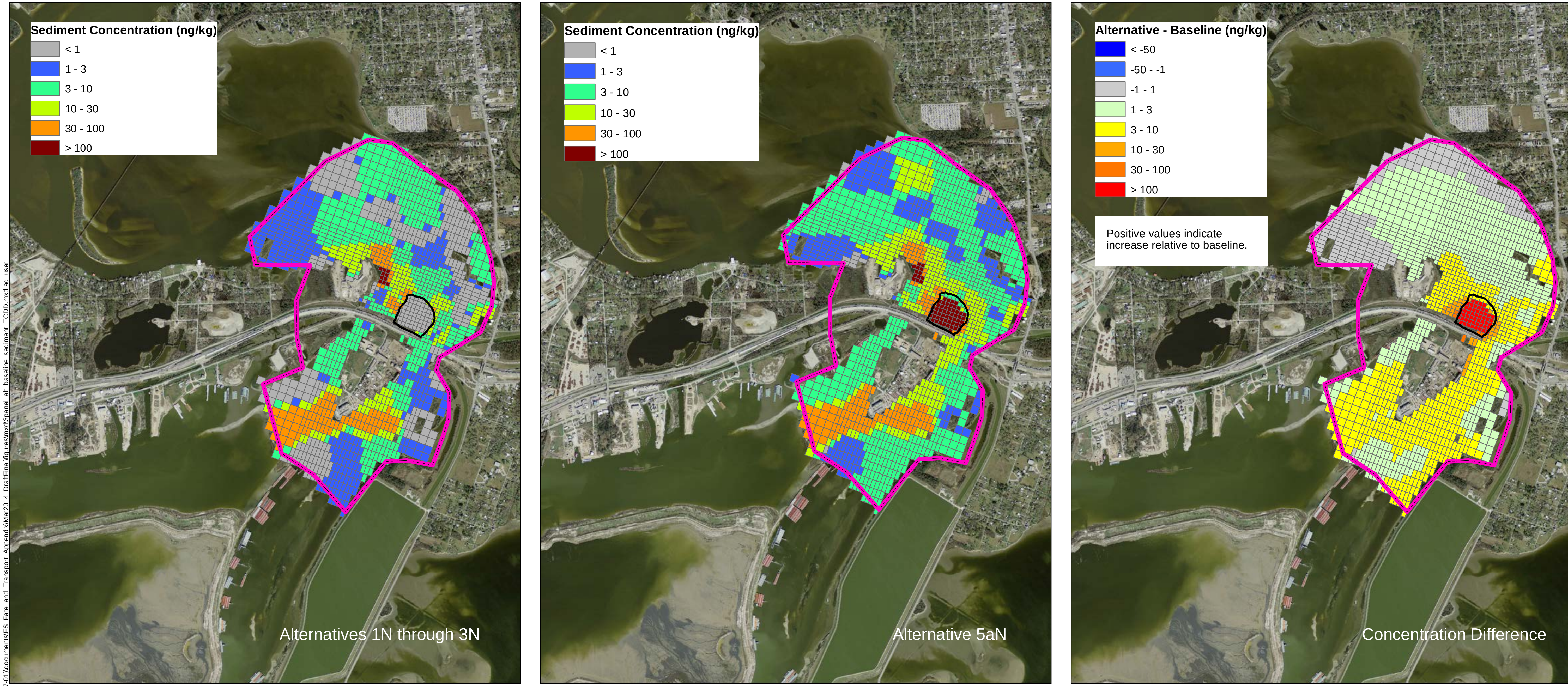
ANCHOR QEA

Figure 4-6b
Model-Predicted Surface Sediment (top 6 inches) TCDD Concentrations at the End of the First Model Year for Alternatives 1N through 3N and Alternative 5N Simulations
Feasibility Study
San Jacinto River Waste Pits Superfund Site



LEGEND

Perimeter of Northern Impoundments

USEPA's Preliminary Site Perimeter

NOTES:
Orthoimagery presented herein are enhanced 50-cm (0.5-meter) Digital Orthophoto Quarter-Quads (DOQQs) images from the 2008 USDA-FSA National Agriculture Imagery Program (NAIP) and 2009 Texas Orthoimagery Program (TOP) aerial imagery acquisitions.

0 1 2 Miles

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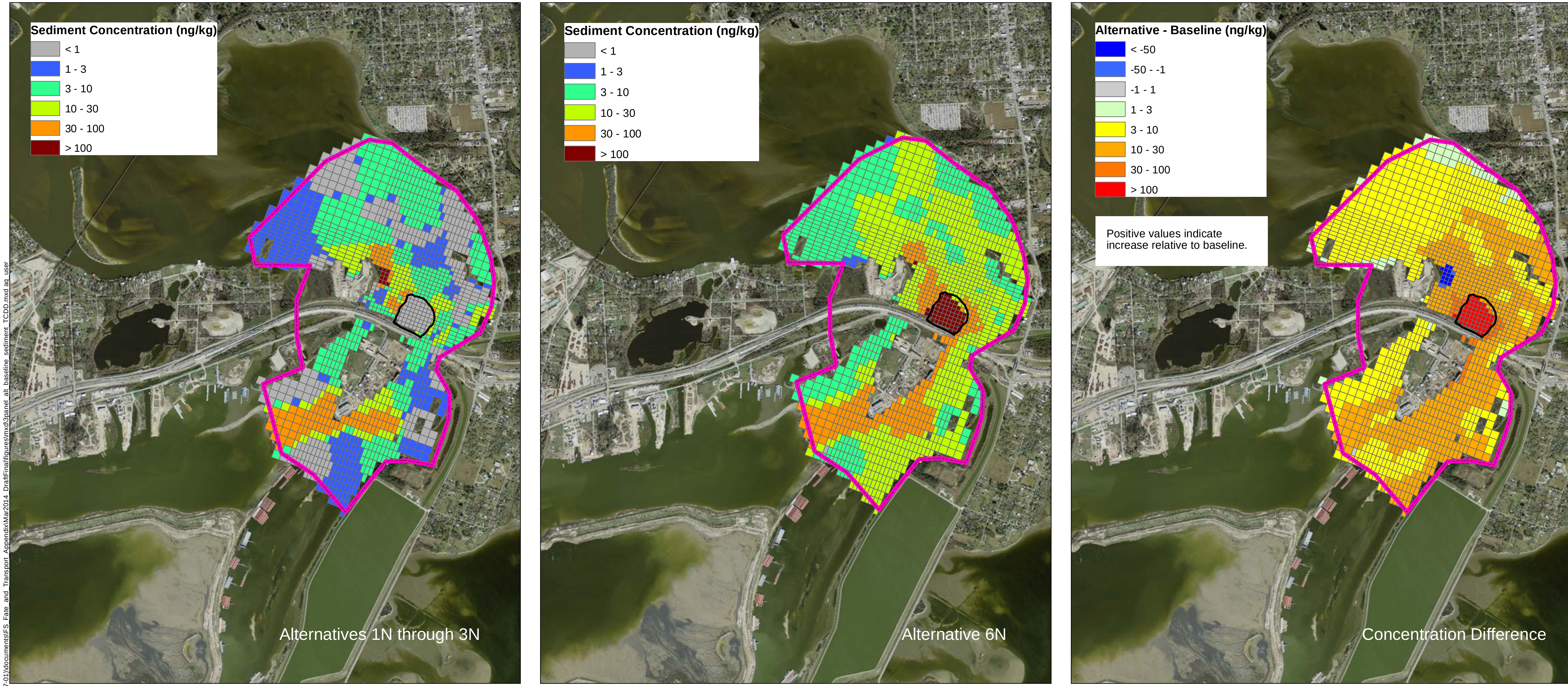
Figure 4-6c
Model-Predicted Surface Sediment (top 6 inches) TCDD Concentrations at the End of the First Model Year for Alternatives 1N through 3N and Alternative 5aN Simulations
Feasibility Study
San Jacinto River Waste Pits Superfund Site

ANCHOR QEA



LEGEND

Perimeter of Northern Impoundments

USEPA's Preliminary Site Perimeter

NOTES:
Orthoimagery presented herein are enhanced 50-cm (0.5-meter) Digital Orthophoto Quarter-Quads (DOQQs) images from the 2008 USDA-FSA National Agriculture Imagery Program (NAIP) and 2009 Texas Orthoimagery Program (TOP) aerial imagery acquisitions.

0 1 2 Miles

Figure 4-6d
Model-Predicted Surface Sediment (top 6 inches) TCDD Concentrations at the End of the First Model Year for Alternatives 1N through 3N and Alternative 6N Simulations
Feasibility Study
San Jacinto River Waste Pits Superfund Site

ANCHOR QEA

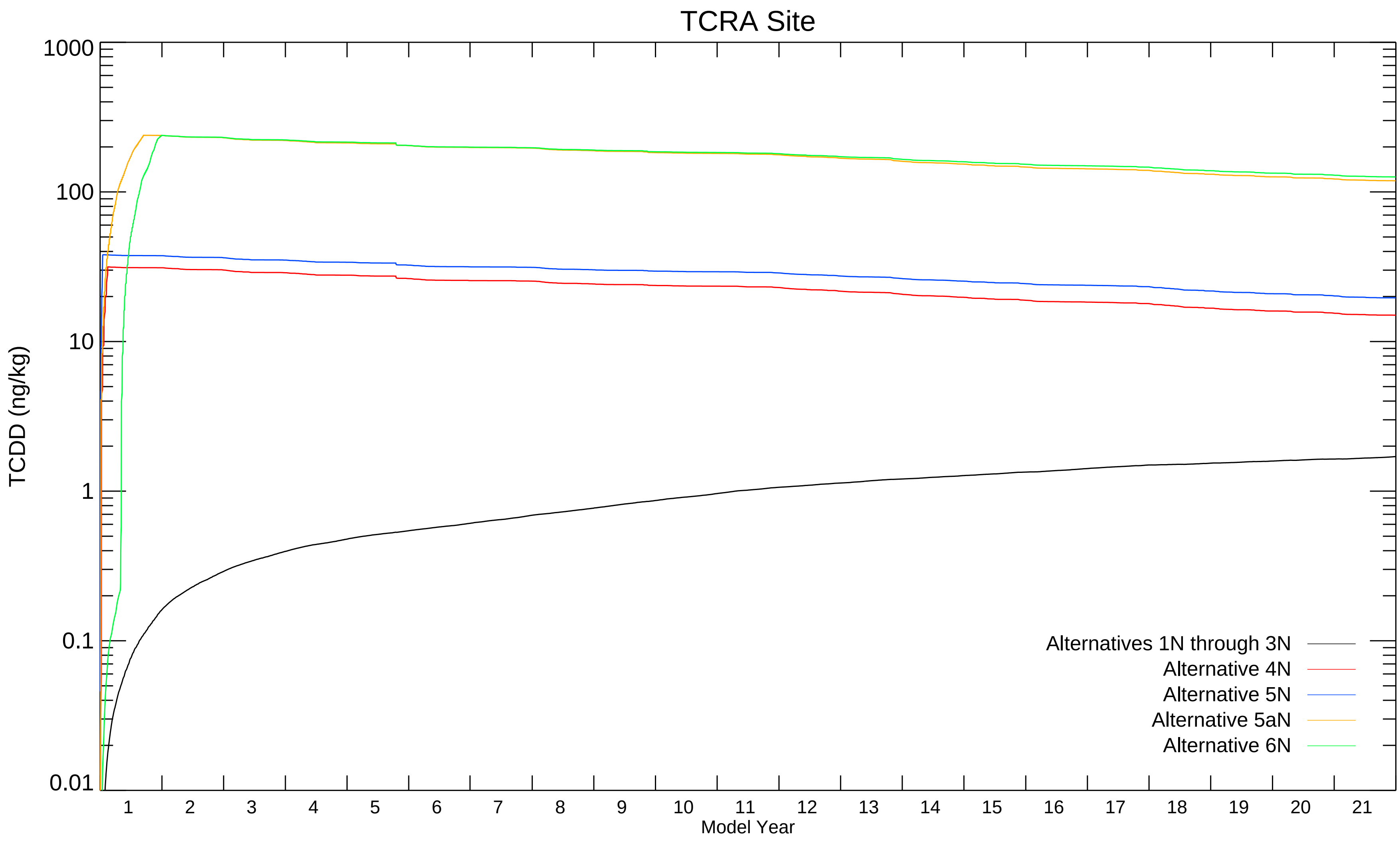


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Figure 4-7

Time Series of Model-Predicted Surface Sediment (top 6 inches) TCDD Concentrations Averaged over the TCRA Site for Alternatives 1N through 3N and Alternatives 4N, 5N, 5aN, and 6N Simulations
Feasibility Study
San Jacinto River Waste Pits Superfund Site

ANCHOR QEA

ATTACHMENT 1 (ON CD)
COMPLETE SET OF MODEL OUTPUT GRAPHICS FOR TCDD AND TCDF

DRAFT FINAL INTERIM FEASIBILITY STUDY
APPENDIX B: HYDRODYNAMIC CAP MODELING

SAN JACINTO RIVER WASTE PITS SUPERFUND SITE

Prepared for

International Paper Company

McGinnes Industrial Maintenance Corporation

Prepared by

Anchor QEA, LLC

614 Magnolia Avenue

Ocean Springs, Mississippi 39564

March 2014

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LIST OF ACRONYMS AND ABBREVIATIONS

ACES	Automated Coastal Engineering System
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
cfs	cubic feet per second
EFDC	Environmental Fluid Dynamics Code
FS	Feasibility Study
H:VI-10	horizontal to vertical Interstate 10
mph	miles per hour
NAVD88	North American Vertical Datum of 1988
pcf	pounds per cubic foot
psf	pounds per square foot
RAWP	Removal Action Work Plan
S_f	safety factor
Site	San Jacinto River Waste Pits Superfund Site
SJRF	San Jacinto River Fleet
TCRA	Time Critical Removal Action
USACE	U.S. Army Corps of Engineers
USEPA	U.S. Environmental Protection Agency

1 INTRODUCTION

This appendix to the Feasibility Study Report (FS Report) for the San Jacinto River Waste Pits Superfund Site (Site) presents the results of the hydrodynamic evaluation of a Permanent Cap as defined in the FS Report (Permanent Cap) considered as part of the remedial alternatives for the area north of Interstate 10 (I-10). The Permanent Cap is included in Alternatives 3N, 4N, 5N, and 5aN described in the main text of the FS Report. Alternative 6N does not include a Permanent Cap. Specifically, this appendix documents the following:

- The design rock size for a Permanent Cap, focusing on the factor of safety for armor rock on slopes in the wave-breaking (i.e., surf) zone in the area of the impoundments located north of I-10 (i.e., Northern Impoundments) where a Time Critical Removal Action (TCRA) has already been completed (TCRA Site)
- The effect of varying assumptions for the design storm event magnitude on predicted stable armor rock sizes
- An evaluation of the effect of wind- and vessel-generated forces on the size of armor rock required
- Modeling of flood impacts during and after construction for each of the remedial alternatives.

1.1 Background

The TCRA included design and installation of an armored cap as described in the FS Report over the TCRA Site (Armored Cap). The Armored Cap was designed to provide immediate containment of materials in the former Northern Impoundments and to be compatible with a final Site remedy. As with any cap design, the factor of safety can be increased, which ultimately will reduce the potential for long-term cap maintenance needs.

Subsequent to completing the TCRA, U.S. Environmental Protection Agency (USEPA) raised questions about the basis of design for the TCRA, specifically the protectiveness of a cap design that is based on the 100-year return-interval storm, which is recommended in USEPA's Contaminated Sediment Remediation Guidance for Hazardous Waste Sites (USEPA 2005). At USEPA's request, the United States Army Corps of Engineers (USACE) prepared a report addressing the design and construction of the Armored Cap (USACE 2013). Details regarding the review of the Armored Cap design and construction are provided in the FS

Report. The Armored Cap was designed considering a range of storms up to the 100-year return interval. In support of the FS, additional evaluations were performed to consider a range of specific modeled events as well as an extreme-level storm event with a 500-year return interval.

1.2 Permanent Cap

The FS Report includes a Permanent Cap as an element for several alternatives, which entails flattening the slopes of the existing Armored Cap by adding additional armor rock material to increase the factor of safety. The Permanent Cap would entail construction of 5 feet horizontal to 1 foot vertical (5H:1V) slopes along the central, western, and southern berms (flattening these berms from 2H:1V to 5H:1V) to increase the factor of safety in the wave-breaking zone and flattening the submerged slopes from 2H:1V to 3H:1V to increase the factor of safety for submerged slopes. Such measures would exceed recommendations made by USACE in its review of the Armored Cap design and construction, as described in the FS Report.

Armor Cap D material, as described in the TCRA Final Removal Action Work Plan (RAWP; Anchor QEA 2010), would be used for the Permanent Cap. This is a natural stone material with the following estimated gradation:

- D_{100} = 15 inches
- D_{85} = 12 inches
- D_{50} = 10 inches
- D_{15} = 8 inches

1.3 Design Storm Event Evaluation

In addition to evaluating design slopes and armor size for the Permanent Cap, this appendix describes the analysis that was performed to evaluate the long-term protectiveness of the Permanent Cap under a variety of storm conditions, including several actual storms that have occurred in the vicinity of the Site. An evaluation of current velocities and stable cap grain size was performed for wind- and vessel-generated waves breaking in the surf zone, as well as for river currents, during the following storm and flood scenarios:

- 5-year flood
- 10-year flood
- 25-year flood
- 50-year flood
- 100-year flood
- 500-year flood
- Hurricane Ike
- Tropical Storm Allison
- October 1994 Harris County flood

2 DESIGN AND PERFORMANCE CRITERIA

USEPA and USACE's Guidance for In-Situ Subaqueous Capping of Contaminated Sediments (USACE 1998) states:

> *The cap component for stabilization/erosion protection has a dual function…to stabilize the contaminated sediments being capped…[and] to make the cap itself resistant to erosion.*

In addition, USEPA's Contaminated Sediment Remediation Guidance for Hazardous Waste Sites (USEPA 2005) states:

> *[T]he design of the erosion protection features of an in-situ cap (i.e., armor layers) should be based on the magnitude and probability of occurrence of relatively extreme erosive forces estimated at the capping site. Generally, in-situ caps should be designed to withstand forces with a probability of 0.01 per year, for example, the 100-year storm.*

The Armored Cap was designed to provide isolation of underlying sediment and protection from erosive forces in the San Jacinto River (i.e., waves and currents). The Permanent Cap will provide enhanced long-term protection of the underlying materials. The evaluation of the Permanent Cap was performed using methods developed by USEPA and USACE specifically for in situ caps, such as methods included in Armor Layer Design of Guidance for In Situ Subaqueous Capping of Contaminated Sediments (Maynord 1998).

In addition to the recommended 100-year storm design criterion, this appendix considers a range of storm and flood scenarios up to a 500-year storm to assess the sensitivity of the stable armor rock size to the magnitude of the storm and to evaluate the performance of the Permanent Cap under these extreme scenarios.

3 WIND WAVE AND VESSEL WAKE EVALUATION

This section describes evaluations of wind-generated waves and vessel-generated wakes, both of which were used to assess the Permanent Cap that is described in the FS.

3.1 Wind-Generated Waves

Winds blowing across the surface of waterbodies transmit energy to the water, and waves are formed. The size of these wind-generated waves depends on the wind velocity, the length of time the wind is blowing, and the extent of open water over which it blows (i.e., the "fetch" length; USACE 1991).

The wind-generated wave evaluation performed as part of this assessment consisted of the following major components:

- Obtaining historical wind speeds and directions near the TCRA Site
- Conducting a statistical evaluation of wind data to estimate various return-interval wind speeds for the largest fetch distances adjacent to the TCRA Site
- Estimating the corresponding wave height and period from the wind data

3.1.1 Wind Data Evaluation

Hourly wind measurements (i.e., speed and direction) from 1973 through July 2012 were obtained from George Bush Intercontinental Airport in Houston, Texas. A wind rose diagram for these data, illustrating how wind speed and direction are typically distributed for the TCRA Site, is shown in Figure 1. Wind data were reported in 2-minute averages every hour. As depicted in Figure 1, the prevailing winds in the area are from the south and southeasterly directions, although there can be significant wind events from the north.

The methodology used to estimate wind speeds for wave prediction was consistent with that described in Part II – Chapter 2 of USACE's Coastal Engineering Manual (USACE 2006). A statistical evaluation was performed on the maximum annual wind speeds to estimate various return-interval wind speeds from the north and northwest (the two longest fetch distances that could create wind-generated waves that could impact the TCRA Site). Figure 2 shows fetch distances from the north and northwest used in the calculation.

Five candidate probability distribution functions were fitted to the maximum 2-minute averaged annual wind speeds to develop representative wind speeds with different return periods. The candidate distribution functions evaluated were Fisher-Tippet Type I and Weibull distributions with the exponent *k* varying from 0.75 to 2.0. The return-interval wind speeds used in the design were chosen from the distribution that best fit these data. Figures 3 and 4 show plots of the computed return-interval wind speeds for winds blowing from north and northwest, respectively.

3.1.2 Wave Prediction

The USACE Automated Coastal Engineering System (ACES) computer program was used to model wave growth and propagation due to winds (USACE 1992). The ACES program was developed by USACE and is an accepted worldwide reference for modeling water wave mechanics and properties. To compute the wave height for each direction, the wind speed was applied along the fetch distance shown in Figure 2 for each direction. The wave height and period were determined using the ACES Wave Prediction Module. Tables 3-1 and 3-2 summarize the results for winds from the north and northwest, respectively.

Table 3-1
Computed Significant Wave Heights and Periods for Winds Blowing from the North (0.8-mile fetch length)

Description	2-year	5-year	10-year	25-year	50-year	100-year
Wind speed (miles per hour)	26.9	33.0	37.0	42.1	45.9	49.7
Significant wave height (feet)	0.71	0.88	0.99	1.13	1.24	1.34
Wave period (seconds)	1.49	1.60	1.67	1.75	1.80	1.85

Table 3-2
Computed Significant Wave Heights and Periods for Winds Blowing from the Northwest (1.4-mile fetch length)

Description	2-year	5-year	10-year	25-year	50-year	100-year
Wind Speed (miles per hour)	29.2	34.3	37.7	41.9	45.1	48.2
Significant Wave Height (feet)	0.99	1.17	1.28	1.42	1.53	1.63
Wave Period (seconds)	1.80	1.91	1.97	2.05	2.10	2.15

Note:
In the ACES Wave Prediction Module, the 2-minute averaged wind speeds input to ACES were converted to 15-minute averaged wind speeds in the wave generation model, because the wave generation process correlates to 15-minute interval wind speeds. Shorter-duration gusts are generally not sufficient for significant wave generation.

Because the estimated 100-year wind speed from the north (49.7 miles per hour [mph]) was below the maximum northerly wind speed measured (53.0 mph), a calculation of the wave height and period was performed using the maximum measured wind speed. The computed significant wave height and period for a wind speed of 53.0 mph from the north was 1.43 feet and 1.90 seconds, respectively.

Based on this evaluation, wind-generated significant wave heights could range from 0.71 to 1.63 feet.

3.2 Vessel Wake Evaluation

Waves can also be generated by a boat moving through the water. These vessel-generated waves are often referred to as wakes. An evaluation was performed to estimate the potential vessel-generated wake heights associated with tugboats that may operate in the river near the TCRA Site and in particular in the vicinity of the San Jacinto River Fleet (SJRF) barge fleeting operations that were established near the TCRA Site, subsequent to the original TCRA design. The limited water depth in the area of the TCRA Site prohibits large vessels from operating close to the cap.

Based on information provided by local vessel operators, vertical clearances of bridges limit river operations to smaller tugboats north of I-10 and tugboats operating in this area typically move at speeds between 2 and 4 knots (2.3 to 4.6 mph), which minimize vessel wakes ("no wake") but allow for steerage and control. Local vessel operators also state that the largest tugboats that operate north of I-10 adjacent to the TCRA Site are typically 400- to 800-horsepower class craft. These tugboats operate in the main channel of the San Jacinto River. Based on bathymetric surveys conducted in the vicinity of the TCRA Site, a 26-foot-deep channel is located 250 feet east of the TCRA Site, a 20-foot-deep channel is located 950 feet northeast of the TCRA Site, and a 16-foot-deep channel is located 1,350 feet north of the TCRA Site.

Based on a review of the river bathymetry and the location of the SJRF area, tugboats operating to support the SJRF barge activities operate in 12 to 16 feet of water approximately 430 feet or more north and northwest of the TCRA Site. In the Final Sampling and Analysis Plan for Pre-Construction Baseline Site Assessment, San Jacinto River Fleet Property, Harris County, Texas (Tolunay-Wong 2012), SJRF has proposed to install a line of pylons approximately 430 feet from the TCRA Site, physically separating SJRF operations from the TCRA Site.[1]

The TCRA Site is also marked with floating buoys located around the perimeter of the eastern cell. These buoys provide for an additional visible warning to vessel operators to minimize the potential for inadvertent vessel operations in close proximity to the Armored Cap.

The Sorensen-Weggel method (Sorensen and Weggel 1984; Weggel and Sorensen 1986) was used to estimate potential vessel wakes for tugboats. The Sorensen-Weggel method is an empirical model (developed from available laboratory and field data on vessel-generated waves) used to predict maximum wave height as a function of vessel speed, vessel geometry, water depth, and distance from the sailing line. This model is applicable to various vessel types (ranging from tugboats to large tankers), vessel speeds, and water depths. The method calculates the wave height generated at the bow of a vessel as a function of the vessel speed, distance from the sailing line, water depth, vessel displacement volume, and vessel hull geometry (i.e., vessel length and draft).

[1] Nothing contained in this appendix is intended to acknowledge that Respondents concur in the appropriateness or sufficiency of the line of pylons proposed by SJRF as a measure to address impacts from SJRF's operations.

For the vessel wake calculation, a tugboat with a length of 75 feet and a displacement of 7,800 cubic feet was used. This vessel size is typical of tugboats that can physically fit beneath the relatively low I-10 Bridge and was selected for the design evaluation based on conversations with local marine contractors who operate tugboats in the San Jacinto River upstream of I-10. Vessels were conservatively assumed to operate 250 to 1,000 feet from the TCRA Site. Water depths used in the calculation ranged from 12 to 26 feet. As described above, vessels operate at speeds from 2 to 4 knots (essentially a "no wake zone" speed). A vessel-wake calculation was performed for vessels traveling at the high end of the expected speed, 4 knots. An additional scenario was considered for vessels traveling at 8 knots—this higher speed representing a conservative case that is expected to overestimate potential wake impacts. Table 3-3 presents a summary of the results of the vessel-generated wave evaluation.

Table 3-3
Vessel-Generated Wave Heights

Vessel Class	Water Depth (feet)	Vessel Speed (knots)	Distance from Sailing Line (feet)	Wave Height (feet)
Tugboat operating in the river channel	16	4	250	0.0
			1,000	0.0
		8	250	1.0
			1,000	0.6
	26	4	250	0.0
			1,000	0.0
		8	250	1.1
			1,000	0.7
Tugboat operating at the SJRF barge area	12	4	430	0.0
		8		0.8
	16	4	430	0.0
		8		0.8

Note:
SJRF = San Jacinto River Fleet

The results indicate that vessel wakes at the TCRA Site would be less than 1.2 feet.

In summary, wind-generated waves are estimated to be less than 1.7 feet and vessel-generated wakes are expected to be less than 1.2 feet at the TCRA Site. The vessel wake results, combined with the wind-generated wave results, are used to evaluate required armor rock sizes in the wave-breaking zone of the Permanent Cap, as discussed below.

3.3 Evaluation of Armor Layer Material

Due to the amount of turbulence generated by breaking waves in the surf zone, the armor layer was modeled in the TCRA design as a rubble mound berm (i.e., a sloped berm [or revetment] consisting of rock). Armor stone for sloped berms was sized using guidance from USACE 2006 as part of the original TCRA design. USACE guidance was used because the methodology to evaluate armor stone sizes for sediment caps presented in USEPA's design guidance (Maynord 1998) does not consider the effects of waves breaking on a cap, as would be the case for the sloped berms at the TCRA Site. The surf zone is defined as the region extending from the location where the waves begin to break to the limit of wave run-up on the shoreline slope. Within the surf zone, wave-breaking is the dominant hydrodynamic process (USACE 2006).

The ACES Rubble Mound Revetment Design Module was used to evaluate the armor stone gradation and thickness in the surf zone. The ACES methodology is based on van der Meer's (1988) paper entitled "Deterministic and Probabilistic Design of Breakwater Armor Layers." The ACES method assumes that waves would propagate and break on the slope of the armor layer. The structure was assumed to be permeable, thereby minimizing wave reflection. Stable particle sizes (i.e., armor sizes) were evaluated using the model for the proposed Permanent Cap slope of 5H:1V.

Revetments used for coastal protection projects are often designed allowing for some movement of the armor layer, which could necessitate maintenance over time. The revetment design methodology allows consideration of variable amounts of displacement (movement) of the armor layer. The amount of displacement considered can be categorized as follows:

- **No Displacement**: Little to no armor stone displacement due to wave energy

- **Minor Displacement**: Minimal movement (less than 5 percent) of armor stones displaced due to wave energy and potentially redistributed within or in the near vicinity of the armor layer
- **Intermediate Displacement**: Displacement ranges from moderate to severe; armor stones are expected to be displaced

The existing Armored Cap rock was designed for minimal movement (Anchor QEA 2010), also referred to as the Minor Displacement scenario in the rubble mound design guidance. The Minor Displacement scenario is the same as that applied at other Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) cap sites (e.g., Onondaga Lake Superfund Site in Syracuse, New York, and Lower Fox River Superfund Site in Green Bay, Wisconsin) to ensure protectiveness.

For design of the Permanent Cap, the No Displacement and Minor Displacement scenarios were evaluated for slopes constructed at 5H:1V using a wave height of 1.63 feet and wave period of 2.15 seconds, the maximum wave height and wave period shown in Tables 3-1 and 3-2.

Table 3-4 presents the computed median and maximum particle sizes and acceptable ranges of layer thickness for the specific materials, based on the ACES calculation.

Table 3-4
Median (D_{50}) and Maximum (D_{100}) Particle Size and Thickness –
Significant Wave Height of 1.63 feet and Period of 2.15 Seconds – Natural Stone Materials

Particle Size/Thickness	Natural Stone[1] (5H:1V)	
	No Displacement (inches)	Minor Displacement[2,3] (inches)
D_{50} (median particle size)	8.3	3.3
D_{100} (maximum particle size)	13.2	5.3
Range of thickness of armor layer[4]	12.5 to 17	5 to 7

Notes:
1. Assumes a unit weight of 165 pounds per cubic foot.
2. Computed using No Displacement and Minor Displacement scenarios. No Displacement represents little to no movement of armor stones. Minor Displacement refers to minimal movement of the armor stones under extreme wave action. Repairs associated with such events (if any) would be handled as part of a maintenance program.
3. Minor Displacement was the design scenario for the Armored Cap .
4. Thickness ranges based on guidance from Maynord (1998) and USACE (1994).

The analysis shows that the Armor Cap D material (with a median particle size [D_{50}] of approximately 10 inches and a maximum [D_{100}] of approximately 15 inches) would provide long-term protection at the TCRA Site. Although a factor of safety is not specifically included in the calculation, the Armor Cap D material proposed for the Permanent Cap is three times larger than that required under the Minor Displacement scenario; Armor Cap D also exceeds the criteria for the No Displacement scenario.

4 DESIGN STORM EVALUATION

4.1 Background

Hydrodynamic flows, particularly during high-flow events, can result in elevated water velocities and corresponding bed shear stresses, which have the potential to erode sediments. To evaluate current velocities and stable particle size to resist these velocities, the hydrodynamic model developed as part of the TCRA design was used. The model framework, boundary conditions, development, and calibration is described in detail in Appendix I of the RAWP (Anchor QEA 2010), which considered a range of design events up to the 100-year storm.

Based on inquiries from USEPA during development of the FS, the sensitivity of the cap design was assessed for additional storm events as well as an extreme 500-year recurrence interval storm to evaluate the protectiveness of the cap design. In response to this inquiry, the model presented in Appendix I of the RAWP was updated and run for these additional scenarios.

4.2 Model Update and Simulations

Elevations of the Northern Impoundments in the model were updated based on a survey performed in April 2013, after completion of the TCRA. High-flow event hydrodynamic simulations were conducted using the updated model. Predicted current velocities within the study area were used to calculate the median particle diameter (D_{50}) for the cover material and to compare this diameter to the design of the Permanent Cap.

Varying events were simulated to capture the maximum velocities that may act upon the Permanent Cap. Using a constant upstream flow rate, the 5-, 10-, 25-, 50-, 100-, and 500-year high-flow events were simulated (the downstream tidal elevations are described in Appendix I of Anchor QEA 2010). In addition for comparison, measured data from the following three actual events were used in simulations with the hydrodynamic model:

- The October 1994 Harris County Flood (that occurred between October 11 and 25, 1994)
- Tropical Storm Allison (that occurred between June 2 and 16, 2001)

- Hurricane Ike (that occurred between September 7 and 21, 2008)

Design equations to compute the stable particle size to resist river currents use depth-averaged velocities and water depth. Figure 5 shows a depiction of depth-averaged velocity in comparison to the actual distribution of velocity that would be expected in a naturally flowing system. The hydrodynamic model used in the analysis computed depth-averaged velocities. To demonstrate that the range of storm events considered cover the full range of flows that produce the maximum velocities over the TCRA Site, maximum depth-averaged velocities were computed at various locations over the Northern Impoundments. Figure 6 shows the locations where the depth-averaged velocities were computed. Figure 7 shows the maximum depth-averaged velocity for each event at each location. Figure 8 shows the corresponding water depth at the time of the maximum velocity at each location.

The results of this analysis indicate that the peak of depth-averaged velocities over the cap vary in location for each storm and flood event evaluated (Figure 7). This is primarily due to the variable topographic and bathymetric profile of the surface of the cap and is expected because the water surface elevations in the San Jacinto River vary by storm event. As a result, the water depth, flow patterns, and scour velocities vary spatially across the Northern Impoundments for each storm event depending on the depth of the water at various locations on the cap. In many areas of the cap, as the water depth becomes deeper with larger storm events, the maximum depth averaged velocity decreases. This is especially true for the 500-year flood event.

4.3 Stable Particle-Size Calculation

The stable particle size (expressed as D_{50}) to resist the flow velocity and related bed shear stress was estimated using the Maynord (1998) method. The method presented in Maynord (1998) and shown below is based on the USACE's Hydraulic Design of Flood Control Channels (USACE 1994). This method uses depth-averaged velocity and flow depth to determine the stable median armor stone size (D_{50}).

$$D_{50} = S_f C_s C_v C_T C_G d \left[\left(\frac{\gamma_w}{\gamma_s - \gamma_w} \right)^{1/2} \frac{V}{\sqrt{K_1 g d}} \right]^{2.5} \tag{1-1}$$

where:

D_{50}	=	Median particle size in feet
S_f	=	Safety factor = 1.5 (from page A-6 of Maynord 1998). Per Maynord (1998), the minimum safety factory for riprap design is 1.1. A safety factor of 1.3 was used for the TCRA to be more conservative and protective. For the Permanent Cap, a safety factor of 1.5 is used in this calculation (a more detailed discussion is presented below).
C_s	=	Stability coefficient for incipient failure = 0.3 for angular rock (from page A-6 of Maynord 1998)
C_V	=	Velocity distribution coefficient = 1.0 (from page A-6 of Maynord 1998)
C_T	=	Blanket thickness coefficient = 1.0 for flood flows and thickness = D_{100} (from page A-6 of Maynord 1998)
C_G	=	Gradation coefficient = $(D_{85}/D_{15})^{1/3}$
D_{85}/D_{15}	=	Gradation uniformity coefficient = 1.55 for Armor Cap D material (with D_{85} = 11.8 inches and D_{15} = 7.6 inches)
d	=	Water depth in feet (from the hydrodynamic model)
γ_s	=	Unit weight of stone = 165 pounds per cubic foot
γ_w	=	Unit weight of water = 62.4 pounds per cubic foot
V	=	Maximum depth-averaged velocity in feet per second (from the hydrodynamic model)
K_1	=	Side slope correction factor = 1.0 for a slope of 5H:1V (from Plate B-39 from USACE 1994)
g	=	Acceleration due to gravity = 32.2 feet per second squared

As described above, a safety factor of 1.5 was used in the calculation. Maynord (1998) recommends a minimum safety factory for riprap design of 1.1. In addition, as described in the following from USACE (1994):

> *Equation 3-3 gives a rock size that should be increased to resist hydrodynamic and a variety of nonhydrodynamic-imposed forces and/or uncontrollable physical conditions. The size increase can best be accomplished by including the safety factor, which will be a value greater than unity. The minimum safety factor is S_f = 1.1.*

For the Armored Cap design, the safety factor (S_f) was increased to 1.3 in Maynord's equation from the recommended 1.1 as a conservative method to account for variations in bathymetry and topography and the associated potential variations in velocities and turbulence intensity for small-scale site variations that are smaller than the two-dimensional Environmental Fluid Dynamics Code (EFDC) model grid resolution. For the Permanent Cap evaluation, the safety factor was further increased to 1.5.

As an example, Table 4-1 summarizes the armor stone D_{50} results based on a berm slope of 5H:1V and a safety factor of 1.5 for the maximum velocity predicted for the western berm area of the TCRA Site.

Table 4-1
Median (D_{50}) Particle Size to Resist River Currents

Location	Event	Maximum Depth-Average Velocity (feet per second)	Water Depth (feet)	D_{50} (inches)
Western berm	5-year flood	3.1	1.3	0.7
	10-year flood	1.8	1.4	0.2
	25-year flood	6.7	2.4	4.1
	50-year flood	6.4	4.6	3.1
	100-year flood	7.1	7.7	3.5
	500-year flood	3.4	18.7	0.5
	Hurricane Ike	2.2	1.4	0.3
	Tropical Storm Allison	2.5	1.2	0.4
	October 1994 Harris County Flood	6.5	2.5	3.7

As shown in Figure 6 and Table 4-1, the range of design storms for this evaluation is appropriate for the FS, and storms with return-intervals greater than 100-years result in lower velocities than some of the more frequent storms. The events that control the selection of the stable particle size are between the 10- and 100-year events (depending on location).

As can be seen from these results, the Armor Cap D materials exceed the computed median (D_{50}) particle size with a conservative safety factor of 1.5; therefore, the use of Armor Cap D materials on flatter slopes is an appropriate assumption for the design of the Permanent Cap.

4.4 Wave and Current Combinations

Outside the surf zone, orbital velocities from waves combined with currents can increase bottom shear stresses. Combining extreme river current with extreme orbital velocity forces is considered to be very conservative, because the probability of both extreme events occurring simultaneously is very low.

The armor stone is designed to resist forces due to waves breaking on the Armored Cap (i.e., waves would propagate and break on the western, central, or southern berm armor stone). Within the surf zone (the location where waves break), wave-breaking is the dominant hydrodynamic process (USACE 2006).

An example is provided below to evaluate the stability of Armor Cap D material for a combination of bottom velocities due to superimposed wave and current forces if the berm was overtopped.

The bottom shear stress due to the combination of waves and currents can be calculated using the quadratic stress law (Christoffersen and Jonsson 1985), as shown in the following equation:

$$\tau = \rho_w \left(C_{f,c} u_c^2 + C_{f,w} u_w^2 \right) \qquad (1\text{-}2)$$

where:

τ	=	Bottom shear stress
ρ_w	=	Density of water
$C_{f,c}$	=	Bottom friction coefficient for currents
u_c	=	Maximum current velocity
$C_{f,w}$	=	Bottom friction coefficient for waves
u_w	=	Maximum bottom velocity due to waves

An example is provided below using the results for the EFDC model grid cell along the western berm with the highest computed bed shear stresses due to currents as computed by the EFDC model. In the example, the maximum bed shear stress due to flows computed by the model are added to the computed bed shear stresses due to waves, and a stable particle size is determined based on those stresses. The stable particle size is computed for the 25- and 100-year return-interval flow events conservatively assuming that the 100-year return-interval wave occurs at the same time as these events.

For the 25-year return-interval flow event, the computed bed shear stress is 19.1 Pascals (0.399 pounds per square foot [psf]) for the model grid cell. For the 100-year return-interval flow event, the computed bed shear stress is 14.8 Pascals (0.309 psf) for the model grid cell.

The bottom friction coefficient for waves is computed using the following equation (van Rijn 1993):

$$C_{f,w} = 0.045 \left(\frac{u_w A_w}{\upsilon}\right)^{-0.2} \tag{1-3}$$

where:

$C_{f,w}$	=	Bottom friction coefficient for waves
u_w	=	Maximum bottom velocity due to waves
A_w	=	Peak orbital excursion
ν	=	Kinematic viscosity of water

Maximum bottom velocities and peak orbital excursions for the 100-year return-interval wave were computed with water depths over the western berm set equivalent to the 25- and 100-year return-interval flow events using the Linear Wave Theory Module in ACES. Based on this analysis, the estimated bed shear stress due to waves is 5.39 Pascals (0.113 psf) for the 25-year event and 0.581 Pascals (0.0121 psf) for the 100-year event. The shear stresses due to waves are higher for the 25-year return-interval flow event as compared with the 100-year return-interval flow event, because water depths over the berm are lower. Table 4-2 summarizes the results of this analysis.

Table 4-2

Summary of Combined Forces from Currents and Waves

Flood Flow Return-Interval	Forces from Currents			Forces from Waves					Combined Forces	
	Maximum Depth-Averaged Velocity Computed by EFDC Model (m/s)	Maximum Shear Stress Computed by EFDC Model (Pa)	Maximum Shear Stress Computed by EFDC Model (psf)	Peak Orbital Velocity Computed in ACES (m/s)	Peak Orbital Excursion Computed in ACES (meters)	$C_{f,w}$	Computed Shear Stress For Waves (Pa)	Computed Shear Stress For Waves (psf)	Combined Shear Stress due to Waves and Currents (Pa)	Combined Shear Stress due to Waves and Currents (psf)
25-year	2.03	19.1	0.399	0.725	0.248	0.0102	5.39	0.113	24.5	0.511
100-year	2.15	14.8	0.309	0.180	0.0610	0.0179	0.581	0.0121	15.4	0.322

Notes:
ACES = Automated Coastal Engineering System
$C_{f,w}$ = Bottom friction coefficient for waves
EFDC = Environmental Fluid Dynamics Code
m/s= meters per second
Pa = Pascals
psf = pounds per square foot

The stable median diameter (D_{50}) for particles subject to a given shear stress can be estimated based on the approach described by Shields (1936). The correlation between shear stress and particle size presented below represents the point at which the subject particle begins to move or "rock" on the bed and does not necessarily imply significant transport of particles of this size. In addition, Shields' work is based on a bed of uniform particles and does specifically account for the increased stability resulting from a well-graded armor layer constructed from a range of angular particles, thus the use of the Shields model is conservative compared to actual conditions at the site.

$$\tau_{*c} = \frac{\tau_c}{(\gamma_s - \gamma) D_{50}} \qquad (1\text{-}4)$$

where:

τ_{*c} = Critical shear stress parameter (psf)

τ_c = Critical shear stress (threshold of motion; psf)

γ_s = Specific weight of the particle (psf)

γ = Specific weight of the water

D_{50} = Median particle size (feet)

Shields provides a plot of dimensionless critical shear stress versus a dimensionless Reynolds number. This graphical representation, commonly known as the Shields diagram, is widely used to determine a general relationship for incipient motion. Rouse (1939) fitted a mean curve to the zone of these data points, above which particles are considered to be in motion, and showed that at higher values of the Reynolds number (i.e., coarse sediments/larger grain sizes, and/or fully turbulent flow), the critical shear stress parameter approaches a constant value of 0.060. Since then, others have proposed more conservative values for the critical shear stress parameter, ranging from 0.039 by Laursen (1963) to 0.045 by Yalin and Karahan (1979).

Rearranging Equation 1-4 above to solve for median particle size, substituting a specific weight of 165 pounds per cubic foot (pcf) for natural materials such as the Armor Cap D materials (and assuming that the wave event occurs during a freshwater flow event), and a conservative critical shear stress parameter of 0.039, yields the following relationship:

$$D_{50} = \frac{\tau}{4} \quad (1\text{-}5)$$

The maximum combined bed shear stresses for combined waves and currents for the 25- and 100-year return-interval events are 0.511 and 0.322 psf, respectively. The median particle size (D_{50}) to resist the combined waves and currents ranges between 1.0 and 1.5 inches using this method, which is substantially lower than the median particle size of 10 inches for Armor Cap D material.

4.5 Evaluation of the Potential Change in Water Surface Elevation

The hydrodynamic model described above was used to assess potential changes in water surface elevations during the 100-year return-interval flow event as a result of construction of each alternative.

The 100-year return-interval flow event was simulated for the following alternatives with the hydrodynamic model:

- Existing conditions, based on the January 2013 survey of the TCRA Site
- During construction conditions for Alternatives 4N and 5aN, where sheetpile barriers would be placed in the river
- Post-construction (long-term) conditions for Alternatives 3N, 4N, 5N, 5aN, and 6N

The spatial distribution of the maximum predicted water surface elevation at the center of the channel, from the I-10 Bridge to 4 miles upstream can be found in Figures 9 through 16. Model predicted results were available at each cell along the centerline of the channel within this 4-mile reach. Results were then averaged over a 0.2-mile segment of the river in the proceeding figures. A comparison is made between current conditions (orange line) and the post-remedy condition (black line). Table 4-3 presents the maximum change in water surface elevations modeled for each scenario.

Table 4-3
Comparison of Water Surface Elevations During the 100-Year Return-Interval Flow Event

Scenario	Water Surface Elevation Change (feet)					
	Lower-Bound			Upper-Bound		
	Minimum	Average	Maximum	Minimum	Average	Maximum
Alternative 3	-0.01	-0.01	0.00	-0.02	-0.01	0.00
Alternative 4	0.01	0.01	0.01	0.00	0.01	0.01
Alternative 4 during construction	-0.07	0.02	0.04	-0.07	0.01	0.03
Alternative 5	-0.01	-0.01	0.00	-0.02	-0.01	0.00
Alternative 5a	-0.05	-0.04	0.03	-0.04	-0.03	0.03
Alternative 5a during construction	-0.39	0.16	0.24	-0.36	0.18	0.26
Alternative 6	-0.05	-0.04	0.03	-0.04	-0.03	0.03

Results indicate a maximum increase in water surface elevation of 0.26 feet for Alternative 5a with the sheetpile wall during construction. For the other alternatives, the model results indicate there is negligible and likely immeasurable change in the water surface elevation during the 100-year flood as a result of the implementation of the alternatives. Figures 9 through 18 present the results of these flood modeling scenarios graphically showing the modeled water surface elevation upstream of the I-10 bridge for each scenario compared to current conditions.

4.6 Extreme Events During Construction

As described in Section 5 of the FS Report, the results from the model simulations of various extreme events were used to estimate the probability that the work area could become inundated during construction (when the Armored Cap would be removed to allow for stabilization work or removal of materials located beneath the cap to be performed) based on the estimated construction duration for each alternative. Using the hydrodynamic modeling results, the maximum water surface elevation associated with different return period storms was assessed. Considering a range of potential construction durations of 6 to 24 months, the chance of reaching or exceeding the maximum predicted water surface was calculated. Table 4-4 present the results of this analysis. For construction durations that are different from those shown in the table, the percent chance of occurrence can be estimated by interpolation.

Table 4-4

Likelihood of Exceeding Maximum Predicted Water Surface

Return Period (Years)	Maximum Predicted Water Surface Elevation (feet NAVD88)	Flow Rate (cfs)	Construction Duration (Months)			
			6	12	18	24
			Percent Chance of Occurrence			
2	2.5	38,400	29	50	65	75
3	3.5	56,700	17	31	42	52
5	4.9	82,100	11	20	28	36
10	5.1	126,000	5.1	10	15	19
25	8.0	202,000	2.0	4.0	5.9	8.0
50	10.8	277,000	1.0	2.0	3.0	4.0
100	13.9	372,000	0.5	1.0	1.5	2.0

Notes:

The maximum predicted water surface elevation shown in the table for the 2- and 3-year return-interval flow events is the average water surface elevation for these flow rates based on the long-term simulation.

The maximum predicted water surface elevation shown in the table for the 5-, 10-, 25-, 50- and 100-year return-interval flow events was the average of the maximum water surface elevations from the upper bound and lower bound extreme event simulations.

NAVD88 = North American Vertical Datum of 1988.

cfs = cubic feet per second.

As shown in Table 4-4, construction projects with longer durations have a greater likelihood that, during the course of construction, high-water surface elevations would occur in the river as a result of storm events. While the flood modeling indicates that the construction would likely not have a measureable impact on the high-water surface elevation (and thus would not have regulatory implications), high-water conditions could pose a risk to in-water work, particularly if water quality control structures are overtopped, inundating the work area.

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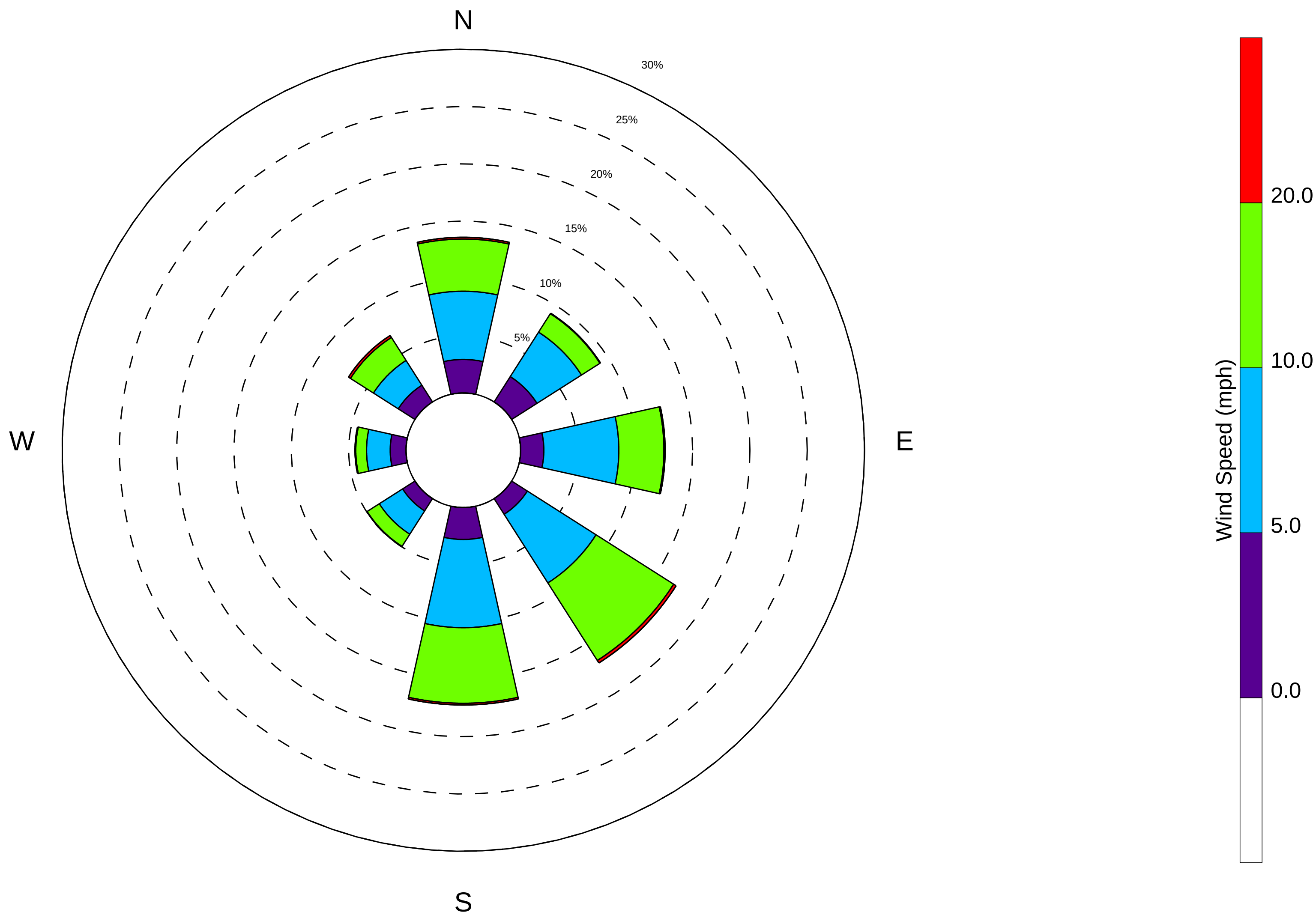
FIGURES



Maximum Recorded Wind Speed: 63.3 mph

Calm Winds 14.07%

Figure 1

Wind Rose Diagram

Feasibility Study - Appendix B: Hydrodynamic Cap Modeling

San Jacinto River Waste Pits Superfund Site

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Note: Bins represent direction from where wind is blowing from, in 45 degree increments. Wind rose developed from wind measurements at NCDC Station 12960 (George Bush Intercontinental Airport) from 1973 to 2012.

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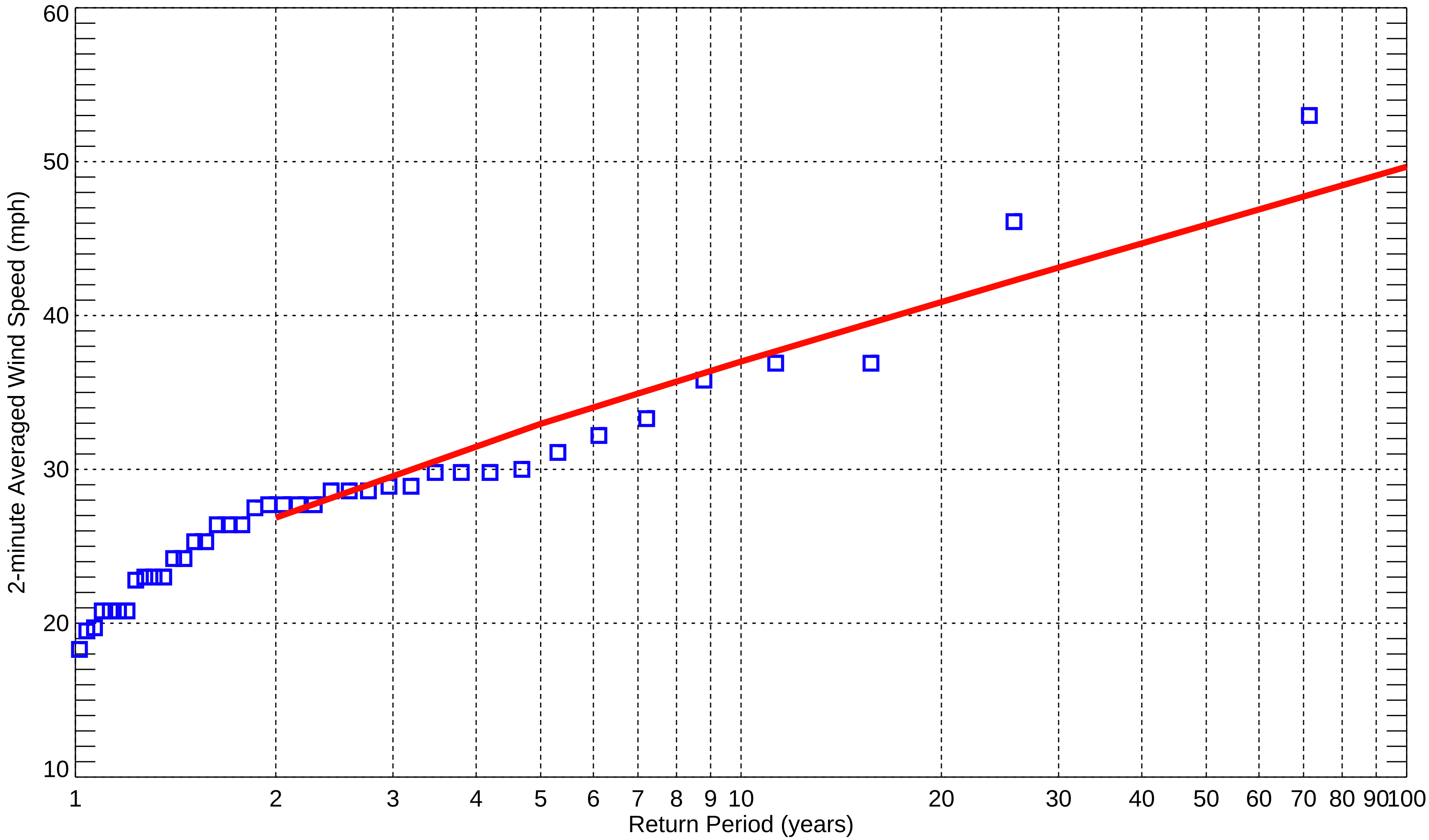
Figure 2
Fetch Distances
Feasibility Study - Appendix B: Hydrodynamic Cap Modeling
San Jacinto River Waste Pits Superfund Site



Annual Maximum Winds
Fisher-Tippett Type 1 (FT-1) Distribution

Figure 3

Return-Interval Wind Speeds (North)
Feasibility Study–Appendix B: Hydrodynamic Cap Modeling
San Jacinto River Waste Pits Superfund Site

The wind record is from 1973 to 2012 at the George Bush Intercontinental Airport.

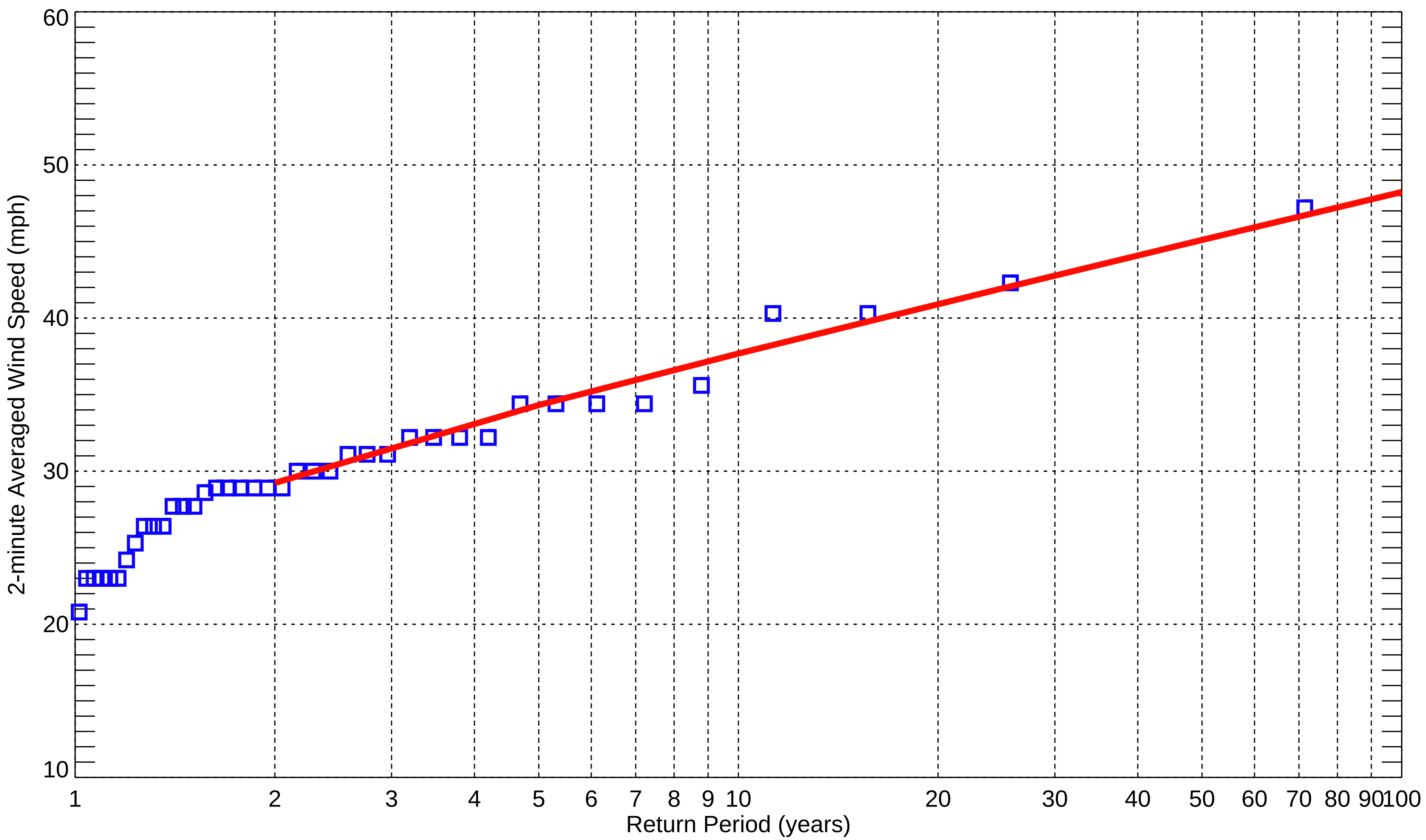


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Figure 4

Return-Interval Wind Speeds (Northwest)
Feasibility Study–Appendix B: Hydrodynamic Cap Modeling
San Jacinto River Waste Pits Superfund Site

The wind record is from 1973 to 2012 at the George Bush Intercontinental Airport.

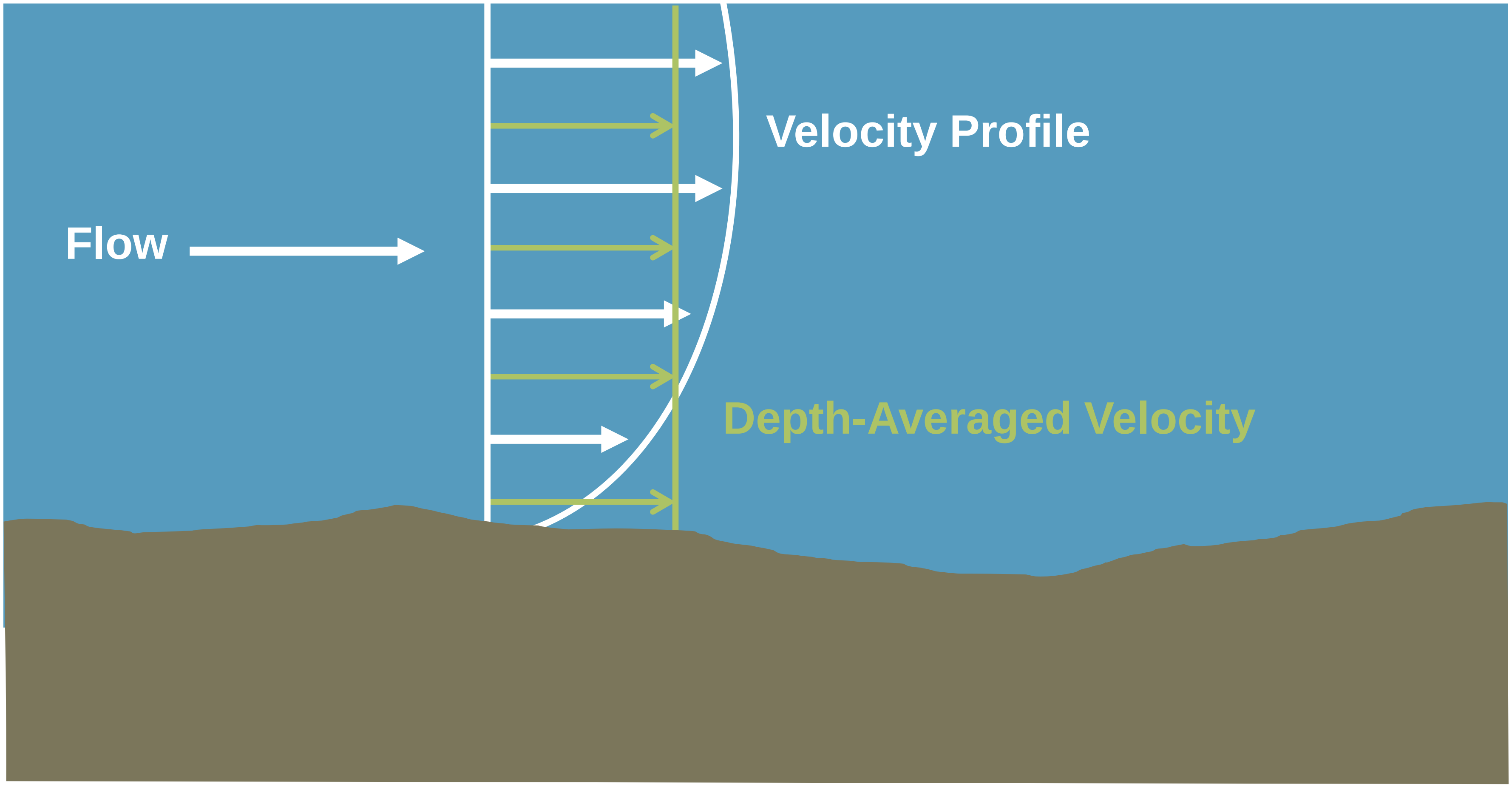

Figure 5
Depth-Averaged Velocity Description
Feasibility Study - Appendix B: Hydrodynamic Cap Modeling
San Jacinto River Waste Pits Superfund Site

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Figure 6
High-Flow Simulation Plot Locations
Feasibility Study - Appendix B: Hydrodynamic Cap Modeling
San Jacinto River Waste Pits Superfund Site

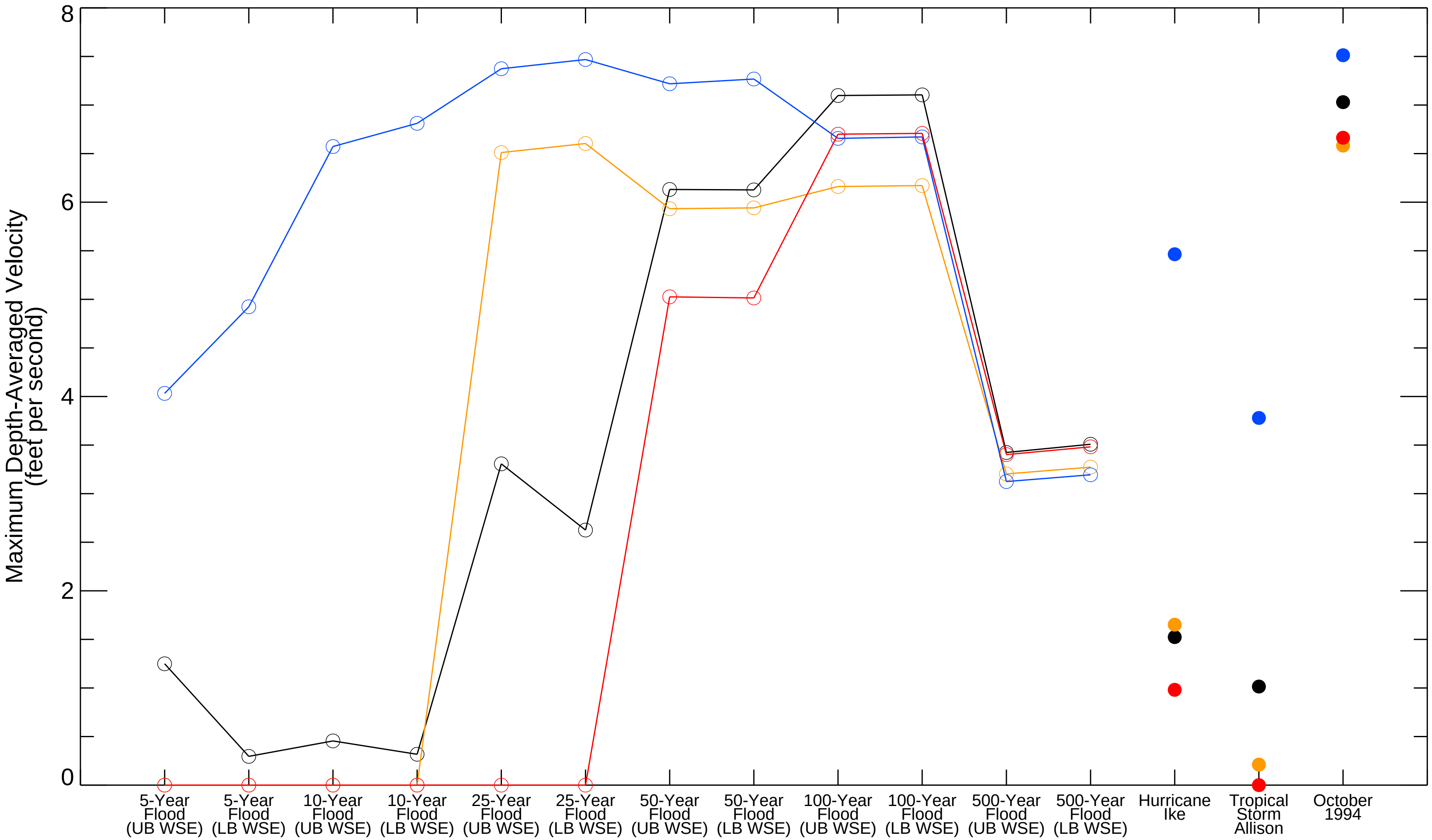

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Figure 7

Maximum Depth-Averaged Velocity During High-Flow Simulations
Feasibility Study - Appendix B: Hydrodynamic Cap Modeling
San Jacinto River Waste Pits Superfund Site

Note: The water surface elevations at the downstream boundary are denoted with UB WSE and LB WSE to represent upper-bound and lower-bound conditions, respectively.

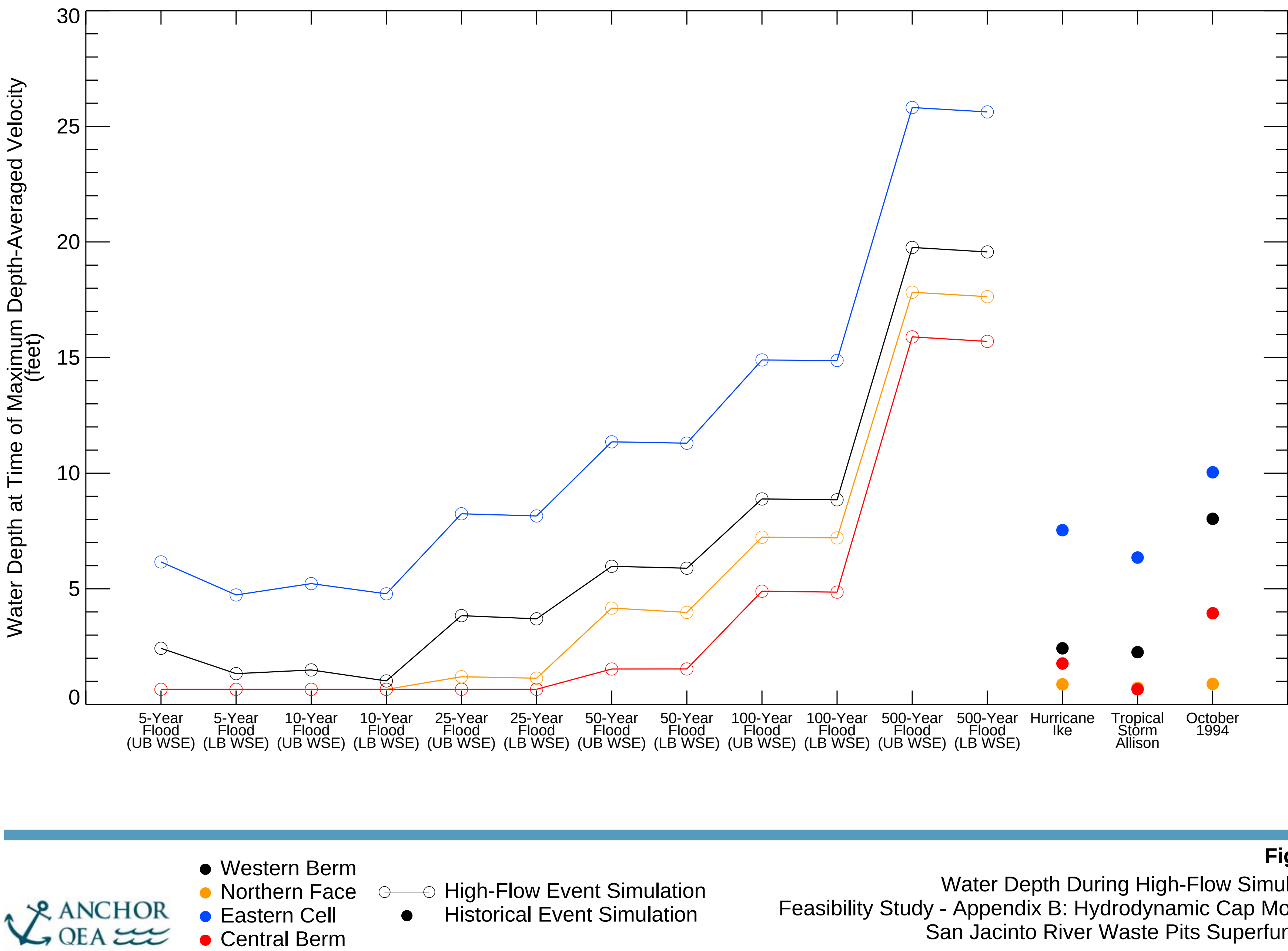

Figure 8

Water Depth During High-Flow Simulations
Feasibility Study - Appendix B: Hydrodynamic Cap Modeling
San Jacinto River Waste Pits Superfund Site

Note: The water surface elevations at the downstream boundary are denoted with UB WSE and LB WSE to represent upper-bound and lower-bound conditions, respectively.

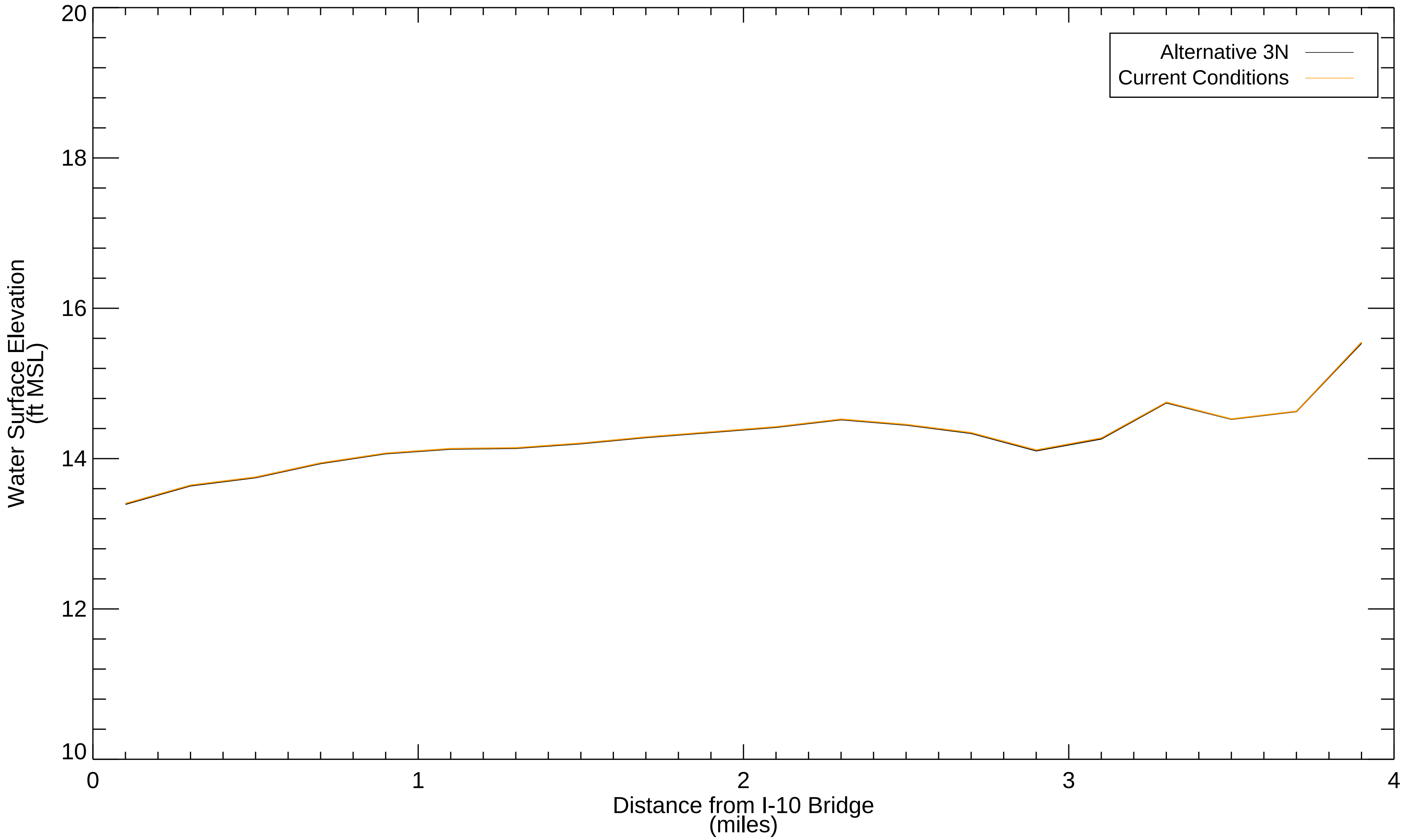

Figure 9

Alternative 3N Comparison of Pre- and Post-Water Surface Elevations
During the 100-Year High-Flow Event: Lower-Bound Stage Height Condition
Feasibility Study - Appendix B: Hydrodynamic Cap Modeling
San Jacinto River Waste Pits Superfund Site

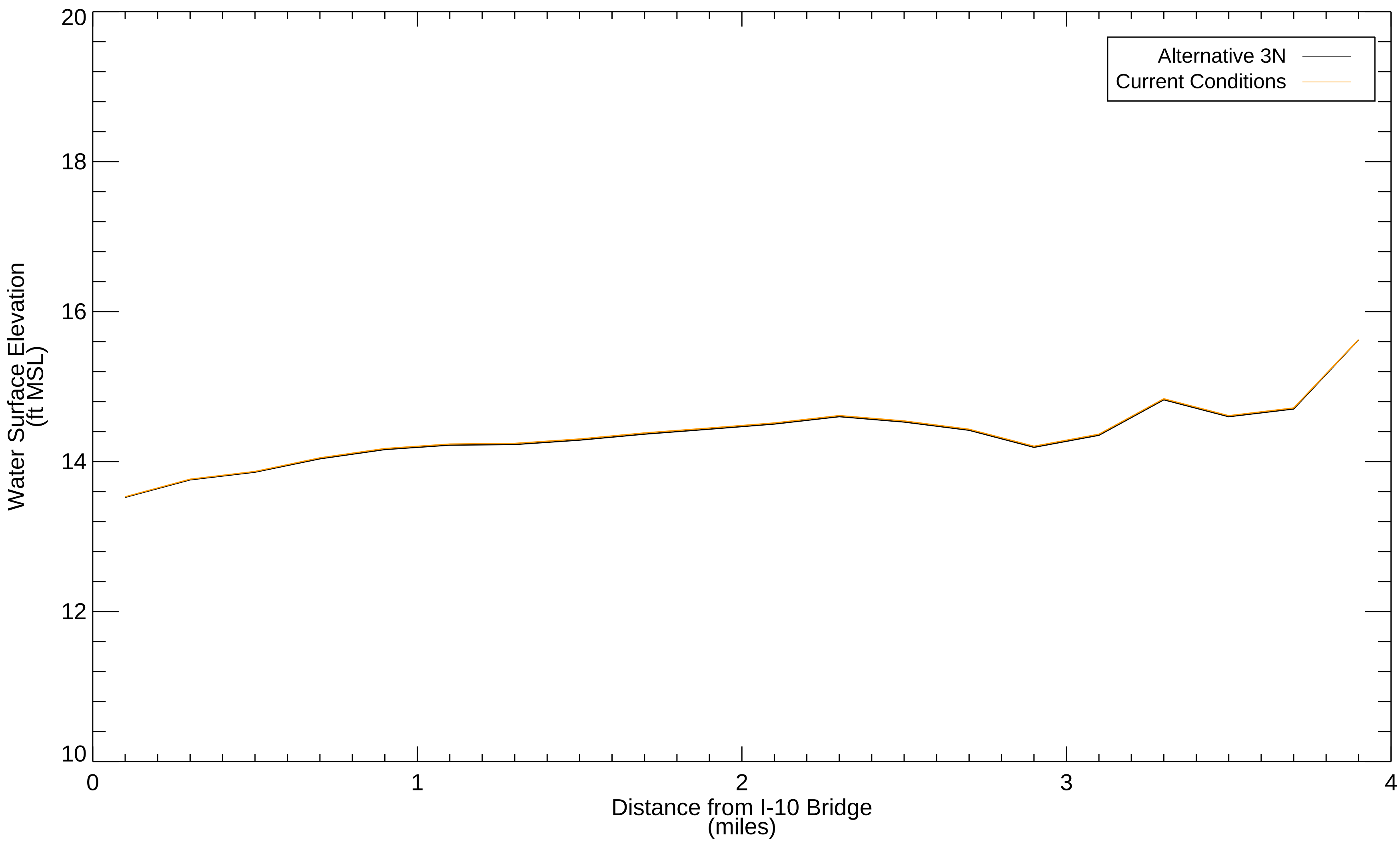

Figure 10

Alternative 3N Comparison of Pre- and Post-Water Surface Elevations
During the 100-Year High-Flow Event: Upper-Bound Stage Height Condition
Feasibility Study - Appendix B: Hydrodynamic Cap Modeling
San Jacinto River Waste Pits Superfund Site

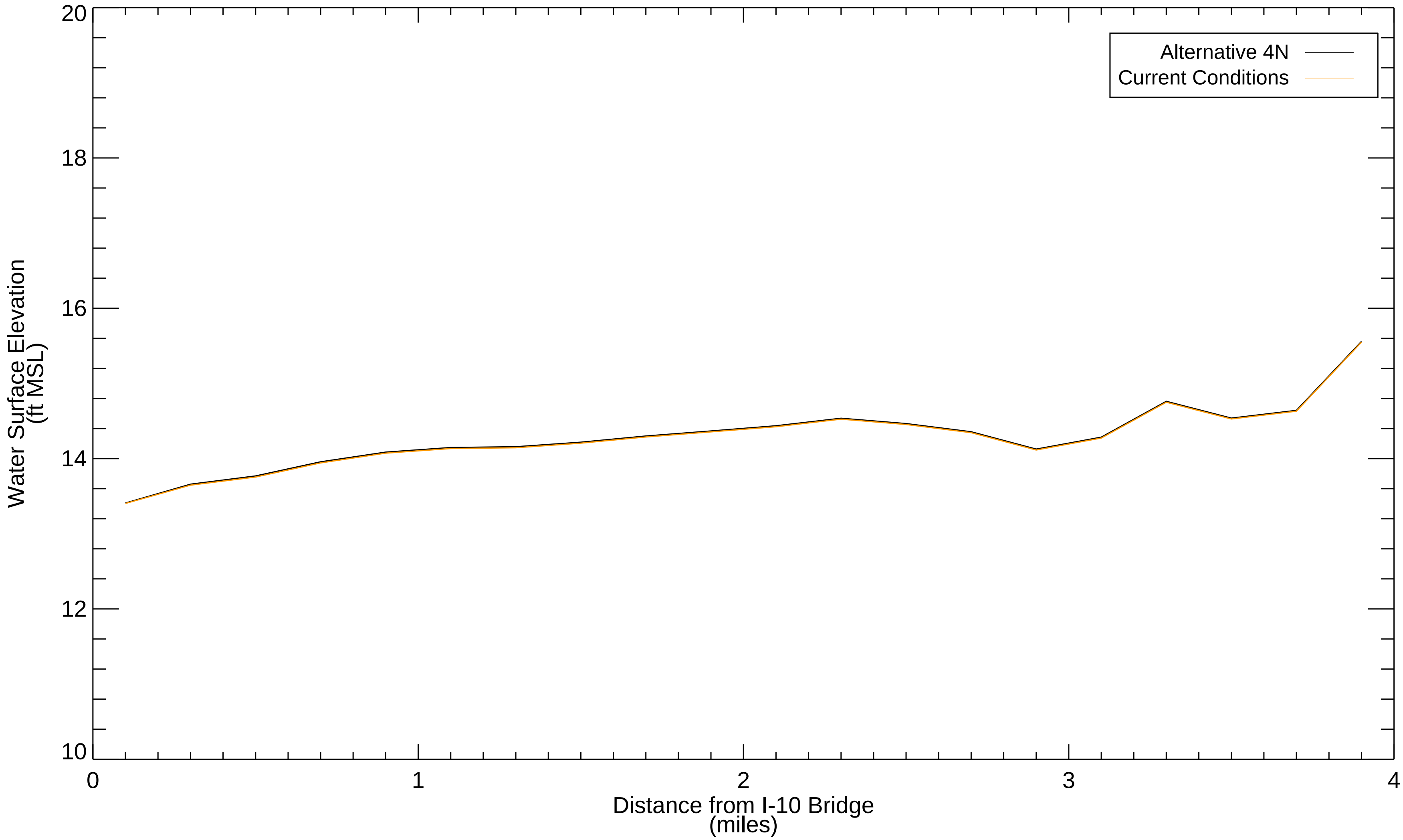

Figure 11

Alternative 4N Comparison of Pre- and Post-Water Surface Elevations
During the 100-Year High-Flow Event: Lower-Bound Stage Height Condition
Feasibility Study - Appendix B: Hydrodynamic Cap Modeling
San Jacinto River Waste Pits Superfund Site

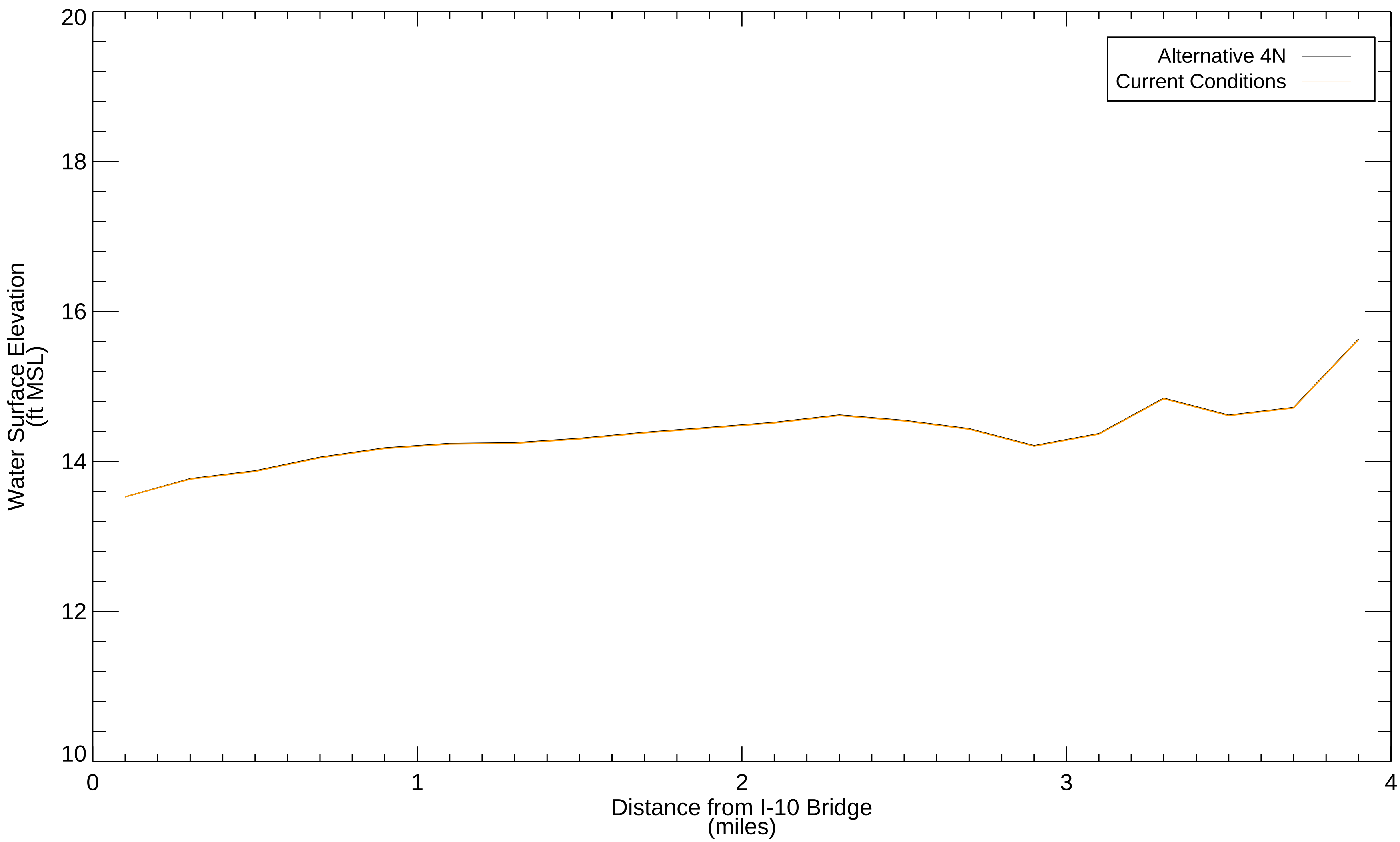

Figure 12

Alternative 4N Comparison of Pre- and Post-Water Surface Elevations
During the 100-Year High-Flow Event: Upper-Bound Stage Height Condition
Feasibility Study - Appendix B: Hydrodynamic Cap Modeling
San Jacinto River Waste Pits Superfund Site

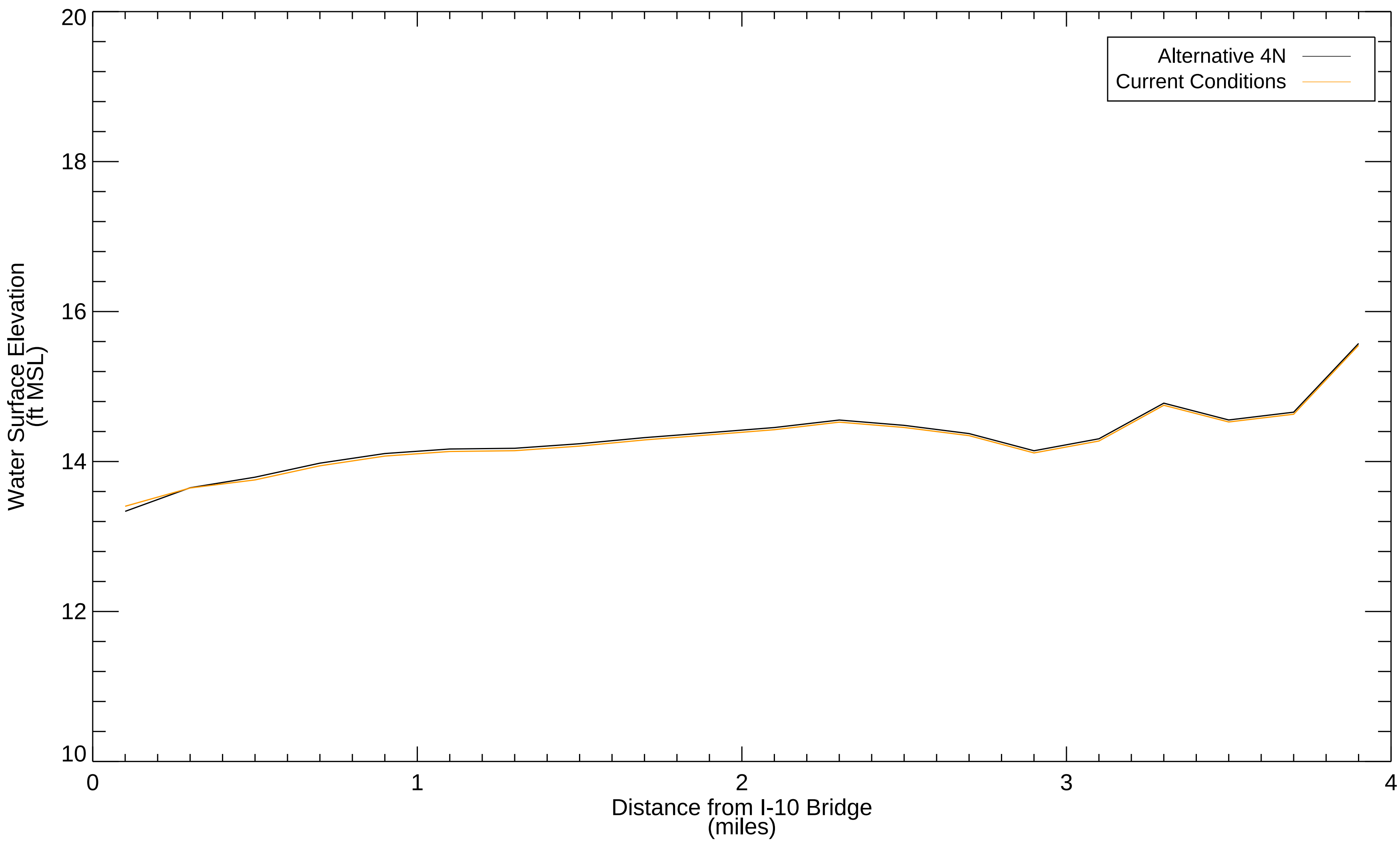

Figure 13

Alternative 4N During Construction Comparison of Pre- and Post-Water Surface Elevations
During the 100-Year High-Flow Event: Lower-Bound Stage Height Condition
Feasibility Study - Appendix B: Hydrodynamic Cap Modeling
San Jacinto River Waste Pits Superfund Site

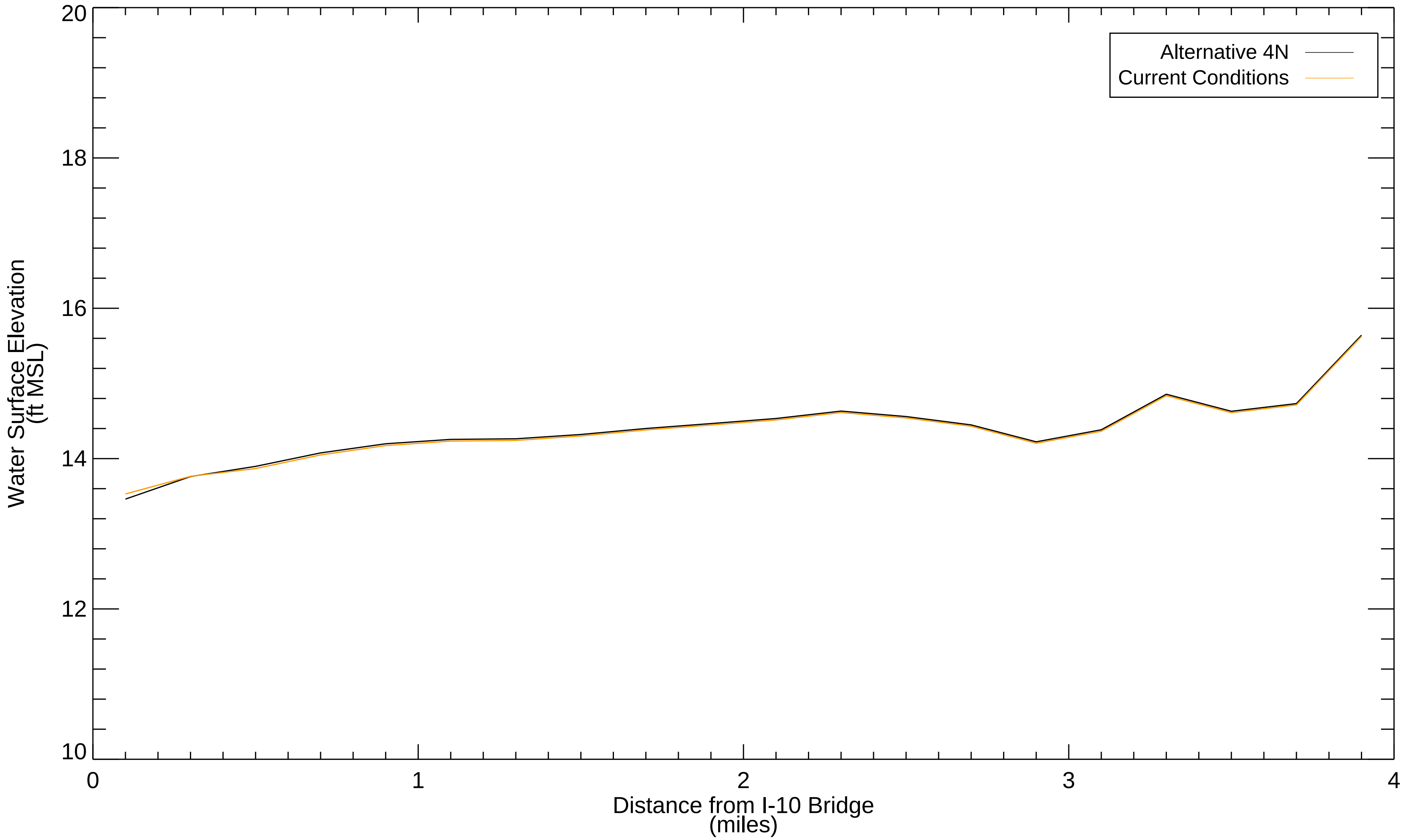

Figure 14

Alternative 4N During Construction Comparison of Pre- and Post-Water Surface Elevations
During the 100-Year High-Flow Event: Upper-Bound Stage Height Condition
Feasibility Study - Appendix B: Hydrodynamic Cap Modeling
San Jacinto River Waste Pits Superfund Site

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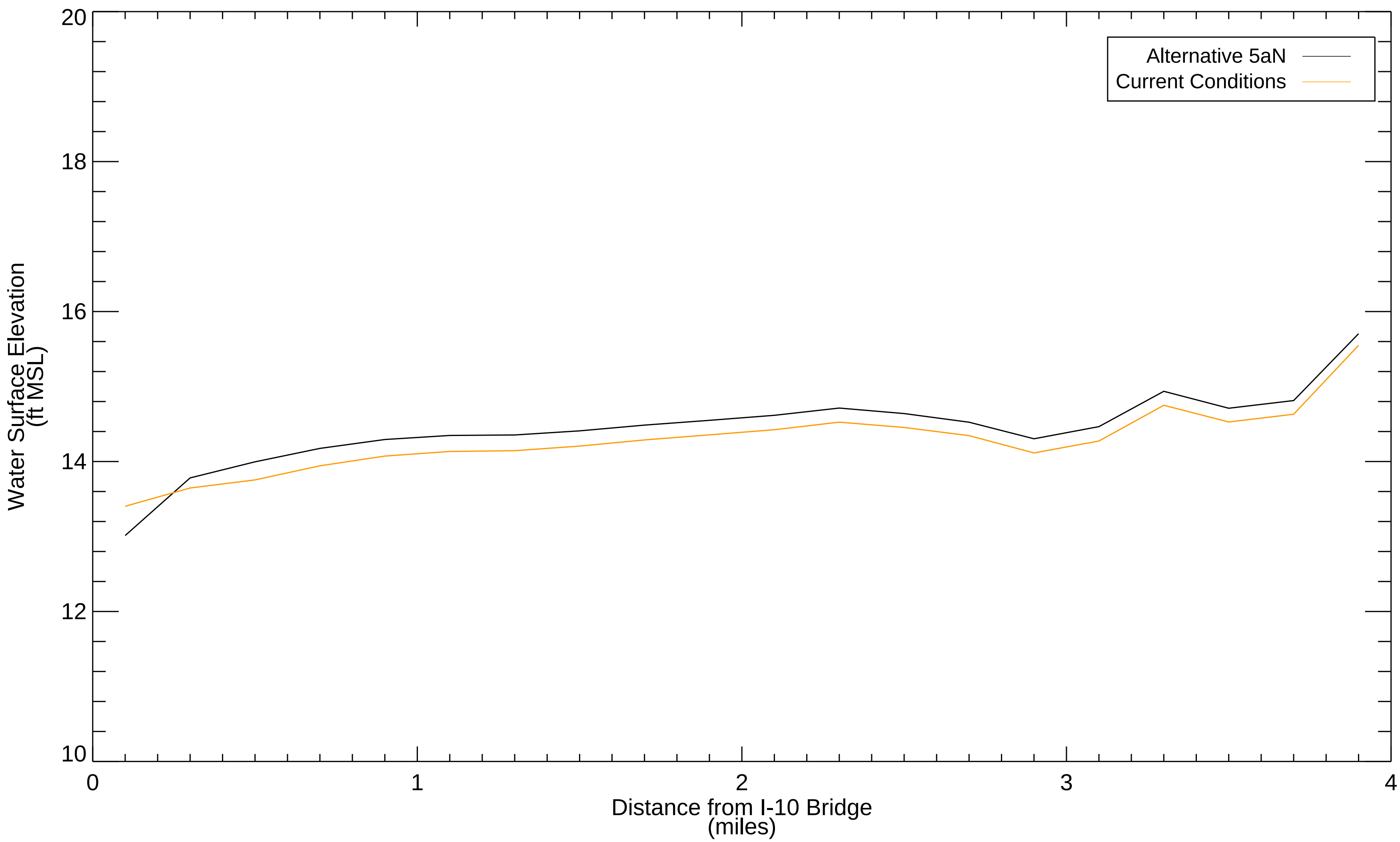

Figure 15

Alternative 5aN During Construction Comparison of Pre- and Post- Water Surface Elevations
During the 100-Year High-Flow Event: Lower-Bound Stage Height Condition
Feasibility Study - Appendix B: Hydrodynamic Cap Modeling
San Jacinto River Waste Pits Superfund Site

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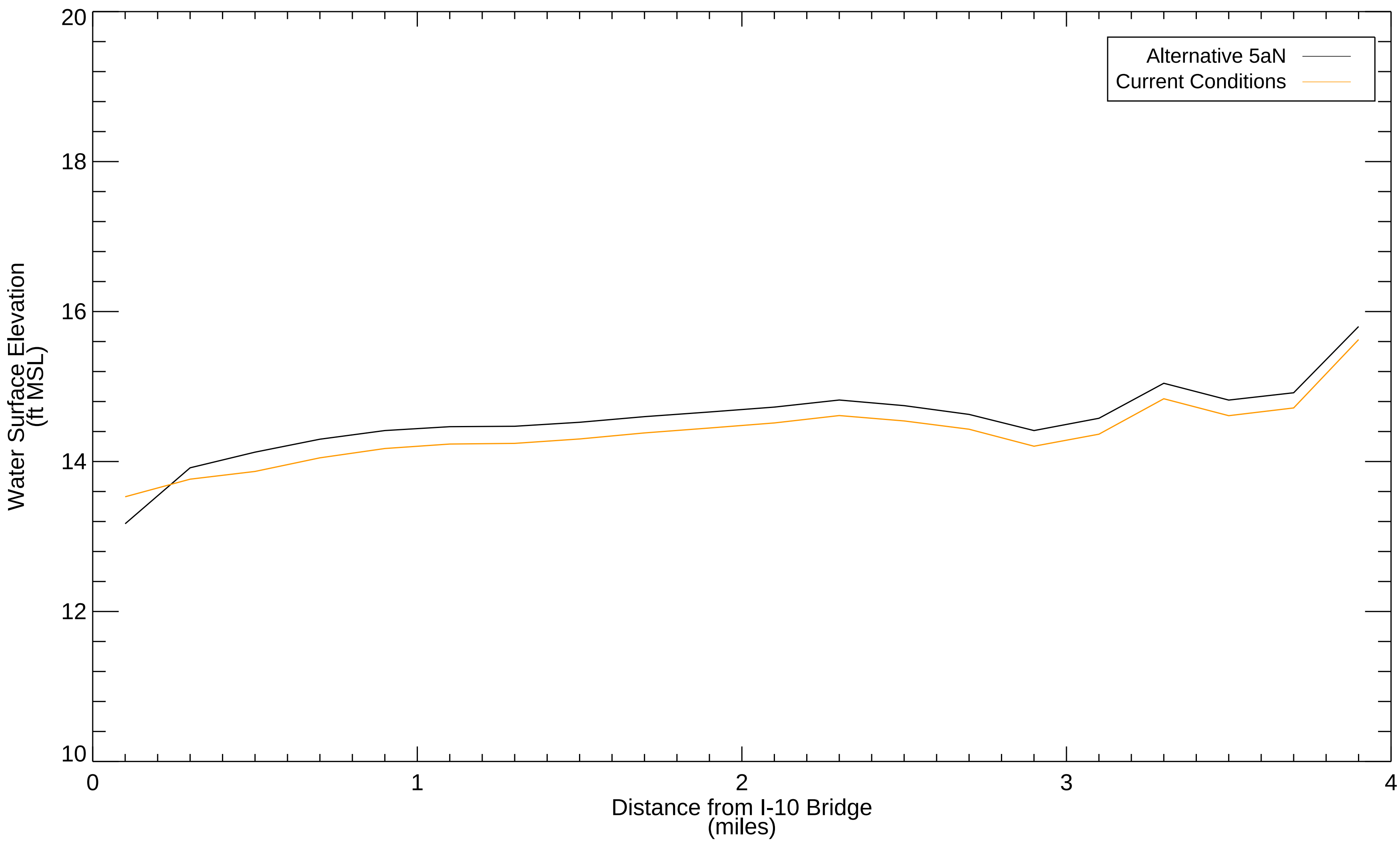

Figure 16

Alternative 5aN During Construction Comparison of Pre- and Post-Water Surface Elevations
During the 100-Year High-Flow Event: Upper-Bound Stage Height Condition
Feasibility Study - Appendix B: Hydrodynamic Cap Modeling
San Jacinto River Waste Pits Superfund Site

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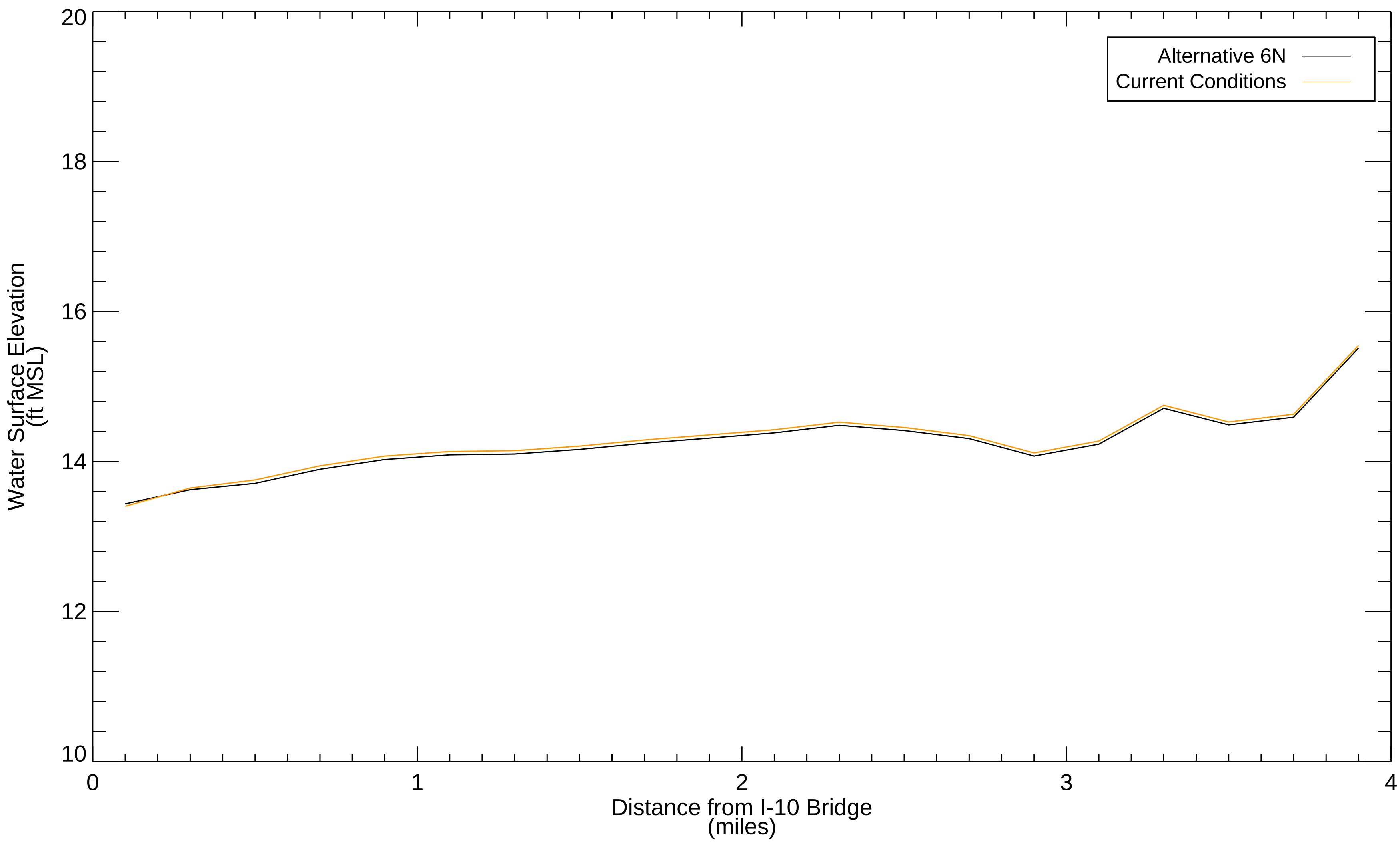

Figure 17

Alternative 6N Comparison of Pre- and Post- Water Surface Elevations
During the 100-Year High-Flow Event: Lower-Bound Stage Height Condition
Feasibility Study - Appendix B: Hydrodynamic Cap Modeling
San Jacinto River Waste Pits Superfund Site

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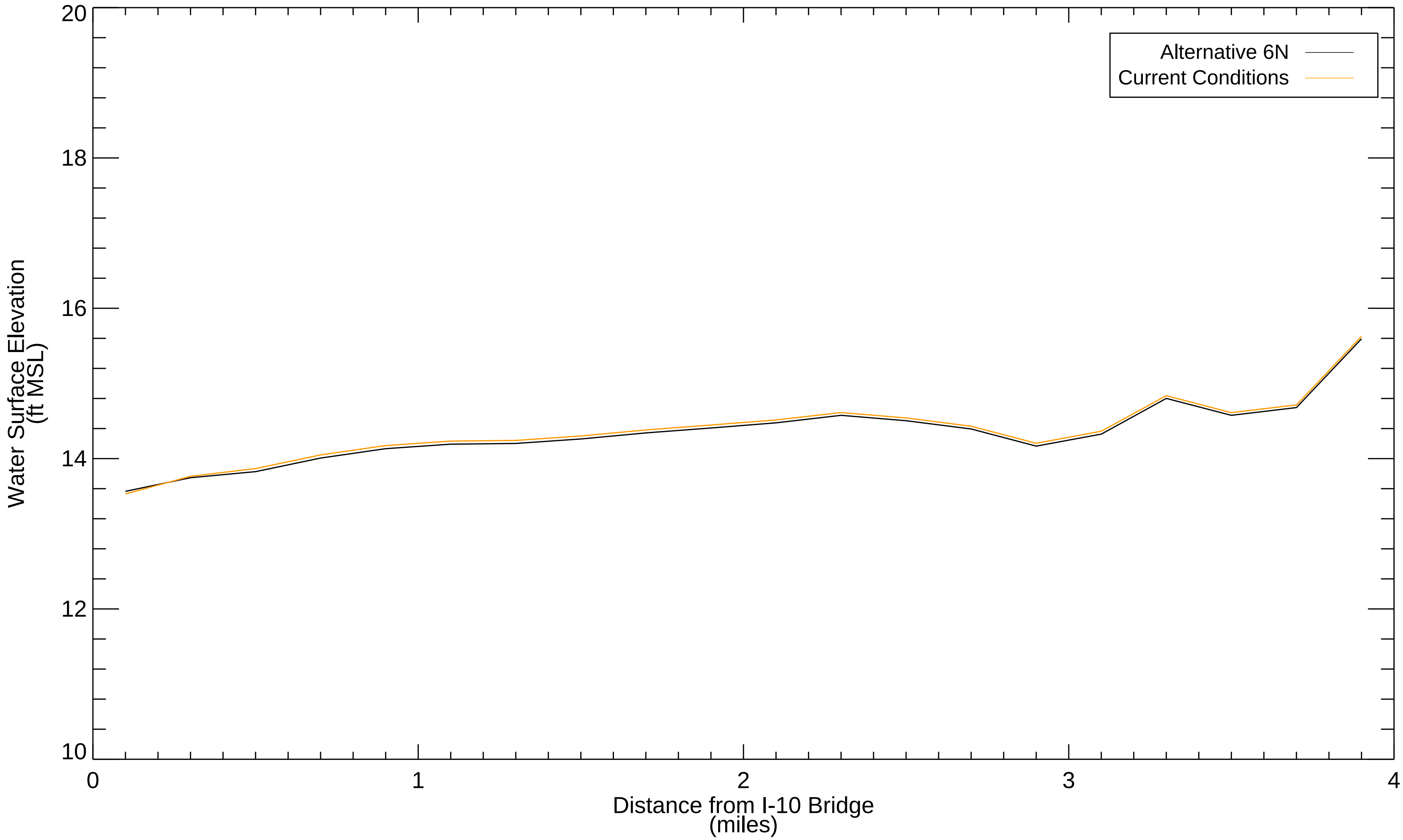

Figure 18

Alternative 6N Comparison of Pre- and Post- Water Surface Elevations
During the 100-Year High-Flow Event: Upper-Bound Stage Height Condition
Feasibility Study - Appendix B: Hydrodynamic Cap Modeling
San Jacinto River Waste Pits Superfund Site

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DRAFT FINAL INTERIM FEASIBILITY STUDY REPORT

APPENDIX C: REMEDIAL ALTERNATIVE COST DEVELOPMENT

SAN JACINTO RIVER WASTE PITS SUPERFUND SITE

Prepared for

International Paper Company

McGinnes Industrial Maintenance Corporation

Prepared by

Anchor QEA, LLC

614 Magnolia Avenue

Ocean Springs, Mississippi 39564

March 2014

REMEDIAL ALTERNATIVE COST DEVELOPMENT

This appendix summarizes the approaches used to develop remedial alternative quantities and cost estimates for the San Jacinto River Waste Pits Superfund Site Feasibility Study (FS). *A Guide to Developing and Documenting Cost Estimates During the Feasibility Study* (USEPA 2000) was followed to develop these cost estimates and was supplemented with professional judgment where appropriate in estimating daily costs and production rates. Professional judgment drew on the recently completed Time Critical Removal Action (TCRA; Anchor QEA 2011), as well as other construction projects in the region.

The remainder of this appendix discusses the following:

- Method for developing unit costs for the construction elements, including:
  - Defining each construction task
  - Discussion of the cost approach for each construction task
- Method for developing quantities for each construction element

UNIT COST DEVELOPMENT

The cost estimate consists of direct and indirect cost elements:

- Direct Construction Tasks
  - Mobilization/Demobilization and Setup
  - Permanent Cap Protective Berm
  - Permanent Cap Construction
  - Treatment
  - Removal and Disposal
  - Armored Cap Restoration
  - Demolition (Area South of Interstate-10)
  - Replacement (Area South of Interstate-10)
  - Soil Management Plan and Notices (Institutional Controls; Area South of Interstate 10)
- Indirect Construction Tasks
  - Engineering Design

- Construction Administration/Observation
- U.S. Environmental Protection Agency (USEPA) 5-Year Review (net present value)
- Institutional Controls (Northern Impoundments and Area South of Interstate 10; net present value)
- Long-Term Armored Cap Monitoring (net present value)
- Long-Term Natural Recovery Monitoring (net present value)
- Cap Maintenance (Armored Cap and Permanent Cap; net present value)

Table 1 provides a summary of unit cost assumptions for the cost sub-elements of each cost element bulleted above. Where appropriate, the source of the assumption is presented.

USEPA (2000) states that contingencies for detailed analysis of alternatives can be as high as 50 percent. For this FS, a contingency of 30 percent of the total direct construction costs was assumed.

As described in the Final Interim Feasibility Study Report, the cost of designing and implementing the TCRA exceeded $9 million. The construction cost, as reported in the Remedial Action Completion Report (RACR) (USEPA 2012), is $8.7 million. Additional costs not reported in the RACR include design and construction oversight. For purposes of these cost estimates, the cost of the TCRA has been assumed to be $9 million.

REMEDIAL ELEMENT QUANTITY ASSUMPTIONS

The total cost of a remedial alternative will be a function of the unit costs for each remedial element (Table 1) and the quantity of each remedial element. Table 2 summarizes assumptions used to develop the quantities of the remedial alternative elements.

REFERENCES

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Corporation and International Paper Company. November 2010. Revised February 2011.

USEPA (U.S. Environmental Protection Agency), 2000. *A Guide to Developing and Documenting Cost Estimates During the Feasibility Study*. USEPA 540-R-00-002 OSWER 9355.0-75. July 2000.

USEPA, 2012. Revised Final Removal Action Completion Report, San Jacinto River Waste Pits Superfund Site. May 2012.

Table 1
Unit Cost Assumptions

Element		Unit Cost	Unit	Source and/or Comment
Mobilization/ Demobilization and Setup	Mobilization and Demobilization – Northern Impoundments	8 to 15% of Direct Construction Costs	%	Engineering judgment. Higher due to marine work/equipment. Includes property rental for transfer sites.
	Mobilization and Demobilization – Area South of Interstate 10	$50,000 - $250,000	Lump Sum	Engineering judgment. Dependent on scope.
	Environmental Protection and Erosion Control	$5,000 - $300,000	Lump Sum	TCRA contractor bids and similar work with larger scope.
	Construction, Payment, and As-built Surveys – Northern Impoundments	$100,000 - $300,000	Lump Sum	Engineering judgment and TCRA contractor bids.
	Construction, Payment, and As-built Surveys – Area South of Interstate 10	$20,000	Lump Sum	Engineering judgment and limited confined area.
	Construction Materials Testing	$15,000	Each	Engineering judgment and TCRA contractor bids.
	Water Quality Engineering Controls	$100,000 - $1,600,000	Lump Sum	Engineering judgment and TCRA contractor bids. Lower cost for silt curtain; higher cost for combination rock berm and sheetpiling.
Permanent Cap Protective Berm	Rock Rubble Mound Construction	$107	Ton	USA Environment costs for installing D rock for TCRA construction. Assumed site access and production rates consistent with those achieved during the TCRA construction.
Permanent Cap Construction	Additional Armor Rock Placement	$107	Ton	USA Environment costs for installing D rock for TCRA construction; assumed site access and production rates consistent with those achieved during the TCRA construction.

Element		Unit Cost	Unit	Source and/or Comment
Treatment	Temporary Sheetpile Installation	$1,300	Linear Foot	TCRA contractor bids used as basis. Increased to account for additional king piles to support dewatering within the sheet piling.
	In Situ Solidification	$34	Cubic Yard	Actual USA Environment TCRA costs.
	Sheetpile Dewatering	$7,800	Day	RS Means and prior project bids for treatment costs.
Removal and Disposal	Upland Armored Cap Removal	$72	Cubic Yard	TXDOT average bid costs. Increased cost to account for slower production (thinner precision cuts) and assumed work can be performed in the dry with land-based construction equipment during low tide windows.
	In-water Armored Cap Removal	$92	Cubic Yard	TCRA contractor bid prices for dredging. Increased due to thinner precision cuts. Assumed that water based excavation equipment is necessary.
	Land-based Sediment Excavation	$12	Cubic Yard	TXDOT Average Bid Costs with increase for environmental considerations and slower production; assume that work can be performed in the dry with land based construction equipment during low tide windows.
	Water-based Sediment Excavation/Dredging	$46	Cubic Yard	TCRA contractor bids.
	Armored Cap Wash Water Treatment and Disposal	$530	Ton	Quote from Veolia assuming > 5% solids to treat water.
	Wellpoint Dewatering and Treatment	$400,000	Lump Sum	Previous project estimates.
	Replace Excavated Soil	$3.50	Cubic Yard	RS Means.

Element		Unit Cost	Unit	Source and/or Comment
	Offsite Haul and Disposal of Armored Cap (Debris Landfill)	$48	Ton	Actual USA Environment TCRA cost.
	Stabilization of Sediment/Soil prior to Shipment	$30	Cubic Yard	Engineering judgment and information from Waste Management. Assumed mixing diatomaceous earth with sediment.
	Offsite Haul and Disposal of Sediment (Class 1)	$110	Ton	Discussion with U.S. Department of Ecology.
	Offsite Haul and Disposal of Soil (Class 2)	$55	Ton	Prior experience in Texas on other similar projects.
	Dredge Residuals Cover/Backfill	$30	Cubic Yard	Prior project experience.
Armored Cap Restoration	Replacement Cap Geotextile	$6.25	Square Yard	USA Environmental TCRA costs.
	Replacement Cap Armor Stone A/B	$78	Ton	USA Environmental TCRA costs.
	Replacement Cap Armor Stone C/D	$107	Ton	USA Environmental TCRA costs.
Demolition (Area South of Interstate 10)	Concrete Pad (6 inch thick)	$7.54	Square Foot	RS Means.
	House with 4-inch-thick foundation	$7.89	Square Foot	RS Means.
Replacement Construction (Area South of Interstate 10)	Concrete Pad (6 inch thick)	$5.38	Square Foot	RS Means.
	House with 4-inch-thick foundation	$125	Square Foot	Review of online Houston housing costs.
Soil Management Plan	Bollards	$741.26	Each	RS Means.

Element		Unit Cost	Unit	Source and/or Comment
and Notices (Institutional Controls; Area South of Interstate 10)	Marker Layer	$0.67	Square Yard	Prior project experience.
Indirect Construction Costs	Engineering Design – Northern Impoundments	6 to 12% of Direct Construction Costs	$	Engineering judgment and complexity of marine work.
	Engineering Design – Area South of Interstate 10	$40,000 to $200,000	Lump Sum	Engineering judgment.
	Construction Administration/Observation – Northern Impoundments	6 to 12% of Direct Construction Costs	%	Engineering judgment. More extensive monitoring than upland.
	Construction Administration/Observation – Area South of Interstate 10	5 to 10% of Direct Construction Costs	%	Engineering judgment.
	USEPA 5-Year Review	Net Present Value	Lump Sum	Assumed $50,000 for USEPA costs every 5 years for 30 years for the Northern Impoundments and $50,000 for the Area South of Interstate 10. Assumed discount rate of 7% to determine net present value.
	Institutional Controls – Northern Impoundments	Net Present Value	Lump Sum	Assumed that as part of construction there are Institutional Controls costs for enforcement tools, proprietary controls, and informational devices. After construction, yearly costs of $10,000 for enforcement tools and $5,000 for informational devices for Alternatives 1N through 5aN and $4,000 per year for Alternative 6N for 30 years. Assumed discount rate of 7% to determine net present value.

Element		Unit Cost	Unit	Source and/or Comment
	Soil Management Plan and Notices (Institutional Controls) – Area South of Interstate 10	$100,000	Lump Sum	Two elements: 1) deed notices that document the presence of contamination, specific locations of affected areas, and if appropriate, protective measures that need to be used (e.g., PPE and HAZWOPER training); 2) soil management plan that would be recorded with the deed to describe how any excavated soil would be managed. Engineering judgment.
Indirect Construction Costs (continued)	Long-Term Armored Cap Monitoring	Net Present Value	Lump Sum	Assumed $25,000 cap monitoring events in Year 1, 2, 5, 10, 15, and 30. Assumed discount rate of 7% to determine net present value.
	Long-Term Natural Recovery Monitoring	Net Present Value	Lump Sum	Assumed $75,000 cap monitoring events in years 1, 2, 5, 10, 15, and 30. Assumed discount rate of 7% to determine net present value.
	Armored Cap Maintenance	Net Present Value	Lump Sum	Assumed $100,000 cap maintenance in Year 1 and 2. Assumed discount rate of 7% to determine net present value.

Notes:
% = percent
PPE = personal protective equipment
TCRA contractor bids = prices were based on the bids received for the 2010 TCRA removal action
TXDOT average bid costs = Texas Department of Transportation average low bid unit prices 3-month statewide average January through March 3013 (http://www.txdot.gov/business/letting-bids/average-low-bid-unit-prices.html)
RS Means = prices obtained from 2014 RS Means Online library for the Houston area.
USEPA = U.S. Environmental Protection Agency

Table 2
Quantity Assumptions

Element	Assumption	Source and/or Comment
Sediment and Soil Unit Weight	1.4 tons per cubic yard	Typical assumption for silty and sandy sediments (excavated material)
Armor Stone Unit Weight	1.8 tons per cubic yard	Typical assumption for engineered cap material
Sediment Residual Cover Thickness	6-inch-thick sand layer	Assumes 9 inches placed to obtain a 6-inch cover
Rock Rubble Mound Construction	5 foot high, 2 feet horizontal to 1 foot vertical (2H:1V) side slopes along the northwestern perimeter	Create a 5-foot-high rubble mound with the intent of stopping any larger vessels from striking the cap
Permanent Armor Rock on Slopes	5H:1V for upland armor rock and 3H:1V for offshore armor rock	Volume determined from CAD
Removal of Armored Cap	18-inch-thick cap over the area of removal	Typical Armored Cap thickness
Dredging/Excavation	Total removal volume is neat line volume plus 1-foot overdredge plus 10% to account for side slopes	Neatline volume determined from CAD, depths vary with target removal concentrations
Armored Cap Stone Washing	Assumes 0.025 tons of water needed to wash a ton of rock	Based on Armored Cap stone removal volumes and commercial pressure water volumes
Sheetpile Wall	Measured length	Area determined from CAD
Solidification/Stabilization	Volume the same as the calculated excavation volumes with 1-foot overstabilization and 10% growth	Neatline volume determined from CAD, depths vary with target removal concentrations
Landfill Disposal	Tonnage is the calculated excavation volumes increased by the unit weight and amount of additive needed for handling	From dredge volumes
Armor Stone Replacement	1 foot for A and B/C rock and 2 foot for C/D rock	Area determined in CAD and converted to tons
House and Concrete Pad in Area South of Interstate 10	4-inch-thick house foundation and 6-inch-thick concrete pad with rebar	Areas measured in Google Earth. Assumed house debris was 50 pounds per square feet and concrete pad debris was 150 pounds per cubic feet

SAN JACINTO FEASIBILITY STUDY ALTERNATIVES							
	ALT 1N	**ALT 2N**	**ALT 3N**	**ALT 4N**	**ALT 5N**	**ALT 5aN**	**ALT 6N**
Elements:	- Armored Cap OMM	- Institutional Controls - MNR - Armored Cap OMM	- Institutional Controls - MNR - Permanent Cap - Permanent Cap OMM	- Institutional Controls - MNR - Permanent Cap - Partial Solidification - Permanent Cap OMM	- Institutional Controls - MNR - Permanent Cap - Partial Removal; Disposal - Permanent Cap OMM	- Institutional Controls - MNR - Permanent Cap - Partial Removal; Disposal - Permanent Cap OMM	- Institutional Controls - MNR - Full Removal; Disposal
DIRECT CONSTRUCTION ITEMS							
Mobilization/Demobilization and Setup							
Mobilization/Demobilization			$ 177,170	$ 1,117,000	$ 1,420,000	$ 3,440,000	$ 4,560,000
Environmental Protection and Erosion Control			$ 100,000	$ 100,000	$ 300,000	$ 300,000	$ 300,000
Construction Payment and As-Built Surveys			$ 100,000	$ 100,000	$ 300,000	$ 300,000	$ 300,000
Construction Materials Testing			$ 15,000	$ 30,000	$ 30,000	$ 30,000	$ 30,000
Water Quality Engineering Controls					$ 100,000	$ 1,651,000	$ 100,000
Permanent Cap Protective Berm							
Rock Rubble Mound Construction			$ 311,300	$ 311,315	$ 311,315	$ 311,315	
Permanent Cap Construction							
Additional Permanent Cap Rock Placement			$ 654,835	$ 655,000	$ 655,000	$ 268,000	
Treatment							
Temporary Sheet Pile Installation				$ 1,040,000			
Sheet Pile Dewatering				$ 171,000			
In Situ Solidification				$ 1,783,000			
Removal and Disposal							
Upland Armored Cap Excavation				$ 443,000	$ 443,000	$ 443,000	$ 443,000
Inwater Armored Cap Excavation				$ 212,000	$ 212,000	$ 1,951,000	$ 2,180,000
Armored Cap Wash Water Treatment & Disposal				$ 424,000	$ 406,000	$ 1,300,000	$ 1,432,000
Offsite Haul & Disposal of Armored Cap (Debris Landfill)				$ 730,000	$ 730,000	$ 2,337,000	$ 2,576,000
Land-based Sediment Excavation					$ 536,000	$ -	$ -
Water-based Sediment Excavation/Dredging					$ 336,000	$ 6,330,000	$ 9,205,000
Stabilization of Sediment prior to Shipment					$ 1,536,000	$ 4,065,000	$ 5,911,000
Offsite Haul & Disposal of Sediment (Class 1 Landfill)					$ 8,800,000	$ 23,309,000	$ 33,891,000
Dredge Residuals Cover/Backfill					$ 1,560,000	$ 411,000	$ 594,000
Armored Cap Restoration							
Replacement Cap Geotextile				$ 141,000	$ 141,000		
Replacement Cap Armor Stone A				$ 648,000	$ 648,000		
Replacement Cap Armor Stone C/D				$ 657,000	$ 657,000		
IN-DIRECT CONSTRUCTION COST ITEMS							
Engineering Design			$ 162,960	$ 684,960	$ 1,147,000	$ 2,786,760	$ 3,691,320
Construction Administration/Observation			$ 162,960	$ 684,960	$ 1,147,000	$ 2,786,760	$ 3,691,320
Long Term Costs							
EPA 5 Year Review (Net Present Value)	$ 108,000	$ 108,000	$ 108,000	$ 108,000	$ 108,000	$ 108,000	$ 108,000
Institutional Controls (Net Present Value)	$ -	$ 286,000	$ 286,000	$ 286,000	$ 286,000	$ 286,000	$ 70,000
Long Term MNR Monitoring (Net Present Value)	$ -	$ 264,000	$ 264,000	$ 264,000	$ 264,000	$ 264,000	$ 264,000
Long Term Cap Monitoring (Net Present Value)	$ 88,000	$ 88,000	$ 88,000	$ 88,000	$ 88,000	$ 88,000	
Long Term Cap Maintenance (Net Present Value)	$ 181,000	$ 181,000	$ 181,000	$ 181,000	$ 181,000	$ 181,000	
TOTAL OPINION OF PROBABLE COST							
Subtotal (Construction + In-Direct Construction)	$ 400,000	$ 1,000,000	$ 2,700,000	$ 10,900,000	$ 22,400,000	$ 53,000,000	$ 69,400,000
Contingency (30%)	$ 100,000	$ 300,000	$ 800,000	$ 3,300,000	$ 6,700,000	$ 15,900,000	$ 20,800,000
Alternative Subtotal	$ 500,000	$ 1,300,000	$ 3,500,000	$ 14,200,000	$ 29,100,000	$ 68,900,000	$ 90,200,000
TCRA Design and Construction Cost	$ 9,000,000	$ 9,000,000	$ 9,000,000	$ 9,000,000	$ 9,000,000	$ 9,000,000	$ 9,000,000
TOTAL Opinion of Probable Cost	**$ 9,500,000**	**$ 10,300,000**	**$ 12,500,000**	**$ 23,200,000**	**$ 38,100,000**	**$ 77,900,000**	**$ 99,200,000**

Client: IPC & MIMC
Project: San Jacinto Feasibility Study
Project No.: 090557-01.03

Prepared by: Renee Robertson
Date: 2-28-14
Reviewed by: John Verduin

Engineer's Estimate of Project Quantities & Probable Cost Worksheet
Alternative 1N - No Action

Item	Description	Plan Qty.	Unit	Unit Price	Total
DIRECT CONSTRUCTION COSTS					
0001	Mobilization/Demobilization	$ -	%	15%	$ -
0002	Environmental Protection and Erosion Control	0	LS	$100,000	$ -
0003	Construction Payment and As-Built Surveys	0	LS	$100,000	$ -
0004	Construction Materials Testing	0	EA	$15,000	$ -
0005	Additional Armor Rock Placement	0	TON	$107	$ -
DIRECT CONSTRUCTION TOTAL:					$ -
IN-DIRECT CONSTRUCTION COSTS					
0006	Engineering Design	$ -	%	12%	$ -
0007	Construction Administration/Observation	$ -	%	12%	$ -
0008	EPA 5 Year Review (Net Present Value)	1	LS	$108,000	$ 108,000.00
0009	Institutional Controls (Net Present Value)	0	LS	$286,000	$ -
0010	Long Term MNR Monitoring (Net Present Value)	0	EA	$264,000	$ -
0011	Long Term Cap Monitoring (Net Present Value)	1	LS	$88,000	$ 88,000.00
0012	Cap Maintenance (Net Present Value)	1	LS	$181,000	$ 181,000.00
IN-DIRECT CONSTRUCTION TOTAL:					$ 377,000.00
PROJECT TOTAL					$ 377,000.00
PROJECT ROUNDED TOTAL:					**$ 400,000.00**
30% Contingency					**$ 120,000.00**
TCRA Design and Construction Cost					**$ 9,000,000.00**
TOTAL ESTIMATED COST					**$ 9,520,000.00**

Client: IPC & MIMC
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Engineer's Estimate of Project Quantities & Probable Cost Worksheet
Alternative 2N - Institutional Controls, MNR, and OMM

Item	Description	Plan Qty.	Unit	Unit Price	Total
DIRECT CONSTRUCTION COSTS					
0001	Mobilization/Demobilization	$ -	%	15%	$ -
0002	Environmental Protection and Erosion Control	0	LS	$100,000	$ -
0003	Construction Payment and As-Built Surveys	0	LS	$100,000	$ -
0004	Construction Materials Testing	0	EA	$15,000	$ -
0005	Additional Armor Rock Placement	0	TON	$107	$ -
DIRECT CONSTRUCTION TOTAL:					$ -
IN-DIRECT CONSTRUCTION COSTS					
0006	Engineering Design	$ -	%	12%	$ -
0007	Construction Administration/Observation	$ -	%	12%	$ -
0008	EPA 5 Year Review (Net Present Value)	1	LS	$108,000	$ 108,000.00
0009	Institutional Controls (Net Present Value)	1	LS	$286,000	$ 286,000.00
0010	Long Term MNR Monitoring (Net Present Value)	1	LS	$264,000	$ 264,000.00
0011	Long Term Cap Monitoring (Net Present Value)	1	LS	$88,000	$ 88,000.00
0012	Cap Maintenance (Net Present Value)	1	LS	$181,000	$ 181,000.00
IN-DIRECT CONSTRUCTION TOTAL:					$ 927,000.00
PROJECT TOTAL					$ 927,000.00
PROJECT ROUNDED TOTAL:					**$ 1,000,000.00**
30% Contingency					**$ 300,000.00**
TCRA Design and Construction Cost					**$ 9,000,000.00**
TOTAL ESTIMATED COST					**$ 10,300,000.00**

Client: IPC & MIMC
Project: San Jacinto Feasibility Study
Project No.: 090557-01.03

Prepared by: Renee Robertson
Date: 2-28-14
Reviewed by: John Verduin

Engineer's Estimate of Project Quantities & Probable Cost Worksheet
Alternative 3N - Permanent Cap

Item	Description	Plan Qty.	Unit	Unit Price	Total
DIRECT CONSTRUCTION COSTS					
0001	Mobilization/Demobilization	$ 1,181,135	%	15%	$ 177,170.25
0002	Environmental Protection and Erosion Control	1	LS	$100,000	$ 100,000.00
0003	Construction, Payment and As-Built Surveys	1	LS	$100,000	$ 100,000.00
0004	Construction Materials Testing	1	EA	$15,000	$ 15,000.00
0005	Rock Rubble Mound Construction	2,900	TON	$107	$ 311,300.00
0006	Additional Permanent Cap Rock Placement	6,100	TON	$107	$ 654,835.00
DIRECT CONSTRUCTION TOTAL:					$ 1,358,000.00
IN-DIRECT CONSTRUCTION COSTS					
0007	Engineering Design	$ 1,358,000	%	12%	$ 162,960.00
0008	Construction Administration/Observation	$ 1,358,000	%	12%	$ 162,960.00
0009	EPA 5 Year Review (Net Present Value)	1	LS	$108,000	$ 108,000.00
0010	Institutional Controls (Net Present Value)	1	LS	$286,000	$ 286,000.00
0011	Long Term MNR Monitoring (Net Present Value)	1	LS	$264,000	$ 264,000.00
0012	Long Term Cap Monitoring (Net Present Value)	1	LS	$88,000	$ 88,000.00
0013	Cap Maintenance (Net Present Value)	1	LS	$181,000	$ 181,000.00
IN-DIRECT CONSTRUCTION TOTAL:					$ 1,252,920.00
PROJECT TOTAL					$ 2,610,920.00
PROJECT ROUNDED TOTAL:					**$ 2,700,000.00**
30% Contingency					**$ 810,000.00**
TCRA Design and Construction Cost					**$ 9,000,000.00**
TOTAL ESTIMATED COST					**$ 12,510,000.00**

Client: IPC & MIMC
Project: San Jacinto Feasibility Study
Project No.: 090557-01.03

Prepared by: Renee Robertson
Date: 2-28-14
Reviewed by: John Verduin

Engineer's Estimate of Project Quantities & Probable Cost Worksheet
Alternative 4N - Partial Solidification

Item	Description	Plan Qty.	Unit	Unit Price	Total
DIRECT CONSTRUCTION COSTS					
0001	Mobilization/Demobilization	$ 7,445,315	%	15%	$ 1,117,000.00
0002	Environmental Protection and Erosion Control	1	LS	$100,000	$ 100,000.00
0003	Construction Payment and As-Built Surveys	1	LS	$100,000	$ 100,000.00
0004	Construction Materials Testing	2	EA	$15,000	$ 30,000.00
0005	Rock Rubble Mound Construction	2,900	TON	$107	$ 311,315.00
0006	Additional Armor Rock Placement	6,100	TON	$107	$ 655,000.00
0007	Remove Armored Cap - Land Based	6,200	CY	$72	$ 443,000.00
0008	Remove Armored Cap - Water Based	2,300	CY	$92	$ 212,000.00
0009	Wash Water Armored Cap - Treat and Dispose	800	TON	$530	$ 424,000.00
0010	Dispose Armored Cap - Debris Landfill	15,300	TON	$48	$ 730,000.00
0011	Temporary Sheet Pile	800	LF	$1,300	$ 1,040,000.00
0012	Sheet Pile Dewatering	22	DAY	$7,800	$ 171,000.00
0013	In situ Solidification	52,000	CY	$34	$ 1,783,000.00
0014	Replace Geotextile	22,600	SY	$6.25	$ 141,000.00
0015	Replace Armor Rock A/B	8,280	TON	$78	$ 648,000.00
0016	Replace Armor Rock C/D	6,120	TON	$107	$ 657,000.00
DIRECT CONSTRUCTION TOTAL:					$ 8,562,000.00
IN-DIRECT CONSTRUCTION COSTS					
0017	Engineering Design	$ 8,562,000	%	8%	$ 684,960.00
0018	Construction Administration/Observation	$ 8,562,000	%	8%	$ 684,960.00
0019	EPA 5 Year Review (Net Present Value)	1	LS	$108,000	$ 108,000.00
0020	Institutional Controls (Net Present Value)	1	LS	$286,000	$ 286,000.00
0021	Long Term MNR Monitoring (Net Present Value)	1	LS	$264,000	$ 264,000.00
0022	Long Term Cap Monitoring (Net Present Value)	1	LS	$88,000	$ 88,000.00
0023	Cap Maintenance (Net Present Value)	1	LS	$181,000	$ 181,000.00
IN-DIRECT CONSTRUCTION TOTAL:					$ 2,296,920.00
PROJECT TOTAL					$ 10,858,920
PROJECT ROUNDED TOTAL:					**$ 10,900,000.00**
30% Contingency					**$ 3,270,000.00**
TCRA Design and Construction Cost					**$ 9,000,000.00**
TOTAL ESTIMATED COST					**$ 23,170,000.00**