REPORT

DRAFT TIME CRITICAL REMOVAL ACTION ALTERNATIVES ANALYSIS SAN JACINTO RIVER WASTE PITS SUPERFUND SITE

Prepared for

U.S. Environmental Protection Agency, Region 6

On behalf of

McGinnes Industrial Maintenance Corporation

And

International Paper Company

Prepared by

Anchor QEA, LLC

614 Magnolia Avenue

Ocean Springs, Mississippi 39564

May 2010

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LIST OF ACRONYMS AND ABBREVIATIONS

ACBM	articulated concrete block mat
ADCP	acoustic Doppler current profiler
AOC	Administrative Order on Consent
BMPs	best management practices
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act (a.k.a, Superfund)
cfs	cubic feet per second
D_{50}	median diameter
I-10	Interstate Highway 10
IPC	International Paper Company
MIMC	McGinnes Industrial Maintenance Corporation
MSL	mean sea level
NAVD 88	North American Vertical Datum of 1988
ng/kg	nanograms per kilogram
NPL	National Priorities List
NTCRA	non-Time Critical Removal Action
OM&M	operations, monitoring and maintenance
RI/FS	Remedial Investigation/Feasibility Study
Site	San Jacinto River Waste Pits Superfund Site
TCDD	2,3,7,8-tetrachlorodibenzo-p-dioxin
TCEQ	Texas Commission on Environmental Quality
TCRA	Time Critical Removal Action
TOC	total organic carbon
UAO	Unilateral Administrative Order
USACE	United States Army Corps of Engineers
USEPA	United States Environmental Protection Agency

1 INTRODUCTION

1.1 Project Background

The San Jacinto River Waste Pits Superfund Site (Site) is located on the San Jacinto River, east of Houston, in Harris County, Texas (Figure 1). On March 19, 2008, the United States Environmental Protection Agency (USEPA) listed the Site on the National Priorities List (NPL) and USEPA issued a Unilateral Administrative Order (UAO), Docket No. 06-03-10, to International Paper Company (IPC) and McGinnes Industrial Maintenance Corporation (MIMC) (collectively, the Respondents) on November 20, 2009, (USEPA 2009). The 2009 UAO directs IPC and MIMC to conduct a Remedial Investigation and Feasibility Study (RI/FS) for the Site.

In addition, MIMC and IPC entered into an Administrative Order on Consent (AOC), Docket No. 06-03-10, to conduct a Time Critical Removal Action (TCRA) in April 2010 (USEPA 2010). The TCRA is to stabilize the Site, temporarily abating any release of polychlorinated dibenzo-p-dioxins and polychlorinated dibenzofurans into the waterway until the Site is fully characterized and a remedy is selected (USEPA 2010).

After the TCRA has been completed, USEPA will make a determination about the need for future actions at the Site. This report was prepared pursuant to the requirements of the AOC, which calls for a comparative evaluation of various alternatives for the TCRA. A brief description and history of the Site are provided in Section 1.2, a summary of existing physical conditions relevant to the TCRA is provided in Section 1.3, and a summary of extent and major elements of the TCRA is provided in Section 1.4 to provide a basis for the analyses presented in subsequent sections.

1.2 Site Description and History

The Site consists of a set of impoundments approximately 15.7 acres in size, built in the mid-1960s for disposal of paper mill wastes. The Site also includes the surrounding areas containing sediments and soils potentially contaminated with the waste materials that had been disposed of in the impoundments. The set of impoundments is located on a 20-acre parcel on the western bank of the San Jacinto River, in Harris County, Texas, immediately north of the Interstate Highway 10 (I-10) Bridge over the San Jacinto River (Figure 1).

In 1965, the impoundments were constructed by forming berms within the estuarine marsh, just north of what was then Texas State Highway 73 (now I-10), to the west of the main river channel. The two primary impoundments at the Site were divided by a central berm running lengthwise (north to south) through the middle, and were connected with a drain line to allow flow of excess water (including rain water) from the impoundment located to the west of the central berm, into the impoundment located to the east of the central berm (Figure 1).

In 1965 and 1966, pulp and paper mill wastes (both solid and liquid) were reportedly transported by barge and unloaded at the Site into the impoundments. The wastes deposited in the impoundments have recently been found to be contaminated with polychlorinated dibenzo-p-dioxins, polychlorinated furans (dioxins and furans), and some metals (TCEQ and USEPA 2006). Physical changes at the Site in the 1970s, 1980s, and 1990s, including regional subsidence of land in the area due to large-scale groundwater extraction and sand mining within the river and marsh to the west of the impoundments, have resulted in partial submergence of the berms and exposure of the contents of the impoundments to surface waters. Based on permit reviews, aerial photograph interpretation, recent bathymetric survey results, and an evaluation of the distribution of dioxin in surface sediments surrounding the Site, it appears that sand mining-related dredging occurred in the vicinity of the perimeter berm at the northwest corner of the impoundments in 1997 or 1998. These dredging activities appear to have impacted the berms on the northwestern portion of the impoundment.

1.3 Existing Conditions

The impoundments are currently occupied by late-successional stage estuarine riparian vegetation to the west of the central berm, and are consistently submerged even at low tide to the east of the central berm. Estuarine riparian vegetation also lines the upland area that runs parallel to I-10. A sandy intertidal zone is present along the shoreline throughout much of the Site.

1.3.1 Bathymetry

The bathymetry and geometry of the San Jacinto River in the vicinity of the Site may be separated into three regions: 1) vicinity of waste impoundments (i.e., within about 0.5 mile of the waste impoundments); 2) upstream of the waste impoundments (i.e., extending about 4 miles upstream of the waste impoundments); and 3) downstream of I-10 Bridge to the confluence with the Houston Ship Channel. In the vicinity of the waste impoundments, a large portion of the area is relatively shallow, with water depths of about 2 to 6 feet. The shallow areas contain some intertidal zones that may have an exposed sediment bed during low tide conditions. The area located to the west and northwest of the waste impoundments has been affected by past sand mining operations, with the dredged areas having typical water depths of 16 to 18 feet. The main channel of the river (upstream of the I-10 Bridge) is located to the north and east of the waste impoundments, with typical depths of 20 to 30 feet in the channel.

In the region upstream of the waste impoundments, the San Jacinto River winds northward through an unconfined channel (10 to 20 feet deep) that is surrounded by a relatively wide area of shallower water (typically 3 to 4 feet, or less). The river becomes confined to a single channel about 4 miles upstream of the waste impoundments, with this single channel continuing upstream to the Lake Houston dam.

Downstream of the I-10 Bridge, the main channel of the river extends for about 2 miles until the confluence with the Houston Ship Channel. The main channel is navigable with depths ranging from 15 to 30 feet. Shallower areas exist along the eastern shore of the main channel, with depths of 6 feet or less. The old river channel branches off from the main channel about 0.5 miles downstream of the I-10 Bridge. Water depths in the old river channel are typically 6 feet or less.

1.3.2 Hydrography

Flow rates in the San Jacinto River in the vicinity of the Site are partially controlled by the Lake Houston dam, which is located about 28 miles upstream of the waste impoundments. The average flow in the river is 2,200 cubic feet per second (cfs). Floods in the river primarily occur during tropical storms (e.g., hurricanes) or intense thunderstorms. Extreme

flood events have flow rates of 200,000 cfs or greater. The October 1994 flood had a peak discharge of 360,000 cfs, which has a return period of greater than 100 years. River stage height during the October 1994 flood had a maximum value of 27 feet above mean sea level (MSL).

The river in the vicinity of the waste impoundments is affected by diurnal tides, with a typical tidal range of 1 to 2 feet. Tidal range varies over a 14-day cycle, 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 at the Site. Tropical storms can cause storm surges with water levels that are significantly higher than typical tidal elevations. 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.

Salinity in the vicinity of the waste impoundments generally ranges between 10 and 20 parts per thousand during low to moderate flow conditions in the river. During floods, salinity values will approach freshwater conditions.

1.4 Streamlined Risk Evaluation

USEPA directed MIMC and IPC to collect additional soil and sediment data along the perimeter of the Site in a request received by email on Friday, March 26, 2010, to determine the potential area requiring stabilization as part of the TCRA. The sampling was conducted April 13 to April 15, 2010, and included surface sediment and soil sampling and analysis of dioxins and furan congeners and total organic carbon (TOC) at 25 locations in and near the impoundments located along five transects, with five stations located along each transect.

The results of the TCRA sediment and soil sampling are provided in Figure 2. This figure shows that surface sediments and soils within the footprint of the former waste impoundments exceed relevant criteria (330 nanograms per kilogram [ng/kg] 2,3,7,8-tetrachlorodibenzo-p-dioxin [TCDD] organic carbon normalized, or 4.5 ng/kg TCDD non-organic carbon normalized) established by USEPA as requiring immediate action within the original bermed perimeter.

As described in the Action Memorandum (USEPA 2010, Appendix A), the TCRA involves the following major elements:

- Public access restrictions must be put in place
- Immediate design and construction of a physical protective barrier surrounding Waste Ponds 1 and 2 that addresses the release, or threat of release of dioxins and furans into the San Jacinto River
  - Any concentrations greater than 330 ng/kg of TCDD organic carbon normalized (or 4.5 ng/kg TCCD non-organic carbon normalized) in the sediment will be considered part of the source area of contamination within the original 1966 berm placement, and must be addressed with the protective barrier
- Design and construction of the barrier 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. This includes accounting for seasonal severe weather events.

1.5 Purpose of Document

This document presents an engineering evaluation and cost analysis to compare several conceptual design alternatives for the TCRA. The following major topics are discussed:

- Evaluation criteria used
- Technology screening for removal action strategies
- Design criteria used to develop removal action alternatives
- Description of the removal action alternatives considered
- Comparative evaluation of the removal action alternatives
- Recommended removal action alternative
- References and appendices to provide additional details as appropriate

2 EVALUATION CRITERIA

Five removal action alternatives were selected in consultation with USEPA and evaluated following Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) guidance against the following three criteria:

- Effectiveness
- Implementability
- Cost

The evaluation of each of these criteria is described below.

2.1 Effectiveness Evaluation

Based on the Action Memorandum (USEPA 2010, Appendix A), the following removal action objectives for the TCRA were identified:

- Control erosion of waste materials
  - Source materials are considered sediments located within the original 1966 berm footprint and with concentrations greater than or equal to 330 ng/kg TCDD organic carbon normalized or 4.5 ng/kg TCDD non-organic carbon normalized. (USEPA 2010, Appendix A, IV.A.1; Page 9; 2nd paragraph)
  - Erosion can occur from upland runoff, river and tidal currents, waves, and propeller wash. (USEPA 2010, Appendix A, III.A.4)
  - Technologies used to control erosion "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 2010, Appendix A, IV.A.1; Page 9; 3rd paragraph)
- Prevent direct human contact with the waste materials. (USEPA 2010, Appendix A, IV.A.1; Page 9; 1st paragraph). Humans come into contact with the material accessing the Site by land and water.
- Prevent benthic contact with the waste materials. (USEPA 2010, Appendix A, III.B)

- Ensure that the "actions are consistent with any long term remediation strategies that may be developed for the Site." (USEPA 2010, Appendix A, V.A.2). Whatever action is applied for the TCRA should not constrain the future non-Time Critical Removal Action (NTCRA) remedy.

Based on these objectives, the effectiveness evaluation will focus on the following:

- The effectiveness of the remedy to isolate waste or sediments with concentrations of 2,3,7,8 TCDD above the action levels described above from exposure or transport off site to addresses the release, or threat of release, of dioxins and furans into the San Jacinto River from the Site
- The potential ability of the remedy to withstand and remain in place and effective during and after extreme weather events (see Appendices A and B for more detail on design storm event and hydrodynamic model description)
- The potential effectiveness of the technology to prevent benthic contact with the waste materials
- The potential effectiveness of the technology to prevent direct human contact with the waste materials
- The potential impacts to human health and the environment during construction
- The potential effectiveness and consistency of the technologies with any long-term remediation strategies for the Site

2.2 Implementability Evaluation

The implementability criterion focuses on:

- Availability of the materials and equipment to implement the technologies
- Availability of skilled labor to implement the technologies
- Expected construction challenges or constraints for a specific technology
- Potential impacts of the remedy on navigation and/or flood control

In addition to evaluating technical issues associated with implementability, the evaluation also includes the expected construction duration for each alternative. There is a preference for actions that require a shorter duration to implement.

2.3 Cost Evaluation

Costs for the different alternatives will be developed to an accuracy of +/-30 percent for comparative purposes. The focus of the cost evaluation is to make comparative estimates for alternatives with relative accuracy. As described in Appendix C, the costs include capital and operations, maintenance, and monitoring (OM&M) costs. As recommended by the USEPA, OM&M costs are assumed for a period of 7 years before future actions are implemented at the Site.

3 INITIAL TECHNOLOGY SCREENING

There are three general categories of technologies that are applicable to removal actions at sediments sites. This section provides a technical screening and discusses potential project-specific considerations as they apply to these technologies. The three categories of technologies are:

- Removal
- Containment
- Treatment

These strategies were initially screened from the wide range of technologies available by considering their successful implementation under similar conditions at other NPL sites.

3.1 Removal

Removal entails the excavation of soils or sediments that exceed specified criteria. Once excavated, the material would be managed in an engineered containment facility, either on site or off site.

For the Site, the scope of removal could entail excavation both above and below the existing water surface. Excavation above the water surface could be accomplished with conventional earthwork equipment (e.g., backhoes, excavators, or dozers). Within most areas of the river, excavation would need to be performed using a water-based operation (i.e., dredging).

Because of the shallow-water nature of most of the Site, the appropriate dredging technology would need to be carefully considered. The material barge required by a conventional clamshell derrick (mechanical dredging) would likely require more water depth than is present on the Site. Thus, dredging would need to be performed with a hydraulic dredge or marsh-buggy excavator. A marsh-buggy excavator would have limited application at the Site due to the deeper water present in the northwestern area. Thus, water-based removals would be performed with a hydraulic dredge at the Site.

Once excavation has been completed, the excavated materials need to be managed. For on-site management, appropriate controls would be required to contain the material. To manage material from a hydraulic dredging operation, geotubes can be used to contain the dredge material and to facilitate controlled dewatering of the sediment. The Site does not have enough surface area to create a settling basin to manage the dredge material. For off-site disposal, an appropriate and approved receiving facility must be identified. In this case, excavated material would need to be loaded onto trucks and transferred to the off-site location for disposal.

Hydraulic dredging with on-site management using geotubes is a common strategy that has been used on other cleanup projects. The technology is well understood, and is readily available. Thus, it has been retained for further evaluation as a component of the alternatives considered in this report.

3.2 Containment

Containment entails physically separating the contaminants of concern from environmental receptors. For the TCRA, isolation would be necessary for all sediments that are actively eroding, or could potentially erode within the historic footprint of the impoundments.

There are several strategies for containment. Commonly, containment for sediments entails placement of a cover of clean sediment and/or aggregate on top of target materials (Palermo et. al. 1998; USEPA 2005), or a man-made cover of geotextile and/or cast-in-place concrete. Containment can also be achieved by constructing a physical barrier (e.g., sheet pile wall or geotube berm) around the area of interest.

As noted under the discussion for removal, the Site has limited water depth. Based on conversations with a local marine contractor (Orion 2010), measures to construct granular or sheet pile containment from the water (e.g., through the use of a flexi-float barge setup) could pose a risk for barge grounding and/or catastrophic equipment loss. As a result of these discussions, the construction of containment for the conceptual alternatives has been assumed to be performed from the land where the water is shallow.

3.2.1 Granular Containment Cover

Granular containment cover entails the placement of a layer of aggregate with a gradation that has been sized to withstand a design-level erosion event. This placement could be done from the land, or from the water. Depending on the required gradation of the granular material, it could be sourced from a local quarry, from a remote quarry, or from a local concrete recycling operation. Granular containment covers are commonly used for sediment cleanup projects (USEPA 2005).

3.2.2 Articulated Concrete Block Mat Containment Cover

The articulated concrete block mat (ACBM) containment cover entails placement of a multi-layer, cable-reinforced geotextile fabric over the cover area, and pumping the interstitial pockets of the fabric with a lean concrete grout. Once the grout hardens an interconnected pillow-like structure of concrete remains in place to act as a protective cover. The hardened structure prevents penetration of the surface by human or benthic organisms, and prevents further erosion of the covered sediment.

Past project experience has identified potential scour and undermining of ACBM materials when the installed edge is submerged within a flowing water body. To address this potential concern, the ACBM cover includes a perimeter scour apron constructed of rock material for all submerged edges of the mattress.

The ACBM containment cover strategy has been used on other remedial projects, although it is not as commonly used as granular covers have been.

3.2.3 Sheet Pile Containment Wall

Sheet pile containment can be used to physically separate soils and sediments from the surrounding environment with a vertical wall. The sheet pile would be installed using conventional pile-driving equipment staged from a land-based operation or from a barge, depending on Site access constraints. Sheet pile walls can be designed to have very low permeability if the specific goal of containment is to prevent migration of dissolved phase contamination.

Two materials are commonly used for sheet pile containment: steel and composite (i.e., vinyl). Each material has advantages and disadvantages compared to the other.

Steel sheet piles are readily available in a variety of cross sections and strengths. Steel is relatively expensive and heavy to handle on site, requiring larger installation equipment. However, steel is very strong and can resist higher lateral loads before significant deflections occur. Also, steel can withstand high forces and bending moments produced during driving and vibrating through fill and adverse soil conditions. Steel can also be field-welded to make repairs or lengthen sheets. Finally, steel may have a salvage value that can reduce the overall cost of its use, depending on the condition of the sheets.

Composite sheet piles are also available in a variety of cross sections and strengths. Compared to steel, composite sheet piles are less expensive and lighter to handle. Composite sheets are typically very flexible compared to steel and can be subject to significant deflections under lateral loads. They are also less resistant to impact loads compared to steel sheets. Composite sheets must be installed with a specialized mandrel that allows the sheet to be driven or vibrated in to its tip elevation without damaging the sheet. Once the composite sheet is driven to depth, the mandrel is detached from the sheet and pulled back up from below the ground surface for reuse in the next sheet installation. Composite sheets are expected to have zero salvage value when used in a remedial environment. Based on feedback from USEPA during alternatives development, and after conversations with a composite material supplier, composites may still be appropriate for use in the TCRA and could present the opportunity for reduced costs compared to the use of steel. Thus, composite sheets were selected for the conceptual alternatives that involve a sheet pile containment structure. The potential limitations of composite materials would be further evaluated during detailed design. The costs to switch to steel sheet piles from composite are presented in the cost evaluation section.

Sheet piles are sensitive to unbalanced, or cantilevered, loading. In typical shoreline applications, lateral support against wave and water forces is provided by the soil behind the sheet pile. However, in the application considered for this TCRA, the sheet pile would be surrounded by water on both sides, and a provision would need to be made to balance the hydraulic forces on both sides of the sheet pile.

There are several strategies to provide additional lateral support against hydraulic forces. First, a rock or gabion buttress could be constructed on both sides of the wall to reduce the cantilever height. In addition, weep holes can be installed through the sheets to allow water to pass through the sheets and prevent unbalanced water loads from developing on one side of the sheet.

The use of gabion walls for a sheet pile buttress was not considered in detail for this evaluation. Gabion walls are considered potentially difficult to install under water compared to a rock revetment. However, if the TCRA contractor were to determine that gabion walls would be a preferred strategy for constructing a sheet pile buttress; their use would be further considered during detailed design.

In addition to considering lateral support for cantilevered sheet piles, scour potential at the base of the sheet pile must be considered. The hydrodynamic modeling described in Section 4.3 can be used to help identify areas where the presence of a vertical wall could increase the potential for localized scour. To prevent undermining, a scour apron would need to be constructed using aggregate placed at the base of the wall.

3.2.4 Geotube Containment Berm

In addition to their use to contain dredged sediment, geotubes can be used to construct the core of a barrier berm around a site. In this application, geotubes would be filled with a granular material that would provide some structural integrity to the core of the berm in the event that the geotube deteriorated. The outside edges and top of the berm would be constructed of traditional aggregate material around the geotube to provide protection to the berm core.

While the use of a geotube to create the core of an isolation berm has not been expressly included in the alternatives development, this option could be suggested as a value engineering opportunity by the TCRA contractor.

As with removal, isolation is a common strategy that has been used on many cleanup projects. The technology is readily available and multiple strategies for effective isolation

have been demonstrated at other sites. Thus, it has been retained for further evaluation as a component of the alternatives considered in this report.

3.3 Treatment

In situ treatment was screened from further evaluation as a strategy not considered applicable for the TCRA for the following reasons:

- Specific in situ treatment technologies have not been identified that would be applicable for dioxin in sediments
- In situ treatment technologies often require specialty contractors that would limit the ability to complete technology evaluation, design, and construction in a reasonable timeframe
- If a candidate technology were to be identified, the short timeframe for the TCRA precludes a pilot test verification program

Ex situ treatment might be appropriate following a removal. However, ex situ treatment options were not expressly considered as part of this document because either: 1) treatment for off-site disposal would be dictated by applicable regulations and facility permits; or 2) on-site management of sediments within geotubes would not require treatment (with the possible exception of a flocculant additive to facilitate dewatering).

Based on this initial screening, the following technologies were retained for detailed evaluation:

- Isolating the Site from land access using fencing (implemented and in place)
- Removing the waste and sediments by dredging
- Confining removed waste and sediments in the upland portion of the waste pit
- Covering the waste and sediments with granular materials
- Covering the waste and sediments with man-made materials
- Isolating the waste and sediments on site from the river using sheet piling

Five removal action alternatives were developed in consultation with USEPA based on combinations of these technologies, and considering the design criteria discussed in Section 4.

4 DESIGN CRITERIA AND GUIDANCE USED TO DEVELOP ALTERNATIVES

This section describes the design assumptions that were used in assembling and evaluating the TCRA alternatives.

4.1 TCRA Time Frame

The TCRA is the initial action that will occur at the Site, and is expected to be followed by future actions, including a NTCRA associated with the RI/FS being conducted at the Site. As such, the TCRA is an interim remedy that will serve its primary function for an expected 5- to 7-year timeframe before future actions are implemented at the Site. As described in Appendix C, OM&M costs are computed based on an expected 7-year TCRA duration.

4.2 Water Levels

The primary forces that the TCRA must resist are the hydrodynamic loads from the river system. The magnitude of these forces is related to runoff in the San Jacinto drainage basin north of the Site. The predominant forces develop from increased velocities and bed shear stress that result from a flood event. To a lesser extent, the Site is affected by daily tidal cycles, wind, and passing vessel wakes.

Appendix A presents a discussion of the design storm event. Table 1 presents a summary of water levels for a variety of conditions based on the hydrodynamic modeling summarized below and described in detail in Appendices A and B. All water levels and elevations discussed in this report are presented in the project vertical datum, which is the North American Vertical Datum of 1988 (NAVD 88).

4.3 Hydrodynamic Modeling

To understand the Site-specific hydrodynamic loading that can be expected under a variety of flow conditions, a detailed model was developed for the Site. The details of this model are described in Appendix B. The results of the model are used in conjunction with USEPA and United States Army Corps of Engineers (USACE) guidance (USEPA 2005; USACE 1998) to predict river bed shear stresses, which, in turn, are used to predict scour potential and to select appropriate-sized aggregates for granular covers described in Section 3. The

hydrodynamic model also provides predicted water surface elevations under a variety of conditions. Water levels for selected model scenarios are summarized in Table 1.

4.4 Reference Guidance

There are several relevant guidance documents published by USEPA and USACE for the selection and design of appropriate remedial strategies for sediment sites. The following documents were considered when assembling alternatives for the TCRA:

- *Contaminated Sediment Remediation Guidance for Hazardous Waste Sites*, USEPA, December 2005
- *USEPA Guidance for In-Situ Subaqueous Capping of Contaminated Sediments (ARCS Program),* Palermo et al., 1998
- *Guidance for Subaqueous Dredge Material Capping*, USACE, June 1998
- *Technical Guidelines for Environmental Dredging of Contaminated Sediments*, USACE, September 2008

5 DESCRIPTION OF ALTERNATIVES CONSIDERED

5.1 Alternative 1 – Sheet Pile and Granular Cover

Alternative 1 entails the following major elements (Figure 3):

- Construction of a security fence on the uplands to prevent unauthorized access to the Site (completed April 29, 2010)
- Construct an access road and laydown pad
- Construction of a sheet pile isolation wall around the impoundment alignment
- Installation of granular cover within the contained area
- Protection of the shoreline of the Western Cell with geotextile and granular cover
- Repair areas of damaged vegetation in the Western Cell with geotextile and granular cover
- Use of appropriate health and safety and environmental control measures during construction

Figures 4 and 5 present representative cross sections for Alternative 1. Due to the shallow water in the Eastern Cell, the sheet pile cannot be installed using a conventional barge and pile-driving setup. To construct the sheet pile in this area, an access road or rock platform would be built along the centerline of the sheet pile alignment by end-dumping aggregate from shoreline, and progressively working into the water. The access road would be of sufficient elevation and width to allow the pile-driving equipment to safely work. Based on conversations with local contractors about this approach, the road would have a crest width of 18 feet at an elevation of 2 feet NAVD88.

In the deep-water area of the sheet pile alignment, the sheet pile would be installed from a barge. The sheet pile would have significant unsupported height above the mudline, and thus would be buttressed on both sides by a rock revetment mound to provide lateral support.

The sheet pile would have a top elevation of 4 feet NAVD88. Weep holes would be installed in the sheet pile to allow the river elevation to equalize on both sides of the sheet pile,

preventing the development of an unbalanced hydrostatic pressure that could compromise the integrity of the wall.

As described in Section 3.2.3, the sheet pile material assumed for the conceptual alternative is composite. There is some concern about the ability to drive this material through the rock platform, and any potential effects this activity might have on the durability of the composite material. As discussed subsequently, it could be determined during detailed design that a steel material would be required.

Because the wall would be overtopped in the design storm event, granular cover would be placed within the contained perimeter of the sheet pile. The granular cover gradation would be specified to prevent loss of cover during the design storm event, and corresponds with a coarse gravel material. The granular cover design thickness is based on at least two times the median diameter (D_{50}) of the cover material, and for costing purposes has an assumed thickness of 6 inches, with a 6-inch overplacement allowance. It would be placed from the shore by building a road out into the water using the granular material, and progressively working from the end of the road back to shore with an excavator. The excavator would work by cutting the road down and side casting the road material to the required cover thickness on each side of the road. In the deeper water areas, the granular cover would be placed from a barge.

The high ground in the Western Cell is currently vegetated. The presence of this vegetation acts to stabilize Site soils. Research on the effect of vegetation indicates that the presence of grasses and trees provides significant resistance against shear stress (Fishchenich 2001). The presence of vegetation is expected to stabilize Site soils under the full range of storm conditions considered for the Site. Where vegetation is disturbed during TCRA construction, the area will be repaired by covering the disturbed area with a geotextile and granular cover.

5.1.1 Data Gaps for Alternative 1

Existing bathymetry data was not collected at sufficient density to completely understand the contours of the western shoreline or the nature of the deep channel in the submerged

northwestern portion of the Site. To develop this alternative beyond conceptual design, additional bathymetry data is required.

In addition, the hydrodynamic model described in Appendix B would be improved if Site-specific data were available to calibrate the model. To collect this data, an acoustic Doppler current profiler (ADCP) would be deployed at the Site to measure currents.

5.2 Alternative 2 – Sheet Pile, Granular Cover, Dredge, and Revetment

Alternative 2 entails the following major elements (Figure 6):

- Construction of a security fence on the uplands to prevent unauthorized access to the Site (completed April 29, 2010)
- Construct an access road and laydown pad
- Construction of a sheet pile isolation wall around the Eastern Cell
- Installation of granular cover within the contained area
- Dredging of the deep water in the northwestern corner of the Site
- Consolidation of dredge material in geotubes staged on the high ground in the Western Cell
- Protection of the shoreline of the Western Cell with a rock revetment and an aggregate berm
- Repair areas of damaged vegetation in the Western Cell with geotextile and granular cover
- Use of appropriate health and safety and environmental control measures during construction

Figures 7 and 8 present cross sections for Alternative 2. As with Alternative 1, a rock platform would be built in the shallow water to facilitate sheet pile installation, and in the deeper water the sheet pile would be installed from a barge. Where the unsupported height of the sheet pile wall is significant, a rock buttress would be used to provide additional lateral support. Other details, such as top elevation and the use of weep holes to equalize water pressure are the same as for Alternative 1.

Granular cover would be used in Alternative 2 in the same fashion as Alternative 1.

Alternative 2 includes dredging of the deeper water area in the northwest corner of the Site. A small hydraulic dredge would be used to remove the surface material. Dredge material would be pumped into geotubes located on the high ground in the Western Cell where it would dewater and consolidate. A dredge cut thickness of 18 inches has been assumed in this alternative, with an overdredge allowance of 6 inches.

The north slope of the Western Cell would be protected with a rock revetment. Rock would be appropriately sized to withstand hydrodynamic loads from the design-level event. At the top of the slope in this area, an aggregate berm would be constructed to prevent water from entering the Western Cell during normal tidal cycles. This berm would be constructed to elevation 4 NAVD88.

5.2.1 Data Gaps for Alternative 2

As with Alternative 1, bathymetry would need to be updated to develop the design for this alternative, and the hydrodynamic model could be improved by collecting site-specific current data with an ADCP.

This alternative includes dredging of the deep-water area in the northwestern corner of the Site. Another data gap is the depth profile of contamination. The decision to include this area in the TCRA is based on a review of chemistry results from surface grab samples. In order to design the dredge prism and to set the appropriate required dredge depth, additional data would need to be collected to determine the vertical extent of contamination in this area.

In addition to sediment chemistry, the dewatering behavior of the proposed dredge sediment is unknown. To evaluate the use of geotubes for dewatering, a hanging bag test would be required.

5.3 Alternative 3 – Granular Cover and Revetment

Alternative 3 entails the following major elements (Figure 9):

- Construction of a security fence on the uplands to prevent unauthorized access to the Site (completed April 29, 2010)
- Construct an access road and laydown pad
- Construction of a rock cover perimeter around the Eastern Cell
- Installation of granular cover within the rock perimeter of the Eastern Cell
- Installation of granular cover over the northwestern corner of the Site
- Protection of the shoreline of the Western Cell with a rock revetment and an aggregate berm
- Repair areas of damaged vegetation in the Western Cell with geotextile and granular cover
- Use of appropriate health and safety and environmental control measures during construction

Figures 10 and 11 provide representative cross sections showing the detail of Alternative 3. The rock perimeter berm would be at least 2 feet thick. However, in the deep channel along the north side of the Site, additional rock would be placed to provide a hydraulic cutoff of this channel. The additional rock fill would be placed to a top elevation of -2 feet NAVD88, consistent with the majority of the rock perimeter fill.

Granular cover, 6 inches thick (with an overplacement allowance of 6 inches), would be placed within the limits of the rock perimeter, and in the deep water in the northwestern corner of the Site. A rock revetment and aggregate berm would be constructed to protect the slope of the Western Cell, as described in Alternative 2.

5.3.1 Data Gaps for Alternative 3

Alternative 3 would require updated bathymetry, as described for Alternative 1. The hydrodynamic model could be improved by collecting site-specific data using ADCP.

5.4 Alternative 4 – Rock Berm, Granular Cover, and Revetment

Alternative 4 entails the following major elements (Figure 12):

- Construction of a security fence on the uplands to prevent unauthorized access to the Site (Completed April 29, 2010)
- Construction of an access road and laydown pad.
- Construction of a rock berm perimeter around the Eastern Cell
- Installation of granular cover within the rock berm
- Installation of granular cover over the northwestern corner of the Site
- Protection of the shoreline of the Western Cell with a rock revetment and an aggregate berm
- Repair areas of damaged vegetation in the Western Cell with geotextile and granular cover
- Use of appropriate health and safety and environmental control measures during construction

Figures 13 and 14 provide representative cross sections showing the details of Alternative 4. The major elements of Alternative 4 are similar to Alternative 3, with the exception of the perimeter berm around the Eastern Cell. This berm, constructed of rock, would be constructed to elevation 1 foot NAVD88 and would serve to minimize hydrodynamic forces on the cover during normal tides. In addition, the berm would impede access to the Site by boats.

5.4.1 Data Gaps for Alternative 4

Alternative 4 would require updated bathymetry, as described for Alternative 1. The hydrodynamic model could be improved by collecting site-specific data using ADCP.

5.5 Alternative 5 – ACBM and Dredge

Alternative 5 entails the following major elements (Figure 15):

- Construction of a security fence on the uplands to prevent unauthorized access to the Site (completed April 29, 2010)
- Construction of an access road and laydown pad

- Installation of ACBM over the Eastern Cell
- Dredging of the deep water area in the northwestern corner of the Site
- Consolidation of dredge material within geotubes staged on the high ground of the Western Cell
- Protection of the shoreline of the Western Cell with an aggregate berm at the top of the slope, and either ACBM or rock on the slope
- Repair areas of damaged vegetation in the Western Cell with geotextile and granular cover
- Protection of the submerged outer edge of the ACBM with a rock scour apron
- Use of appropriate health and safety and environmental control measures during construction

Figures 16 and 17 provide representative cross sections showing the details of Alternative 5. Following completion of dredging in the northwestern area, ACBM would be installed to stabilize sediments in the Eastern Cell. The ACBM would be underlain by a geotextile fabric to facilitate installation and provide another layer of containment for the covered sediments. The installation process would require a skilled crew to pull the geotextile fabric form into its desired configuration using boats, cables, and winches above or at the water surface. Once in position, the fabric form would be sunken below the water surface and pumped full with lean grout to form the concrete pillow structure.

Each panel of the ACBM would be overlapped appropriately to ensure complete coverage of the surface. Panels would be lapped in a shingle-like fashion so that river currents would not undermine the panel overlap. Once all of the ACBM panels are in position, the submerged outer edge of the ACBM would be protected by covering it with a rock scour apron to prevent undermining of the ACBM system.

5.5.1 Data Gaps for Alternative 5

Data gaps for Alternative 5 are the same as for Alternative 2. Updated bathymetry would be required, and information on the vertical extent of contamination, as well as geotube

dewatering, would need to be collected. In addition, the hydrodynamic model would benefit from site-specific data collected using ADCP.

6 COMPARATIVE EVALUATION OF ALTERNATIVES

This section presents a comparative evaluation of the five alternatives described in Section 5, considering the criteria described in Section 2. Table 2 presents a summary matrix of this comparative evaluation, with detailed considerations discussed below.

6.1 Effectiveness

6.1.1 Effectiveness at Isolating Target Sediments

Each alternative can be designed with appropriately-engineered materials to resist the hydrodynamic forces acting on the Site for the design-level weather event. The initial technology screening presented in Section 3 did not consider any alternatives that would be ineffective in achieving one of the primary goals of the TCRA. Thus, all of the alternatives are considered as being equally effective at isolating the target sediments.

6.1.2 Effectiveness at Withstanding Extreme Weather Events

As described above, each alternative would be designed to withstand the design-level weather event according to USEPA and USACE guidance. Thus each alternative ranks equally in effectiveness for this criterion.

6.1.3 Effectiveness at Preventing Benthic and Human Contact

Each alternative uses a proven technology and can be designed to meet the TCRA requirement for preventing both benthic and human contact. Thus, each alternative ranks equally in effectiveness for these criteria.

6.1.4 Potential Impacts to Human Health and the Environment during Construction

Alternatives 1 and 2 include the use of a composite sheet pile material. In order to drive or vibrate a composite sheet pile, a steel mandrel is used to advance the sheets below the mudline. Once the sheet has reached tip elevation, the mandrel is released from the sheet and it is withdrawn from below the ground surface and re-used for the next sheet installation.

Depending on the length of the sheet pile wall, the mandrel would be driven and withdrawn between 500 and 750 times to install the sheet pile. Each time the mandrel is withdrawn; there is some risk of resuspension of contaminated sediments. The construction of the rock platform for the sheet piles will help control the resuspension of contaminated sediments on the mandrel. Compared to Alternatives 3, 4, and 5, Alternatives 1 and 2 have a higher risk of construction-related environmental impacts.

The sheet pile installation also requires heavy equipment and overhead loads. Compared to Alternatives 3, 4, and 5, Alternatives 1 and 2 pose a higher risk to worker health and safety during construction.

Alternatives 2 and 5 include dredging and consolidation of dredge material within the Western Cell. Dredging has an inherent risk for sediment resuspension and residuals generation (USEPA 2005; USACE 2008a). Compared to Alternatives 1, 3, and 4, Alternatives 2 and 5 have a moderately higher risk for environmental impacts related to construction. Water quality impacts would need to be minimized by employing appropriate best management practices (BMPs) for dredging, and by monitoring water quality during construction.

6.1.5 Compatibility with Future Actions at the Site

Analogous to the discussion in Section 3, there are three general categories of future actions that could be taken to address environmental risks at the Site once the TCRA has been completed. These categories are: 1) removal; 2) containment; and 3) treatment. Each alternative has been evaluated to consider its potential compatibility with these three future categories of actions. Table 3 summarizes the results of this evaluation and provides a relative ranking of the alternative for both the Eastern and Western Cells, according to the following system:

- Lowest compatibility
- Low to moderate compatibility
- Moderate to high compatibility
- Highest compatibility

6.1.5.1 Future Removal Activities

All alternatives entail placing granular material or concrete mat across the Eastern Cell. Alternatives 1 and 2 also entail construction of a sheet pile wall in this area. Because the granular cover would need to be excavated for a future removal activity, Alternatives 3 and 4 rank "low to moderate" compatibility for the Eastern Cell. In addition to the granular material, Alternatives 1 and 2 would require removal of the sheet pile wall and access road. The sheet pile removal would cause significant disturbance to existing sediments. Thus, these alternatives rank "lowest" compatibility for future removal activities in the Eastern Cell. Finally, the ACBM would present a substantial challenge to a future removal activity because the concrete would need to be demolished, a construction challenge that would likely cause substantial disturbance to sediments beneath the ACBM cover. Alternative 5 thus ranks "lowest" for compatibility with a future removal activity in the Eastern Cell.

In the Western Cell, all alternatives entail repair of damaged vegetation with a geotextile and granular cover. In addition, Alternatives 2 and 5 include dredging with dredge material consolidation in the Western Cell. Because of the expected moderate amount of filling that might be necessary in Alternatives 3 and 4, these alternatives rank "moderate to high" for compatibility with a future removal action in the Western Cell. Alternatives 2 and 5, because they would contain a rock revetment or ACBM and dredge material after the TCRA was completed, rank "lowest" for compatibility with a future removal activity. Alternative 1, because of the sheet pile wall and granular fill that would need to be removed, ranks "lowest" for compatibility with future removal.

6.1.5.2 Future Containment Activities

Alternatives 1 and 2 entail construction of a sheet pile wall around the Eastern Cell. Construction of a future containment action would likely require the sheet piles to be removed. Thus, these alternatives rank "low to moderate" for compatibility with future containment actions. Alternatives 3 and 4 include placement of granular cover over the Eastern Cell. It is expected that a future containment activity in this area would also entail placement of cover material, which could be built on top of the TCRA surface with little expected difficulty. Thus, Alternatives 3 and 4 rank "highest" for compatibility with future containment activities in the Eastern Cell. The ACBM placed in the Eastern Cell under

Alternative 5 would likely be compatible with a future containment action; however, there might need to be some detail work and/or selective demolition at transition points to facilitate construction of a future containment system. Thus, Alternative 5 ranks "moderate to high" for compatibility with future containment in the Eastern Cell.

Alternative 1, in the Western Cell, would potentially require the sheet pile wall to be removed to facilitate a future containment activity. Thus, this alternative ranks "low to moderate" for compatibility. Alternative 2 includes dredging, with consolidation of dredge material on the high ground of the Western Cell. This area would potentially require modification and/or selective demolition to facilitate future containment. Thus, Alternative 2 ranks "low to moderate" for compatibility. As with the Eastern Cell, Alternatives 3 and 4 include placement of granular cover that could be integrated with a future containment activity relatively easily. Thus, these alternatives rank "highest" for compatibility for future containment. Finally, Alternative 5 considerations for ACBM in the Western Cell are the same as for the Eastern Cell. This factor, as well as the presence of consolidated dredge material on the high ground of the Western Cell (as in Alternative 2), leads to a ranking of "low to moderate" for compatibility with future containment activities.

6.1.5.3 Future Treatment Activities

Future treatment activities, if identified as appropriate for the Site, would require demolition of the sheet piles used for Alternatives 1 and 2 in the Eastern Cell. In addition, the granular cover is additional fill material that would require treatment. Thus, both alternatives rank "lowest" for compatibility with future treatment actions in the Eastern Cell. The granular cover in Alternatives 3 and 4 (as with Alternatives 1 and 2) is additional material requiring treatment in the Eastern Cell, and thus these alternatives rank "low to moderate" for compatibility with future treatment actions in this area. The ACBM in Alternative 5 would prevent most treatment from being performed without significant demolition of the ACBM being done. This alternative ranks "lowest" for compatibility with future treatment.

In the Western Cell, Alternative 1 includes a sheet pile wall that would need to be removed to facilitate future treatment activities, and granular cover that would need to be incorporated into the treatment activity. Alternative 2 includes shoreline armoring and

consolidation of dredge material on the high ground of the Western Cell. Both of these alternatives rank "lowest" for compatibility with future treatment activities. Alternatives 3 and 4 entail placement of granular cover which would need to be managed as part of treatment and thus rank "low to moderate" for compatibility.

6.1.6 Effectiveness Summary

The following is a summary of the effectiveness evaluation:

- Isolating target sediments: All alternatives rank equally.
- Withstanding extreme weather events: All alternatives rank equally.
- Preventing benthic and human contact: All alternatives rank equally.
- Impacts during construction: Alternative 5 ranks highest (the least likely to produce adverse impacts during construction). Alternatives 3 and 4 rank slightly lower. Alternatives 1 and 2 rank lowest.
- Compatibility with future actions at the Site: Alternative 3 ranks highest. Alternative 4 ranks slightly lower.

6.2 Implementability

Implementability considerations are summarized in Tables 4 and 5, and are discussed in detail in this section.

6.2.1 Availability of Labor, Equipment, and Materials

Implementability considers the availability of labor, equipment, and materials to complete the work. With regard to labor and equipment, all of the construction activities described in the alternatives can be completed with locally-available, experienced resources. Alternatives 1 and 2 include composite sheet pile installation. Sheet pile installation will require the use of specialized labor and equipment to install. Composite sheet piles are available from a specialized supplier and have a lead time of approximately 2 to 3 weeks. All alternatives include the use of larger-sized natural stone. This material is not locally available and needs to be shipped in by barge. Delivery lead times for this material are expected to range from 6

to 8 weeks. Alternative 5 uses ACBM, which may require a custom template to be developed to match Site bathymetry and panel layout. This could require a lead time of 4 to 8 weeks.

Because lead times are comparable, all alternatives are considered to rank equally for this implementability consideration.

6.2.2 Construction Considerations

Table 5 summarizes constructability considerations for each alternative. For Alternatives 1 and 2, the sheet pile installation will require heavy equipment, a specialized contractor, and construction of a rock platform in the shallow water to facilitate the installation of the wall. Both alternatives also require shallow water placement of granular cover, which would require careful sequencing and consideration for placement.

Alternatives 2 and 5 include dredging, which would require a specialized contractor and make use of the high ground area of the Western Cell for dredge material consolidation with a geotube dewatering system. While the use of hydraulic dredging and geotube dewatering is well demonstrated and commonly used, these techniques would not necessarily be familiar to a typical earthwork contractor.

Alternatives 3 and 4 also include shallow-water placement of granular fill material, and similar constructability considerations apply for these alternatives as for Alternatives 1 and 2.

Alternative 5 includes the specialized construction of ACBM placement. Accurate ACBM placement can be a challenge in river currents. If defects occur during construction (e.g., incomplete grout fill, geotextile damage, or incomplete overlap) they can be very difficult to correct. Finally, the ACBM installation process is most efficient with a large upland laydown area to spread the geotextile prior to placing it into the river.

6.2.3 Navigation and/or Flood Control Impacts

Alternatives 1 and 2 include construction of a rigid structure (sheet pile wall) to elevation 4 feet NAVD88. At higher river stages, wayward vessels could ground on the wall. At lower river stages, vessels could collide with the wall, causing damage to the wall and/or the vessel.

Alternative 4 includes a rock berm to elevation 1 foot NAVD88, which would require signage to alert vessels to the presence of the berm, and would be a hazard to navigation. Alternatives 3 and 5 have the least modification to the profile of the river bed and would have the smallest effect on flood capacity of the river system. Alternatives 1, 2, and 5 result in a hard surface within the river channel (either vertical or horizontal), while Alternatives 3 and 4 rely on a "softer" material.

Alternatives 1 and 2 would likely have the greatest impact on flood flow in the river because they are built to the highest elevation. The sheet pile wall in these alternatives also narrows the channel greater than Alternatives 3, 4, and 5, which would likely; result in an increase in current speed near the Site for Alternatives 1 and 2. Compared to the other alternatives, Alternatives 1 and 2 are expected to have the greatest potential impact on downstream structures near the Site, such as the I-10 Bridge, because the channel cross section is narrowed the most. These factors would need to be further evaluated in detail during final design.

6.2.4 Estimated Duration of Project

Table 4 summarizes the estimated duration of the project. The alternatives are expected to take from 2.6 to 6.1 months to complete, after mobilization has started. There is a preference for alternatives that can be completed in a shorter timeframe.

6.2.5 Implementability Summary

The following is a summary of the implementability evaluation:

- Availability of labor, equipment, and materials: Alternatives 1, 2, and 5 require additional specialty trades compared to Alternatives 3 and 4. All alternatives have similar lead times for aggregates. Alternative 5 has a potential long lead time for the ACBM material.
- Construction considerations: All alternatives are challenged by the shallow water environment. Alternative 5 has additional considerations for ACBM installation, with potential challenges associated with river currents, and the issue that repairs, if necessary, are difficult

- Navigation and/or flood control impacts: Alternatives 1 and 2 provide the highest potential impact for navigation and flood control issues, and the highest potential impact on downstream structures near the Site, such as the I-10 Bridge.

6.3 Cost

6.3.1 Cost Analysis

Estimated costs were developed for each alternative using information collected by contacting various suppliers and contractors, and using best professional judgment for items where prior experience provided a rational basis for the estimate (e.g., design and monitoring costs). Table 6 presents a summary of the estimated cost for each alternative. Appendix C presents details of the cost estimates, including backup information for unit cost and quantity estimates. Costs include the following major elements:

- Construction Costs
  - Mobilization, demobilization, and Site preparation
  - Construction of stabilization measures
  - Environmental controls and survey
- Non-Construction Costs
  - Contingency
  - Design, construction management, and environmental monitoring during construction
  - Operations, monitoring, and maintenance

The target accuracy for the conceptual-level estimates is to be within +/- 30 percent of actual cost based on feedback from USEPA. Each alternative was estimated to the same level of accuracy, thus the relative difference in cost for each alternative would be similar if the assumptions for the estimates were either more or less accurate.

6.3.2 Cost Risk

Alternatives 1 and 2 include a sheet pile wall. For these alternatives, it has been assumed that a lower-cost composite sheet pile section would be used. As previously described, there is some risk with using a composite sheet pile during installation (uncertainty if the sheet pile can be driven through the rock platform), and from impact damage due to river vessel traffic. If it is determined during detailed design or construction that these risks are unacceptable or that the sheet piles cannot be driven through the rock platform, a steel sheet pile would need to be substituted for composite material, at a significantly higher cost. The estimated additional cost for using steel sheet piles as a substitute for composite sheet piles is $1.7 million and $1 million for Alternatives 1 and 2, respectively. In addition to cost risk, the lead time for steel sheet could be as much as 4 months, depending on the type of sheet required.

6.3.3 Cost Summary

Alternative 3 is the most cost-effective alternative, at roughly 51 to 88 percent of the cost of the other alternatives, not considering the cost risks discussed above.

7 RECOMMENDED ALTERNATIVE

Based on the evaluation criteria established in Section 2, Alternative 3 is the preferred alternative for the following reasons:

- Alternative 3 is equally effective as the other alternatives in preventing erosion of the sediments, and is equally effective at preventing benthic and human contact
- Alternative 3 will be capable of withstanding the design storm event. The hydrodynamic modeling provides the proper sizing for aggregate that would be used to resist the design-level storm event.
- Alternative 3 has minimal potential for disturbance (resuspension of contaminated materials) during construction. Any potential for resuspension would be managed with appropriate environmental controls, BMPs, and monitoring
- Alternative 3 also has the least amount of conflicts with any of the range of potential NTCRA technologies, allowing more flexibility with NTCRA selection and design
- Alternative 3 has fewer potential impacts to navigation and flood flow than any of the other alternatives, excluding ACBM, due to its lower profile in the river
- Alternative 3 can be completed in approximately 3 to 4 months
- Alternative 3 is approximately 51 to 88 percent of the cost of the other alternatives

As discussed under the description for Alternative 3, two data gaps were identified for design of the TCRA: 1) Site-specific river current data; and 2) updated bathymetry. Appendix D presents a Sampling and Analysis Plan as required by the AOC (USEPA 2010, Appendix D) to address these data gaps through the deployment of an ADCP, and by collecting additional bathymetric survey data at the Site.

8 REFERENCES

Fischenich, C., 2001. "Stability Thresholds for Stream Restoration Materials," EMRRP Technical Notes Collection (ERDC TNEMRRP-SR-29), U.S. Army Engineer Research and Development Center, Vicksburg, MS. www.wes.army.mil/el/emrrp

Orion, 2010. Personal communications between Orion Marine Group and Anchor QEA, May 2010.

Palermo, M., Maynord, S., Miller, J., and Reible, D., 1998. *Guidance for In-Situ Subaqueous Capping of Contaminated Sediments,* EPA 905-B96-004, Great Lakes National Program Office, Chicago, IL.

TCEQ and USEPA, 2006. *Screening Site Assessment Report San Jacinto River Waste Pits, Channelview, Harris County, Texas*. TXN000606611. Texas Commission on Environmental Quality and U.S. Environmental Protection Agency.

USACE, 1998. *Guidance for Subaqueous Dredged Material Capping.* Technical Report DOER-1. U.S. Army Corps of Engineers, Waterways Experiment Station, Dredging Operations and Environmental Research Program. June 1998.

USACE, 2008a. *The Four Rs of Environmental Dredging: Resuspension, Release, Residual, and Risk*. ERDC/EL TR-08-4. U.S. Army Corps of Engineers, Engineer Research and Development Center (ERDC), Dredging Operations and Environmental Research Program (DOER). January 2008.

USACE, 2008b. *Technical Guidelines for Environmental Dredging of Contaminated Sediments.* ERDC/TL TR-08-29. U.S. Army Corps of Engineers, Engineer Research and Development Center (ERDC), Environmental Laboratory. September 2008.

USEPA, 2000. *Exposure and Human Health Reassessment of 2,3,7,8-tetrachlorodibenzo-pdioxin (TCDD) and Related Compounds.* EPA/600/P-00/001Bc. Draft Final Report. U.S. Environmental Protection Agency, National Center for Environmental Assessment, Washington, DC.

USEPA, 2005. *Contaminated Sediment Remediation Guidance for Hazardous Waste Sites*. EPA-540-R-05-012. December, 2005.

USEPA, 2009. *Unilateral Administrative Order for Remedial Investigation/Feasibility Study.* U.S. EPA Region 6 CERCLA Docket No. 06-03-10. In the matter of: San Jacinto River Waste Pits Superfund Site Pasadena, Texas. International Paper Company, Inc. & McGinnes Industrial Management Corporation, respondents.

USEPA, 2010. *Administrative Settlement Agreement and Order on Consent for Removal Action.* U.S. EPA Region 6 CERCLA Docket No. 06-03-10. In the matter of: San Jacinto River Waste Pits Superfund Site Pasadena, Harris County, Texas. International Paper Company, Inc. & McGinnes Industrial Management Corporation, respondents.

TABLES

Table 1

Water Levels Expected at the Site

Condition[1,2]	Elevation[3]
Mean Higher High Water	1.5
Mean High Water	1.4
Mean Tide Level	0.83
Mean Low Water	0.22
Mean Lower Low Water	0.05
5-year storm	6.3
10-year storm	8.1
25-year storm	10.3
Hurricane Ike	11.0

1 – Tidal elevations based on Battleship Texas State Park gage

2 – Storm and hurricane elevations based on hydrodynamic modeling (see Appendix B)

3 – All elevations presented in feet, NAVD 88 vertical datum

Table 2
Effectiveness Evaluation of Alternatives

Criteria	Alternative 1	Alternative 2	Alternative 3	Alternative 4	Alternative 5
Isolation of sediments	All alternatives considered to rank equally. See text.				
Ability to withstand extreme weather events	All alternatives considered to rank equally. See text.				
Isolation of sediments from benthic contact	All alternatives considered to rank equally. See text.				
Isolation of sediments from human contact	All alternatives considered to rank equally. See text.				
Impacts during construction	– Moderate disturbance from sheet pile installation	– Moderate disturbance from sheet pile installation – Potential for dredging-related water quality impacts	– Minimal disturbance during cover installation	– Minimal disturbance during cover installation	– Least disturbance during ACBM installation – Potential for dredging-related water quality impacts
Compatibility with future actions at Site	See Table 3				

Table 3
Compatibility of Alternatives with Future Actions

Future Action	Alternative 1	Alternative 2	Alternative 3	Alternative 4	Alternative 5
Eastern Cell					
Removal	●	●	○	○	●
Containment	○	○	■	■	□
Treatment	●	●	○	○	●
Western Cell					
Removal	●	●	□	□	●
Containment	○	○	■	■	○
Treatment	●	●	○	○	●

● Lowest compatibility

○ Low to moderate compatibility

□ Moderate to high compatibility

■ Highest compatibility

Table 4
Implementability Evaluation of Alternatives

Criteria	Alternative 1	Alternative 2	Alternative 3	Alternative 4	Alternative 5
Availability of labor and equipment	All alternatives considered to rank equally. See text.				
Availability of materials	All alternatives considered to rank equally. See text.				
Construction considerations	See Table 5.				
Navigation and/or flood control impacts	– Sheet pile hazard to navigation – Sheet pile flow constriction – Hard structure		– Lowest profile	– Berm hazard to navigation	– Hard substrate – Lowest profile
Estimated duration of construction	6.1 months	4.9 months	2.7 months	2.6 months	2.6 months

Table 5
Constructability Considerations for Alternatives

Alternative	Description	Construction Considerations
1	Sheet Pile Granular Cover	– Specialized contractor and heavy equipment for sheet piling – Rock platform necessary for sheet pile installation – Shallow water for granular cover placement
2	Sheet Pile Granular Cover Dredging	– Specialized contractor and heavy equipment for sheet piling – Specialized contractor for dredging – Rock platform necessary for sheet pile installation – Shallow water for granular cover placement
3	Granular Cover Rock Revetment	– Shallow water for granular cover placement
4	Rock Berm Granular Cover Rock Revetment	– Shallow water for granular cover placement
5	ACBM Cover Dredging	– Specialized contractor for ACBM – Specialized contractor for dredging – ACBM installation defects hard to correct – Large laydown area may be needed for ACBM staging – River currents can affect accurate placement of ACBM

Table 6
Estimated Costs for Alternatives

Alternative	Estimated Cost
1	$5.84M
2	$5.08M
3	$3.56M
4	$4.02M
5	$6.94M

1 – See Appendix C for cost details.

2 – Alternatives 1 and 2 were estimated assuming a composite sheet pile material would be used. If a steel sheet pile were determined to be required during detailed design or construction, the estimated cost would increase by approximately 15 to 30 percent for Alternatives 1 and 2.

FIGURES

K:\Jobs\090557-San Jacinto\090557-01 - San Jacinto\09055701-RP-037.dwg FIG-1

May 27, 2010 9:50am ghowell

SOURCE: Google Map Pro 2009

0 500
Scale in Feet

ANCHOR QEA

Figure 1
Vicinity Map
SJRWP TCRA

K:\Jobs\090557-San Jacinto\090557-01 - San Jacinto\09055701-RP-038.dwg FIG 2

May 25, 2010 5:00pm cdavidson

LEGEND:

TCRA Sediment 2, 3, 7, 8-TCDD
Dry Weight and OC Normalized (ng/kg

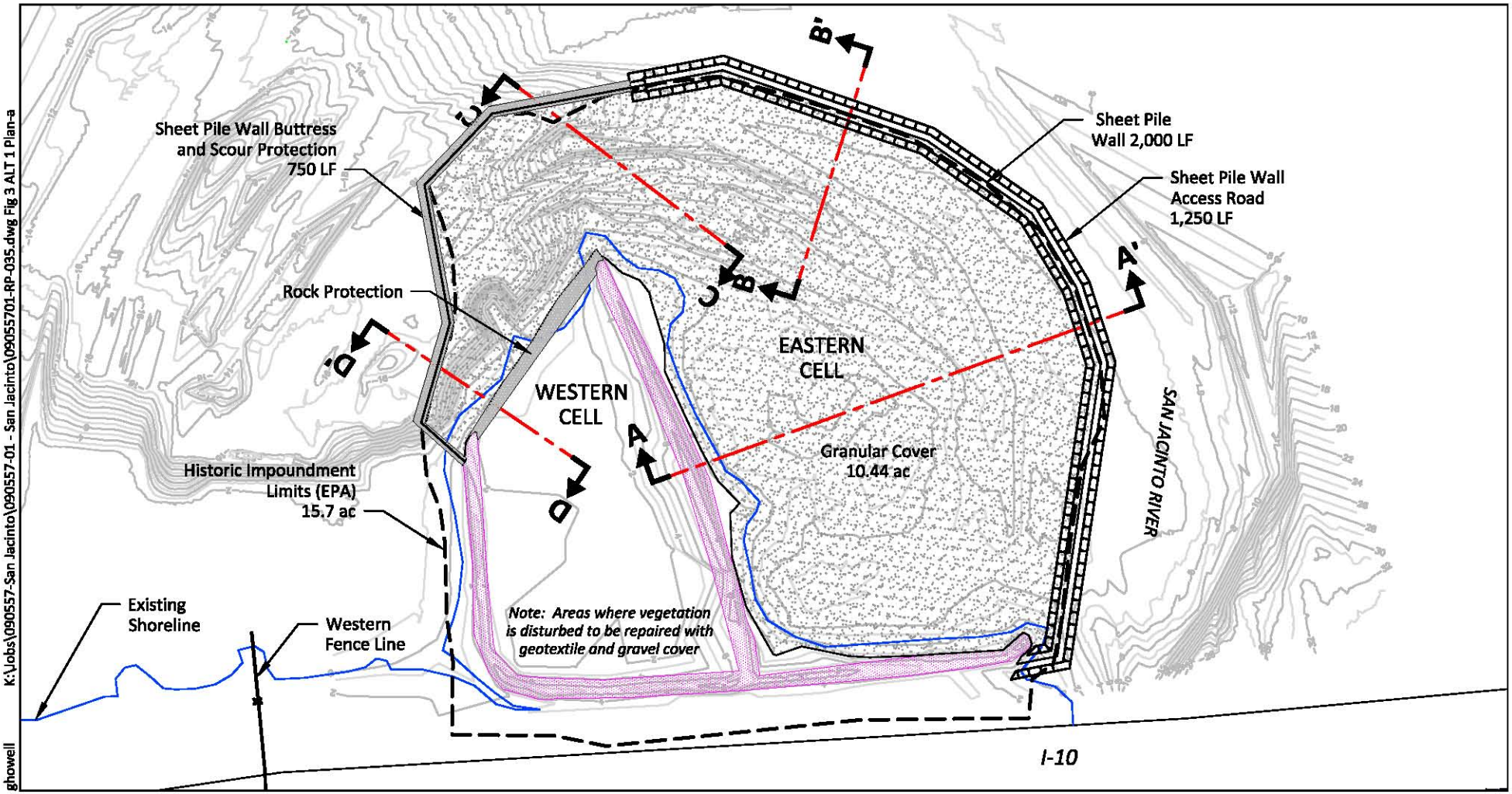
Original (1966) Perimeter of the Impoundments

SOURCE: Aerial Imagery: 0:5-meter January 2009 DOQOs - Texas Strategic Mapping Program (StraMap), TNIS

0 150
Scale in Feet

ANCHOR QEA

Figure 2
TCRA Sample Locations
2 ,3, 7, 8-TCDD (ng/kg
SJRWP TCRA



SOURCE: Drawing prepared from COE
HORIZONTAL DATUM: Texas South Central, NAD83. US Survey Feet.
VERTICAL DATUM: NAVD 88.
NOTE: See Figures 4 and 5 for Cross Sections.

A A — Cross Section Locations and Designation

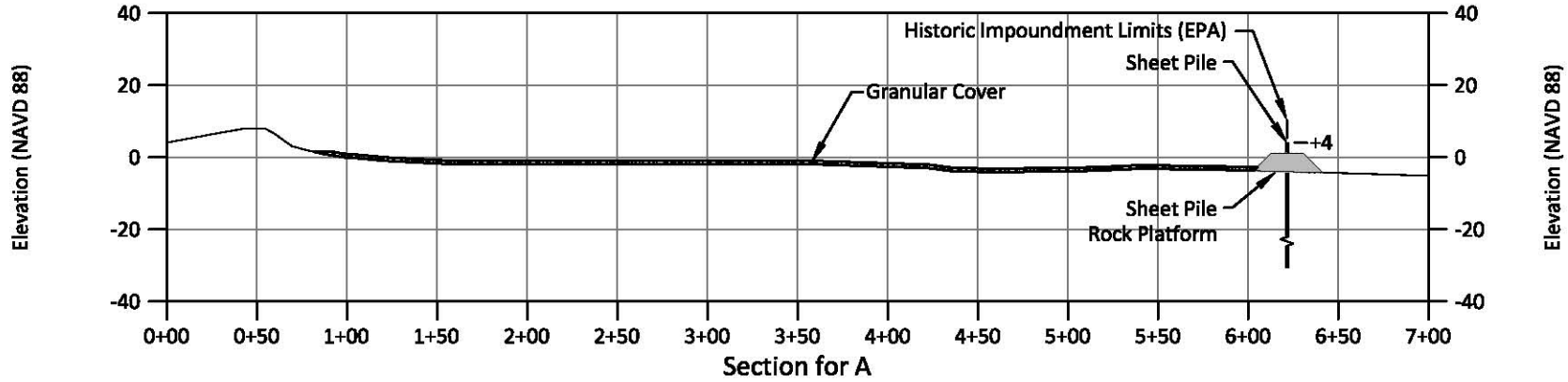
Sheet Pile Wall

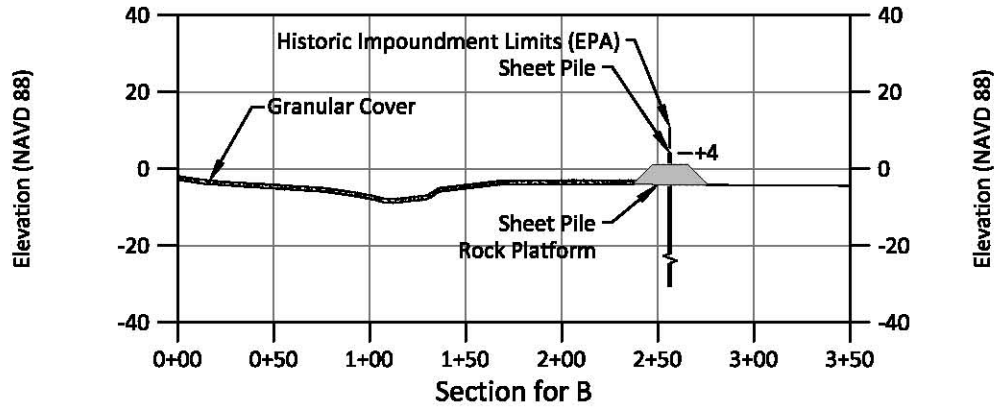
0 200
Scale in Feet

K:\Jobs\090557-San Jacinto\090557-01 - San Jacinto\09055701-RP-035.dwg Fig 3 ALT 1 Plan-a
May 27, 2010 9:56am ghowell

ANCHOR QEA

Figure 3
Alternative 1 Plan View
East and West Impoundment Sheet Pile
SJRWP TCRA





LEGEND:

Rock Cover

Granular Cover

SOURCE: Drawing prepared from COE
HORIZONTAL DATUM: Texas South Central, NAD83. US Survey Feet.
VERTICAL DATUM: NAVD 88.
NOTE: See Figure 3 for Cross Section Locations.

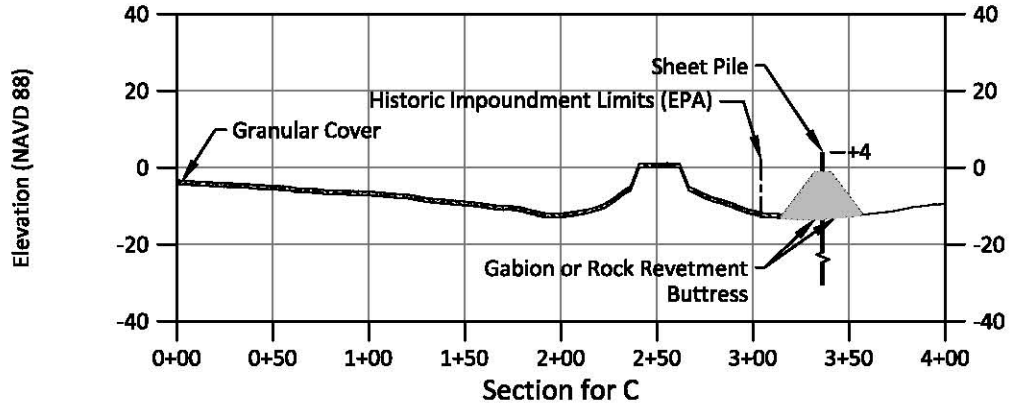
0 100
Scale in Feet
Vertical Exaggeration x2

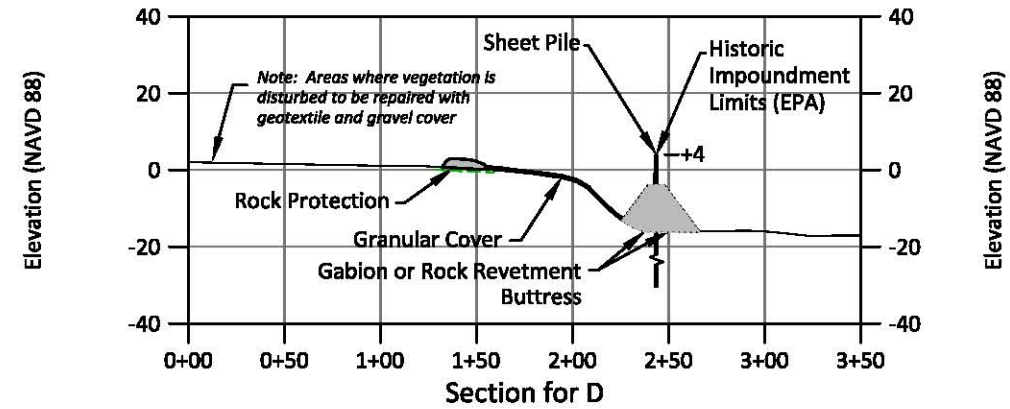
K:\Jobs\090557-San Jacinto\090557-01 - San Jacinto\09055701-RP-035.dwg Fig 4 ALT 1 Sections AB-a

May 25, 2010 4:31pm cdavidson

ANCHOR QEA

Figure 4
Cross Sections A and B - Alternative 1
SJRWP TCRA





LEGEND:

Rock Cover

Granular Cover

SOURCE: Drawing prepared from COE
HORIZONTAL DATUM: Texas South Central, NAD83. US Survey Feet.
VERTICAL DATUM: NAVD 88.
NOTE: See Figure 3 for Cross Section Locations.

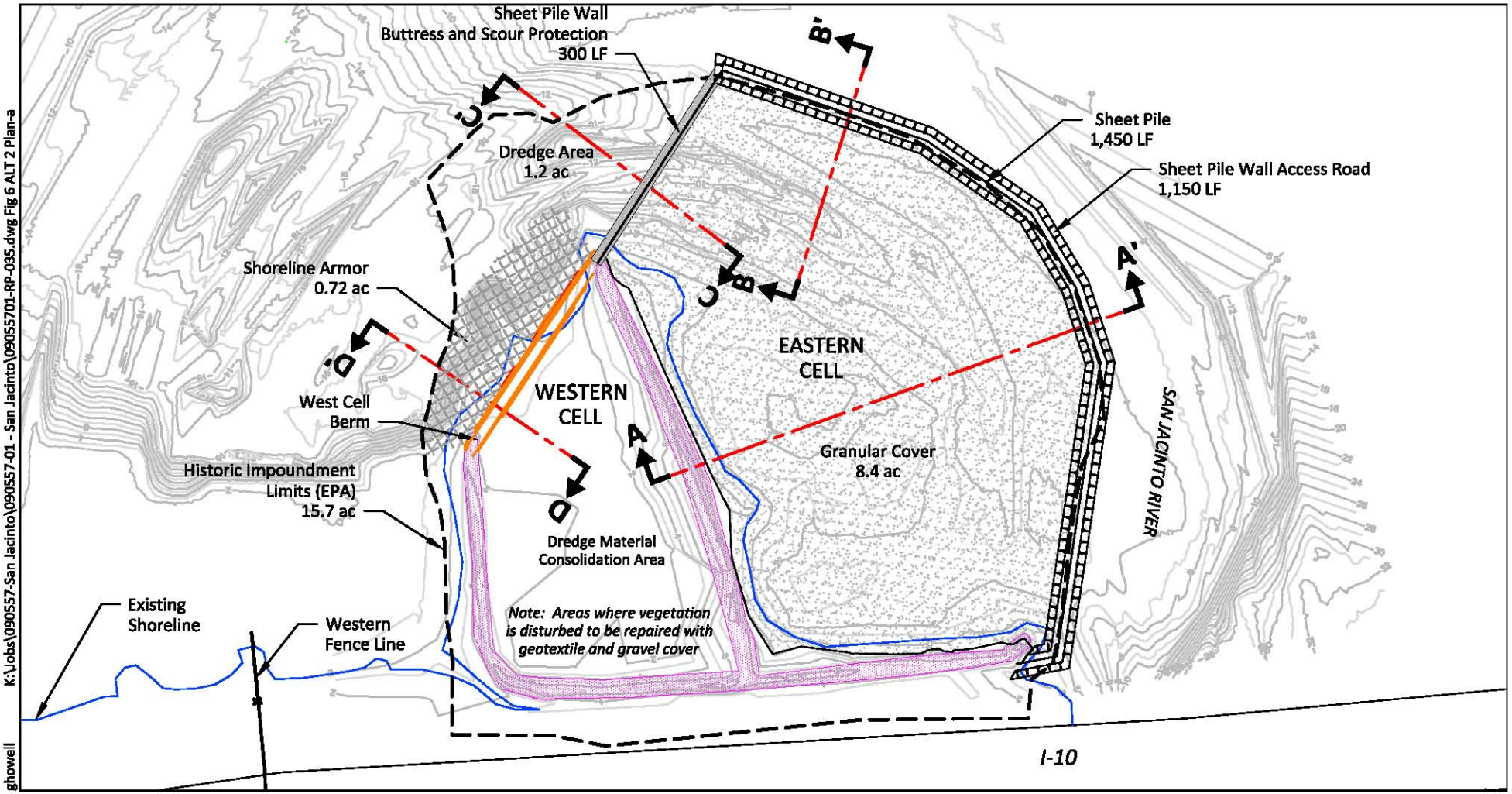
0 100
Scale in Feet
Vertical Exaggeration x2

K:\Jobs\090557-San Jacinto\090557-01 - San Jacinto\09055701-RP-035.dwg Fig 5 ALT 1 Sections CD-a

May 25, 2010 4:30pm cdavidson

ANCHOR QEA

Figure 5
Cross Sections C and D - Alternative 1
SJRWP TCRA



SOURCE: Drawing prepared from COE
HORIZONTAL DATUM: Texas South Central, NAD83. US Survey Feet.
VERTICAL DATUM: NAVD 88.
NOTE: See Figures 7 and 8 for Cross Sections.

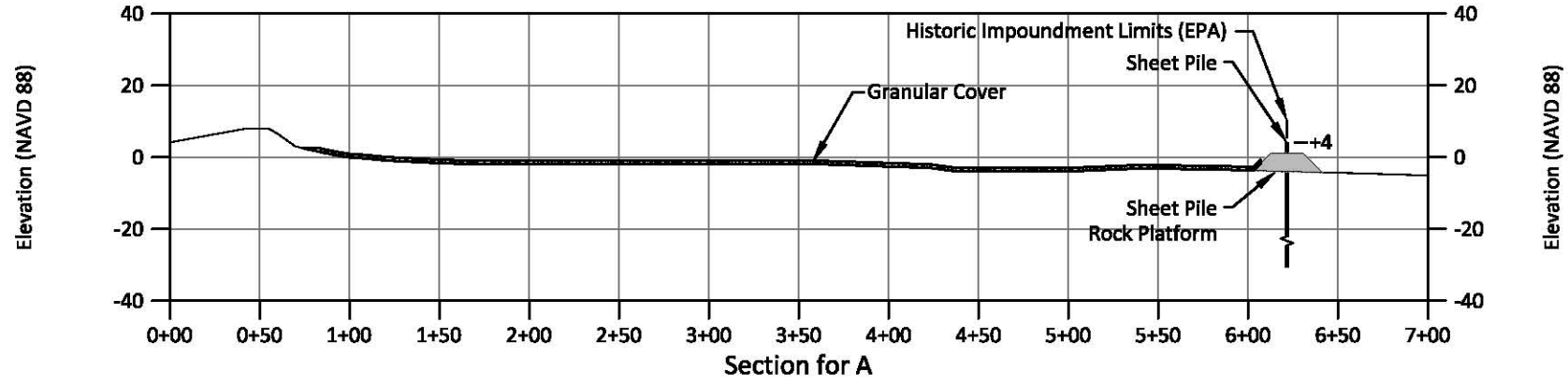
A A Cross Section Locations and Designation

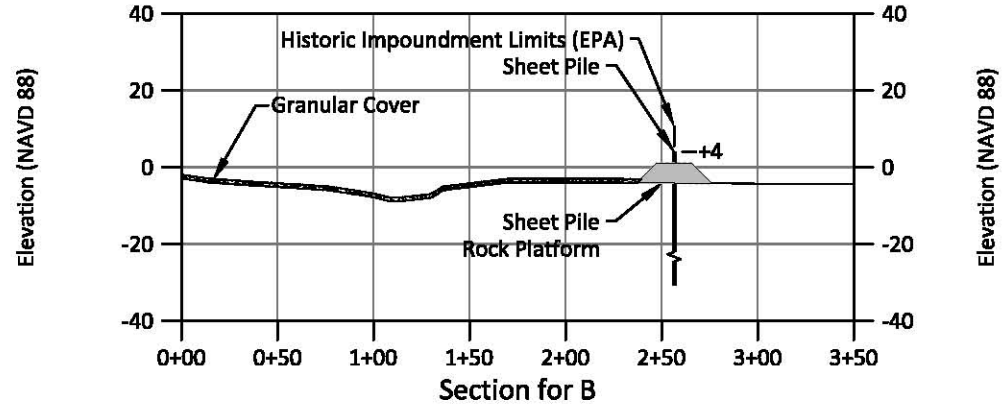
0 200
Scale in Feet

K:\Jobs\090557-San Jacinto\090557-01 - San Jacinto\09055701-RP-035.dwg Fig 6 ALT 2 Plan-a
May 27, 2010 9:57am ghowell

ANCHOR QEA

Figure 6
Alternative 2 Plan View
East Impoundment Sheet Pile, Dredge and Cover
SJRWP TCRA





LEGEND:

Rock Cover

Granular Cover

SOURCE: Drawing prepared from COE
HORIZONTAL DATUM: Texas South Central, NAD83. US Survey Feet.
VERTICAL DATUM: NAVD 88.
NOTE: See Figure 6 for Cross Section Locations.

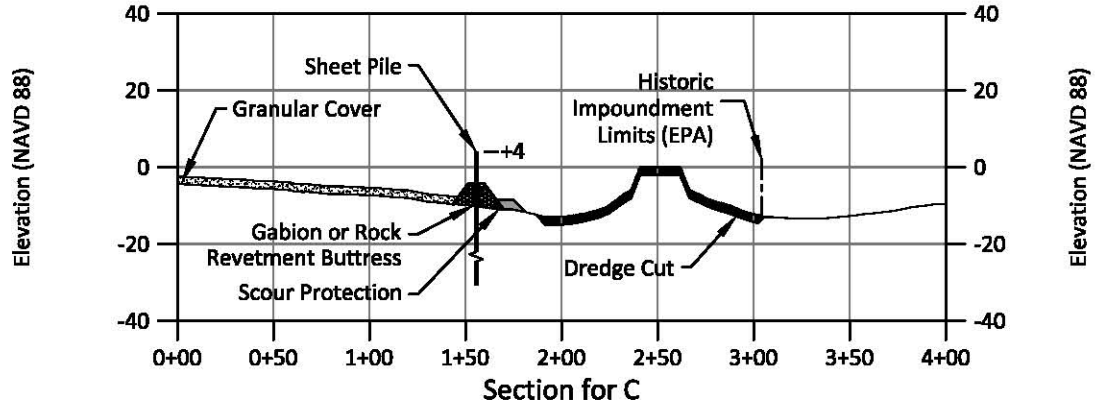
0 100
Scale in Feet
Vertical Exaggeration x2

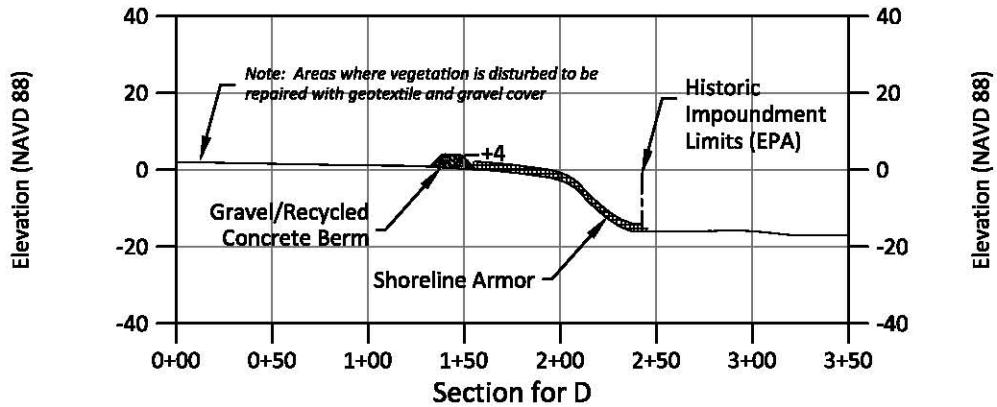
K:\Jobs\090557-San Jacinto\090557-01 - San Jacinto\09055701-RP-035.dwg Fig 7 ALT 2 Sections AB-a

May 25, 2010 4:29pm cdavidson

ANCHOR QEA

Figure 7
Cross Sections A and B - Alternative 2
SJRWP TCRA





LEGEND:

- Rock Cover
- Granular Cover
- Shoreline Armor

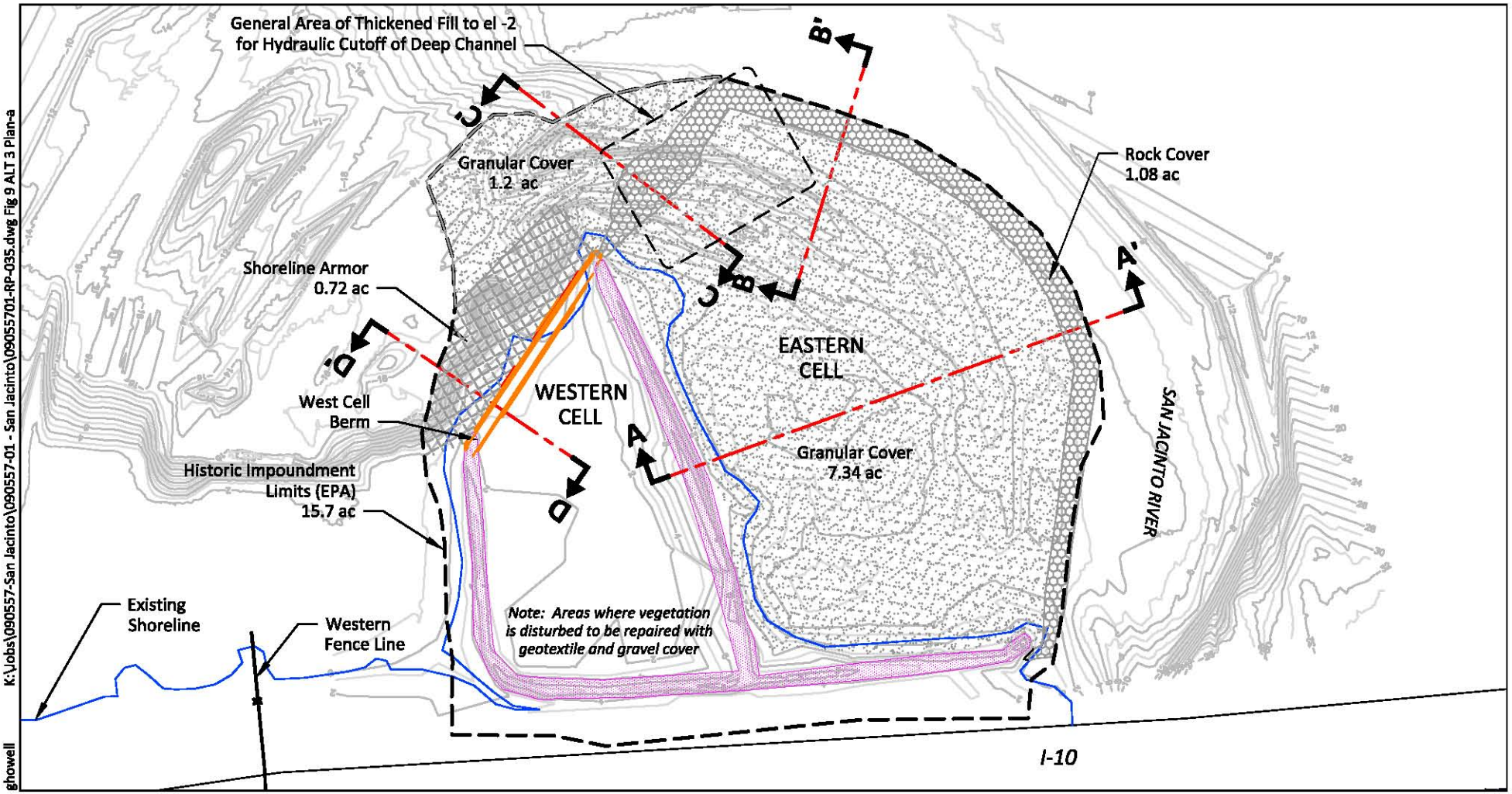
SOURCE: Drawing prepared from COE
HORIZONTAL DATUM: Texas South Central, NAD83. US Survey Feet.
VERTICAL DATUM: NAVD 88.
NOTE: See Figure 6 for Cross Section Locations.

0 100
Scale in Feet
Vertical Exaggeration x2

K:\Jobs\090557-San Jacinto\090557-01 - San Jacinto\09055701-RP-035.dwg Fig 8 ALT 2 Sections CD-a
May 25, 2010 4:28pm cdavidson

ANCHOR QEA

Figure 8
Cross Sections C and D - Alternative 2
SJRWP TCRA



SOURCE: Drawing prepared from COE
HORIZONTAL DATUM: Texas South Central, NAD83. US Survey Feet.
VERTICAL DATUM: NAVD 88.
NOTE: See Figures 10 and 11 for Cross Sections.

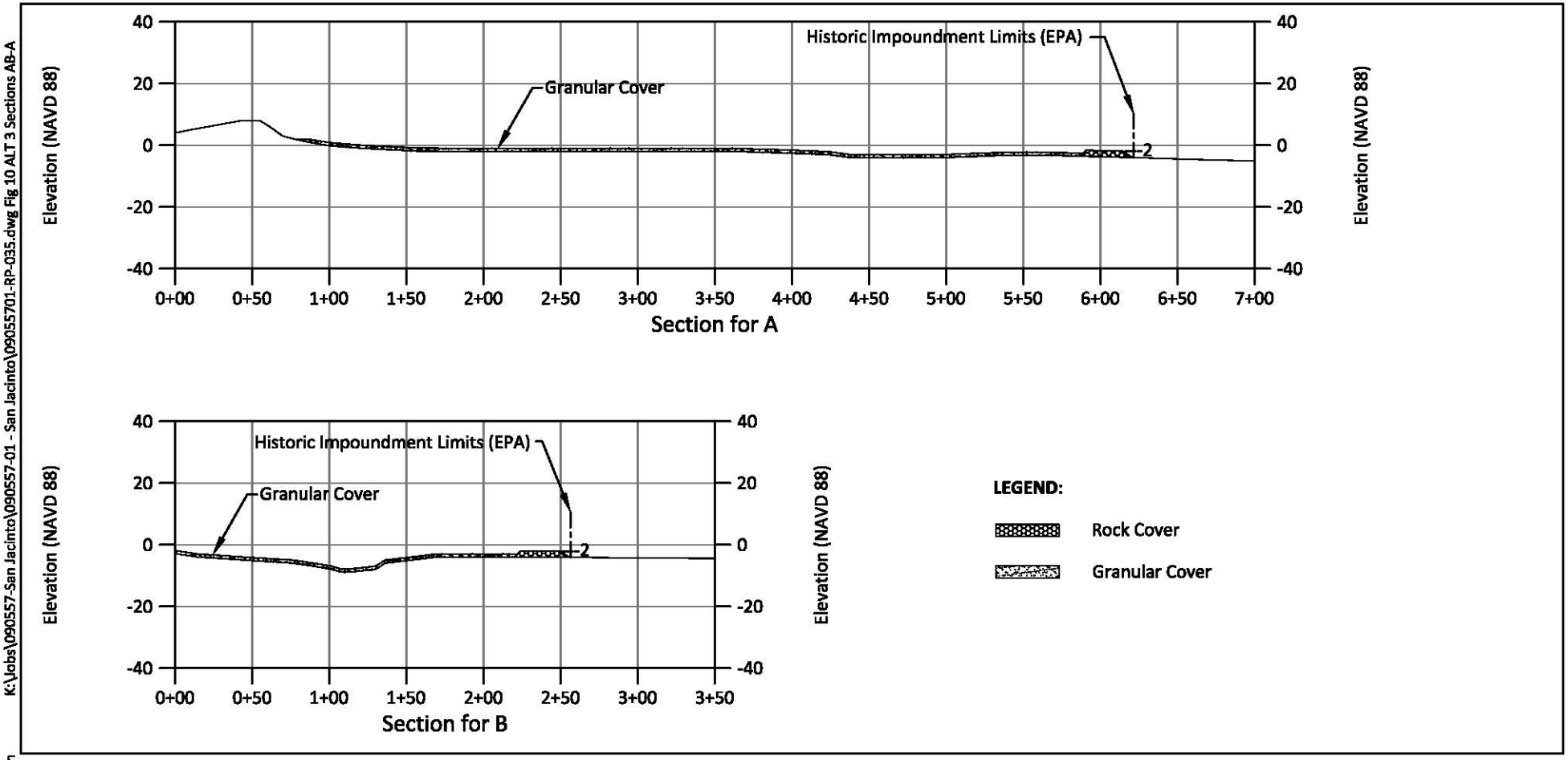
A A Cross Section Locations and Designation

0 200
Scale in Feet

K:\Jobs\090557-San Jacinto\090557-01 - San Jacinto\09055701-RP-035.dwg Fig 9 ALT 3 Plan-a
May 27, 2010 9:58am ghowell

ANCHOR QEA

Figure 9
Alternative 3 Plan View
Sediment Cover
SJRWP TCRA



SOURCE: Drawing prepared from COE
HORIZONTAL DATUM: Texas South Central, NAD83. US Survey Feet.
VERTICAL DATUM: NAVD 88.
NOTE: See Figure 9 for Cross Section Locations.

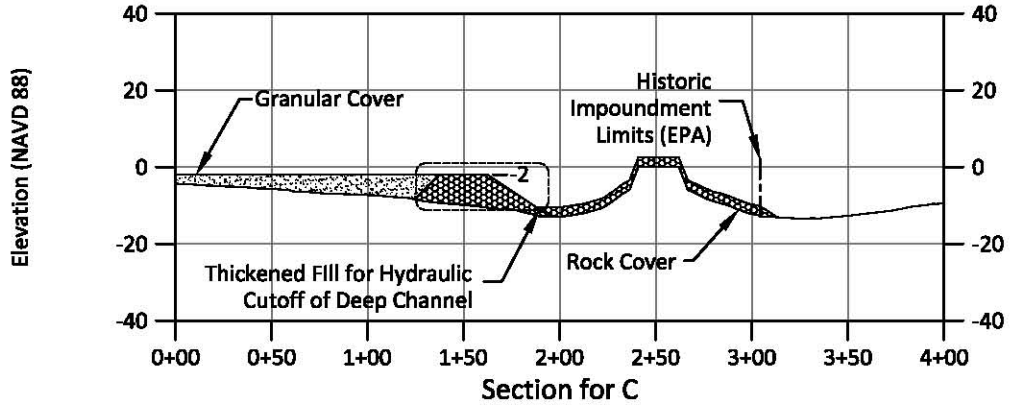
0 100
Scale in Feet
Vertical Exaggeration x2

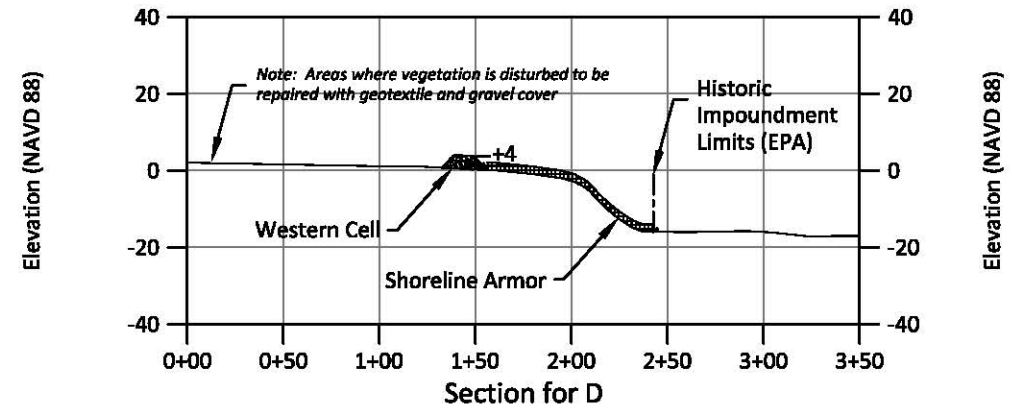
K:\Jobs\090557-San Jacinto\090557-01 - San Jacinto\09055701-RP-035.dwg Fig 10 ALT 3 Sections AB-A

May 25, 2010 4:25pm cdavidson

ANCHOR QEA

Figure 10
Cross Sections A and B - Alternative 3
SJRWP TCRA





LEGEND:

- Rock Cover
- Granular Cover
- Shoreline Armor

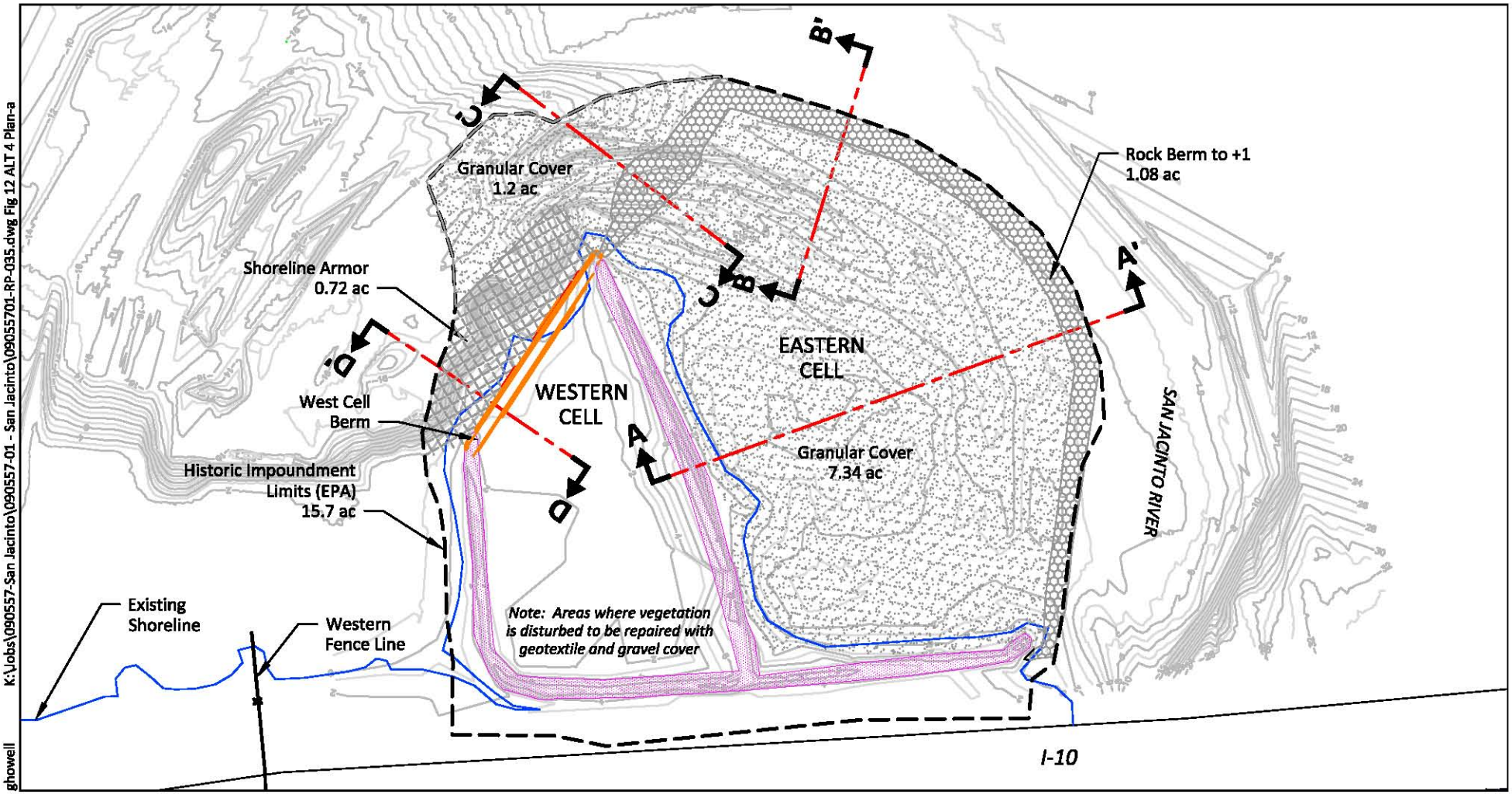
SOURCE: Drawing prepared from COE
HORIZONTAL DATUM: Texas South Central, NAD83. US Survey Feet.
VERTICAL DATUM: NAVD 88.
NOTE: See Figure 9 for Cross Section Locations.

0 100
Scale in Feet
Vertical Exaggeration x2

K:\Jobs\090557-San Jacinto\090557-01 - San Jacinto\09055701-RP-035.dwg Fig 11 ALT 3 Sections CD-a
May 27, 2010 9:58am ghowell

ANCHOR QEA

Figure 11
Cross Sections C and D - Alternative 3
SJRWP TCRA



SOURCE: Drawing prepared from COE
HORIZONTAL DATUM: Texas South Central, NAD83. US Survey Feet.
VERTICAL DATUM: NAVD 88.
NOTE: See Figures 13 and 14 for Cross Sections.

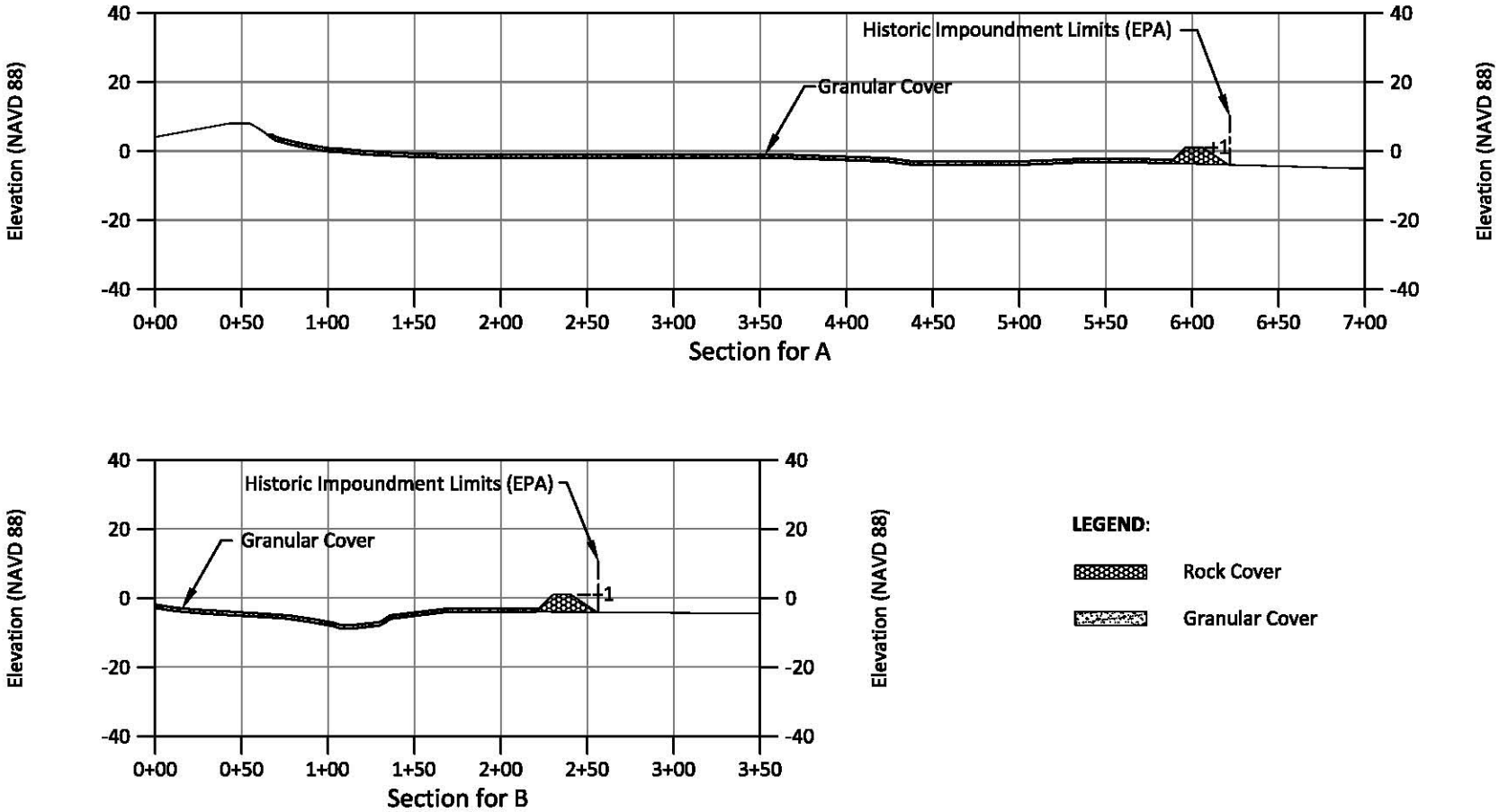
A A Cross Section Locations and Designation

0 200
Scale in Feet

K:\Jobs\090557-San Jacinto\090557-01 - San Jacinto\09055701-RP-035.dwg Fig 12 ALT 4 Plan-a
May 27, 2010 9:59am ghowell

ANCHOR QEA

Figure 12
Alternative 4 Plan View
East Impoundment Berm and Cover
SJRWP TCRA



SOURCE: Drawing prepared from COE
HORIZONTAL DATUM: Texas South Central, NAD83. US Survey Feet.
VERTICAL DATUM: NAVD 88.
NOTE: See Figure 12 for Cross Section Locations.

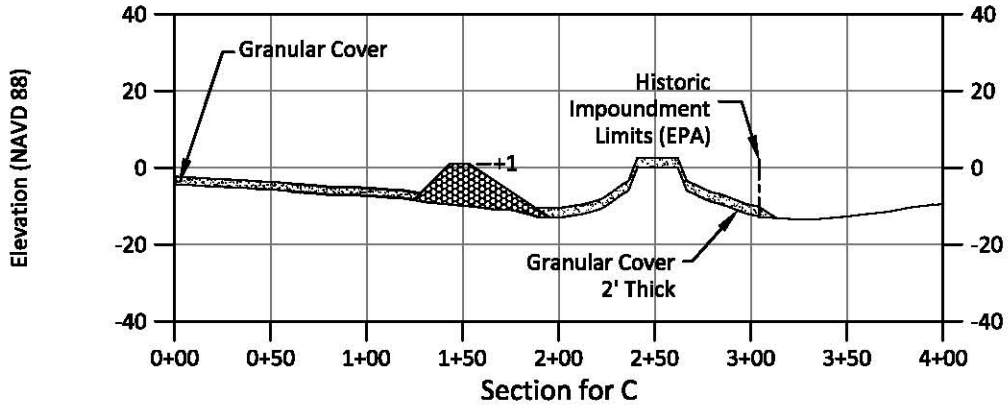
0 100
Scale in Feet
Vertical Exaggeration x2

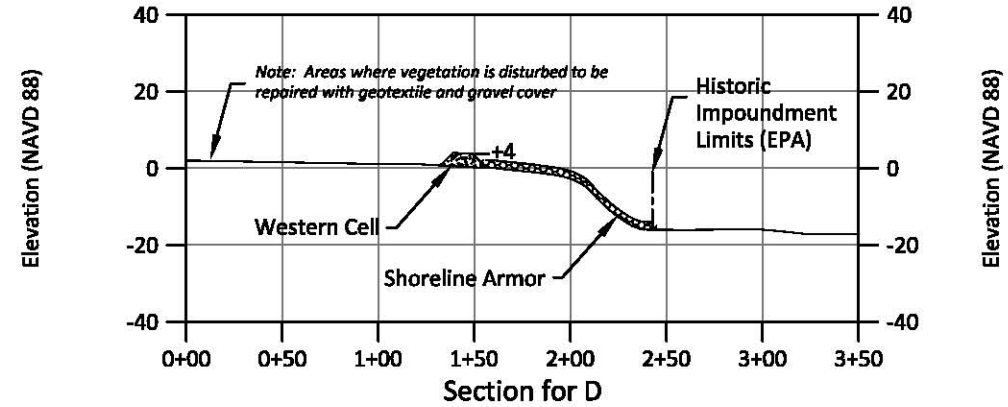
K:\Jobs\090557-San Jacinto\090557-01 - San Jacinto\09055701-RP-035.dwg Fig 13 ALT 4 Sections AB-a

May 25, 2010 4:22pm cdavidson

ANCHOR QEA

Figure 13
Cross Sections A and B - Alternative 4
SJRWP TCRA





LEGEND:

- Rock Cover
- Granular Cover
- Shoreline Armor

SOURCE: Drawing prepared from COE
HORIZONTAL DATUM: Texas South Central, NAD83. US Survey Feet.
VERTICAL DATUM: NAVD 88.
NOTE: See Figure 12 for Cross Section Locations.

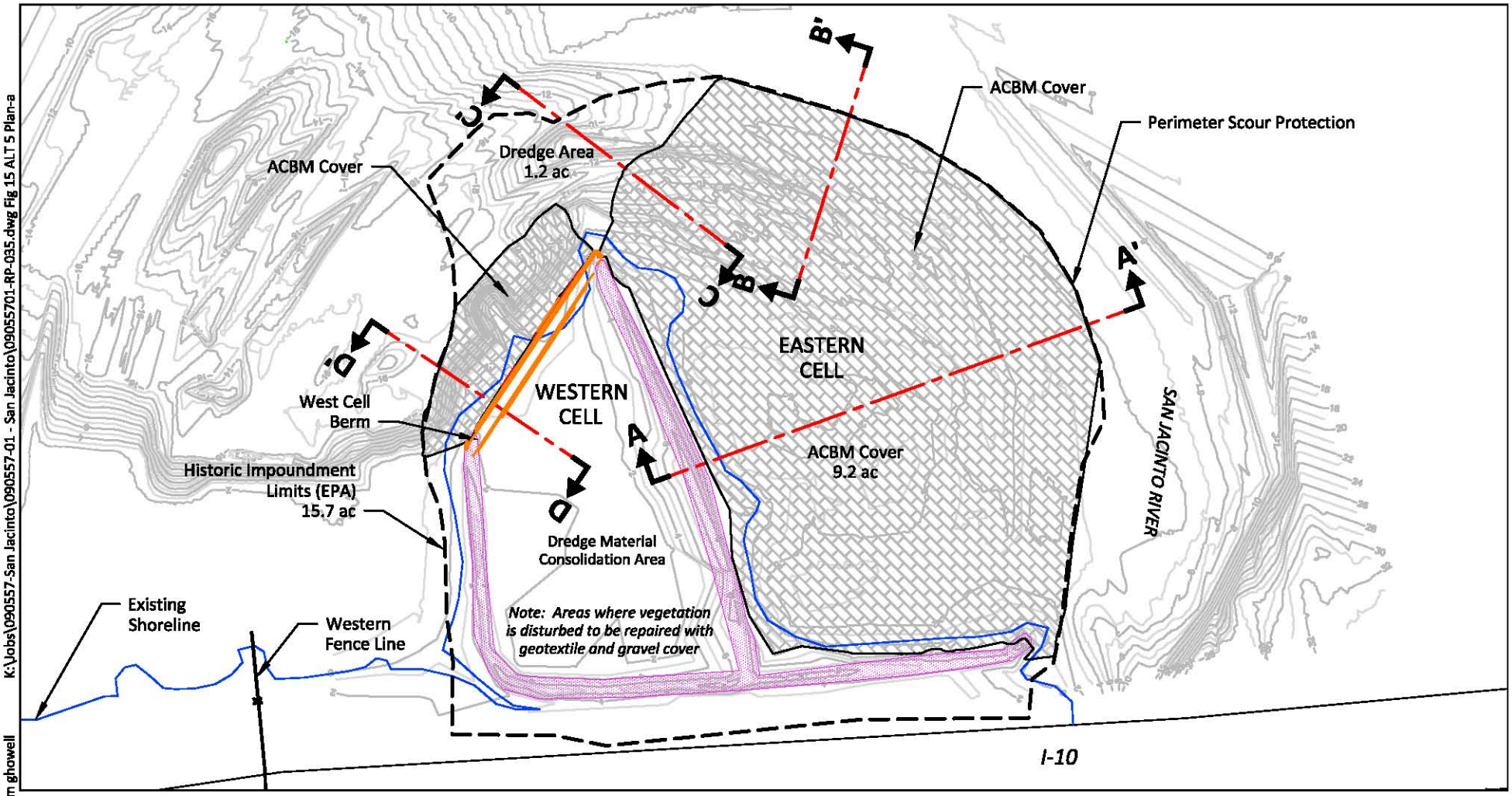
0 100
Scale in Feet
Vertical Exaggeration x2

K:\Jobs\090557-San Jacinto\090557-01 - San Jacinto\09055701-RP-035.dwg Fig 14 ALT 4 Sections CD-a

May 27, 2010 10:00am ghowell

ANCHOR QEA

Figure 14
Cross Sections C and D - Alternative 4
SJRWP TCRA



SOURCE: Drawing prepared from COE
HORIZONTAL DATUM: Texas South Central, NAD83. US Survey Feet.
VERTICAL DATUM: NAVD 88.
NOTE: See Figures 16 and 17 for Cross Sections.

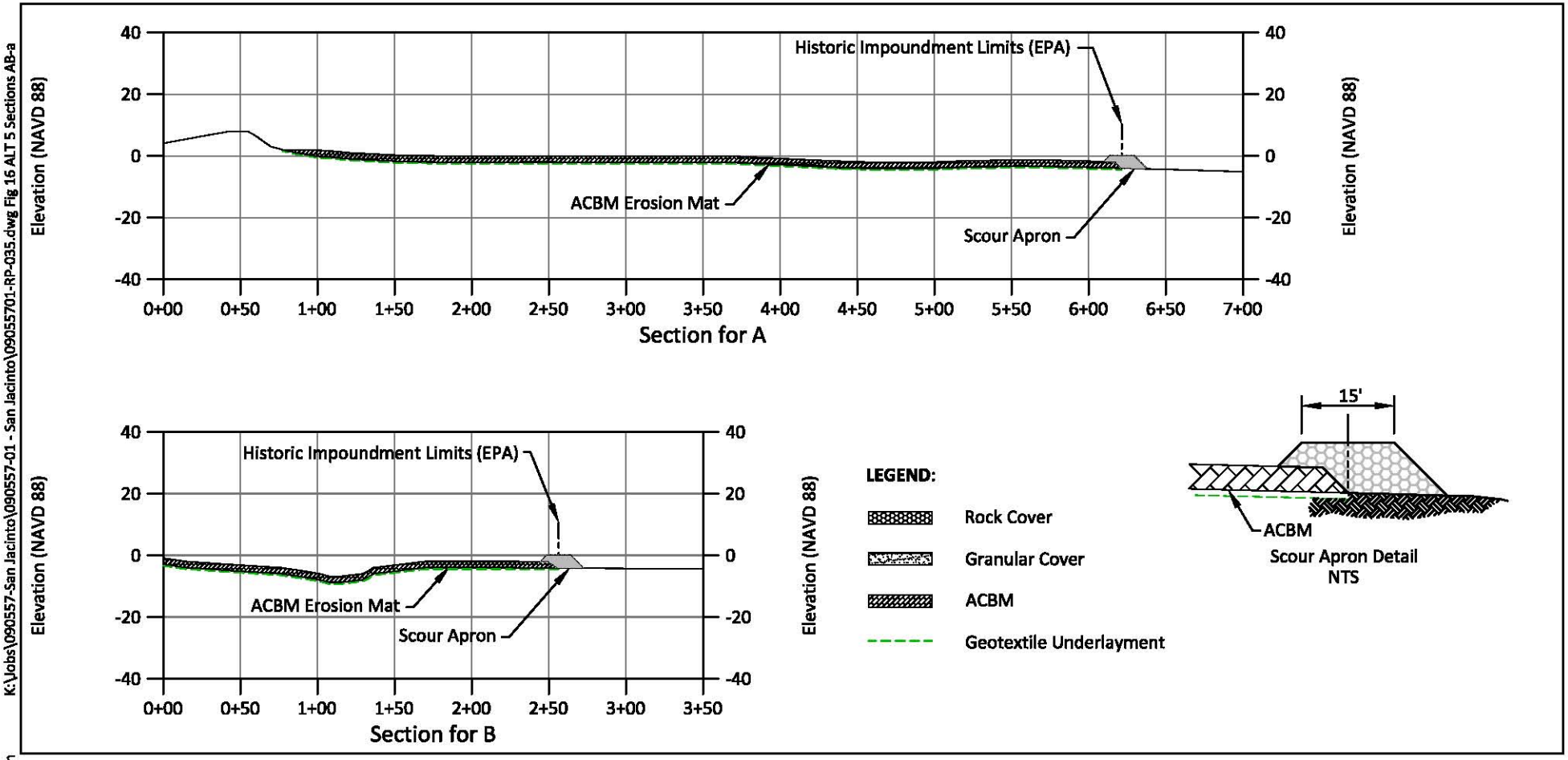
A A Cross Section Locations and Designation

0 200
Scale in Feet

K:\Jobs\090557-San Jacinto\090557-01 - San Jacinto\09055701-RP-035.dwg Fig 15 ALT 5 Plan-a
May 27, 2010 10:00am ghowell

ANCHOR QEA

Figure 15
Alternative 5 Plan View
ACBM Stabilization and Dredge
SJRWP TCRA



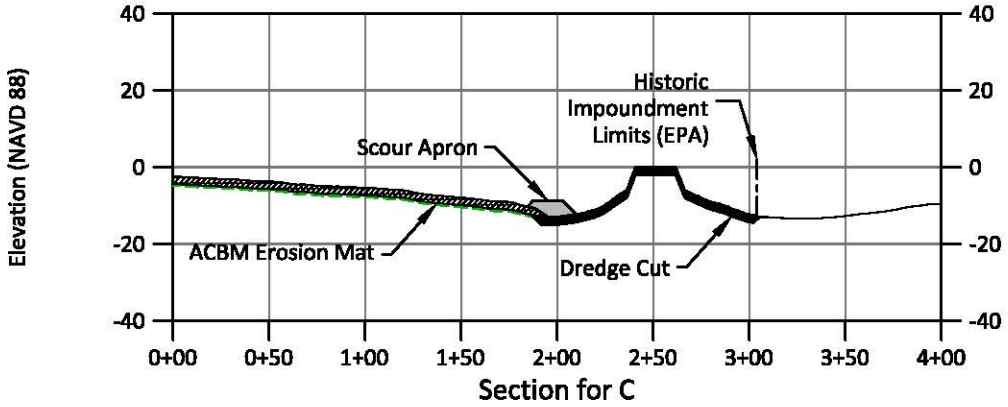
SOURCE: Drawing prepared from COE
HORIZONTAL DATUM: Texas South Central, NAD83. US Survey Feet.
VERTICAL DATUM: NAVD 88.
NOTE: See Figure 15 for Cross Section Locations.

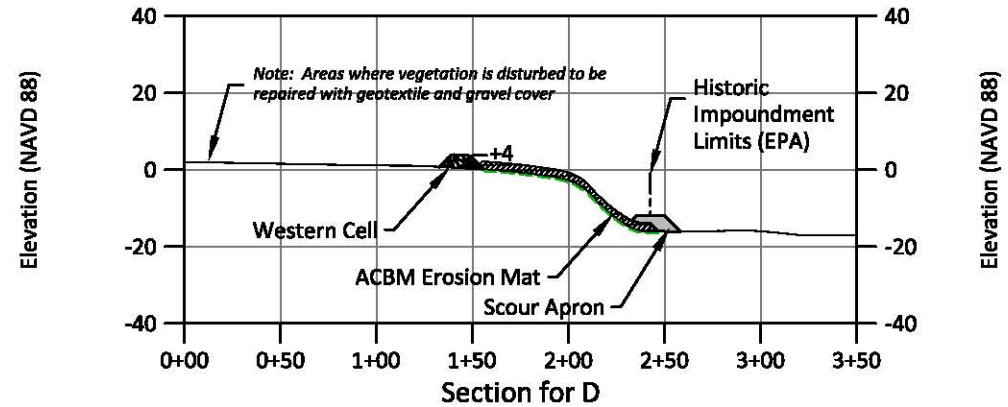
0 100
Scale in Feet
Vertical Exaggeration x2

K:\Jobs\090557-San Jacinto\090557-01 - San Jacinto\09055701-RP-035.dwg Fig 16 ALT 5 Sections AB-a
May 25, 2010 4:18pm cdavidson

ANCHOR QEA

Figure 16
Cross Sections A and B - Alternative 5
SJRWP TCRA





LEGEND:

- Rock Cover
- Granular Cover
- ACBM
- Geotextile Underlayment

SOURCE: Drawing prepared from COE
HORIZONTAL DATUM: Texas South Central, NAD83. US Survey Feet.
VERTICAL DATUM: NAVD 88.
NOTE: See Figure 15 for Cross Section Locations.

0 100
Scale in Feet
Vertical Exaggeration x2

K:\Jobs\090557-San Jacinto\090557-01 - San Jacinto\09055701-RP-035.dwg Fig 17 ALT 5 Sections CD-a

May 27, 2010 10:01am ghowell

ANCHOR QEA

Figure 17
Cross Sections C and D - Alternative 5
SJRWP TCRA

APPENDIX A
DESIGN STORM EVENT MEMORANDUM

ANCHOR QEA

614 Magnolia Avenue
Ocean Springs, Mississippi
Phone 228.818.9626
Fax 228.818.9631
www.anchorqea.com

MEMORANDUM

To:	Valmichael Leos, USEPA Mike Hasen, HVJ Associates Ed Barth, USEPA Steve Tzhone, USEPA	**Date:**	May 27, 2010
From:	John Verduin, P.E., Anchor QEA John Laplante, P.E., Anchor QEA Matt Henderson, P.E., Anchor QEA Wendell Mears, Anchor QEA	**Project:**	090557-01
Cc:	David Keith, Anchor QEA Phil Slowiak, International Paper Drew Shafer, March Smith, MIMC		
Re:	Design Storm Event: San Jacinto Superfund Site Time Critical Removal Action		

The purpose of this Design Storm Event Memorandum is to define the storm event to be used to design the Time Critical Removal Action (TCRA) for the San Jacinto Superfund Site (Site). The TCRA will be implemented within the next year. Concurrent to the TCRA, International Paper and MIMC (Respondents) are completing a Non-Time Critical Removal Action (NTCRA) Engineering Evaluation/Cost Assessment (EE/CA) to select the appropriate long-term removal action for the Site. The NTCRA is anticipated to be completed within the next two to seven years.

The United States Environmental Protection Agency (USEPA) April 2, 2010, memorandum titled, "Request for a Time Critical Removal Action at the San Jacinto Waste Pits Site, Harris County, Texas" states that the technologies used to control erosion "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. Also, the Houston area is visited by seasonal severe weather events (i.e. strong force winds or flooding) and the physical protective barrier must be structurally secure to withstand any potential future extreme weather events" (USEPA 2010; IV.A.1; Page 9; 3rd paragraph).

This memorandum presents the recommended design storm for the TCRA based on a review of guidance documents related to storm events and an analysis of various return-interval storm events in the San Jacinto River.

GUIDANCE FOR RESISTANCE TO DESIGN LEVEL STORM EVENTS

The USEPA and U.S. Army Corps of Engineers (USACE) have developed storm event performance criteria for contaminated sediments sites. For example, USEPA's and USACE's "Guidance for In-Situ Subaqueous Capping of Contaminated Sediments" (Palermo et al. 1998) and USEPA's "Contaminated Sediment Remediation Guidance for Hazardous Waste Sites" (2005) provide guidance for design of technologies to resist design storm events. "Contaminated Sediment Remediation Guidance for Hazardous Waste Sites" also states that erosion protection features 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."

Following USEPA guidance, a permanent remedy would be designed to resist a flow event with a return-period of 100 years. However, the risk of a 100-year storm occurring in the 2- to 7-year time period is only 2 to 6.8 percent. Given the low probability of this occurring, sizing materials to resist this event would be impractical for the short timeframe that the TCRA is expected to be in place. In addition, if a rare, extreme event did occur in the short timeframe, the disruption to the cover system could be easily observed and repaired as necessary. Therefore, an evaluation was performed to determine an equivalent storm event for a shorter design life span shorter than the typical 100-year design.

ANALYSIS OF STORM DATA RETURN PERIODS

As previously discussed, the anticipated design and construction period for the NTCRA is two to seven years, which is the anticipated range of wait time between the completion of TCRA construction and the implementation of the final NTCRA. This period could be shorter or longer depending on uncontrollable events. The purpose of this analysis is to determine the likelihood that the TCRA remedy would experience a flow event greater than the intended design life.

Table 1 presents the probability of occurrence of 2-, 5-, 10-, and 25-year storm events to occur within the two and seven year period). As an example from Table 1, a 5-year flow event has an annual probability of occurring in any given year of 20 percent. The 5-year event would have a 36 percent chance of occurring during a 2-year wait period and a 79 percent chance during a 7-year wait period.

Table 1
Percent Chance of Occurrence

Return Period (years)	Annual Percent Chance of Occurrence (percent)	Period of Concern (years)	
		2	7
2	50	75	99
5	20	36	79
10	10	19	52
25	4	8	25

As previously discussed, USEPA guidance recommends designing permanent engineered caps for a 100-year flow event. Over a 100-year design life, the percent chance of a 100-year flow event occurring is approximately 63 percent.

As described in the USEPA guidance, the design life for most civil works projects such as bridges or dams is approximately 50 years (Palermo et al. 1998). The probability of a 100-year event occurring in 50-year design life is approximately 40 percent. In addition, in the USACE's "Hydraulic Design for Local Flood Protection Projects", the USACE recommends that "…all channel elements will perform satisfactorily for flows up to and including the annual flood frequency which has a 50 percent probability of being exceeded during the project economic life." A 2-year event has a 50 percent probability of occurrence on an annual basis. For a 7-year design life, the flood event that has a 50 percent probability of occurring is the 10-year event.

For a temporary two- to seven- year TCRA, a flow event with an equivalent chance of occurring during a two to seven year period of approximately 63 percent would correspond to a 2- to 10-year storm event. Therefore, the TCRA will be designed to resist 10-year return-interval flow events in the San Jacinto River consistent with the USEPA and USACE guidance.

REFERENCES

Maynord, S., 1998. Appendix A: Armor Layer Design for the Guidance for In-Situ Subaqueous Capping of Contaminated Sediment. EPA 905-B96-004, Great Lakes National Program Office, Chicago, IL.

Palermo, M., S. Maynord, J. Miller, and D. Reible. 1998. "Guidance for In-Situ Subaqueous Capping of Contaminated Sediments." EPA 905-B96-004, Great Lakes National Program Office, Chicago, IL.

U.S. Army Corps of Engineers (USACE). 1982. "Hydraulic Design for Local Flood Control Projects." ER 1110-2-1405, Washington, D.C.

U.S. Environmental Protection Agency (USEPA). 2005. "Contaminated Sediment Remediation Guidance for Hazardous Waste Sites." EPA-540-R-05-012, Office of Solid Waste and Emergency Response

USEPA. 2010. Memorandum titled, "Request for a Time Critical Removal Action at the San Jacinto Waste Pits Site, Harris County, Texas." From V. Leos to S. Coleman, P.E. April 2, 2010.

APPENDIX B
HYDRODYNAMIC MODELING MEMORANDUM

ANCHOR QEA

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MEMORANDUM

To:	Valmichael Leos, USEPA Mike Hasen, HVJ Associates Ed Barth, USEPA Steve Tzhone, USEPA	**Date:**	May 27, 2010
From:	Matt Henderson, PE, Anchor QEA John Verduin, PE, Anchor QEA Wendell Mears, Anchor QEA John Laplante, PE, Anchor QEA	**Project:**	090557-01
Cc:	David Keith, Anchor QEA Phil Slowiak, International Paper Drew Shafer, March Smith, MIMC		
Re:	San Jacinto Superfund Site Time Critical Removal Action Methodology for Evaluating Cover Material Sizes		

At the May 12, 2010, San Jacinto Superfund Site (Site) Time Critical Removal Action (TCRA) alternatives evaluation meeting between the Respondents and the U.S. Environmental Protection Agency (USEPA) in Houston, Texas, USEPA requested information on the methodology used to evaluate the required size of armor materials needed to resist erosion. This memorandum summarizes the methodology that is being used to assess the size of the TCRA cover materials for the Site.

The USEPA April 2, 2010, memorandum titled, "Request for a Time Critical Removal Action at the San Jacinto Waste Pits Site, Harris County, Texas" states that the technologies used to control erosion "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. Also, the Houston area is visited by seasonal severe weather events (i.e. strong force winds or flooding) and the physical protective barrier must be structurally secure to withstand any potential future extreme weather events" (USEPA 2010; IV.A.1; Page 9; 3rd paragraph).

Below, we discussed the methodology followed for evaluating the cover material, describe the hydrodynamic model, discuss the process used to determine the stable grain size given the hydrodynamic forces, and conclude with what will be done as part of final design.

METHODOLOGY FOR EVALUATING COVER MATERIAL

The primary objective of the cover material is to prevent exposure and erosion of the materials located on the Site while the non-TCRA is being designed and implemented. The cover material is being designed using methods developed by the USEPA and the U.S. Army Corps of Engineers (USACE) and presented in "Armor Layer Design of Guidance for In-Situ Subaqueous Capping of Contaminated Sediments" (Maynord 1998).

As described above, high flows resulting from rainfall runoff and storm surges can occur in the San Jacinto River. These high flows can result in elevated velocities (and associated bed shear stress) at the Site and have the potential to erode and/or resuspend the materials at the Site. To evaluate the velocities and shear stresses at the Site for various return-interval flow events, a hydrodynamic model was developed. This model was used to compute velocities, water depths, and bed shear stresses at the Site under various flow conditions. Results were used to compute representative particle sizes (diameters) that will resist erosion associated with current velocities using the methods presented in Maynord (1998).

HYDRODYNAMIC MODEL DESCRIPTION

As described above, a hydrodynamic model was developed to simulate flow in the lower San Jacinto River at the Site and nearby regions. The model being used is the Environmental Fluid Dynamics Code (EFDC), which is supported by the USEPA. EFDC is a general purpose hydrodynamic model capable of simulating flow in rivers, lakes, reservoirs, estuaries, and coastal oceans. The EFDC hydrodynamic model of the lower San Jacinto River basin is a two-dimensional, depth-averaged model and predicts flow velocity, water depth, and shear stress. The EFDC model for the lower San Jacinto River was initially developed to evaluate flow and sediment transport patterns in the San Jacinto River to support the sampling plan design for the non-TCRA chemical fate and transport modeling study. The model was subsequently refined for use in evaluating flow velocities at the Site. Details of the model development are briefly summarized below.

The following information is needed to develop the hydrodynamic model:

1. Bathymetry of the San Jacinto River and topography of the floodplain in the vicinity of the Site
2. Flow at the upstream model boundary
3. Tidal elevations at the downstream boundary

The model domain consists of orthogonal grid cells, extending from the confluence of the San Jacinto River and the Houston Ship Channel to approximately 7 river miles upstream. The model grid cell size is 100-foot by 100-foot in the areas farthest from the Site and is refined to 50-foot by 50-foot at the Site. The model consists of 32,361 elements. The model bathymetry was estimated by interpolating National Oceanic and Atmospheric Administration (NOAA) point bathymetry measurements, supplemented by the bathymetry collected in the immediate area of the Site in February 2009. Floodplain topography in the vicinity of the Site was estimated from the U.S. Geological Survey (USGS) Digital Elevation Model (DEM).

Fifteen-day simulations were conducted at constant flow rates equal to the 5-, 10-, and 25-year flow. Inflow at the upstream boundary was estimated using daily average flows measured at six upstream USGS gauging stations. The daily flows were summed and prorated by the ratio of the drainage area at the Lake Houston Dam to the combined drainage area of the six upstream stations. The Lake Houston is a water supply reservoir. Water supply reservoirs attempt to maintain water levels as high as possible to assure the largest water supply in times of drought. These reservoirs do not provide significant storage during flood events (Harris County Flood Control District 2010). A flood frequency analysis was performed on the adjusted flows to estimate the 5-, 10-, and 25-year flow rates. Stage height measured at the NOAA tidal station at Battleship Texas State Park, Texas from September 1 to 15, 2005, was used as the downstream boundary condition. Upper and lower-bound sensitivity analyses were performed by increasing the stage height by the difference between mean sea level and mean higher high water, and decreasing the stage height by the difference between mean sea level and mean lower low water. In addition, Hurricane Ike (which impacted the area in September 2008) was also simulated with the hydrodynamic model. Measurements of flow at the Lake Houston Dam during the event were used as the inflow boundary condition for the model simulation. The nearest NOAA tidal station with

continuous stage height data during the event is Eagle Point, Texas. A relationship was found between long-term (1993 to 2009) data collected at the Eagle Point, Texas station and the Morgans Point, Texas station. This relationship was used to predict the storm surge at the downstream boundary during the event.

STABLE PARTICLE SIZE TO RESIST CURRENT VELOCITIES

The method presented in Maynord (1998) is based on the USACE's "Hydraulic Design of Flood Control Channels" (USACE 1994). This method uses velocity and flow depth computed by the depth-averaged hydrodynamic model to determine the size of the cover material.

Equation 2 from Maynord (1998) is

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

where:

D_{50}	=	median particle size in feet
S_f	=	safety factor
C_s	=	stability coefficient for incipient failure
C_V	=	velocity distribution coefficient
C_T	=	blanket thickness coefficient
C_G	=	gradation coefficient = $(D_{85}/D_{15})^{1/3}$
D_{85}/D_{15}	=	gradation uniformity coefficient
d	=	water depth in feet
γ_s	=	unit weight of stone
γ_w	=	unit weight of water
V	=	maximum depth-averaged velocity in feet per second
K_1	=	side slope correction factor
g	=	acceleration due to gravity

Stable particle sizes were computed for the Site for each alternative using the equation above. The need for filter layer between the stable particles sizes and the materials at the Site considering Site conditions and design life will be evaluated as part of the design.

CONCLUSION

A hydrodynamic model has been developed to assess the flow velocities and water depths at the Site under various flow events in the lower San Jacinto River. Stable particles sizes to cover the Site and resist the forces from various flow events for the different alternatives were computed using the hydrodynamic model results and USEPA design guidance. As part of final design the hydrodynamic model and stable particle size for the selected alternative will be refined. The final gradation and filter requirements will be submitted as part of the TCRA Work Plan that includes the final design package.

REFERENCES

Harris County Flood Control District. 2010. San Jacinto Watershed Website. http://www.hcfcd.org/l_sanjacriver.html. Accessed on May 27, 2010.

Maynord, S., 1998. *Appendix A: Armor Layer Design for the Guidance for In-Situ Subaqueous Capping of Contaminated Sediment.* EPA 905-B96-004, Great Lakes National Program Office, Chicago, IL.

USACE (U.S. Army Corps of Engineers), 1994. *Hydraulic Design of Flood Control Channels*. Engineering Manual EM 1110-2-1601. U.S. Army Corps of Engineers. Washington, DC.

USEPA (U.S. Environmental Protection Agency), 2010. Memorandum titled, "Request for a Time Critical Removal Action at the San Jacinto Waste Pits Site, Harris County, Texas." From V. Leos to S. Coleman, P.E. April 2, 2010.

APPENDIX C
COST ESTIMATE DETAIL

SAN JACINTO RIVER WASTE PIT - TIME CRITICAL REMEDIAL ACTION
COST ESTIMATE SUMMARY TABLE

TCRA ALTERNATIVE	COST ($M)
Alternative 1: Rock Platform to Support Land-Based Installation Operations, Vinyl Sheet Pile Wall with Scour Protection to Historic Impound Limits along entire Site, Granular Cover to Elevation -1 Inside Wall	**$5.84**
Alternative 2: Rock Platform to Support Land-Based Installation Operations, Eastern Cell Vinyl Sheet Pile Wall with Scour Protection to Historic Impound Limits, Granular Cover to Elevation -1 Inside Wall, Western Cell Control Berm and Shoreline Armoring, Dredging to Geobags in Northwestern Area	**$5.08**
Alternative 3: Granular Cover over Eastern Cell, Eastern Cell Clay Cover and Rock Cover Layers, Western Cell Control Berm, Granular Cover in Northwestern Area	**$3.56**
Alternative 4: Granular Cover over Eastern Cell, Eastern Cell Earth Berm and Rock Berm to Elevation +1, Western Cell Control Berm and Shoreline Armoring, Granular Cover in Northwestern Area	**$4.02**
Alternative 5: Western Cell Control Berm, ACBM Cover over entire Eastern Cell and Shoreline of Western Cell, Dredging to Geobags in Northwestern Area	**$6.94**

ITEM	Alternative 1 Full Sheet Pile	Alternative 2 East Sheet Pile	Alternative 3 - 2 Cover	Alternative 4 + 1 Berm	Alternative 5 ACBM
Mobilization and Site Preparation					
Mobilization/Demobilization	$ 325,000	$ 390,000	$ 250,000	$ 280,000	$ 575,000
Health and Safety	$ 69,000	$ 56,000	$ 32,000	$ 31,000	$ 31,000
Quality Control	$ 69,000	$ 56,000	$ 32,000	$ 31,000	$ 31,000
Access Road Construction	$ 80,000	$ 80,000	$ 80,000	$ 80,000	$ 80,000
Environmental Controls	$ 172,000	$ 172,000	$ 172,000	$ 172,000	$ 172,000
Survey					
Survey Control and Material Placement Surveys	$ 12,000	$ 8,000	$ 12,000	$ 12,000	$ 12,000
Sheet Pile					
Rock Platform	$ 446,000	$ 409,000	$ -	$ -	$ -
Steel Sheetpile Wall Construction	$ 1,380,000	$ 822,000	$ -	$ -	$ -
Sheet Pile Buttress and Scour Protection	$ 495,000	$ 199,000	$ -	$ -	$ -
Cover and Shoreline Protection					
Eastern Cell					
Eastern Cell Granular Cover	$ 783,000	$ 630,000	$ 725,000	$ 656,000	$ -
Eastern Cell Rock Cover/Berm	$ -	$ -	$ 490,000	$ 857,000	$ -
Eastern Cell Geotextile - Rock	$ -	$ -	$ 29,000	$ 32,000	$ -
Eastern Cell ACBM Cover	$ -	$ -	$ -	$ -	$ 2,956,000
Western Cell					
Western Cell Geotextile - Granular Cover	$ 27,000	$ -	$ -	$ -	$ -
Western Cell Granular Cover	$ 34,000	$ -	$ -	$ -	$ -
Western Cell Geotextile - Shoreline Armoring	$ -	$ 20,000	$ 20,000	$ 20,000	$ -
Western Cell Rock Shoreline Armoring	$ -	$ 320,000	$ 320,000	$ 320,000	$ -
Western Cell ACBM Shoreline Armoring	$ -	$ -	$ -	$ -	$ 252,000
Western Cell Rock Protection	$ 28,000	$ -	$ -	$ -	$ -
Western Cell Berm	$ -	$ 51,000	$ 51,000	$ 51,000	$ 51,000
Western Cell Vegetation Repair - Geotextile	$ 11,000	$ 11,000	$ 11,000	$ 11,000	$ 11,000
Western Cell Vegetation Repair - Granular Cover	$ 23,000	$ 23,000	$ 23,000	$ 23,000	$ 23,000
Northwestern Area					
Northwestern Area Granular Cover	$ -	$ -	$ 96,000	$ 96,000	$ -
ACBM Perimeter Protection	$ -	$ -	$ -	$ -	$ 357,000
Dredging and Dewatering					
Northwestern Area Hydraulic Dredging	$ -	$ 33,000	$ -	$ -	$ 33,000
Geobag Dewatering					
Geotextile Layer	$ -	$ 25,000	$ -	$ -	$ 25,000
Bedding Layer	$ -	$ 10,000	$ -	$ -	$ 10,000
Purchase and Setup Bags	$ -	$ 99,000	$ -	$ -	$ 99,000
Maintenance	$ -	$ 12,000	$ -	$ -	$ 12,000
Total Construction Cost	$ 3,954,000	$ 3,426,000	$ 2,343,000	$ 2,672,000	$ 4,730,000
Contingency	$ 1,187,000	$ 1,028,000	$ 703,000	$ 802,000	$ 1,419,000
Non-Construction Costs					
Engineering Design	$ 100,000	$ 100,000	$ 100,000	$ 100,000	$ 100,000
Construction Management	$ 317,000	$ 274,000	$ 188,000	$ 214,000	$ 379,000
Close Out & Documentation	$ 20,000	$ 17,000	$ 12,000	$ 14,000	$ 24,000
Regulatory Compliance Documentation	$ 45,000	$ 45,000	$ 45,000	$ 45,000	$ 45,000
Environmental Monitoring during Construction	$ 152,000	$ 123,000	$ 68,000	$ 66,000	$ 65,000
OM & M	$ 61,000	$ 68,000	$ 97,000	$ 110,000	$ 181,000
Total Non-Construction Cost	$ 1,882,000	$ 1,655,000	$ 1,213,000	$ 1,351,000	$ 2,213,000
TOTAL COST	**$ 5,836,000**	**$ 5,081,000**	**$ 3,556,000**	**$ 4,023,000**	**$ 6,943,000**

SAN JACINTO RIVER WASTE PIT - TIME CRITICAL REMEDIAL ACTION

COST ESTIMATE TABLE

Alternative 1: Rock Platform Construction, Composite Sheet Pile Wall at Historic Impound Limits along entire Site, Targeted Scour Protection, Granular Cover over Eastern and Western Cells

Item No.	Description	Estimated Quantity	Unit	Unit Price	Estimated Amount	Notes
Project Set Up						
1	Mobilization/Demobilization	1	LS	$ 325,000	$ 325,000	Includes sheet pile mob/demob costs
	Health & Safety	1	LS	$ 69,000	$ 69,000	Planning, staffing and implementation
	Quality Control	1	LS	$ 69,000	$ 69,000	Planning, staffing and implementation
2	Environmental Controls	1	LS	$ 172,000	$ 172,000	Maritime signage/fishing advisory markers, reinforced wire fencing, access gates, silt fencing, turbidity curtain
3	Access Road Construction	1	LS	$ 80,000	$ 80,000	
4	Survey Control and Material Placement Surveys	3	EA.	$ 4,000	$ 12,000	
Site Protection						
5	Rock Platform	15,900	TONS	$ 28.00	$ 446,000	18-foot wide rock platform for land-based sheetpile wall installation
6	Sheetpile Wall Construction	86,250	SF	$ 16.00	$ 1,380,000	Vinyl sheetpile wall to be installed at the Historic Impoundment Limits with water depths reaching 16-feet up to elevation +4 NAVD 88
7	Rock Buttress and Scour Protection					
	Inner Wall Protection	5,100	TONS	$ 29.00	$ 148,000	Assumes bull rock 12-ft high inside wall at 1.5H:1V slope
	Outer Wall Protection	4,950	TONS	$ 70.00	$ 347,000	Assumes large limestone rock 12-ft high inside wall at 1.5H:1V slope
Eastern Cell Protection						
8	Eastern Cell Granular Cover	27,000	TONS	$ 29.00	$ 783,000	10.44 acres, 0.5-ft cover and 0.5-ft overplacement
Western Cell Protection						
9	Western Cell Cover					
	Rock Protection	990	TONS	$ 28.00	$ 28,000	40-Foot wide rock protection at top-of-slope
	Granular Cover	1,300	TONS	$ 26.00	$ 34,000	6-Inch layer of granular cover over slope
	Geotextile	5,350	SQ YD	$ 5.00	$ 27,000	Placed beneath granular cover on slope
	Vegetated Area Repair - Geotextile	2,670	SQ YD	$ 4.00	$ 11,000	Geotextile and granular cover over vegetated areas disturbed by operations
	Vegetated Area Repair - Granular Cover	790	TONS	$ 29.00	$ 23,000	Geotextile and granular cover over vegetated areas disturbed by operations
				Direct Construction Costs Subtotal	**$ 3,954,000**	
Non-Construction Costs						
10	Contingency			30%	$ 1,187,000	
11	Engineering Design	1	LS	$ 100,000	$ 100,000	
12	Construction Management			8%	$ 317,000	
13	Close Out & Documentation			0.50%	$ 20,000	
14	Regulatory Compliance Documentation	1	LS	$ 45,000	$ 45,000	
15	Environmental Monitoring	6.1	MO	$ 25,000	$ 152,000	
16	OM & M	1	LS	$ 61,000	$ 61,000	
				In-Direct Construction Costs Subtotal	**$ 1,882,000**	
				Total Option Costs	**$ 5,836,000**	

SAN JACINTO RIVER WASTE PIT - TIME CRITICAL REMEDIAL ACTION

COST ESTIMATE TABLE

Alternative 1: Rock Platform Construction, Composite Sheet Pile Wall at Historic Impound Limits along entire Site, Targeted Scour Protection, Granular Cover over Eastern and Western Cells

General Comments:

- This alternative includes the operations to complete the recommended Time Critical Remedial Action (TCRA). A vinyl sheetpile wall will be constructed around the perimeter of the cell. The wall will be driven through a rock platform constructed in the shallow water areas of the site to elevation +2-feet NAVD 88 to support land-based installation operations. Rock will be installed at the toe of the sheetpile wall in the deep water area of the site for scour protection. The eastern cell of the waste pit will be protected with a 2-foot layer of granular cover.
- Costs and quantities have been rounded off as appropriate.
- All costs have been provided in 2010 dollars and include material and labor unless otherwise noted. Unit costs are estimated using standard estimating guides (e.g., Means Site Work and Landscape Cost Data), vendors, professional judgment, and experience from similar projects.
- Costs do not include property costs (where applicable), access costs, legal fees, Agency oversight, or public relations efforts.
- These estimates are developed using current and generally accepted engineering cost estimation methods. Note that these estimates are based on assumptions concerning future events and actual costs may be affected by known and unknown risks including, but not limited to, changes in general economic and business conditions, site conditions that were unknown to Anchor QEA at the time the estimates were performed, future changes in site conditions, regulatory or enforcement policy changes, and delays in performance. Actual costs may vary from these estimates and such variations may be material. Anchor QEA is not licensed as accountants or securities attorneys and, therefore, make no representations that these costs form an appropriate basis for complying with financial reporting requirements for such costs.

Notes and Assumptions:

1. Mobilization and demobilization costs include all equipment mob/demob related costs. Includes construction of the site laydown/staging area.
2. Assumes repairing/improving approximately 1,600-feet of roadway at the site. Roadway will be 20-feet wide and will consist of 9-inches of processed concrete rubble. A geotextile layer will be placed beneath the constructed roadway.
3. Environmental control include floating access restriction and reinforced wire fencing construction to limit access to the site.
4. The contractor shall perform a minimum of 3 progress surveys throughout material placement operations. Survey specifications and requirements shall be in accordance with the contract documents.
5. An 18-foot wide rock platform will be constructed along the shallow water areas of the historic berm alignment. This platform will be used to provide access for the sheetpiling equipment and the steel sheeting will be driven through the center of the platform. The platform will be constructed to a minimum elevation of +2-feet NAVD 88 and will have 2H:1V side-slopes on the interior and exterior of the platform.
6. Assumes that a vinyl sheetpile wall will be constructed around the perimeter of the waste pit along the historic berm alignment. The sheetpile wall will be driven through the rock platform in the shallow water areas of the site and will be installed from a barge at water depths reaching up to 16-feet in the deep water area of the site. The sheetpile wall will be installed up to elevation +4-feet NAVD 88.
7. Assumes 12-foot high rock layer on both sides of the sheet pile wall at a 1.5H:1V slope; use bull rock on inside of wall and limestone/granite rock on outside of wall.
8. Granular cover for the eastern cell assumes 0.5 feet of material placed over the specified placement area of the eastern cell and extending into the northern area of the cell. Includes a 0.5 foot overplacement allowance.
9. The outer area of the western cell will be protected by placing a layer of rock along the top-of-slope and by placing a 0.5-foot cover layer over the slope. A geotextile will be placed beneath the cover layer. Assumes construction will disturb 0.5-acre of vegetation on the west cell; areas with disturbed vegetation will receive geotextile and 6-inch granular cover.

SAN JACINTO RIVER WASTE PIT - TIME CRITICAL REMEDIAL ACTION

COST ESTIMATE TABLE

Alternative 2: Rock Platform Construction, Eastern Cell Composite Sheet Pile Wall with Scour Protection to Historic Impound Limits, Granular Cover to Elevation -1 Inside Wall, Western Cell Control Berm and Shoreline Armoring, Dredging to Geobags in Northwestern Area

Item No.	Description	Estimated Quantity	Unit	Unit Price	Estimated Amount	Notes
Project Set Up						
1	Mobilization/Demobilization	1	LS	$ 390,000	$ 390,000	Includes dredging and sheet pile mob/demob costs
	Health & Safety	1	LS	$ 56,000	$ 56,000	Planning, staffing and implementation
	Quality Control	1	LS	$ 56,000	$ 56,000	Planning, staffing and implementation
2	Environmental Controls	1	LS	$ 172,000	$ 172,000	Maritime signage/fishing advisory markers, reinforced wire fencing, access gates, silt fencing, turbidity curtain
3	Access Road Construction	1	LS	$ 80,000	$ 80,000	
4	Survey Control and Material Placement Surveys	2	EA.	$ 4,000	$ 8,000	
Eastern Cell Protection						
5	Rock Platform	14,600	TONS	$ 28.00	$ 409,000	18-foot wide rock platform for land-based sheetpile wall installation
6	Sheetpile Wall Construction	48,300	SF	$ 17.00	$ 822,000	Vinyl sheetpile wall to be installed around the Eastern Cell along the Historic Impoundment Limits to elevation +4 NAVD 88
7	Rock Buttress and Scour Protection					
	Inner Wall Protection	2,040	TONS	$ 29.00	$ 60,000	Assumes bull rock 12-ft high inside wall at 1.5H:1V slope
	Outer Wall Protection	1,980	TONS	$ 70.00	$ 139,000	Assumes large limestone rock 12-ft high inside wall at 1.5H:1V slope
Eastern Cell Protection						
8	Granular Cover	21,700	TONS	$ 29.00	$ 630,000	8.4 acres, 0.5-ft cover and 0.5-ft overplacement
Western Cell Protection						
9	West Cell Berm	1,800	TONS	$ 28.00	$ 51,000	Rock berm from elevation 0 to +4 along existing western cell shoreline
10	Shoreline Armoring	4,700	TONS	$ 68.00	$ 320,000	0.72 acres. Assume 2.0-foot thick armor layer.
	Geotextile	3,840	SQ YD	$ 5.00	$ 20,000	Placed beneath shoreline armoring
11	Vegetated Area Repair - Geotextile	2,670	SQ YD	$ 4.00	$ 11,000	Geotextile and granular cover over vegetated areas disturbed by operations
12	Vegetated Area Repair - Granular Cover	790	TONS	$ 29.00	$ 23,000	Geotextile and granular cover over vegetated areas disturbed by operations
Dredging						
13	Hydraulic Dredging	4,700	CY	$ 7.00	$ 33,000	1.2 acres
14	Geobag Dewatering					
	Geotextile	6,210	SQ YD	$ 4.00	$ 25,000	Placed beneath bedding layer
	Bedding Layer	700	CY	$ 14.00	$ 10,000	4-inch bedding layer to protect geobag
	Purchase and Setup Bags	6	EA.	$ 16,500	$ 99,000	
	Maintenance	6	EA.	$ 2,000	$ 12,000	
				Direct Construction Costs Subtotal	**$ 3,426,000**	
Non-Construction Costs						
15	Contingency			30%	$ 1,028,000	
16	Engineering Design	1	LS	$ 100,000	$ 100,000	
17	Construction Management			8%	$ 274,000	
18	Close Out & Documentation			0.50%	$ 17,000	
19	Regulatory Compliance Documentation	1	LS	$ 45,000	$ 45,000	
20	Environmental Monitoring	4.9	MO	$ 25,000	$ 123,000	
21	OM & M	1	LS	$ 68,000	$ 68,000	
				In-Direct Construction Costs Subtotal	**$ 1,655,000**	
				Total Option Costs	**$ 5,081,000**	

SAN JACINTO RIVER WASTE PIT - TIME CRITICAL REMEDIAL ACTION

COST ESTIMATE TABLE

Alternative 2: Rock Platform Construction, Eastern Cell Composite Sheet Pile Wall with Scour Protection to Historic Impound Limits, Granular Cover to Elevation -1 Inside Wall, Western Cell Control Berm and Shoreline Armoring, Dredging to Geobags in Northwestern Area

General Comments:

- This alternative includes the operations to complete the recommended Time Critical Remedial Action (TCRA). A vinyl sheetpile wall will be constructed around the perimeter of the eastern cell to the Historical Impoundment Limits. The sheetpile wall will be driven through a rock platform constructed in the shallow water areas of the site to elevation +2-feet NAVD 88 to support land-based installation operations. Rock will be installed at the toe of the sheetpile wall in the deep water area of the site for scour protection. The control berm will be constructed to protect the existing shoreline of the western cell. Additional rock slope protection will be placed in the northwestern area of the site.
- Costs and quantities have been rounded off as appropriate.
- All costs have been provided in 2010 dollars and include material and labor unless otherwise noted. Unit costs are estimated using standard estimating guides (e.g., Means Site Work and Landscape Cost Data), vendors, professional judgment, and experience from similar projects.
- Costs do not include property costs (where applicable), access costs, legal fees, Agency oversight, or public relations efforts.
- These estimates are developed using current and generally accepted engineering cost estimation methods. Note that these estimates are based on assumptions concerning future events and actual costs may be affected by known and unknown risks including, but not limited to, changes in general economic and business conditions, site conditions that were unknown to Anchor QEA at the time the estimates were performed, future changes in site conditions, regulatory or enforcement policy changes, and delays in performance. Actual costs may vary from these estimates and such variations may be material. Anchor QEA is not licensed as accountants or securities attorneys and, therefore, make no representations that these costs form an appropriate basis for complying with financial reporting requirements for such costs.

Notes and Assumptions:

1. Mobilization and demobilization costs include all equipment mob/demob related costs. Includes construction of the site laydown/staging area.
2. Assumes repairing/improving approximately 1,600-feet of roadway at the site. Roadway will be 20-feet wide and will consist of 9-inches of processed concrete rubble. A geotextile layer will be placed beneath the constructed roadway.
3. Environmental control include floating access restriction and reinforced wire fencing construction to limit access to the site.
4. The contractor shall perform a minimum of 2 progress surveys throughout material placement operations. Survey specifications and requirements shall be in accordance with the contract documents.
5. An 18-foot wide rock platform will be constructed along the shallow water areas of the historic berm alignment around the eastern cell. This platform will be used to provide access for the sheetpiling equipment and the vinyl sheeting will be driven through the center of the platform. The platform will be constructed to a minimum elevation of +2-feet NAVD 88 and will have 2H:1V side-slopes on the interior and exterior of the platform.
6. Assumes that a vinyl sheetpile wall will be constructed around the perimeter of the waste pit along the historic berm alignment around the eastern cell. The sheetpile wall will be installed at water depths reaching up to 12-feet. The sheetpile wall will be installed up to elevation +4-feet NAVD 88.
7. Assumes 12-foot high rock layer on both sides of the sheet pile wall at a 1.5H:1V slope; use bull rock on inside of wall and limestone/granite rock on outside of wall.
8. Granular cover for the eastern cell assumes 0.5 feet of material placed over the specified placement area of the eastern cell and extending into the northern area of the cell. Includes a 0.5 foot overplacement allowance.
9. Western cell berm assumes a 8-foot crest width, 3 Horizontal:1 Vertical (3H:1V) slopes on the outer face and 2H:1V slopes on the inner face. The rock berm will be constructed so that the top-of-berm is at a minimum elevation of +4 NAVD 88. Assumes the rock berm will be constructed of 3- to 5-inch rock.
10. Additional rock protection will be installed on the slopes at the northwestern corner of the cell. The rock protection will be placed in a 2.5-foot thick layer over the area. A geotextile layer will be placed beneath the rock.

11, 12. Assumes construction will disturb 0.5-acre of vegetation on the west cell; areas with disturbed vegetation will receive geotextile and 6-inch granular cover.

13. Hydraulic dredging is anticipated to be conducted using a 6- to 8-inch diameter dredge. Dredging will be conducted 24 hours per day, 6 days per week and is estimated to operate at a 150 cy/hour production rate. Assumes 75% uptime.
14. Dredged material will be pumped directly in to geobags staged on the western cell of the waste pit. The dewatering area wil be covered with a geotextile layer, topped by a 4-inch bedding layer. It is anticipated that six 900-cubic yard geobags will be required to accommodate the total estimated dredge volume.

SAN JACINTO RIVER WASTE PIT - TIME CRITICAL REMEDIAL ACTION

COST ESTIMATE TABLE

Alternative 3: Granular Cover over Eastern Cell, Eastern Cell Clay Cover and Rock Cover Layers, Western Cell Control Berm, Granular Cover in Northwestern Area

Item No.	Description	Estimated Quantity	Unit	Unit Price	Estimated Amount	Notes
1	Mobilization/Demobilization	1	LS	$ 250,000	$ 250,000	
	Health & Safety	1	LS	$ 32,000	$ 32,000	Planning, staffing and implementation
	Quality Control	1	LS	$ 32,000	$ 32,000	Planning, staffing and implementation
2	Access Road Construction	1	LS	$ 80,000	$ 80,000	
3	Environmental Controls	1	LS	$ 172,000	$ 172,000	Maritime signage/fishing advisory markers, reinforced wire fencing, access gates, silt fencing, turbidity curtain
4	Perform 3 Material Placement Surveys	3	EA.	$ 4,000	$ 12,000	
Eastern Cell Protection						
5	Granular Cover	25,000	TONS	$ 29.00	$ 725,000	7.34 acres; includes area of thickened fill to Ele. -2 for Hydraulic Cutoff
6	Rock Cover	7,200	TONS	$ 68.00	$ 490,000	1.08 acres; includes area of thickened fill to Ele. -2 for Hydraulic Cutoff
	Geotextile	5,750	SQ YD	$ 5.00	$ 29,000	Placed beneath rock cover layer
Western Cell Protection						
7	West Cell Berm	1,800	TONS	$ 28.00	$ 51,000	Rock berm from elevation 0 to +4 along existing western cell shoreline
8	Shoreline Armoring	4,700	TONS	$ 68.00	$ 320,000	0.72 acres
	Geotextile	3,840	SQ YD	$ 5.00	$ 20,000	Placed beneath shoreline armoring
9	Vegetated Area Repair - Geotextile	2,670	SQ YD	$ 4.00	$ 11,000	Geotextile and granular cover over vegetated areas disturbed by operations
10	Vegetated Area Repair - Granular Cover	790	TONS	$ 29.00	$ 23,000	Geotextile and granular cover over vegetated areas disturbed by operations
Northwestern Area						
11	Granular Cover	3,300	TONS	$ 29.00	$ 96,000	1.2 acres
				Direct Construction Costs Subtotal	**$ 2,343,000**	
Non-Construction Costs						
12	Contingency			30%	$ 703,000	
13	Engineering Design	1	LS	$ 100,000	$ 100,000	
14	Construction Management			8%	$ 188,000	
15	Close Out & Documentation			0.50%	$ 12,000	
16	Regulatory Compliance Documentation	1	LS	$ 45,000	$ 45,000	
17	Environmental Monitoring	2.7	MO	$ 25,000	$ 68,000	
18	OM & M	1	LS	$ 97,000	$ 97,000	
				In-Direct Construction Costs Subtotal	**$ 1,213,000**	
				Total Option Costs	**$ 3,556,000**	

SAN JACINTO RIVER WASTE PIT - TIME CRITICAL REMEDIAL ACTION

COST ESTIMATE TABLE

Alternative 3: Granular Cover over Eastern Cell, Eastern Cell Clay Cover and Rock Cover Layers, Western Cell Control Berm, Granular Cover in Northwestern Area

General Comments:

- This alternative includes the operations to complete the recommended Time Critical Remedial Action (TCRA). The eastern cell of the waste pit will be covered with a granular layer designed to resist the anticipated erosional forces that will act upon the cell during the governing storm event flow. Along the perimeter of the sand/gravel layer placement, a 2-foot thick rock layer will be placed. At the northern extents of the site where water depths reach up to -18-ft, additional granular fill and rock protection will be placed to achieve an elevation of -2-ft for hydraulic cutoff of the deep channel. Additional rock slope protection will be placed in the northwestern corner of the cell.
- Costs and quantities have been rounded off as appropriate.
- All costs have been provided in 2010 dollars and include material and labor unless otherwise noted. Unit costs are estimated using standard estimating guides (e.g., Means Site Work and Landscape Cost Data), vendors, professional judgment, and experience from similar projects.
- Costs do not include property costs (where applicable), access costs, legal fees, Agency oversight, or public relations efforts.
- These estimates are developed using current and generally accepted engineering cost estimation methods. Note that these estimates are based on assumptions concerning future events and actual costs may be affected by known and unknown risks including, but not limited to, changes in general economic and business conditions, site conditions that were unknown to Anchor QEA at the time the estimates were performed, future changes in site conditions, regulatory or enforcement policy changes, and delays in performance. Actual costs may vary from these estimates and such variations may be material. Anchor QEA is not licensed as accountants or securities attorneys and, therefore, make no representations that these costs form an appropriate basis for complying with financial reporting requirements for such costs.

Notes and Assumptions:

1. Mobilization and demobilization costs include all equipment mob/demob related costs. Includes construction of the site laydown/staging area.
2. Assumes repairing/improving approximately 1,600-feet of roadway at the site. Roadway will be 20-feet wide and will consist of 9-inches of processed concrete rubble. A geotextile layer will be placed beneath the constructed roadway.
3. Environmental control include floating access restriction and reinforced wire fencing construction to limit access to the site.
4. The contractor shall perform a minimum of 3 progress surveys throughout material placement operations. Survey specifications and requirements shall be in accordance with the contract documents.
5. Granular cover for the eastern cell assumes 0.5 feet of material placed over the specified placement area. Includes a 0.5 foot overplacement allowance.
6. Assumes a 2-foot thick rock cover placed over a 1.08-acre on the outer-most region of the eastern cell. A geotextile layer will be placed beneath the rock cover.
7. Western cell berm assumes a 8-foot crest width, 3 Horizontal:1 Vertical (3H:1V) slopes on the outer face and 2H:1V slopes on the inner face. The rock berm will be constructed so that the top-of-berm is at a minimum elevation of +4 NAVD 88. Assumes the rock berm will be constructed of 3- to 5-inch rock. Assumes a conversion factor of 1.9 tons/cubic yard.
8. Assumes placement of a 2.5-foot thick rock armor layer over the entire 0.72-acre shoreline armoring area adjacent to the western cell. A geotextile layer will be placed beneath the rock.

9, 10. Assumes construction will disturb 0.5-acre of vegetation on the west cell; areas with disturbed vegetation will receive geotextile and 6-inch granular cover.

11. Additional cover will be installed on the slopes at the northwestern corner of the cell. The granular cover layer will cover from +1 NAVD 88 to -14 NAVD 88. The granular cover will be 0.5-feet thick with a 0.5-foot allowable overplacement.

SAN JACINTO RIVER WASTE PIT - TIME CRITICAL REMEDIAL ACTION

COST ESTIMATE TABLE

Alternative 4: Granular Cover over Eastern Cell, Eastern Cell Earth Berm and Rock Berm to Elevation +1, Western Cell Control Berm and Shoreline Armoring, Granular Cover in Northwestern Area

Item No.	Description	Estimated Quantity	Unit	Unit Price	Estimated Amount	Notes
1	Mobilization/Demobilization	1	LS	$ 280,000	$ 280,000	
	Health & Safety	1	LS	$ 31,000	$ 31,000	Planning, staffing and implementation
	Quality Control	1	LS	$ 31,000	$ 31,000	Planning, staffing and implementation
2	Access Road Construction	1	LS	$ 80,000	$ 80,000	
3	Environmental Controls	1	LS	$ 172,000	$ 172,000	Maritime signage/fishing advisory markers, reinforced wire fencing, access gates, silt fencing, turbidity curtain
4	Survey Control and Material Placement Surveys	3	EA.	$ 4,000	$ 12,000	
Eastern Cell Protection						
5	Granular Cover	22,600	TONS	$ 29.00	$ 656,000	7.34 acres; 0.5-ft cover and 0.5-ft overplacement
6	TCRA Rock Berm	12,600	TONS	$ 68.00	$ 857,000	1.08 acres; rock berm to be constructed to elevation +1 NAVD 88
	Geotextile	6,260	SQ YD	$ 5.00	$ 32,000	Placed beneath TCRA rock berm
Western Cell Protection						
7	West Cell Berm	1,800	TONS	$ 28.00	$ 51,000	Rock berm from elevation 0 to +4 along existing western cell shoreline
8	Shoreline Armoring	4,700	TONS	$ 68.00	$ 320,000	0.72 acres
	Geotextile	3,840	SQ YD	$ 5.00	$ 20,000	Placed beneath shoreline armoring
9	Vegetated Area Repair - Geotextile	2,670	SQ YD	$ 4.00	$ 11,000	Geotextile and granular cover over vegetated areas disturbed by operations
10	Vegetated Area Repair - Granular Cover	790	TONS	$ 29.00	$ 23,000	Geotextile and granular cover over vegetated areas disturbed by operations
Northwestern Area						
11	Granular Cover	3,300	TONS	$ 29.00	$ 96,000	1.2 acres
				Direct Construction Costs Subtotal	**$ 2,672,000**	
Non-Construction Costs						
12	Contingency			30%	$ 802,000	
13	Engineering Design	1	LS	$ 100,000	$ 100,000	
14	Construction Management			8%	$ 214,000	
15	Close Out & Documentation			0.50%	$ 14,000	
16	Regulatory Compliance Documentation	1	LS	$ 45,000	$ 45,000	
17	Environmental Monitoring	2.6	MO	$ 25,000	$ 66,000	
18	OM & M	1	LS	$ 110,000	$ 110,000	
				In-Direct Construction Costs Subtotal	**$ 1,351,000**	
				Total Option Costs	**$ 4,023,000**	

SAN JACINTO RIVER WASTE PIT - TIME CRITICAL REMEDIAL ACTION

COST ESTIMATE TABLE

Alternative 4: Granular Cover over Eastern Cell, Eastern Cell Earth Berm and Rock Berm to Elevation +1, Western Cell Control Berm and Shoreline Armoring, Granular Cover in Northwestern Area

General Comments:

- This alternative includes the operations to complete the recommended Time Critical Remedial Action (TCRA). A rock berm will be constructed around the perimeter of the eastern cell. Additional rock slope protection will be placed in the northwestern corner of the cell. The eastern cell of the waste pit will be covered with a granular layer designed to resist the anticipated erosional forces that will act upon the cell during the governing storm event flow.
- Costs and quantities have been rounded off as appropriate.
- All costs have been provided in 2010 dollars and include material and labor unless otherwise noted. Unit costs are estimated using standard estimating guides (e.g., Means Site Work and Landscape Cost Data), vendors, professional judgment, and experience from similar projects.
- Costs do not include property costs (where applicable), access costs, legal fees, Agency oversight, or public relations efforts.
- These estimates are developed using current and generally accepted engineering cost estimation methods. Note that these estimates are based on assumptions concerning future events and actual costs may be affected by known and unknown risks including, but not limited to, changes in general economic and business conditions, site conditions that were unknown to Anchor QEA at the time the estimates were performed, future changes in site conditions, regulatory or enforcement policy changes, and delays in performance. Actual costs may vary from these estimates and such variations may be material. Anchor QEA is not licensed as accountants or securities attorneys and, therefore, make no representations that these costs form an appropriate basis for complying with financial reporting requirements for such costs.

Notes and Assumptions:

1. Mobilization and demobilization costs include all equipment mob/demob related costs. Includes construction of the site laydown/staging area.
2. Assumes repairing/improving approximately 1,600-feet of roadway at the site. Roadway will be 20-feet wide and will consist of 9-inches of processed concrete rubble. A geotextile layer will be placed beneath the constructed roadway.
3. Environmental control include floating access restriction and reinforced wire fencing construction to limit access to the site.
4. The contractor shall perform a minimum of 3 progress surveys throughout material placement operations. Survey specifications and requirements shall be in accordance with the contract documents.
5. Granular cover for the eastern cell assumes 0.5 feet of material placed over the specified placement area. Includes a 0.5 foot overplacement allowance.
6. TCRA rock berms assumes a 10-foot crest width, 3 Horizontal:1 Vertical (3H:1V) slopes on the outer face and 2H:1V slopes on the inner face. The rock berm will be constructed so that the top-of-berm is at a minimum elevation of +1 NAVD 88. Assumes the rock berm will be constructed of 3- to 5-inch rock. Assumes a conversion factor of 1.9 tons/cubic yard. A geotextile layer will be placed beneath the rock berm.
7. Western cell berm assumes a 8-foot crest width, 3 Horizontal:1 Vertical (3H:1V) slopes on the outer face and 2H:1V slopes on the inner face. The rock berm will be constructed so that the top-of-berm is at a minimum elevation of +4 NAVD 88. Assumes the rock berm will be constructed of 3- to 5-inch rock. Assumes a conversion factor of 1.9 tons/cubic yard.
8. Assumes placement of a 2.5-foot thick rock armor layer over the entire 0.72-acre shoreline armoring area adjacent to the western cell. A geotextile layer will be placed beneath the rock.

9, 10. Assumes construction will disturb 0.5-acre of vegetation on the west cell; areas with disturbed vegetation will receive geotextile and 6-inch granular cover.

11. Additional cover will be installed on the slopes at the northwestern corner of the cell. The granular cover layer will cover from +1 NAVD 88 to -14 NAVD 88. The granular cover will be 0.5-feet thick with a 0.5-foot allowable overplacement.

SAN JACINTO RIVER WASTE PIT - TIME CRITICAL REMEDIAL ACTION

COST ESTIMATE TABLE

Alternative 5: Western Cell Control Berm, ACBM Cover over entire Eastern Cell and Shoreline of Western Cell, Dredging to Geobags in Northwestern Area

Item No.	Description	Estimated Quantity	Unit	Unit Price	Estimated Amount	Notes
1	Mobilization/Demobilization	1	LS	$ 575,000	$ 575,000	Includes dredging mob/demob costs
	Health & Safety	1	LS	$ 31,000	$ 31,000	Planning, staffing and implementation
	Quality Control	1	LS	$ 31,000	$ 31,000	Planning, staffing and implementation
2	Access Road Construction	1	LS	$ 80,000	$ 80,000	
3	Environmental Controls	1	LS	$ 172,000	$ 172,000	Maritime signage/fishing advisory markers, reinforced wire fencing, access gates, silt fencing, turbidity curtain
4	Perform 3 Material Placement Surveys	3	EA.	$ 4,000	$ 12,000	
Eastern Cell Protection						
5	ACBM Placement over Eastern Cell	369,400	SF	$ 8.00	$ 2,956,000	8.48 acres
Western Cell Protection						
6	West Cell Berm	1,800	TONS	$ 28.00	$ 51,000	Rock berm from elevation 0 to +4 along existing western cell shoreline
7	ACBM Shoreline Armoring	31,400	SF	$ 8.00	$ 252,000	0.72 acres
8	Vegetated Area Repair - Geotextile	2,670	SQ YD	$ 4.00	$ 11,000	Geotextile and granular cover over vegetated areas disturbed by operations
9	Vegetated Area Repair - Granular Cover	790	TONS	$ 29.00	$ 23,000	Geotextile and granular cover over vegetated areas disturbed by operations
Scour Protection Apron						
10	Scour Protection	5,100	TONS	$ 70.00	$ 357,000	Assumes 15-foot wide scour protection apron at toe of ACBM
Dredging						
11	Hydraulic Dredging	4,700	CY	$ 7.00	$ 33,000	1.2 acres
12	Geobag Dewatering					
	Geotextile	6,210	SQ YD	$ 4	$ 25,000	Placed beneath the bedding layer
	Bedding Layer	700	CY	$ 14	$ 10,000	4-inch bedding layer to protect geobag
	Purchase and Setup Bags	6	EA.	$ 16,500	$ 99,000	
	Maintenance	6	EA.	$ 2,000	$ 12,000	
				Direct Construction Costs Subtotal	**$ 4,730,000**	
Non-Construction Costs						
13	Contingency			30%	$ 1,419,000	
14	Engineering Design	1	LS	$ 100,000	$ 100,000	
15	Construction Management			8%	$ 379,000	
16	Close Out & Documentation			0.50%	$ 24,000	
17	Regulatory Compliance Documentation	1	LS	$ 45,000	$ 45,000	
18	Environmental Monitoring	2.6	MO	$ 25,000	$ 65,000	
19	OM & M	1	LS	$ 181,000	$ 181,000	
				In-Direct Construction Costs Subtotal	**$ 2,213,000**	
				Total Option Costs	**$ 6,943,000**	

SAN JACINTO RIVER WASTE PIT - TIME CRITICAL REMEDIAL ACTION

COST ESTIMATE TABLE

Alternative 5: Western Cell Control Berm, ACBM Cover over entire Eastern Cell and Shoreline of Western Cell, Dredging to Geobags in Northwestern Area

General Comments:

- This alternative includes the operations to complete the recommended Time Critical Remedial Action (TCRA). ACBM will be placed over the entirety of the eastern cell to the Historical Impoundment Limits and along the shoreline of the western cell to protect the western cell control berm. The control berm will be constructed to protect the existing shoreline of the western cell. Additional rock slope protection will be placed in the northwestern area of the site.
- Costs and quantities have been rounded off as appropriate.
- All costs have been provided in 2010 dollars and include material and labor unless otherwise noted. Unit costs are estimated using standard estimating guides (e.g., Means Site Work and Landscape Cost Data), vendors, professional judgment, and experience from similar projects.
- Costs do not include property costs (where applicable), access costs, legal fees, Agency oversight, or public relations efforts.
- These estimates are developed using current and generally accepted engineering cost estimation methods. Note that these estimates are based on assumptions concerning future events and actual costs may be affected by known and unknown risks including, but not limited to, changes in general economic and business conditions, site conditions that were unknown to Anchor QEA at the time the estimates were performed, future changes in site conditions, regulatory or enforcement policy changes, and delays in performance. Actual costs may vary from these estimates and such variations may be material. Anchor QEA is not licensed as accountants or securities attorneys and, therefore, make no representations that these costs form an appropriate basis for complying with financial reporting requirements for such costs.

Notes and Assumptions:

1. Mobilization and demobilization costs include all equipment mob/demob related costs. Includes construction of the site laydown/staging area.
2. Assumes repairing/improving approximately 1,600-feet of roadway at the site. Roadway will be 20-feet wide and will consist of 9-inches of processed concrete rubble. A geotextile layer will be placed beneath the constructed roadway.
3. Environmental control include floating access restriction and reinforced wire fencing construction to limit access to the site.
4. Assumes ACBM placement over a 8.48-acrea area of the eastern cell and northern portion of the site.
5. Western cell berm assumes a 8-foot crest width, 3 Horizontal:1 Vertical (3H:1V) slopes on the outer face and 2H:1V slopes on the inner face. The rock berm will be constructed so that the top-of-berm is at a minimum elevation of +4 NAVD 88. Assumes the rock berm will be constructed of 3- to 5-inch rock. Assumes a conversion factor of 1.9 tons/cubic yard.
6. Assumes placement of ACBM over the entire 0.72-acre shoreline armoring area adjacent to the western cell.

7, 8. Assumes construction will disturb 0.5-acre of vegetation on the west cell; areas with disturbed vegetation will receive geotextile and 6-inch granular cover.

9. Assumes a 15-foot wide scour protection apron placed at the toe of slope of the ACBM placement .
10. The contractor shall perform a minimum of 3 progress surveys throughout material placement operations. Survey specifications and requirements shall be in accordance with the contract documents.
11. Hydraulic dredging is anticipated to be conducted using a 6- to 8-inch diameter dredge. Dredging will be conducted 24 hours per day, 6 days per week and is estimated to operate at a 150 cy/hour production rate. Assumes 75% uptime.
12. Dredged material will be pumped directly in to geobags staged on the western cell of the waste pit. The dewatering area wil be covered with a geotextile layer, topped by a 4-inch bedding layer. It is anticipated that six 900-cubic yard geobags will be required to accommodate the total estimated dredge volume.

QUANTITITES COMMON TO ALL ALTERNATIVES

Item 2 Access Road Construction

Key Assumptions:

Construct an all weather Access Road from the Big Star Property to the site.

Consists of three items:

1. 9-inch thick surface course (processed concrete rubble)
2. geotextile fabric underlayment
3. equipment and labor costs to install geotextile and surface course

Surface Course Volume:	Dimension	Unit
length of improved area for road	1600	FT
width of improved area for road	20	FT
width of laydown area	20	FT
length of laydown area	20	FT
thickness of surface course (processed concrete rubble)	0.75	FT
volume of surface course material	900	CY

Surface Course Weight:		
conversion to tons from Southern Crushed Conc.	2	Ton/CY
surface course	1800	Tons

Geotextile:		
length of improved area for road	1600	FT
width of improved area for road	20	FT
width of laydown area	20	FT
length of laydown area	20	FT
geotextile fabric underlayment	3600	SY

Equipment and Labor:

Labor	Hours	Rate	Total
Superintendent	40	$30	$1,200
Equipment Operators	100	$32	$3,200
Laborers	40	$15	$600
			$5,000
	Fringes	55%	$2,750
	Home OH	2%	$200
		Labor Subtotal:	$7,950
Equipment			
Truck	40	$50	$2,000
Dozer	50	$80	$4,000
Excavator	50	$120	$6,000
Mob via truck to site	2	$1,500	$3,000
		Equipment Subtotal:	$15,000

Labor and Equipment Subtotal:		$22,950
Labor and Equipment Overhead:	12%	$2,800
Labor and Equipment Total:		$25,750
Access Road Profit Margin:		10%

ALTERNATIVE 1 QUANTITIES

Item 4 Perform Material Placement Surveys

Material placement surveys to verify material quantities	3	

Item 5 Rock Platform

Key Assumptions:

18 foot wide berm at crest
Top elevation +2 feet
2H:1V side slopes
Assumed 6 inches of consolidation during construction
Berm needed in shallow waters only (2,000 feet total berm length, of which 1,250 feet are in shallow water at southern portion of sheet pile wall)

Volume:

Length of Rock Platform	1,250	FT
Width of Rock Platform at Crest	18	FT
Bottom of Platform Elev. (NAVD 88)	-4	FT
Top of Platform Elev. (NAVD 88)	2	FT
Side Slopes (XH:1V)	2	
Volume of Rock	225,000	CU FT
Volume of Rock	8,333	CY

Weight:

Assumed unit weight of rock	1.9	TON/CY
Weight of Rock	15,900	TON

Item 6 Sheetpile Wall

Key Assumptions:

Shallow water sheet pile top elevation:	4	FT
Shallow water sheet pile tip elevation:	-20	FT
Shallow water sheet pile length :	24	FT
Shallow water length of piling:	1,250	FT
Shallow water sheet pile area:	30,000	SQ FT
Deep water sheet pile top elevation:	4	FT
Deep water sheet pile tip elevation:	-56	FT
Deep water sheet pile length:	60	FT
Deep water length of piling:	750	FT
Deep water sheet pile area:	45,000	SQ FT
Contingency for sheet pile length pending design:	15%	
Sheet pile area	86,250	SQ FT

ALTERNATIVE 1 QUANTITIES

Item 7 Rock Buttress and Scour Protection

Key Assumptions:

Use 3" x 5" bull rock (crushed concrete) as scour protection on inside of sheet pile wall

Use large rock (limestone/granite rock) on outside of sheet pile wall

Length of scour protection area	750	FT
Height of scour protection area	12	FT
Width of scour proection area (assume 1.5H:1V)	18	FT

Volume:

Volume on each side of wall	3,000	CY

Weight:

Assumed Unit Weight, inside of wall	1.7	TONS/CY
Total Weight, inside of wall	5,100	TONS
Assumed Unit Weight, outside of wall	1.65	TONS/CY
Total Weight, outside of wall	4,950	TONS

Item 8 Eastern Cell Granular Cover

Key Assumptions:

Layer thickness of granular material	0.5	FT
Overplacement allowance	0.5	FT
Area of granular material placement	10.44	ACRE

Volume:

Area of granular material placement	454,766	SQ FT
Volume of granular material (not including overplacement)	8,430	CY
Volume of granular material (including overplacement)	16,850	CY

Weight:

Assumed unit weight of granular protection material	1.6	TONS/CY
Tons of granular material	27,000	TONS

ALTERNATIVE 1 QUANTITIES

Item 9 Western Cell Cover
Rock Protection

Key Assumptions:		
Layer Thickness	1.0	FT
Width	40	FT
Length	350	FT
Volume:		
Rock Protection	519	CY
Weight:		
Assumed Unit Weight	1.9	TONS/CY
Total Weight	990	TONS

Granular Cover

Key Assumptions:		
Layer Thickness	0.5	FT
Width	125	FT
Length	350	FT
Geotextile (Includes 10% overlapping factor)	5,350	SQ YD
Volume:		
Rock Protection	810	CY
Weight:		
Assumed Unit Weight	1.6	TONS/CY
Total Weight	1,300	TONS

Vegetated Area Repair

Key Assumptions:		
Disturbed areas will receive geotextile placement and granular cover.		
Area disturbed by operations requiring repair	0.5	ACRE
Thickness of granular cover	0.5	FT
Geotextile Area:		
Disturbed area	21,780	SQ FT
Overplacement	10%	
Geotextile	23,958	SQ FT
Geotextile	2,670	SQ YD
Granular Cover		
Volume:		
Granular Cover	403	CY
Overplacement and loss of materials	20%	
Granular Cover	490	CY
Weight:		
Assumed Unit Weight	1.6	TONS/CY
Total Weight	790	TONS

ALTERNATIVE 2 QUANTITIES

Item 4 Perform Material Placement Surveys

Material placement surveys to verify material quantities	2	

Item 5 Rock Platform

Key Assumptions:

18 foot wide berm at crest
Top elevation +2 feet
2H:1V side slopes
Assumed 6 inches of consolidation during construction
Berm needed in shallow waters only (2,000 feet total berm length, of which 1,250 feet are in shallow water at southern portion of sheet pile wall)

Volume:

Length of Rock Platform	1,150	FT
Width of Rock Platform at Crest	18	FT
Bottom of Platform Elev. (NAVD 88)	-4	FT
Top of Platform Elev. (NAVD 88)	2	FT
Side Slopes (XH:1V)	2	
Volume of Rock	207,000	CU FT
Volume of Rock	7,667	CY

Weight:

Assumed unit weight of rock	1.9	TON/CY
Weight of Rock	14,600	TON

Item 6 Sheetpile Wall

Key Assumptions:

Shallow water sheet pile top elevation:	4	FT
Shallow water sheet pile tip elevation:	-20	FT
Shallow water sheet pile length :	24	FT
Shallow water length of piling:	1,150	FT
Shallow water sheet pile area:	27,600	SQ FT
Deep water sheet pile top elevation:	4	FT
Deep water sheet pile tip elevation:	-44	FT
Deep water sheet pile length:	48	FT
Deep water length of piling:	300	FT
Deep water sheet pile area:	14,400	SQ FT
Contingency for sheet pile length pending design:	15%	
Sheet pile area	48,300	SQ FT

ALTERNATIVE 2 QUANTITIES

Item 7 Rock Buttress and Scour Protection

Key Assumptions:

Use 3" x 5" bull rock (crushed concrete) as scour protection on inside of sheet pile wall
Use large rock (limestone/granite rock) on outside of sheet pile wall

Length of scour protection area	300	FT
Height of scour protection area	12	FT
Width of scour proection area (assume 1.5H:1V)	18	FT

Volume:

Volume on each side of wall	1,200	CY

Weight:

Assumed Unit Weight, inside of wall	1.7	TONS/CY
Total Weight, inside of wall	2,040	TONS
Assumed Unit Weight, outside of wall	1.7	TONS/CY
Total Weight, outside of wall	1,980	TONS

Item 8 Eastern Cell Granular Cover

Key Assumptions:

Layer thickness of granular material	0.5	FT
Overplacement Allowance	0.5	FT
Area of granular material placement	8.40	ACRE

Volume:

Area of granular material placement	365,904	SQ FT
Volume of granular material (not including overplacement)	6,780	CY
Volume of granular material (including overplacement)	13,560	CY

Weight:

Assumed unit weight of granular protection material	1.6	TONS/CY
Tons of granular material	21,700	TONS

Item 9 Western Cell Berm

Key Assumptions

Exterior Slope (XH:1V)	3	
Interior Slope (XH:1V)	2	
Bottom of berm elevation	0	FT
Top of berm elevation	4	FT
Width of berm at crest	8	FT
Length of berm	350	FT

Volume:

Berm Volume per linear foot	72	CU FT
Berm Volume	933	CY

Weight:

Assumed unit weight of granular protection material	1.9	TON/CY
Tons of material	1,800	

Item 10 Shoreline Armoring

Key Assumptions

Layer thickness	2.0	FT
West cell shoreline armoring area	0.72	ACRE
Geotextile (Includes 10% overlapping factor)	3,840	SQ YD

Volume:

Overplacement and loss of armoring materials	20%	
West cell shoreline armoring area	31,363	SQ FT
West cell volume (not including overplacement)	2,330	CY
West cell volume (including overplacement)	2,800	CY

Weight:

Assumed unit weight of granular protection material	1.65	TON/CY
Tons of granular protection material	4,700	TON

ALTERNATIVE 2 QUANTITIES

Items 11 and 12 - Vegetated Area Repair

Key Assumptions:

Disturbed areas will receive geotextile placement and granular cover.		
Area disturbed by operations requiring repair	0.5	ACRE
Thickness of granular cover	0.5	FT

Geotextile Area:

Disturbed area	21,780	SQ FT
Overplacement	10%	
Geotextile	23,958	SQ FT
Geotextile	2,670	SQ YD

Granular Cover:

Volume:

Granular Cover	403	CY
Overplacement and loss of materials	20%	
Granular Cover	490	CY

Weight:

Assumed Unit Weight	1.6	TONS/CY
Total Weight	790	TONS

Item 13 Hydraulic Dredging

Key Assumptions

Dredge Area	1.2	ACRE
Dredge cut depth	1.5	FT
Overdredging allowance	0.5	FT
Dredge bulking factor	20%	

Volume:

Dredge volume (not including bulking factor)	3,872
Dredge volume	4,700

Item 14 Geobag Dewatering

Key Assumptions

900-Cubic yard geobag capacity		
Dewatering Area (Hand calculation)	50,772	SF
Thickness of Bedding Layer	0.33	FT
Volume of Bedding Layer	700	CY
Geotextile (Includes 10% overlapping factor)	6,210	SQ YD

# of Geotextile Tubes

Geobags required	6

ALTERNATIVE 3 QUANTITIES

Item 4 Perform Material Placement Surveys

Material placement surveys to verify material quantities	3	

Item 5 Eastern Cell Granular Cover

Key Assumptions:

Layer thickness of granular material	0.5	FT
Overplacement Allowance	0.5	FT
Area of granular material placement	7.34	ACRE
Overplacement and loss of materials	20%	
Additional volume is required for deep water area to bring elevation to -2 feet to construct remainder of cover		
Original bottom of deep water area	-9	FT
Top elev. of deep water area to begin layer	-4	FT
Deep water area requiring additional fill	6,720	SQ FT

Volume:

Area of granular material placement	319,730	SQ FT
Volume for thickened fill area prior to 0.5-ft cover	1,250	CY
Volume of granular material for 0.5-ft cover (no overplacement)	5,930	CY
Volume of granular material (no overplacement)	7,180	CY
Volume of granular material (including overplacement)	13,110	CY

Weight:

Assumed unit weight of granular protection material	1.9	TONS/CY
Tons of granular material	25,000	TONS

Item 6 Eastern Cell Rock Cover

Key Assumptions:

Layer thickness of rock cover	2.0	FT
Area of rock material placement	1.1	ACRE
Additional volume is required for deep water area to bring elevation to -2 feet to construct remainder of earth cover		
Original bottom of deep water area	-9	FT
Top elev. of deep water area to begin earthen layer	-4	FT
Deep water area requiring additional fill	4,480	SQ FT
Geotextile Layer (Includes 10% overlapping factor)	5,750	SQ YD

Volume:

2-foot cover volume	3,490	CY
additional volume to -2 feet	830	CY
total cover volume	4,320	CY

Weight:

Assumed unit weight of rock cover material	1.65	TON/CY
Tons of material:	7,200	TON

ALTERNATIVE 3 QUANTITIES

Item 7 Western Cell Berm

Key Assumptions		
Exterior Slope (XH:1V)	3	
Interior Slope (XH:1V)	2	
Bottom of berm elevation	0	FT
Top of berm elevation	4	FT
Width of berm at crest	8	FT
Length of berm	350	FT
Volume:		
Berm Volume per linear foot	72	CU FT
Berm Volume	933	CY
Weight:		
Assumed unit weight of material	1.9	TON/CY
Tons of material	1,800	TON

Item 8 Shoreline Armoring

Key Assumptions		
Layer thickness	2.0	FT
West cell shoreline armoring area	0.72	ACRE
Geotextile (Includes 10% overlapping factor)	3,840	SQ YD
Volume:		
Overplacement and loss of materials	20%	
West cell shoreline armoring area	31,363	SQ FT
West cell volume (not including overplacement)	2,330	CY
West cell volume (including overplacement)	2,800	CY
Weight:		
Assumed unit weight of material	1.65	TON/CY
Tons of material	4,700	TON

Items 9 and 10 - Vegetated Area Repair

Key Assumptions:		
Disturbed areas will receive geotextile placement and granular cover.		
Area disturbed by operations requiring repair	0.5	ACRE
Thickness of granular cover	0.5	FT
Geotextile Area:		
Disturbed area	21,780	SQ FT
Overplacement	10%	
Geotextile	23,958	SQ FT
Geotextile (Includes 10% overlapping factor)	2,670	SQ YD
Granular Cover:		
Volume:		
Granular Cover	403	CY
Overplacement and loss of materials	20%	
Granular Cover	490	CY
Weight:		
Assumed Unit Weight	1.6	TONS/CY
Total Weight	790	TONS

Item 11 Northwestern Area Granular Cover

Key Assumptions:		
Layer thickness	0.5	FT
Overplacement Allowance	0.5	FT
Northwestern rock cover area size	1.2	ACRE
Volume:		
Northwestern rock cover area	1,936	CY
Weight:		
Assumed unit weight of material	1.7	TON/CY
Tons of material:	3,300	TON

ALTERNATIVE 4 QUANTITIES

Item 4 Perform Material Placement Surveys

Material placement surveys to verify material quantities	3	

Item 5 Eastern Cell Granular Cover

Key Assumptions:		
Layer thickness of granular material	0.5	FT
Overplacement Allowance	0.5	FT
Area of granular material placement	7.34	ACRE
Volume:		
Area of granular material placement	319,730	SQ FT
Volume of granular material (not including overplacement)	5,930	CY
Volume of granular material (including overplacement)	11,850	CY
Weight:		
Assumed unit weight of granular protection material	1.9	TONS/CY
Tons of granular material	22,600	TONS

Item 6A TCRA Rock Berm

Key Assumptions		
Exterior Slope (XH:1V)	3	
Interior Slope (XH:1V)	2	
Bottom of berm elevation	-4	FT
Top of berm elevation	1	FT
Width of berm at crest	8	FT
Length of berm	1,550	FT
Geotextile (Includes 10% overlapping factor)	6,260	SQ YD
Volume:		
Berm Volume per linear foot	103	CU FT
Berm Volume	5,884	CY
Weight:		
Assumed unit weight of material	1.65	TON/CY
Tons of material	9,800	

Item 6B TCRA Rock Berm

Key Assumptions:		
Additional volume is required for deep water area to bring elevation to -4 feet to construct remainder of rock berm		
Exterior Slope (XH:1V)	3	
Interior Slope (XH:1V)	2	
Original bottom of deep water area	-9	FT
Top elev. of deep water area to begin rock berm	-4	FT
Length of deep water portion of berm	300	FT
Volume:		
Width of deep water portion of berm at crest	33	FT
Deep water berm volume per linear foot	228	CU FT
Deep water berm volume	1,685	CY
Weight:		
Assumed unit weight of material	1.65	TON/CY
Tons of material	2,800	

ALTERNATIVE 4 QUANTITIES

Item 7 Western Cell Berm

Key Assumptions		
Exterior Slope (XH:1V)	3	
Interior Slope (XH:1V)	2	
Bottom of berm elevation	0	FT
Top of berm elevation	4	FT
Width of berm at crest	8	FT
Length of berm	350	FT
Volume:		
Berm Volume per linear foot	72	CU FT
Berm Volume	933	CY
Weight:		
Assumed unit weight of material	1.9	TON/CY
Tons of material	1,800	TON

Item 8 Shoreline Armoring

Key Assumptions		
Layer thickness	2.0	FT
West cell shoreline armoring area	0.72	ACRE
Geotextile (Includes 10% overlapping factor)	3,840	SQ YD
Volume:		
Overplacement and loss of materials	20%	
West cell shoreline armoring area	31,363	SQ FT
West cell volume (not including overplacement)	2,330	CY
West cell volume (including overplacement)	2,800	CY
Weight:		
Assumed unit weight of material	1.65	TON/CY
Tons of material	4,700	TON

Items 9 and 10 - Vegetated Area Repair

Key Assumptions:		
Disturbed areas will receive geotextile placement and granular cover.		
Area disturbed by operations requiring repair	0.5	ACRE
Thickness of granular cover	0.5	FT
Geotextile Area:		
Disturbed area	21,780	SQ FT
Overplacement	10%	
Geotextile	23,958	SQ FT
Geotextile	2,670	SQ YD
Granular Cover:		
Volume:		
Granular Cover	403	CY
Overplacement and loss of materials	20%	
Granular Cover	490	CY
Weight:		
Assumed Unit Weight	1.6	TONS/CY
Total Weight	790	TONS

Item 11 Northwestern Area Granular Cover

Key Assumptions:		
Layer thickness	0.5	FT
Overplacement Allowance	0.5	FT
Northwestern rock cover area size	1.2	ACRE
Volume:		
Northwestern rock cover area	1,936	CY
Weight:		
Assumed unit weight of material	1.7	TON/CY
Tons of material:	3,300	TON

ALTERNATIVE 5 QUANTITIES

Item 4 Perform Material Placement Surveys

Material placement surveys to verify material quantities	3	

Item 5 ACBM Placement over Eastern Cell

Key Assumptions:		
Area of ACBMplacement	8.5	ACRE
Volume:		
Area of ACBM placement	369,400	SQ FT

Item 6 Western Cell Berm

Key Assumptions		
Exterior Slope (XH:1V)	3	
Interior Slope (XH:1V)	2	
Bottom of berm elevation	0	FT
Top of berm elevation	4	FT
Width of berm at crest	8	FT
Length of berm	350	FT
Volume:		
Berm Volume per linear foot	72	CU FT
Berm Volume	933	CY
Weight:		
Assumed unit weight of material	1.9	TON/CY
Tons of material	1,800	TON

Item 7 ACBM Shoreline Armoring - West Cell

Key Assumptions:		
Area of ACBMplacement	0.7	ACRE
Volume:		
Area of ACBM placement	31,400	SQ FT

Items 8 and 9 - Vegetated Area Repair

Key Assumptions:		
Disturbed areas will receive geotextile placement and granular cover.		
Area disturbed by operations requiring repair	0.5	ACRE
Thickness of granular cover	0.5	FT
Geotextile Area:		
Disturbed area	21,780	SQ FT
Overplacement	10%	
Geotextile	23,958	SQ FT
Geotextile	2,670	SQ YD
Granular Cover:		
Volume:		
Granular Cover	403	CY
Overplacement and loss of materials	20%	
Granular Cover	490	CY
Weight:		
Assumed Unit Weight	1.6	TONS/CY
Total Weight	790	TONS

ALTERNATIVE 5 QUANTITIES

Item 10 Scour Protection

Key Assumptions:

Assumes 15-foot wide scour protection apron at toe of ACBM		
Layer thickness of scour protection	3.0	FT
Length of affected slope	1,854	FT
Placement width	15	FT
Volume:		
Area of scour protection	3,090	CY
Weight:		
Assumed unit weight of scour protection material	1.65	TONS/CY
Tons of scour protection material	5,100	TONS

Item 11 Hydraulic Dredging

Key Assumptions

Dredge Area	1.2	ACRE
Dredge cut depth	1.5	FT
Overdredging allowance	0.5	FT
Dredge bulking factor	20%	
Volume:		
Dredge volume (not including bulking factor)	3,872	
Dredge volume	4,700	

Item 12 Geobag Dewatering

Key Assumptions

900-Cubic yard geobag capacity		
Dewatering Area (Hand calculation)	50,772	SF
Thickness of Bedding Layer	0.33	FT
Volume of Bedding Layer	700	CY
Geotextile (Includes 10% overlapping factor)	6,210	SQ YD
# of Geotextile Tubes		
Geobags required	6	

ALL ALTERNATIVES

Item 2 Access Road Construction			
Southern Crushed Concrete	$ 15.46	per ton FOB job site; crushed road base	
Cherry Crushed Concrete	$ 17.60	per ton FOB job site; includes sales tax	
Geotextile Fabric	$4.00	SQ YD	Mirafi 160N

Item 3 Environmental Controls			
Maritime Signage and Fishing Advisory Markers	$15,000	LS	
Reinforced Wire Fencing	$55,000	LS	
Silt Fencing	4,100	LF	
Silt Fencing Unit Cost	$2	$/LF	From locally available materials, installation costs from *RS Means Heavy Construction 2008*
Silt Fencing Total Cost	$8,200		
Turbidity Curtain	2,350	LF	Hand calculation
Turbidity Curtain Unit Cost	$40	$/LF	Based on as-built costs on a similar project
Turbidity Curtain Total Cost	$94,000		
Total	**$172,000**		

Non-Construction Items	
Contingency	30%
Engineering Design	$100,000
Construction Management	8%
Close Out & Documentation	0.50%
Regulatory Compliance Documentation	$45,000
Environmental Monitoring - Sampling	$25,000

ALTERNATIVE 1

Item 1 Mobilization/Demobilization			
Key Assumptions:			
Sheet pile equipment mob/demob costs:	$65,000	personal communication, Mark Coyle of Orion Construction, 5-18-2010	
Allowance to improve boat slip at SE corner of project site	$50,000		
Remaining construction mob/demob costs:	$210,000	10 percent of construction costs, not including steel pile installation	
Mobilization/Demobilization Total:	$325,000		
Health and Safety	$69,000	Assumes one employee working half-time for duration of project, rate of $110/hr, plus initial development costs	
Quality Control	$69,000	Assumes one employee working half-time for duration of project, rate of $110/hr, plus initial development costs	
Item 4 Surveying			
Progress Survey	$4,000	EA.	
Item 5 Rock Platform			
Rock Protection in NW Boundary	$28.00	TON	3" x 5" Bull Rock quote from Cherry Crushed Concrete, $20.80 per ton, 1.7 tons/cy Add $2 to back dump in place along road way with trucks or belay using front end loader
Item 6 Sheetpile Wall			
Material Cost			
Vinyl Sheetpile Unit Cost ($/SF):	$8.50	personal communication, Vito Phelan of Crane Materials International, 5-21-2010 (see Material Prices tab)	
Installation Cost			
Personnel/Eqpmt./Consumables per day:	$8,500	personal communication, Mark Coyle of Orion Construction, 5-18-2010	
Shallow water (LF/day)	40.0		
Deep water (LF/day)	30.0		
Installation rate, weighted average (SF/day)	1,280		
Installation Cost ($/SF)	$6.60		
Total Cost ($/SF):	$16		
Days Required	57		

Item 7 Scour Protection			
Inner Wall - Processed concrete bull rock	$29.00	TON	3" x 5" Bull Rock quote from Cherry Crushed Concrete, $20.80 per ton, 1.7 tons/cy - deep water placement
Outer Wall - Natural Rock	$70.00	TON	Large limestone or granite rock barged to site
Item 8 Eastern Cell Granular Cover			
Granular Cover Cost	$29.00	TON	Sand and gravel mix: 5 parts bank sand, 5 parts processed concrete, and 1 part large limestone rock.
Item 9 Western Cell Cover			
Processed Concrete Bull Rock	$28.00	TON	3" x 5" Bull Rock quote from Cherry Crushed Concrete, $20.80 per ton, 1.7 tons/cy
Western Cell Granular Cover	$26.00	TON	Processed Concrete quote from Cherry Crushed Concrete, $17.60 per ton, 1.9 tons/cy
Western Cell Gran Cover Geotextile	$5.00	SQ YD	Mirafi 1120N
Geotextile Fabric	$4.00	SQ YD	Mirafi 160N
Granular Cover Cost	$29.00	TON	
Item 16 OM&M			
Key Assumptions:			
One cap maintenance repair event of 5% of original cap volumes in Year 3			
Bathymetric survey annually for 7 years			
Interest Rate	5%		
Total Cost of Placed Cap ($)	$845,000	includes east cell granular cover, west cell granular cover, and west cell rock protection	
Anticipated Cap Repairs (% of Placed)	5%		
LTM for Cap ($ NPV)	$37,000		
Bathymetric Survey ($)	$4,000	Verbal quote from Rob Roman of Hydrographic Technologies	
LTM for Survey ($ NPV)	$24,000	annual survey in years 1-7	
Total OM&M	$61,000		

ALTERNATIVE 2

Item 1 - Mobilization/Demobilization			
Key Assumptions:			
Sheet pile equipment mob/demob costs:	$65,000	personal communication, Mark Coyle of Orion Construction, 5-18-2010	
Allowance to improve boat slip at SE corner of project site	$50,000		
Hydraulic dredging	$65,000	dredge mobilization/demobilization ($50K) based on locally available dredges (<25 miles) + and appr. 1,500 LF of pipeline ($15K)	
Remaining construction mob/demob costs:	$210,000	10 percent of construction costs, not including hydraulic dredging and steel pile installation	
Mobilization/Demobilization Total:	$390,000		
Health and Safety	$56,000	Assumes one employee working half-time for duration of project, rate of $110/hr, plus initial development costs	
Quality Control	$56,000	Assumes one employee working half-time for duration of project, rate of $110/hr, plus initial development costs	
Item 4 Surveying			
Progress Survey	$4,000	EA.	
Item 5 Rock Platform			
Rock Protection in NW Boundary	$28.00	TON	3" x 5" Bull Rock quote from Cherry Crushed Concrete, $20.80 per ton, 1.7 tons/cy Add $2 to back dump in place along road way with trucks or belay using front end loader
Item 6 Sheetpile Wall			
Material Cost			
Vinyl Sheetpile Unit Cost ($/SF):	$8.50	personal communication, Vito Phelan of Crane Materials International, 5-21-2010 (see Material Prices tab)	
Installation Cost			
Personnel/Eqpmt./Consumables per day	$8,500	personal communication, Mark Coyle of Orion Construction, 5-18-2010	
Shallow water (LF/day)	40.0	personal communication, Mark Coyle of Orion Construction, 5-18-2010	
Deep water (LF/day)	30.0	personal communication, Mark Coyle of Orion Construction, 5-18-2010	
Installation rate, weighted average (SF/day)	1,070		
Installation Cost ($/SF)	$7.90		
Total Cost ($/SF):	$17		
Days Required	39		

Item 7 Scour Protection			
Inner Wall - Processed concrete bull rock	$29.00	TON	3" x 5" Bull Rock quote from Cherry Crushed Concrete, $20.80 per ton, 1.7 tons/cy - deep water placement
Outer Wall - Large limestone or granite rock	$70.00	TON	Large limestone or granite rock barged to site - deep water placement
Item 8 Eastern Cell Granular Cover			
Granular Cover Cost	$29.00	TON	Sand and gravel mix: 5 parts bank sand, 5 parts processed concrete, and 1 part large limestone rock.
Item 9 Western Cell Cover			
Processed Concrete Bull Rock	$28.00	TON	3" x 5" Bull Rock quote from Cherry Crushed Concrete, $20.80 per ton, 1.7 tons/cy
Item 10 Shoreline Armoring			
Natural Rock	$68.00	TON	Large limestone or granite rock barged to site
Geotextile	$5.00	SQ YD	Mirafi 1120N
Item 11 Vegetated Area Repair - Geotextile			
Geotextile Fabric	$4.00	SQ YD	Mirafi 160N
Item 12 Vegetated Area Repair - Granular Cover			
Granular Cover Cost	$29.00	TON	

Item 13 Dredging

Information for this item obtained from:

Phone Call with David Guillot — T.W Laquay Dredging 361-552-2010

Phone Call with Tony Cazalas — C&C Marine 251-232-8587

$2500 a day for ownership cost for dredge, pipe and small boat
Run 24/7 to get the job done
3-4 guys on the night crew
5-6 guys on the day crew
400 HP main engine driving pump and hydraulics
Swinging Ladder Dredge
Fuel for dredge, small boats etc $2500 / day
150 cy/hr in material
Make a 3 ft set every 1.2 min/ 50 min per hour
Clean pump 2 hrs for every 24 hours of operation

Operators	$20.00	
Laborers	$15.00	
PerDiem	$50.00	
Fuel Cost	$2.25	per gal

Both indicated 24/7 operations, maybe one day a week off.

Ownership Operations

		No.	Hours/Day	Rate	Total
Ownership		1		$2,500	
Operations:					
	Fuel	1		$2,916	$2,916
	Operators	2	8	$20	$320
	Ops OT	2	4	$30	$240
	Laborers	6	12	$15	$1,080
	Labor OT	6	4	$23	$540
	Super	1	8	$30	$240
	Clerk	1	8	$10	$80
	Per Diem	9	1	$125	$1,125
					$3,625
			Labor w/ Fringes	42%	$5,148
			Day Rate w/ OH	22%	$12,887
			Day Rate w/ Profit	9.40%	**$14,099**

hr/day	cy/hr	gross %	cy/day	$/day	unit price
18	150	20%	2,160	$ 5,148	$ 2.38

Hrs Uptime/day	18	HR
Dredge rate	150	CY/HR
Gross %	20%	
Dredge rate	2,160	CY/DAY
Day rate	$14,099	
Unit rate	**$7**	**PER CY**

Item 14 Geobag Dewatering

Geobag Capacity (cy):	900	
HDPE Pipeline ($/lf):	$10	
HDPE Pipeline (lf):	1500	
Purchase and Setup:	$16,500	per bag
Maintenance:	$2,000	per bag
Geotextile Layer ($/sq yd):	$4.00	Mirafi 160N

Item 21 OM&M

Key Assumptions:

One cap maintenance repair event of 5% of original cap volumes in Year 3

Bathymetric survey annually for 7 years

Interest Rate	5%	
Total Cost of Placed Cap ($)	$1,001,000	includes east cell granular cover, west cell berm, and west cell armoring
Anticipated Cap Repairs (% of Placed)	5%	
LTM for Cap ($ NPV)	$44,000	
Bathymetric Survey ($)	$4,000	Verbal quote from Rob Roman of Hydrographic Technologies
LTM for Survey ($ NPV)	$24,000	annual survey in years 1-7
Total OM&M	$68,000	

ALTERNATIVE 3

Item 1 - Mobilization/Demobilization			
Key Assumptions:			
Allowance to improve boat slip at SE corner of project site	$50,000		
Remaining construction mob/demob costs:	$200,000	10 percent of construction costs	
Mobilization/Demobilization Total:	$250,000		
Health and Safety	$32,000	Assumes one employee working half-time for duration of project, rate of $110/hr, plus initial development costs	
Quality Control	$32,000	Assumes one employee working half-time for duration of project, rate of $110/hr, plus initial development costs	
Item 4 Surveying			
Progress Survey	$4,000	EA.	
Item 5 Granular Cover			
Granular Cover Cost	$29.00	TON	Sand and gravel mix: 5 parts bank sand, 5 parts processed concrete, and 1 part large limestone rock.
Item 6 Rock Cover			
Natural Rock	$68.00	TON	Large limestone or granite rock barged to site
Geotextile	$5.00	SQ YD	Mirafi 1120N
Item 7 Western Cell Berm			
Processed Concrete Bull Rock	$28.00	TON	3" x 5" Bull Rock quote from Cherry Crushed Concrete, $20.80 per ton, 1.7 tons/cy
Item 8 Shoreline Armoring			
Natural Rock	$68.00	TON	Large limestone or granite rock barged to site
Geotextile	$5.00	SQ YD	Mirafi 1120N
Item 9 Vegetated Area Repair - Geotextile			
Geotextile Fabric	$4.00	SQ YD	Mirafi 160N
Item 10 Vegetated Area Repair - Granular Cover			
Granular Cover Cost	$29.00	TON	
Item 11 Northwestern Area			
Granular Cover Cost	$29.00	TON	Sand and gravel mix: 5 parts bank sand, 5 parts processed concrete, and 1 part large limestone rock.
Item 18 OM&M			
Key Assumptions:			
One cap maintenance repair event of 5% of original cap volumes in Year 3			
Bathymetric survey annually for 7 years			
Interest Rate	5%		
Total Cost of Placed Cap ($)	$1,682,000	includes east cell granular cover, east cell rock cover, west cell berm, west cell armoring, and NW area rock cover	
Anticipated Cap Repairs (% of Placed)	5%		
LTM for Cap ($ NPV)	$73,000		
Bathymetric Survey ($)	$4,000	Verbal quote from Rob Roman of Hydrographic Technologies	
LTM for Survey ($ NPV)	$24,000	annual survey in years 1-7	
Total OM&M	$97,000		

ALTERNATIVE 4

Item 1 - Mobilization/Demobilization			
Key Assumptions:			
Allowance to improve boat slip at SE corner of project site	$50,000		
Remaining construction mob/demob costs:	$230,000	10 percent of construction costs	
Mobilization/Demobilization Total:	$280,000		
Health and Safety	$31,000	Assumes one employee working half-time for duration of project, rate of $110/hr, plus initial development costs	
Quality Control	$31,000	Assumes one employee working half-time for duration of project, rate of $110/hr, plus initial development costs	
Item 4 Surveying			
Progress Survey	$4,000	EA.	
Item 5 Granular Cover			
Granular Cover Cost	$29.00	TON	Sand and gravel mix: 5 parts bank sand, 5 parts processed concrete, and 1 part large limestone rock.
Item 6 TCRA Rock Berm			
Natural Rock	$68.00	TON	Large limestone or granite rock barged to site
Geotextile	$5.00	SQ YD	Mirafi 1120N
Item 7 Western Cell Berm			
Processed Concrete Bull Rock	$28.00	TON	3" x 5" Bull Rock quote from Cherry Crushed Concrete, $20.80 per ton, 1.7 tons/cy Add $2 to back dump in place along road way with trucks or belay using front end loader
Item 8 Shoreline Armoring			
Natural Rock	$68.00	TON	Large limestone or granite rock barged to site
Geotextile	$5.00	SQ YD	Mirafi 1120N
Item 9 Vegetated Area Repair - Geotextile			
Geotextile Fabric	$4.00	SQ YD	Mirafi 160N
Item 10 Vegetated Area Repair - Granular Cover			
Granular Cover Cost	$29.00	TON	
Item 11 Northwestern Area			
Granular Cover Cost	$29.00	TON	Sand and gravel mix: 5 parts bank sand, 5 parts processed concrete, and 1 part large limestone rock.
Item 18 OM&M			
Key Assumptions:			
One cap maintenance repair event of 5% of original cap volumes in Year 3			
Bathymetric survey annually for 7 years			
Interest Rate	5%		
Total Cost of Placed Cap ($)	$1,980,000	includes east cell granular cover, TCRA rock berm, west cell berm, west cell armoring, and NW area rock cover	
Anticipated Cap Repairs (% of Placed)	5%		
LTM for Cap ($ NPV)	$86,000		
Bathymetric Survey ($)	$4,000	Verbal quote from Rob Roman of Hydrographic Technologies	
LTM for Survey ($ NPV)	$24,000	annual survey in years 1-7	
Total OM&M	$110,000		

ALTERNATIVE 5

Item 1 - Mobilization/Demobilization			
Key Assumptions:			
Allowance to improve boat slip at SE corner of project site	$50,000		
Hydraulic dredging	$65,000	dredge mobilization/demobilization ($50K) based on locally available dredges (<25 miles) + and appr. 1,500 LF of pipeline ($15K)	
Remaining construction mob/demob costs:	$410,000	10 percent of construction costs, not including hydraulic dredging	
Scour protection	$50,000	mobilize barge to perform scour protection placement based on locally available equipment	
Mobilization/Demobilization Total:	$575,000		
Health and Safety	$31,000	Assumes one employee working half-time for duration of project, rate of $110/hr, plus initial development costs	
Quality Control	$31,000	Assumes one employee working half-time for duration of project, rate of $110/hr, plus initial development costs	
Item 4 Surveying			
Progress Survey	$4,000	EA.	
Item 5 ACBM Placement over Eastern Cell			
ACBM Purchase & Placement	$8.00	SF	From 1/11/2010 AQ estimate by W. Mears
Item 6 Western Cell Berm			
Processed Concrete Bull Rock	$28.00	TON	3" x 5" Bull Rock quote from Cherry Crushed Concrete, $20.80 per ton, 1.7 tons/cy Add $2 to back dump in place along road way with trucks or belay using front end loader
Item 7 ACBM Shoreline Armoring - West Cell			
ACBM Purchase & Placement	$8.00	SF	From 1/11/2010 AQ estimate by W. Mears
Item 8 Vegetated Area Repair - Geotextile			
Geotextile Fabric	$4.00	SQ YD	Mirafi 160N
Item 9 Vegetated Area Repair - Granular Cover			
Granular Cover Cost	$29.00	TON	
Item 10 Scour Protection Apron			
Natural Rock	$70.00	TON	Large limestone or granite rock barged to site
Item 11 Hydraulic Dredging			
Consult unit pricing for Alternative 2, Item 11			
Item 12 Geobag Dewatering			
Consult unit pricing for Alternative 2, Item 12			
Geotextile	$4.00	SQ YD	Mirafi 160N
Item 19 OM&M			
Key Assumptions:			
One cap maintenance repair event of 5% of original cap volumes in Year 3			
Bathymetric survey annually for 7 years			
Interest Rate	5%		
Total Cost of Placed Cap ($)	$3,616,000	includes ACBM (east and west), west cell berm, and scour apron	
Anticipated Cap Repairs (% of Placed)	5%		
LTM for Cap ($ NPV)	$157,000		
Bathymetric Survey ($)	$4,000	Verbal quote from Rob Roman of Hydrographic Technologies	
LTM for Survey ($ NPV)	$24,000	annual survey in years 1-7	
Total OM&M	$181,000		

Materials

Natural Rock

Gradation:	600 lb. mix - D_{85} = 600 lb stone		
Source:	Phone conversation with Bill Shaw of Luhr Brothers (5-21-2010)		
Material Cost:	-	TON	
Installation Cost:	-	TON	
Total Cost:	$68.00	TON	shallow water placement - (Includes delivery, offload and placement costs)
Total Cost:	$70.00	TON	deep water placement - (Includes delivery, offload and placement costs)
Unit Weight	1.65	TON/CY	
Notes:	Large limestone or granite rock barged to site		

3" x 5" Bull Rock

Gradation:	3" x 5"		
Source:	Quote from Cherry Crushed Concrete, $20.80 per ton, 1.7 tons/cy		
Material Cost:	$20.80	TON	
Installation Cost:	$6.40	TON	shallow water placement - from *RS Means Heavy Construction 2008* , 1.5 min cycle, 3 cy bucket
Installation Cost:	$7.90	TON	deep water placement - from *RS Means Heavy Construction 2008* , 3 min cycle, 3 cy bucket
Total Cost:	$28.00	TON	shallow water placement
Total Cost:	$29.00	TON	deep water placement - Rock buttress in Alts 1 & 2, NW area of Alt 3 & 4,
Unit Weight:	1.7	TON/CY	
Notes:	Used for scour protection and rock protection in NW boundary. For access roads, end dump the access roads from south to north. Use excavator to side cast material in both east and west directions, digging away the access road as he returns to shore. Add $2 to back dump in place along road way with trucks or belay using front end loader		

Processed Concrete

Gradation:	TXDOT Item 247	
Source:	Quote from Cherry Crushed Concrete, $17.60 per ton, 1.9 tons/cy	
Material Cost:	$17.60	TON
Installation Cost:	$6.40	TON
Total Cost:	$24.00	TON
Unit Weight:	1.9	TON/CY
Notes:	Used for rock cover, processed concrete layer base, or western cell shoreline armor.	

Sand Cover

Gradation:	ASTM C 136 - 35.3% retained on #50 Sieve, 96.4% retained on #200 Sieve - Gradation from Mega Sand	
Source:	Quote from Mega Sand, 7.25 per cy delivered to the site.	
Material Cost:	$7.25	CY
Installation Cost:	$6.40	CY
Total Cost:	$14.00	CY
Unit Weight:	1.2	TON/CY
Notes:	Used as a portion of the sand/gravel mix below.	

Sand/Gravel Mix

Gradation:	N/A	
Source:	N/A	
Material Cost:	$22.00	TON
Installation Cost:	$6.40	TON
Total Cost:	$29.00	TON
Unit Weight:	1.6	TON/CY
Notes:	Mix of 5 parts bank sand, 5 parts processed concrete, and 1 part large limestone rock. Add $2.00/ton end dump cost and $4.53/ton placement cost to arrive at final in-place cost.	

Rip Rap

Gradation:	Grade I Riprap (12" x 18")	
Source:	Quote from Cherry Crushed Concrete, $29.30 per ton, 1.4 tons/cy	
Material Cost:	$29.30	TON
Installation Cost:	$6.40	TON
Total Cost:	$36.00	TON
Unit Weight:	1.4	TON/CY
Notes:	N/A	

Other:

Mirafi 160N	$4.00	SQ YD	Engineer's estimate from Scott Dull of Tencate (919.740.9989) on 5-25-2010
Mirafi 1120N	$5.00	SQ YD	Engineer's estimate from Scott Dull of Tencate (919.740.9989) on 5-25-2010
ACBM	$8.00	SQ FT	From 1/11/2010 AQ estimate by W. Mears
Vinyl Sheetpile	$8.50	SQ FT	Quotation from Vito Phelan, Crane Materials International, 5-21-2010. $7.23/sq. ft. for SG625 sheet piling. Added 15% for contractor markup and rounded to $8.50/sq.ft.
Steel Sheetpile	$23.00	SQ FT	Quotation from Chris Hughes of Skyline Steel (281.992.4000) on 5-25-2010 for AZ19-700 series sheet pile. Added 15% for contractor markup

	OPTION 1	OPTION 2	OPTION 3	OPTION 4	OPTION 5
MOB/DEMOB	8	8	8	8	8
GRANULAR COVER RATE (TONS/DAY)	920	920	920	920	-
GRANULAR COVER QUANT	28,300	21,700	25,000	22,600	-
GRANULAR COVER DAYS	**31**	**24**	**28**	**25**	**0**
ROCK COVER RATE (TONS/DAY)	890	-	890	890	-
ROCK COVER QUANT (TONS)	990	-	10,500	3,300	-
ROCK COVER DAYS	**2**	**0**	**12**	**4**	**0**
CLAY COVER RATE (CY/DAY)	-	-	520	-	-
CLAY COVER QUANT (CY)	-	-	7,200	-	-
CLAY COVER DAYS	**0**	**0**	**14**	**0**	**0**
ROCK BERM RATE (TONS/DAY)	-	-	-	550	-
ROCK BERM QUANT (TONS)	-	-	-	12,600	-
ROCK BERM RATE DAYS	**0**	**0**	**0**	**23**	**0**
WEST CELL BERM RATE (TONS/DAY)	-	550	550	550	550
WEST CELL BERM QUANT (TONS)	-	1,800	1,800	1,800	1,800
WEST CELL BERM RATE DAYS	**0**	**4**	**4**	**4**	**4**
HYDRAULIC DREDGING RATE (CY/DAY)	-	2,160	-	-	2,160
HYDRAULIC DREDGING QUANT (CY)	-	4,700	-	-	4,700
HYDRAULIC DREDGING DAYS	**0**	**3**	**0**	**0**	**3**
GEOBAG SET UP DAYS	**0**	**4**	**0**	**0**	**4**
ROCK PLATFORM RATE (TONS/DAY)	550	550	-	-	-
ROCK PLATFORM QUANT (TONS)	15,900	14,600	-	-	-
ROCK PLATFORM RATE DAYS	**29**	**27**	**0**	**0**	**0**
SHEETPILE INSTALL RATE (LF/DAY)	35	35	-	-	-
SHEETPILE INSTALL QUANT (LF)	2,000	1,450	-	-	-
SHEETPILE INSTALL DAYS	**58**	**42**	**0**	**0**	**0**
SCOUR PROTECTION RATE (LF/DAY)	-	-	-	-	550
SCOUR PROTECTION QUANT (LF)	-	-	-	-	5,100
SCOUR PROTECTION DAYS	**0**	**0**	**0**	**0**	**10**
ROCK BUTTRESS RATE (TON/DAY)	500	500	0	0	0
ROCK BUTTRESS QUANT (TON)	10,050	4,020	0	0	0
ROCK BUTTRESS DAYS	**21**	**9**	**0**	**0**	**0**
ACBM INSTALL RATE (SF/DAY)	-	-	-	-	12,000
ACBM INSTALL QUANT (SF)	-	-	-	-	400,800
ACBM INSTALL DAYS	**0**	**0**	**0**	**0**	**34**
TOTAL DAYS	149	121	66	64	63
MONTHS	6.08	4.94	2.69	2.61	2.57

APPENDIX D
DRAFT – ADCP AND BATHYMETRIC DATA SAMPLING AND ANALYSIS PLAN

DRAFT – ADCP AND BATHYMETRIC DATA SAMPLING AND ANALYSIS PLAN

SAN JACINTO RIVER WASTE PITS SUPERFUND SITE

Prepared for

U.S. Environmental Protection Agency, Region 6

On behalf of

McGinnes Industrial Maintenance Corporation

And

International Paper Company

Prepared by

Anchor QEA, LLC

614 Magnolia Avenue

Ocean Springs, Mississippi 39564

May 2010

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Attachment A Datasheet for Teledyne Workhorse ADCP

LIST OF ACRONYMS AND ABBREVIATIONS

ADCP	acoustic Doppler current profiler
cfs	cubic feet per second
CTD	conductivity, temperature, and depth
DQOs	data quality objectives
EFDC	Environmental Fluid Dynamics Code
IPC	International Paper Company
MIMC	McGinnes Industrial Maintenance Corporation
NOAA	National Oceanic and Atmospheric Administration
QAPP	Quality Assurance Project Plan
RAWP	Removal Action Work Plan
RI/FS	Remedial Investigation/Feasibility Study
SAP	Sampling and Analysis Plan
Site	San Jacinto River Waste Pits Superfund Site
TCRA	Time Critical Removal Action
USACE	U.S. Army Corps of Engineers
USEPA	U.S. Environmental Protection Agency
USGS	U.S. Geologic Survey

1 INTRODUCTION

This Sampling and Analysis Plan (SAP) to support site-specific river current and bathymetric data collection for the San Jacinto River Waste Pits Superfund Site (the Site) was prepared on behalf of International Paper Company (IPC) and McGinnes Industrial Maintenance Corporation (MIMC; collectively referred to as the Respondents). Figure 1 presents a vicinity map of the Site.

This SAP is an appendix to the Time Critical Removal Action (TCRA) Alternatives Analysis for the Site. This plan is a companion plan to the Remedial Investigation/Feasibility Study (RI/FS) Work Plan (Anchor QEA and Integral 2010) and references that document where appropriate. The text in this plan is abstracted from a SAP Addendum submitted to the U.S. Environmental Protection Agency (USEPA) for a chemical and fate and transport modeling study (Anchor QEA 2010) at the Site.

1.1 Purpose

The river current and bathymetry data collection will be undertaken to address the following objectives:

- Collect Site-specific river current data in the vicinity of the Site using an acoustic Doppler current profiler (ADCP). This data will be used to refine the hydrodynamic model near the Site. The hydrodynamic model will be used to develop Site-specific design criteria for the TCRA design.
- Update and improve the data density for the river bottom contours by collecting additional bathymetric survey information around the Site. This information will be used to update the hydrodynamic model and to prepare detailed design plans to be included with the TRCA Removal Action Work Plan (RAWP).

1.2 Work Plan Organization

Section 1 of this SAP presents an introduction and brief overview of the project, while Section 2 describes the problem addressed by this plan. The modeling framework and approach is presented in Section 3. Data gaps and data quality objectives (DQOs) for the modeling study are described in Section 4. Field studies to be conducted in support of the

modeling analyses are presented in Section 5. The schedule for the study is presented in Section 6.

2 PROBLEM DEFINITION

2.1 Statement of the Problem

The hydrodynamic model would be improved with Site-specific river current information, which can be used to verify model calibration at the Site. The model would be further improved with an updated bathymetry survey.

The bathymetry of the Site has some recognized inaccuracies that were noted during visual inspections made at low river stages. These inaccuracies occur because the existing Site bathymetry was collected on widely-spaced transects taken in the early stages of the reconnaissance investigation and missed key shoreline features at the Site.

2.2 Primary Objectives of Study

The main goal of the work discussed in this SAP is to collect site-specific data to support the TCRA.

The hydrodynamic model will be used to establish the expected flow-related forces acting on the submerged Site stabilization features that are constructed for the TCRA. The hydrodynamic model will provide insight into specific hydrodynamic processes at the Site.

This model will also be used to answer questions related to episodic high-flow events in the San Jacinto River and storms (e.g., hurricanes):

- What size of material will resist erosion during high-flow events or storms?
- What is the potential depth of scour related to high-flow events, and where would this scour potentially occur?

The bathymetric data will be used to update the hydrodynamic model, and to provide a more accurate base map for use in the TCRA design.

3 MODELING FRAMEWORK AND APPROACH

Conducting a hydrodynamic modeling study will produce information that reliably represents current and future conditions at the Site and that can be used for decision-making. The development of a hydrodynamic model will make it possible to understand the river flow and velocity conditions at the Site under a variety of scenarios. In addition, the models can be used to quantitatively evaluate the effectiveness of potential removal actions.

The bathymetry data will be used both in the hydrodynamic model, and to provide an updated base map for the TCRA design.

3.1 Description of Modeling Framework

The hydrodynamic model simulates the movement of water in the San Jacinto River, and accounts for the effects of the following factors on water movement: freshwater inflow from upstream of the Study Area; tides; spatially variable bathymetry and geometry; and estuarine circulation resulting from density differences between seawater and freshwater. The hydrodynamic model is used to simulate temporal and spatial changes in water depth, current velocity, and bed shear stress.

The hydrodynamic model that will be applied in this study is the Environmental Fluid Dynamics Code (EFDC), which is supported by USEPA. EFDC is a three-dimensional hydrodynamic model capable of simulating time-variable flow in rivers, lakes, reservoirs, estuaries, and coastal areas. The model solves the conservation of mass, momentum, and salt equations, which are the fundamental equations governing the movement of water in an estuary. The effects of density-driven processes on circulation in an estuary, such as the San Jacinto River, are incorporated into EFDC. In addition, the model includes a sophisticated turbulence closure algorithm that simulates the effects of vertical turbulence on estuarine circulation. A characteristic of EFDC that is of importance for this study is the flooding-drying feature, which makes it possible to realistically simulate the flooding and drying of inter-tidal areas caused by tidal action in the study area. The model has been applied to a wide range of environmental studies in large number of rivers, estuaries, and coastal ocean areas. A complete description of the model is given in Hamrick (1992).

3.2 Hydrodynamic Modeling

The primary objective of the hydrodynamic data collection is to improve the calibration of the hydrodynamic model. The main tasks that will be conducted during this phase are:

- Compile and analyze available data related to hydrology and hydrodynamics
- Conduct field studies to support modeling study
- Analyze hydrodynamic data
- Update the hydrodynamic model
- Use the hydrodynamic model to refine TCRA design criteria

4 DATA GAPS AND DATA QUALITY OBJECTIVES

4.1 Data Gaps and DQOs

Development of the hydrodynamic model, which includes construction of the numerical grid, will require the following types of Site-specific data:

- Bathymetry and geometry of the San Jacinto River and banks
- Freshwater inflow from the San Jacinto River (upstream boundary) and tributaries
- Water surface elevation and salinity at the downstream boundary

Calibration and validation of the hydrodynamic model will require the following data:

- Current velocities (magnitude and direction)
- Water surface elevation
- Salinity

A review of available data for the Site indicates that the following data gaps exist:

- Bathymetry in the regions located upstream and downstream of the waste impoundments area
- Calibration data, including current velocity, water surface elevation, and salinity

Sources of data and information to meet the other needs of the hydrodynamic model are listed in Table 1.

Table 1
Data Sources for Hydrodynamic Model Development and Calibration

Data Need	Data Sources
Bathymetry and geometry	National Oceanic and Atmospheric Administration (NOAA) Nautical Chart bathymetry data; bathymetry data collected during 2009 in vicinity of waste impoundments
Freshwater inflow from San Jacinto River	Coastal Water Authority discharge at Lake Houston dam; U.S. Geologic Survey (USGS) gauging stations on San Jacinto River
Water surface elevation and salinity at the downstream boundary	NOAA tidal gauge station at Battleship Texas State Park

The DQOs for the hydrodynamic model development and calibration are:

- Obtain water surface elevation, current velocity, and salinity data in general accordance with U.S. Geologic Survey (USGS) Report 2005-5183 (Quality Assurance Plan for Discharge Measurements Using Acoustic Doppler Current Profilers) using an ADCP equipped with a conductivity, temperature, and depth (CTD) sensor.
- Obtain bathymetry data in general accordance with U.S. Army Corps of Engineers (USACE) Hydrographic Survey Manual EM 1110-2-1003 (January 2002). These data will be used to realistically represent the geometry of the Site in the model and will have the following characteristics:
    1. Horizontal and vertical data acquisition to sub-meter accuracy
    2. Data obtained relative to HGSCD 33 TSARP monument
    3. Data reproduced in U.S. feet within Texas South Central NAD 83 (horizontal) and NAVD 88 (vertical) coordinate systems.

5 FIELD STUDIES TO SUPPORT TCRA DESIGN

The data gaps described in Section 4 will be fulfilled by conducting various field studies to collect hydrodynamic and bathymetric data. A summary of the field studies to support the modeling study is provided in Table 2.

Table 2
Potential Field Studies to Support Modeling Study

Model	Data Gap	Type of Field Study
Hydrodynamic	Current velocity, water surface elevation, salinity	Deployment of ADCP with CTD sensor
Hydrodynamic	Bathymetry at the Site	Bed elevation along transects
TCRA Design	Bathymetry at the Site	Bed elevation along transects

5.1 Sampling Procedures

The field tasks described in the sections below will follow procedures described in the SAP (Anchor QEA and Integral 2010) that has been previously submitted and approved by USEPA. Additional field procedures not included in that SAP are provided in this document.

5.2 Data Validation and Usability, Analytical Methods, and Quality Control

As part of the RI/FS, data generation and acquisition procedures were described in the SAP (Anchor QEA and Integral 2010). Laboratory and analytical methods were described in Section 2.4 of the SAP; quality control procedures to be followed in the field and by selected laboratories were described in Section 2.5 of the SAP; and data validation and usability were discussed in Section 4 of the SAP. Additionally, quality assurance/quality control procedures are discussed and/or referenced in this SAP as needed.

5.3 Field Studies

The two tasks discussed below were developed to support the design of the TCRA. Data developed during these tasks will also be used to support future work to answer additional study questions and in development of remedial alternatives for the Site.

5.3.1 Current Velocity Study

Anchor QEA will deploy one ADCP equipped with a CTD sensor in the vicinity of the waste impoundments within the Site in at least 6 feet of water depth and record data continuously or every 15 minutes. Figure 2 depicts the proposed ADCP deployment location. The ADCP will be deployed for a 1-month period. It is envisioned that at least two high-flow events will occur during this period. If two high-flow events do not occur during the 1-month period, then the sampling will be extended until the desired number of high-flow events has occurred. The mean flow rate in the San Jacinto River is 2,200 cubic feet per second (cfs), and high-flow events with return periods of 2, 10, and 100 years correspond to flow rates of 31,600, 107,000, and 329,000 cfs, respectively. For the purposes of the current velocity study, a high-flow event will be considered to be an event with a peak flow rate of 10,000 cfs or greater. If the magnitude of high-flow events during the data collection period does not reflect a suitable range of conditions (as determined by the project technical team) or if baseline conditions are not re-established between events to sufficiently identify distinct events, the data collection period may be extended on a bi-weekly basis.

The ADCP uses a type of sonar technology that measures and records water current velocities over a range of depths. An ADCP transmits sound bursts into the water column and suspended particles carried by water currents produce echoes (from these sound bursts). These echoes are "heard" by the ADCP with echoes arriving later, from deeper in the water column, assigned greater depths in the echo record. This allows the ADCP to form vertical profiles of current velocity. The ADCP senses water movement in four orthogonal directions simultaneously, with particles within the current flow moving towards the instrument exhibiting different frequencies from those moving away. This process is known as the Doppler shift, which enables the precise measurement of current speed and direction.

ADCP units have been commercially available for over 25 years and are being used in a variety of industries including oceanography, meteorology (used in weather forecasting), shipping (to monitor tides/currents for optimizing shipping in busy ports), and monitoring applications related to sewer and stormwater monitoring. Within the environmental engineering field, ACDPs have been deployed by the USACE for use as part of model development and calibration for determining dispersion of dredged materials from plumes emanating from dredge sites (i.e., USACE SSFATE model). Additionally, the USGS has been

employing ADCPs since 1985 for measuring stream flow in rivers. A Quality Assurance Project Plan (QAPP) for using these instruments when deployed from research vessels has been developed by the USGS (2005) and will be followed during this project where applicable.

The unit deployed will be a Workhorse ADCP manufactured by Teledyne RDI; a datasheet for the Workhorse ADCP is included in Attachment A for reference. This unit is capable of long-term data logging and will be equipped with a CTD. Both the ADCP and CTD data will be recorded in the internal memory of the ADCP. The location of the ADCP/CTD will be surveyed by Anchor QEA staff or a subcontractor, and a reference location will be established to convert changes in water depth measurements to elevations. The location and elevation information will be given in Texas South Central NAD 83/NAVD 88 coordinate system.

The ADCP/CTD will be deployed and operated following manufacturer's instructions and applicable guidance (USGS 2005). An appropriate interval for downloading data and performing systems checks will be determined from the operating manual.

5.3.2 Bathymetric Survey

A bathymetric survey of the Site will be completed by a subcontractor to map the topography and features of the river bed. In addition to the modeling study, the bathymetric survey data will be used for design of the TCRA and provide information about water-based access to the site. Figure 3 depicts the area of proposed survey coverage.

The bathymetric survey will be performed using electronic survey techniques for both horizontal and vertical data acquisition and will be overseen by a hydrographer who is certified by the American Congress on Surveying and Mapping. At a minimum, the contractor will use a survey-grade echo sounder, operating at 200 KHz, coupled with a positioning system capable of providing sub-meter positioning accuracy. Both the echo sounder and horizontal positioning system data will be collected real-time and use software designed for hydrographic survey data acquisition (i.e., Hypack, HydroPro). The contractor will prepare a survey transect plan that will be sufficient to properly represent the Site

bathymetry and geometry, and will provide water depths to show an access channel from the north for the contract documents.

The bathymetric survey will have sufficient areal coverage to produce a 3-foot by 3-foot grid surface from the bed elevation data obtained during the survey. The contractor will prepare a survey transect plan that will be sufficient to meet this requirement. Cross-channel transects will be continuous, with XYZ data provided at 5-foot intervals in the data files. All survey procedures, data collection equipment, methods, densities and equipment calibration for this survey will follow the criteria of the Navigation and Dredging Support Surveys for soft bottom materials as given in the USACE Hydrographic Survey Manual EM 1110-2-1003 (January 2002). The survey will be performed using electronic survey techniques for both horizontal and vertical data acquisition and results will be mapped relative to HGCSD 33 TSARP monument (published elevation 26.57 NAVD88). The water elevation at the survey location will be monitored during the duration of the survey and all echo sounder data will be reduced by the water elevation readings taken during the survey.

The XYZ data gathered will be processed to produce a 3-foot by 3-foot grid surface of the study area and survey transects data. This will be done via development of a three-dimensional model of the data using a software package such as Trimble's "Terramodel" or a similar software suite. The survey will provide sufficient data density to facilitate model generation through the use of break lines to link points of similar elevation (e.g., following contours). This will allow the hydrographer to guide the model development along areas of similar bed elevation based upon the XYZ data and published NOAA navigation charts. Once the model has been developed, it will be compared to the collected data to ensure that the model properly reflects the river topography. After the completion of the quality control check, the completed model will be used to generate an ASCII XYZ grid file that contains bed elevation data on a grid with 3-foot by 3-foot resolution.

Figure 3 presents the area for updated bathymetric survey data.

6 SCHEDULE

It is anticipated that task-specific activities discussed above will require approximately 2 weeks from approval of the TCRA Alternatives Analysis. Following these planning activities, the various data collection events will be implemented, each lasting approximately 1 month, resulting in a total of 6 weeks to implement the study. This anticipated schedule does not account for unforeseen events such as weather delays or interim agency involvement.

7 REFERENCES

Anchor QEA, 2010. *Draft - Sampling and Analysis Plan Addendum Chemical Fate and Transport Modeling Study San Jacinto River Waste Pits Superfund Site*. Prepared for McGinnes Industrial Maintenance Corporation, International Paper and USEPA, Region 6. May 2010.

Anchor QEA and Integral, 2010. *Draft Remedial Investigation/Feasibility Study Work Plan, San Jacinto Waste Pits Superfund Site.* Prepared for McGinnes Industrial Maintenance Corporation, International Paper and USEPA, Region 6. March 2010.

Hamrick, J.M. 1992. *A Three-Dimensional Environmental Fluid Dynamics Computer Code: Theoretical and Computational Aspects.* College of William and Mary, Virginia Institute of Marine Sciences. Special Report 317. 63 pp.

USACE, 2002. *Hydrographic Survey Manual EM 1110-2-1003.* January 2002.

U.S. Geological Survey (USGS), 2005. *Quality Assurance Plan for Discharge Measurements Using Acoustic Doppler Current Profilers.* USGS Report 2005-5183.

FIGURES

SOURCE: Google Map Pro 2009

0 500
Scale in Feet

K:\Jobs\090557-San Jacinto\090557-01 - San Jacinto\09055701-RP-037.dwg FIG-1

May 27, 2010 3:47pm cdavidson

ANCHOR QEA

Figure 1
Vicinity Map
SJRWP TCRA

K:\Jobs\090557-San Jacinto\090557-01 - San Jacinto\09055701-RP-039.dwg FIG 2

May 28, 2010 1:33pm heriksen

LEGEND:

Proposed ADCP Location

SOURCE: Google Map Pro 2009

0 500
Scale in Feet

Figure 2
ADCP Deployment Location
SJRWP TCRA

ANCHOR QEA

K:\Jobs\090557-San Jacinto\090557-01 - San Jacinto\09055701-RP-039.dwg FIG 3

May 27, 2010 4:46pm cdavidson

LEGEND:

Bathymetric Survey Area (73 Acres)

SOURCE: Google Map Pro 2009

0 500

Scale in Feet

Figure 3
Bathymetric Survey Area
SJRWP TCRA

ANCHOR QEA

ATTACHMENT A
DATASHEET FOR TELEDYNE WORKHORSE ADCP

Workhorse Sentinel

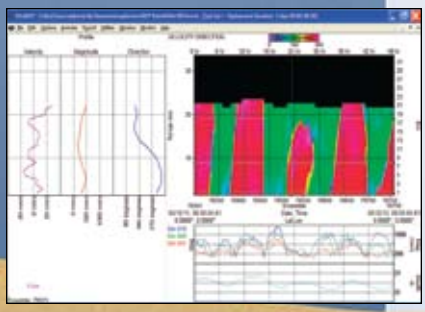
SELF-CONTAINED 1200, 600, 300 kHz ADCP

The Global Leader in High-accuracy Data Collection

The self-contained **Sentinel** is Teledyne RD Instruments' most popular and versatile Acoustic Doppler Current Profiler (ADCP) configuration, boasting thousands of units in operation in over 50 countries around the world.

By providing profiling ranges from 1 to 165m, the high-frequency Sentinel ADCP is ideally suited for a wide variety of applications. Thanks to Teledyne RDI's patented Broadband signal processing, the Sentinel also offers unbeatable precision, with unmatched low power consumption, allowing you to collect more data over an extended period.

The lightweight and adaptable Sentinel is easily deployed on buoys, boats, or mounted on the seafloor. Real-time data can be transmitted to shore via a cable link or acoustic modem, or data can be stored internally for short or long-term deployments. The Sentinel is easily upgraded to include pressure, bottom tracking, and/or directional wave measurement—for the ultimate data collection solution.



The Workhorse Sentinel offers:

- **Versatility:** *Direct reading or self contained, moored or moving, the Sentinel provides precision current profiling data when and where you need it most.*
- **A solid upgrade path:** *The Sentinel has been designed to grow with your needs. Easy upgrades include pressure, bottom tracking, and directional wave measurement.*
- **Precision data:** *Teledyne RDI's patented BroadBand signal processing delivers very low-noise data, resulting in unparalleled data resolution and minimal power consumption.*
- **A four-beam solution:** *Teledyne RDI's patented 4-beam design improves data reliability by providing a redundant data source in the case of a blocked or damaged beam; improves data quality by delivering an independent measure known as error velocity; and improves data accuracy by reducing variance in your data.*

TELEDYNE
RD INSTRUMENTS
A Teledyne Technologies Company

Workhorse Sentinel

SELF-CONTAINED 1200, 600, 300 kHz ADCP

Technical Specifications

Water Profiling						
Depth	*Typical Range[2] 12m*		*Typical Range[2] 50m*		*Typical Range[2] 110m*	
Cell Size[1]	**1200kHz**		**600kHz**		**300kHz**	
Vertical Resolution (m)	Range[3] (m)	Std. Dev.[4] (cm/s)	Range[3] (m)	Std. Dev.[4] (cm/s)	Range[3] (m)	Std. Dev.[4] (cm/s)
0.25m	*11–14*	*12.9*				
0.5m	*13–16*	*6.1*	*39*	*12.9*	*see note [1]*	
1m	*14–18*	*3.0*	*43*	*6.1*	*92–71*	*12.8*
2m	*15–20[2]*	*2.0*	*47*	*3.0*	*102–78*	*6.1*
4m	*see note [1]*		*52[2]*	*2.0*	*113–86*	*3.0*
8m					*126–95[2]*	*2.0*

[1] User's choice of depth cell size is not limited to the typical values specified.
[2] Longer ranges available.
[3] Profiling range based on temperature values at 5°C and 20°C, salinity = 35ppt.
[4] BroadBand mode single-ping standard deviation (Std. Dev.).

Long Range Mode

	Range (m)	Depth Cell Size (m)	Std. Dev. (cm/s)
1200kHz	24	2	3.8
600kHz	70	4	4.2
300kHz	165	8	4.2

Profile Parameters

Velocity accuracy:

- **1200, 600:** 0.3% of the water velocity relative to the ADCP ±0.3cm/s
- **300:** 0.5% of the water velocity relative to the ADCP ±0.5cm/s

Velocity resolution: 0.1cm/s
Velocity range: ±5m/s (default)
±20m/s (maximum)
Number of depth cells: 1–128
Ping rate: 2Hz (typical)

Echo Intensity Profile

Vertical resolution: Depth cell size
Dynamic range: 80dB
Precision: ±1.5dB

Transducer and Hardware

Beam angle: 20°
Configuration: 4-beam, convex
Internal memory: Two PCMCIA card slots; one memory card included
Communications: Serial port selectable by switch for RS-232 or RS-422. ASCII or binary output at 1200-115,200 baud.

Standard Sensors

Temperature (mounted on transducer):
Range: -5° to 45°C
Precision: ±0.4°C
Resolution: 0.01°

Tilt: Range: ±15°
Accuracy: ±0.5°
Precision: ±0.5°
Resolution: 0.01°

Compass (fluxgate type, includes built-in field calibration feature):
Accuracy: ±2° [5]
Precision: ±0.5° [5]
Resolution: 0.01°
Maximum tilt: ±15°

[5] <±1.0° is commonly achieved after calibration

Power

External DC input: 20–50VDC
Internal battery voltage: 42VDC new; 28VDC depleted
Battery capacity: @0°C: 450 watt hours

Environmental

Standard depth rating:
200m; optional to 6000m
Operating temperature: -5° to 45°C
Storage temperature*: -30° to 60°C
Weight in air: 13.0kg
Weight in water: 4.5kg
** Without batteries*

Software

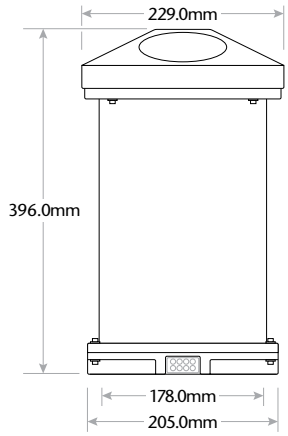
Teledyne RDI's Windows™-based software included:

- WinSC—Data Acquisition
- WinADCP—Data Display and Export

Available Options

- Memory: 2 PCMCIA slots, total 4GB
- Pressure sensor
- External battery case
- High-resolution water-profiling modes
- Bottom tracking
- AC/DC power converter, 48VDC output
- Pressure cases for depths up to 6000m
- Directional Wave Array

Dimensions



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