Appendix 6

Evaluation of Dredged Material for Confined Upland Placement: A Lines-of-Evidence (LOE) and Weight-of-Evidence (WOE) Approach

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Note: Due to the large number of pages, the Appendices to the *Evaluation of Dredged Material for Confined Upland Placement: A Lines-of-Evidence (LOE) and Weight-of-Evidence (WOE) Approach in Support of the Performance of Corrective Actions to Address Design Deficiencies from the Houston Ship Channel Flare (HSC) at Bayport Ship Channel (BSC)* is being provided electronically only as a file on the enclosed Compact Disc.

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Evaluation of Dredged Material For Confined Upland Placement: A Lines-of-Evidence (LOE) and Weight-of-Evidence (WOE) Approach

In Support of the Performance of Corrective Actions to Address Design Deficiencies from the Houston Ship Channel (HSC) Flare at Bayport Ship Channel (BSC)

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List of Acronyms

AE	Assessment Endpoint
ASA	Assistant Secretary of the Army
BCC	Barbours Cut Channel
BSC	Bayport Ship Channel
CDF	Confined Disposal Facility
CFR	Code of Federal Regulations
COC	Chemicals of Concern
CSM	Conceptual Site Model
CW	Civil Works
EA	Environmental Assessment
Elut	Elutriate
ER-L	Effects Range Low
HSC	Houston Ship Channel
HTRW	Hazardous Toxic or Radioactive Waste
LOE	Lines-Of-Evidence
MCY	Million Cubic Yards
O&M	Operation and Maintenance
PA	Placement Area
PAH	Polyaromatic Compounds
PCB	Polychlorinated Biphenyls
PHA	Port Of Houston Authority
RRC	Railroad Commission
SALE	Sequential Analysis of Lines-of-Evidence
SD	Sediment
SVOC	Semi Volatile Organic Compound
SW	Surface Water

SWG Southwest Division, Galveston District of the USACE

TCEQ Texas Commission on Environmental Quality

TPH Total Petroleum Hydrocarbons

USACE United States Army Corps of Engineers

USEPA Unites States Environmental Protection Agency

UTM Upland Testing Manual

VOC Volatile Organic Compound

WOE Weight-Of-Evidence

1.0 INTRODUCTION

This Lines-of-Evidence/Weight-of-Evidence (LOE/WOE) report is being written to support the United States Army Corps of Engineers Galveston Districts' (USACE/SWG) "*Houston Ship Channel Project Deficiency Report*" ("Project") (USACE, 2015).

1.1 Objectives

The objective of this report is to determine if sufficient information currently exists to make a decision as to the need for testing dredged materials under Section 404 of the Clean Water Act (USEPA, 2014) pursuant to Regulatory Guidance Letter No. 06-02 (USACE, 2006). The sediments in question are part of the performance of corrective actions to address design deficiencies from the Houston Ship Channel (HSC) Flare at Bayport Ship Channel (BSC). The compilation, evaluation and integration of Lines-of-Evidence (LOE) will be used to support the premise that there is/is not a *Reason To Believe* (Appendix A) that contamination is/is not present in project sediments at levels to cause/not cause adverse effects, if they were to be moved as part of the corrective action. This report examines and evaluates only chemical impacts to potential ecological resources and receptors. Physical impacts are evaluated separately in the Project EA (AECOM, 2015).

1.2 Project Area

The HSC System is comprised of the HSC, the main side channels of BSC and Barbour's Cut Channel (BCC), as well other minor side channels. The HSC extends 52 miles (Figure B-1) from its juncture with Texas City Channel at the entrance to Galveston Bay and terminates at its turning basin in the city of Houston. From channel mile 0 to channel mile 40 (Boggy Bayou), the authorized channel depth is 45 feet, with a bottom width of 530 feet in the straight sections of the channel. The Bay reach (first 40 miles) is broken into three segments; the Lower-Bay, Mid-

Bay and Upper Bay. This project is located at the junction of the Mid-Bay and Upper-Bay reaches. Many bends in the HSC, above and below the Mid-Bay and Upper-Bay HSC turns near the BSC Flare, are in excess of 600 feet-wide. The remaining channel depth from channel mile 40 to channel mile 52 (turning basin) (Figure B-1) varies from 36 feet to 40 feet, with a bottom width of 300 feet. The HSC is operated with two-way vessel traffic, with adjacent barge lanes in the Bay reach.

The BSC extends 4.1 miles from its juncture with the HSC at mile 20.5 (Appendix B) and terminates at its turning basin. At the confluence of the BSC with the HSC, the channel consists of a flare with a radius of 3,000 feet. The authorized channel depth is currently 40 feet in the BSC, with a bottom width of 300; approximately 2.3 miles of the BSC crosses on the west side of the HSC and Galveston Bay with the remaining 1.8 miles of channel being landlocked. Traffic on the BSC is restricted to one-way traffic. The BSC is being deepened and widened to 45 feet by 400 feet by the Port of Houston Authority (PHA) under the authority of Section 204(f) of WRDA 1986, as amended, with the Assistant Secretary of the Army (Civil Works) (ASA(CW)) approving the assumption of federal Operation and Maintenance (O&M) in May 2014.

Figure 1 shows the current HSC/BSC channel configurations in the corrective action reach.

1.3 Proposed Corrective Action Plan

After considering 6 alternatives offered in the ERDC ship SIM Report, Alternative 3 was selected (USACE, 2015). Alternative 3 has the flare being widened to a 4,000 foot radius plus the addition of a bend easing of 235 feet on the east side of the HSC (Figure 1). The volume of new work dredged material that this project will produce is approximately 1.942 Million Cubic Yards (MCY); 1.523 MCY for the BSC flare 4,000 foot radius and 0.419 MCY for the HSC 235 foot widener (USACE, 2015, also see Appendix B).

This corrective action involves both maintenance and new work materials, defined as:

(a) Maintenance Material: material to be removed from the dredging prism of the current navigational channel that has shoaled in since previous maintenance dredging;

(b) New Work Material: material not within the current navigation channel dredge prism defined above in (a). New work material falls into two categories, virgin and non-virgin material:

  (i) Non-Virgin: refers to material that has not been dredged (i.e. outside of the current navigational channel dredging footprint) that has potential to have been exposed to contamination directly or indirectly from spills, transport, deposition and other mechanisms that would place such contamination within the new work dredging prism;

  (ii) Virgin: refers to new work material that has not been dredged but is at a depth that would make it less likely that exposure to contamination has occurred. An example of virgin material would be undisturbed, consolidated base layer geological formations at depth.

Both the HSC and BSC undergo routine maintenance dredging; these dredge materials are classified under (a) above. New work dredging of the BSC to be completed in 2015 as part of the widening/deepening channel improvement project are materials classified under (b)(i) and (b)(ii) (Anchor, 2014).

Dredging for this corrective action will be performed by hydraulic cutter header with pipeline placement to an Upland Confined Disposal Facility (CDF), specifically Placement Area-14 (PA-14). The sediments are to be piped as a slurry to PA-14 (Figure 1).

1.4 Approach

To answer the objective stated in Section 1.1, the principles of problem formulation must be applied and a Conceptual Site Model (CSM) developed where potential exposure pathways are identified and qualitative and/or quantitative measures are evaluated. The CSM will address the risk question associated with the study objective, and collect LOEs from currently available information on the HSC, BSC and areas surrounding the HSC/BSC flare. The LOEs will be structured to support the overall Assessment Endpoint (AE) of the evaluation. Each LOE will be evaluated sequentially (Hull and Swanson, 2005) and weighed both individually and in aggregate (Suter and Cormier, 2011) to arrive at a conclusion as to the need for predredging physical/ chemical testing of the project sediments prior to initiation of the corrective action.

At the conclusion of the LOE/WOE analysis, one of two conclusions will be drawn:

(1) There is **NO REASON TO BELIEVE** that contamination is present that will be mobilized during dredging/placement; further predredge physical and chemical testing of the dredge prism sediment **WILL NOT** be required; or

(2) There is **REASON TO BELIEVE** that contamination is present at levels that will have adverse effects that will be mobilized during dredging/placement; further predredge physical and chemical testing of the dredge prism **WILL** be required.

1.5 Problem Definition

To identify and structure the information that is needed, the problem formulation process and the development of a CSM specific for this dredging event (Figure 2) is essential (USEPA, 1997). The CSM addresses four issues as explained in Sections 1.5.1 through 1.5.4, after which, Assessment Endpoints (AEs) and Lines-of-Evidence (LOEs) are defined (Section 1.5.5).

1.5.1 Environmental Setting and Possible Contaminated Media

The project area was described in Section 1.2. Two areas (bend easing and flare widening) are to be hydraulically dredged, followed by pipeline placement into the confined section of PA-14. The medium under evaluation is the sediment associated with the corrective action project, with a secondary medium being water released from the PA's weir box after the dredge slurry has settled. Contamination is evaluated in the broad sense as a category; specific contaminants are not being evaluated at this point. Rather, the potential for contamination based upon reason to believe, will be evaluated.

1.5.2 Contaminant Fate and Transport Mechanisms

Dredging will be hydraulic cutter head with pipeline placement. This type of dredging minimizes perturbations and possible releases at the cutter head. No significant releases are expected at the cutter head, however, this potential exposure pathway is included for completeness. The sediments are to be piped as a slurry to the PA, where they will settle. The primary release mechanism for this stage of the project is releases of Chemicals Of Concern (COCs) from the PA that may partition off of the sediment particles into the aqueous phase of the slurry during settling in the PA, to be subsequently discharged at the weir box into Galveston Bay east of PA-14.

1.5.3 Mechanisms of Ecotoxicity and Categories of Receptors

The broader question of whether or not COCs might be released is under evaluation, consequently, categories of receptors both physically impacted by the sediment removal, as well as those potentially impacted by the release of COCs during or after dredging will be considered.

1.5.4 Exposure Pathway Analysis

Stressors can be physical, non-chemical and/or chemical; this evaluation focuses on chemical stressors only. Consequently, screening for potentially complete exposure pathway as part of the development of a specific CSM examine factors that could be associated with a potential to introduce or release chemicals that may adversely impact receptors in the vicinity of the dredge site and PA-14. The risk endpoint in this CSM is whether or not there is reason to believe contamination is present in the dredged materials, and if there is, whether this contamination may be mobilized during dredging, thereby adversely impacting aquatic resources and receptors in the vicinity of the corrective action project.

1.5.5 Assessment Endpoints (AE) and Lines-of-Evidence (LOE)

The Weight-of-Evidence (WOE) approach is the process by which LOEs, are related to an AEs to evaluate whether a significant risk of harm is posed to the environment. These last two terms are defined as follows:

Assessment Endpoints (AEs): explicit expressions of the actual environmental value that is to be protected; usually defined in terms of a specific population or a community function.
Lines-Of-Evidence (LOEs): data used to evaluate the AE; Multiple LOEs, both qualitative and quantitative, are often associated with a single AE.

For this project, we are defining AEs and LOEs as follows:

AE1: Sustainability of aquatic communities in the vicinity of the project footprint during dredging and within the mixing zone of discharge from the PA after dredging

- **LOE 1:** Composition of geological layers within the Beaumont formation in the vicinity of the dredge prism
- **LOE 2:** Infrastructure present within the dredge footprint or within the impact zone of the dredge activities
  - **LOE 2A:** Infrastructure associated with PA-14
  - **LOE 2B:** Infrastructure associated with industrial activity
- **LOE 3:** Ecological resources within the dredge footprint or within the impact zone of the dredge activities

LOE 4: COCs documented within or in proximity to the dredging prism

LOE 4A: COCs from point source releases

LOE 4B: COCs from predredging evaluation of maintenance dredging

LOE 4C: COCs from predredging evaluation of new work dredging

Each of these LOEs is discussed in Section 2.

2.0 LINES-OF-EVIDENCE (LOE)

The USACE and PHA have completed numerous construction projects and dredging events in the HSC and BSC, both before and after construction on Placement Area-14 (PA-14) was completed in 2004. These activities have resulted in a large body of information on the project area, providing sufficient information to evaluate the environmental safety of the proposed corrective action to address design deficiencies from the HSC Bend easing/BSC Flare widening. This section presents 4 LOEs that are currently available to evaluate and support the Reason-To-Believe premise (Appendix A) for sediments associated with this corrective action.

2.1 Geological Formations

The HSC and BSC are located in the Beaumont clay formation (USACE, 2013). The Beaumont Formation is a geological formation from the late Pleistocene period. In terms of broad and categorical characteristics in the Galveston Bay area in Harris County, the Beaumont Formation (USGS White Lake Quadrangle, Map Series Map I-1420(NH-15)), consists of two individually mapped, but intermingled types of delta and lagoonal deposits: (1) delta sand, silt and gravel, consisting of yellowish- to brownish-gray, locally reddish-orange sand, silt and minor fine gravel, intermixed and interbedded; (2) delta silt and clay, consisting of light- to dark-gray clay and silt intermixed and interbedded, containing layers and lenses of decayed organic matter; with fluvial-delta plain, coastal-marsh and lagoonal deposits including plastic and compressible clay (USGS, 2015). In the context of fate and transport, the clay layers in the formation are non-transmissive vertically, while sandy layers can be both vertically and horizontally transmissive.

The Beaumont clay formation is an important LOE, since the vast majority of the volume of new work dredge material will be undisturbed Beaumont clay formation. In this LOE we are comparing broad characteristics of the Beaumont clay formation in the vicinity of the corrective action for both consistency across the locality, as well as for comparability with the Beaumont formation in the BSC where new work channel improvements are underway. The evaluation for this project is limited to reaches from Station 22+00 to 31+00 in the HSC, Station 155+00 to 214+30.265 in the BSC and Station 214+30.265 to Station 241+69.320 in the Bayport Flare (Appendix C, Figure C-1). A total of 40 geotechnical boring records were compiled, depths up to -47 ft MLT (-45+2 ft) extracted and color coded by horizons (Table C-1).

In the bend easing portion of the HSC where the corrective action is to remove sediments, the borings (3ST-100, AM-15 and 72-51) are almost exclusively inorganic plastic clays (fat and lean clays) with some shell and sandy/silt clay in the shallow horizons in AM-15. In the flare widening portion of the BSC where the corrective action is to remove sediment, the borings (BC-8, BC-9, and BC-10) are composed mostly of fat and lean clays with some silt, similar to the stratification exhibited in the boring from the bend easing area. The borings in the flare widening prism did not contain the sand and shell horizons noted in the some of the other HSC (e.g., 93-35, 93-36) and BSC borings (e.g., BF-1 through BF-5). There are sandy layers in some portions of the formation in the project area that may be horizontally transmissive.

In general, the area to be removed as part of the corrective action is similar to areas of the Beaumont Clay formation tested in the BSC in 2014 (Anchor, 2014).

2.1.2 Conclusion – Geological

The portions of the HSC bend and BSC flare that are to be dredged as part of the corrective action are composed predominantly of impermeable layers of fat and lean clays, and do not posses any characteristics that are atypical of sediments already removed in the ship channel construction and maintenance activities in these vicinities.

2.2 Ecological Resources

The ecological resources in and around the project area were inventoried and summarized in the BSC EA (USACE, 2013); a synoptic summary can be found in Appendix D. Based upon the close proximity of the project area to the BSC, these resources and impacts are considered to be representative of this project. On a regional scale, no ecological receptors are expected to be adversely impacted by the corrective action removal, since the project area is so small. During the dredging, temporary localized effects will be felt to local, immobile receptors, such as benthics and bivalves, which include oyster reefs lying adjacent to and within the corrective action footprint. Post-dredging effects may also occur to immobile receptors in the mixing zone outside of the weir box at the PA.

This report evaluates the impacts to oysters from chemical exposures/stressors only. Any loss of oyster reefs will be mitigated as part of the overall project plan.

2.2.1 Conclusion – Ecological Resources

No ecological resources or receptors are expected to be significantly adversely impacted, except the oyster beds that lie within the corrective action footprint. These resources will be impacted because they physically lie within the corrective action footprint; mitigation measures are being implemented (USACE, 2015).

2.3 Infrastructure

Infrastructure is considered in this analysis for its potential to impact the dredging prism due to contaminant release. This report divides infrastructure into two categories:

1. private sector industrial structures (e.g., pipelines, oil/gas wells, service lines) that might be disturbed, damaged or destroyed during dredging, resulting in a release of COCs

2. structures associated with the ship channels (e.g., PAs).

2.3.1 Private Sector/Industrial

Appendices E and F show various types of industrial infrastructure in the vicinity of the proposed corrective action. No oil/gas wells or pipelines run in the vicinity of the project prism (Figure E-1). The closest well cluster (No. 262), located at the southern point of PA-14 directly east of the HSC bend, is well outside of the corrective action footprint (Figure E-1). Dredging is not expected to physically impact any industrial infrastructure such that a release could occur. Potential historical releases, are discussed in detail in Section 2.4.

2.3.2 Placement Areas

PA-14, immediately adjacent to the project, is the nearest PA and where the material from the corrective action removal will be placed. Appendix E (Figures E-2 through E-4) are cross-sectional drawings of PA-14, showing levees on the western side of the PA and the weir boxes/drop boxes on the eastern side of PA14. The weir/drop boxes have a base supported by 8 H-piles that reach depths in the range of 60-70 feet MLT; depths made necessary because of the poor structural support offered by the base layer, which is composed of various types of sandy layers (Appendix E). H-piles are commonly used in weir box construction because of the need for deep foundations (e.g., 60 – 70 Ft MLT) and their excellent driving characteristics in difficult soils.

The H-piles used in the construction of the weir boxes penetrate through both sandy and clay layers in the Beaumont Formation to depths well below project depths. While penetration subsurface materials can potentially create preferential pathways for COCs between the PA on the surface and the base layers at depth along the pile supports, an operational control that takes advantage of the addition of and settling of fine clay material to a CDF can be applied.

When fine grained materials are subjected to consolidation in a CDF, low permeability lenses can form (USACE, 2000). These low permeability lenses can result in what amounts to a self-sealing/self-lining CDF. Although the history of all of the material that has gone into the CDF has not been reviewed, for this report, the predominantly fine texture of the Beaumont formation from which local sediments are drawn, makes this lensing effect possible at PA-14. Since the weir boxes are located on the opposite side of the PA to the corrective action footprint, they are not expected to be physically impacted by removal of material in the corrective action footprint.

2.3.3 Conclusion - Infrastructure

Chemical releases are not expected from either industrial or PA infrastructure.

2.4 Chemicals of Concern (COCs)

The first three LOEs provided qualitative information to support to the Reason-To-Believe premise regarding potential adverse impacts due to COCs that might be mobilized as part of the corrective action in and around the corrective action area. More direct information, both qualitative and quantitative, to support the Reason-to-Believe premise is also available from an evaluation of point source contributors and recent chemical analyses of maintenance and new work dredge materials.

The potential for contaminants to have been introduced to the dredged material, evaluated along with the physical nature of the dredged material and the proposed disposal site, allows case-by-case determinations of whether the proposed discharge of dredged material may result in the mobilization of COCs to proximate ecological receptors.

2.4.1 Point Source Releases

A regulatory database search was performed in accordance with the American Society for Testing and Materials (ASTM) standard: E 1527-13 Standard Practice for Environmental Site Assessments. The search included all databases that met the requirements to perform All Appropriate Inquiry (AAI) under 40 CFR 312. A commercial database vendor, BANKS Environmental Data (Banks), prepared a regulatory database report on May 29, 2015 for a 5-mile radius around the geographic center of the proposed project features (e.g., Flare easing and Bend widening) (Appendix F). A 5-mile search radius is conservative and larger than the typical search radius of 0.25 to 1 mile, but was selected as a search distance to ensure that perspective was gained on frequency of occurrence as a function of distance from the project area. It was recognized at the outset, that for some parameters, this radius might more appropriately be set smaller.

The regulatory listings are limited to and include only those sites that are known to regulatory agencies to be permitted, contaminated, or in the process of evaluation for potential contamination at the time of publication. The databases searched include records of emergency response notifications involving hazardous material releases, sites requiring corrective action following releases of hazardous material or regulated substances, sites with releases requiring no further action, sites that have achieved closure, and sites permitted to store hazardous wastes but not necessarily associated with a release. These include State, Tribal, and Federal records and may involve former or existing industrial sites, landfills, commercial businesses, or areas involved in spill incidents. The effort also included a search of oil and gas wells, and water wells from State records.

The databases searched varied in the time period covered by records, according to when they were implemented, the age of records input into the database, and how recent or how often they are updated. For fixed site corrective action or permitted storage records (e.g., CORRACTS, CERCLIS, RCRA Generator), these typically go back to the mid to early 1980's with records in this search as early as 1983, and source data updated by the database's managing organization in either 2013 or 2015. The emergency response notification records (ERNS) spanned 1982-2014. In all cases, the vendor verified the availability of the most current version of databases in 2015. The database search was supplemented by a search of State permitted wastewater outfalls using 2015 geospatial data of domestic and industrial permitted discharges from the Texas Commission on Environmental Quality for the same 5-mile search radius used for the database search. The results of this search are attached in Appendix F.

Information was collected on two categories of point sources for this evaluation: wastewater outfalls (domestic sewage and process waters) and Hazardous, Toxic or Radioactive Waste (HTRW) releases. Figure F-1 shows the locations of wastewater outfalls within the 5-mile radius and their locations relative to the project area. Figure F-1 indicates all domestic and wastewater outfalls are between 4 and 5 miles from the project site. Given this distance and the inland locations of these outfalls, they would not be expected to contribute to COCs in the project area.

With respect to HTRW sites, the Banks Report (Appendix F) shows a variety of HTRW related sites, both large and small, within a five mile radius of the project area (Figures F-2 and F-4). These releases were acquired from databases sourced from the USEPA, Texas Commission on Environmental Quality (TCEQ) and the Railroad Commission (RRC) databases. Figure F-5 shows water, oil/gas wells, and Figure E-1, discussed earlier in Section 2.3.1 in the context of industrial infrastructure, shows HTRW sites, pipelines and well sites in the area surrounding the project.

Oil and gas wells are present within Galveston Bay, but none are spatially close enough to directly impact the site. Records show that HTRW related sites exist, however, corrective actions were undertaken at the times of release. Recent and new releases are dealt with under emergency response procedures. Older releases that may have occurred and not been cleaned up, will have dissipated over the Bay and will be captured in the chemical analyses of the dredge materials (see Section 2.4.2).

2.4.2 Dredging Events

The most quantitative LOE is the chemical analytical data obtained as part of the HSC/BSC dredging programs. These data are of greatest interest because they are both quantitative and spatially and temporally relevant to current conditions in the vicinity of the corrective action site.

2.4.2.1 Maintenance Dredging Events (HSC and BSC)

Analyses suites, specific analytes and Target Detection Limits (TDLs) for surface water (SW), elutriate and sediment (SD) routinely tested for in maintenance predredging evaluation testing are listed in Appendix G. For HSC maintenance dredging, analyses categories routinely include Semi-Volatile Organic Compounds (SVOCs) which includes Polycyclic Aromatic Hydrocarbons (PAHs), pesticides, Poly Chlorinated Biphenyls (PCBs), metals, dioxins/dibenzofurans, and miscellaneous parameters (ammonia, cyanides, Total Organic Carbon (TOC), Total Petroleum Hydrocarbons (TPH), grain size, total solids/dry weight). Recent dredging events for maintenance work are presented and discussed below (Tables G1 and G2). Each data set (surface water (SW), elutriate and sediment (SD)) discussion is accompanied by a data summary table of detected compounds and a sample location map in Appendix G to show how past channel dredging analyses results relate spatially to the current project area. If an analyte exceeded generic and conservative screening criteria, the result has been highlighted in the data table in Appendix G.

For maintenance dredging events, SW and elutriate analyte concentrations were screened primarily against chronic Texas Marine Water Quality Standards (WQS); sediment analyte concentrations were screened against NOAAs chronic Effects Range-Low (ER-L) criteria. Chronic WQS and ER-Ls are considered conservative generic screening numbers due to the conservatism built into their longer term exposures. Marginal exceedances, defined in this report as concentrations between one to two times the chronic WQS or ER-L, are not considered significant findings in any environmental evaluation due to the conservativeness (i.e., protectiveness) of chronic screening values. Only detected analytes are reported in the data tables. Exceedances of screening criteria are highlighted in the data tables in Appendix G.

Four recent channel maintenance dredging events are summarized:

1. 2009 - Bayport to Morgan's Point (directly in front of PA-14 to approximately 5 miles above PA-14)/Bolivar Road to Redfish Reef below the project area), Tables G-3 through G-5: No exceedances were noted for SW, elutriate or SD.
2. 2011 - HSC Redfish Reef to Bayport (directly in front of PA-14 to approximately 10 miles below in the HSC), Tables G6 through G-8: No exceedances were noted for SW, elutriate or SD.
3. 2012 - BSC (HSC/BSC flare to the end of the landlocked portion of the BSC), Tables G-9 through G-11: SW showed one marginal exceedance near the flare of chronic Texas WQS for copper (5.43 µg/L versus the standard of 3.60 µg/L); elutriate showed one marginal exceedance near the entrance to the landlocked section of the ship channel (4.18 µ/L versus the standard of 3.60 µg/L); SD showed no exceedances. No pattern of exceedances was noted and exceedances were marginal.
4. 2015 - HSC, Mid-Bay (southern tip of PA-15 to just south of placement area M-10), Tables G-12 through G-14: SW showed marginal exceedances for copper (5.51 – 6.11 µg/L versus the standard of 3.60 µg/L) at all sampling locations; however, all results qualified U (non-detect) or J (estimated) and no exceedances for copper or any other analyte were noted for the elutriate. No exceedances in sediment, except for silver, where all exceedances (1.65 – 7.23 mg/kg) of the ER-L (1 mg/kg) at all locations were all qualified U (non-detect).

2.4.2.2 New Work Dredging Events (BSC Widening/Deepening)

Analyses suites, specific analytes and Target Detection Limits (TDLs) for SW, elutriate and SD tested for in the new work predredging evaluation testing are listed in Appendix G. Due to the industrial activity in the BSC and BCC areas, analyses categories for new work predredging evaluation included VOCs, SVOCs including PAHs, pesticides, PCBs, dioxins/dibenzofurans, TPH, metals and miscellaneous parameters (ammonia, cyanide, Total Organic Carbon (TOC), grain size, total solids/dry weight) (Tables G15 and G-16). Recent dredging events for new work are presented and discussed below. Each data set (surface water (SW), elutriate and sediment (SD) discussion is accompanied by a data summary table of detected compounds and a sample location map in Appendix G to show how past channel dredging analyses results relate spatially to the current project area. If an analyte exceeded generic and conservative screening criteria, the result has been highlighted in the data table in Appendix G.

Data from two new work dredging events are available that are temporally relevant to this project; the BSC and BCC. These projects are composed for predominantly virgin material from the subsurface Beaumont clay formation. For new work predredging evaluations, SW and elutriate sample analyte concentrations were screened primarily against acute Texas Marine WQS. Acute WQS are not as conservative as chronic standards, but are still acceptable and protective because the dredging operations are constantly moving as the dredge material is removed and the disturbance is short lived. Sediment analyte concentrations were screened against NOAAs Effects Range-Low (ER-L) and as noted above in Section 2.4.2.1, ER-Ls are considered conservative generic screening numbers due to the conservatism built into their longer exposure periods. Marginal exceedances, defined in this report as concentrations between one to two times the acute WQS or ER-L, are not considered significant findings in any environmental evaluation due to the conservativeness (i.e., protectiveness) of these generic screening values. Only detected analytes are reported in the data tables. Exceedances of screening criteria are highlighted in the data tables in Appendix G.

1. BSC (flare to the turning basin), Tables G-17 through G-19: SW showed no exceedances in chemical analyses, though exceedances of cyanide were noted at some locations within the turning basin and the landlocked portion of the ship channel; there is no Texas WQS, though EPA has a criteria of 0.001 mg/kg and detections ranges from 0.0057 – 0.0092 mg/kg. Elutriate showed no exceedances in chemical analyses though intermittent exceedances (0.0077 – 0.018 mg/kg) of cyanide were again noted 4 of 17 locations. The cyanide detects for the elutriate analyses were qualified "J" and are estimated values. No exceedances were noted for cyanide in sediment at any location. One marginal exceedance (8.5 (J) mg/kg) of arsenic's ER-L of 8.2 mg/kg was noted for in the open bay and six marginal exceedances (22.7 – 28.3 mg/kg) of the nickel ER-L of 20.9 mg/kg were noted spaced over the area being evaluated.
2. BCC (ship channel to the turning basin), Tables G-20 through G-22): SW and elutriate showed no exceedances of conservative screening criteria. In sediment, one marginal exceedance (8.7 mg/kg) qualified "J" of arsenic's ER-L of 8.2 mg/kg was noted and one marginal exceedance (25 mg/kg) of nickel's ER-L of 20.9 mg/kg was noted.

With regards to arsenic and nickel, NOAA's National Status and Trends Program for Marine Quality (NOAA, 2003) shows that in Galveston Bay sediments, arsenic levels averaged 5.91 ± 3.40 mg/kg and nickel averaged 15.09 ± 7.4 mg/kg. BSC and BCC arsenic and nickel levels are consistent with these NOAA findings.

2.4.3 Conclusions - COCs

Point source releases (e.g., municipal or industrial outfalls, HTRW) are not expected to impact COC levels in the project sediments.

Maintenance dredging (2009 through 2015), from approximately 5 miles above to 10 miles below the project area, show no significant or widespread levels of COCs. Sporadic, marginal detections of conservative chronic screening criteria were noted.

New work dredging (2014) for the BSC and BCC tested sediments that came from busy industrial ship channels. These sediments, comprised of both virgin and non-virgin new work material but predominantly of virgin Beaumont clay, showed no significant or widespread levels of COCs. Sporadic, marginal detections of conservative screening criteria were noted for arsenic and nickel in sediment, but these exceedances are consistent with regional levels (NOAA, 2003).

2.5 LOE Conclusions

Evaluation of the 4 main LOE provides the following:

1) Geological: The portions of the HSC and BSC Flare that are to be removed as part of the corrective action are composed predominantly of impermeable layers of fat and lean clays, and do not posses any characteristics that are atypical of sediments already removed in these vicinities
2) Ecological Resources and Receptors: No ecological resources or receptors are expected to be significantly adversely impacted by chemical releases during dredging, or post-dredging
3) Infrastructure: Neither industrial infrastructure nor PA infrastructure have historically been associated with any COC releases, nor will they be physically impacted by the corrective action such that a release would occur.
4) Chemicals of Concern:
    i) no point sources (outfall or HTRW) were within 4 miles of the project area, indicating that no significant contributions to COCs levels in the project sediments would come from municipal sewage and industrial outfalls

ii) sporadic and marginal detections of conservative screening criteria were noted in some maintenance (shoaled surficial sediments) and new work (virgin and non-virgin) dredged materials. Widespread contamination is not present in dredge material in the vicinity of the project.

3.0 WEIGHT-OF-EVIDENCE (WOE)

WOE approaches have been used in Ecological Risk Assessments (ERA) for many years and the approach integrates various types of data, both qualitative and quantitative, to make an overall conclusion of risk. The WOE approach takes into account the strengths and weaknesses of different LOEs when determining whether the results show that a stressor has caused, or could cause, a harmful ecological effect.

The WOE analyses for this case study, combines and applies a Sequential Analyses of Lines-of-Evidence (SALE) (Hull and Swanson, 2005) and a Body-of-Evidence (Suter and Cormier, 2012) approach to this dredging project. These approaches allow risks to be ruled out with the use of certain LOEs, including comparison of measured media chemical concentrations to conservative soil, water or sediment quality guidelines, when such data are available. This processes provides opportunities to exit the risk assessment process when risks are ruled out, when the magnitude of effect is acceptable, or when little or no evidence shows that associations between stressors and effects may be causal.

As stated and explained in detail in Section 2, this evaluation defines stressors as COCs and effects as exceedances of conservative generic screening benchmarks. The specific effect associated with the exceedance of screening benchmark is not considered in the first iteration, other than distinguishing between general acute effects and general chronic effects represented by the benchmarks. If significant exceedances or concerns are noted, then the specific benchmark or mechanism are examined in greater detail in one or more subsequent site-specific iterations. However, it should be noted that in the overall evaluation of COCs, the direct evaluation of COC concentrations in specific media is only one LOE. Other LOE that help us understand how/when COCs might have been introduced, or how they may have been transported to the corrective action site, are also evaluated.

3.1 Approach

The four LOEs in this evaluation were assembled and discussed in Section 2. Each LOE must now be weighted and then the four LOEs weighed in aggregate (Hull and Swanson, 2006; Suter and Cormier, 2011). Consistent with these LOE/WOE approaches, the weighting and weighing approaches presented below will incorporate expert judgment, criteria-based evaluation, logic and causal criteria.

3.1.1 Weighting LOEs Individually

The weighting process includes evaluation of the following causal criteria:

1) **Spatial Correlation:** Effects occur at the same place as exposure.
2) **Temporal Correlation:** Effects occur with or after exposure i.e. at a time that correlates to dredging activities.
3) **Biological Gradient or Strength:** Effects decline as exposure declines in the landscape. Similarly, effects decline as exposure declines over time (or effects increase as exposure increases over time).
4) **Plausibility (mechanism):** It must be known how the stressor causes an effect in the affected organisms, so that it can be determined whether it is plausible that the observed effects are a result of the stressor.
5) **Plausibility (stressor–response):** The magnitude of effect is expected on the basis of the level of the stressor.
6) **Consistency of Stressor-Effect Association:** Repeated observation of effect and stressor is seen in different studies or different locations within the region being studied. In addition, information is available from other regions in which similar (analogous) stressors have caused similar effects.
7) **Experimental Verification:** Effects of the stressor are observed under controlled conditions with concordance of these experimental results with field data.

8) **Specificity of Cause:** The effect tends to be associated with exposure to a particular stressor. Effects should be defined as specifically as possible to increase the specificity of the association between cause and effect.

Using these criteria, an overall causation score for each LOE can be arrived at using the scoring in Table 1. These overall causation scores will be identified in the Overall Strength of Evidence row in Table 2 as strong, moderate or weak. An overall scoring rather than simply adding up scores for each LOE is important. Simple addition implies, incorrectly, that each causal criterion is of equal importance. The USEPA suggests more attention be paid to negative results, which are more likely to be decisive, and that the overall causation score is determined by how consistent and strong the causation evidence is across all causal criteria (USEPA, 2000). In essence, the overall causation score is a measure of the completeness of the causal pathway, which could be considered the link from stressor to response via a plausible mechanism and the plausible stressor response showing spatial and temporal correlation.

If the evidence for causality related to COCs is strong or moderate, the process must continue to the last step of the weighing of LOEs in aggregate. With only weak evidence for each LOE, a weighing of LOEs may be completed or the risk evaluation terminated for the cause under evaluation, depending upon the distribution of scores and the professional judgment of the evaluator.

3.1.2 Weighing LOEs in Aggregate

If the decision is made to proceed to the last step, the LOEs must be weighed in aggregate. The final weighing of evidence involves summarizing causality scores, magnitude of response scores and incorporating the level of uncertainty for each LOE of direct and indirect effect, and for each site or area under evaluation (Hull and Swanson, 2006; Suter and Cormier, 2011). Consistency of scores across all LOE provides a higher level of confidence in the risk management evaluation recommendation. A number of high uncertainty scores for a site or area would indicate that a risk management decision might benefit from more information.

3.2 Ranking of LOEs - Weighting LOEs Individually

The causal criteria used in the weighting process must be placed within the context of the specific project. For this evaluation the following refinements to the causal criteria include:

1) **Spatial Correlation:** It will be assumed that effects will occur at the same place as exposure; exposure is defined as being located within the dredging footprint during dredging, and within the mixing zone from discharge at the PA after dredging.
2) **Temporal Correlation:** The LOE are collected from a temporal window that precedes our project dredging event, but they are extrapolated as being applicable to this event.
3) **Biological Gradient or Strength:** Gradients will not be evaluated; the simplifying assumption that releases will or will not happen is all that is required for this evaluation. This criterion is marked NA for Not Applicable but effects are not completely discounted, as they are evaluated under Specificity of Cause in criterion #8 below.
4) **Plausibility (mechanism):** It is assumed that if COCs are expected, that a mechanism will exist but will be ranked as non-specific for this evaluation.
5) **Plausibility (stressor–response):** It is assumed that if COCs directly related to the corrective action dredging are suspected, that a stressor-response will exist.
6) **Consistency of Stressor-Effect Association:** Local and regional data have been collected and will be used to infer site-specific conditions.
7) **Experimental Verification:** Specific experimental studies have not been undertaken. This criterion is marked NA for Not Applicable.
8) **Specificity of Cause:** Stressor is defined as a chemical stressor for this evaluation; an elevation in the COC concentrations that might be a result of corrective action dredging will be equated to an effect.

Each LOE was described in detail in Section 2, allowing site-specific interpretations of the causal criteria to be made and scored in this section; the results are summarized in Table 2.

The evaluation of causal criteria was similar for all four LOEs. Each LOE in Table 2 shows an overall weak strength of evidence for causality between the corrective action and the sustainability of aquatic communities in the vicinity of the project footprint under expected project exposure conditions (Section 1.5.4). In all but three instances (LOE 1(i), LOE 2(i) and LOE 3(ii)), all causal scoring was either neutral or could not be associated with the overall AE. For the three instances where causal criteria were not scored this way ((LOE 1(i), LOE 2(i) and LOE 3(ii)), causal criteria were not strong (i.e., were moderate).

Under such uniform evaluations, a project may elect to exit the risk assessment or continue to an evaluation of overall WOE; this project proceeded to an evaluation of overall WOE to gain insight into both the magnitude of the response and the uncertainty associated with each LOE.

3.3 Evaluation of Overall WOE - Weighing LOEs in Aggregate

Table 3 summarizes causality scores from Table 2, magnitude of response scores, and factors in the level of uncertainty for direct and indirect effect for each LOE for both the bend easing and the flare widening areas of the project.

Two LOEs had a ranking of “moderate” for uncertainty; LOE 1 (geological layers) and LOE 2 (infrastructure, PA-14). These uncertainty rankings were assigned due to the inherent variability in the Beaumont Clay formation, upon which these LOEs are highly dependent. Although the uncertainty in these two endpoint is moderate, the magnitude and causal link factors were ranked low, rendering the overall LOE consistent with the body of evidence in the evaluation. The remainder of the body of evidence indicates all magnitude of response entries were ranked “small”, and all uncertainty related to the response entries were ranked “low”. These rankings, combined with weak overall causation from Table 2, show a high degree of consistency across

LOEs and show low overall causality. As such, the evaluation of overall WOE supports not proceeding to a risk management decision of further predredging sediment testing. Consistency of scores across all LOEs provides a high level of confidence for decision making.

An overall scoring rather than simply adding up scores for each LOE is important. Simple addition implies, incorrectly, that each causal criterion is of equal importance. The USEPA (USEPA, 2000) suggests more attention be paid to negative results, which are more likely to be decisive and that the overall causation score is determined by how consistent and strong the causation evidence is across all causal criteria

Consistent with Subpart G of the 404(b)(l) guidelines, this LOE/WOE analysis used available information to provide a "reasonable assurance that the proposed discharge material is not a carrier of contaminants" (§230.60(b)) by virtue of the facts that:

- sediments are sufficiently removed from sources of contamination
- proposed dredging site is not proximate to other sources of contamination
- previous testing in the area indicates no significant contamination
- experience and knowledge of the area to be dredged indicate no contamination.

4.0 CONCLUSIONS AND RECOMMENDATION

4.1 Conclusions

The scoring of each LOE using casual criteria showed an overall weak strength of evidence for causality between the corrective action and the sustainability aquatic communities in the vicinity of the project footprint under project exposure conditions.

In the evaluation of overall WOE:

1) all magnitude of response were ranked “small”
2) uncertainties associated to with (1) were ranked “low”, with the exception of the two LOEs associated with the Beaumont Clay formation, which were ranked “moderate”
3) causation was ranked “weak” for all LOEs
4) Taken in aggregate, the concurrence across all LOEs supports decision making

There is **NO REASON TO BELIEVE** that contamination is present that will be mobilized during corrective action dredging/placement; further predredge physical and chemical testing of the dredge prism sediment **WILL NOT** be required.

4.2 Recommendations

Under Section 404 of the Clean Water Act (USEPA, 2014) and pursuant to Regulatory Guidance Letter No. 06-02 (USACE, 2006), no further testing of sediments associated with the corrective actions to address design deficiencies from the Houston Ship Channel (HSC) Flare at Bayport Ship Channel (BSC) are required prior to placement in upland confined PA-14.

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Figures

Figure 1: Project Area

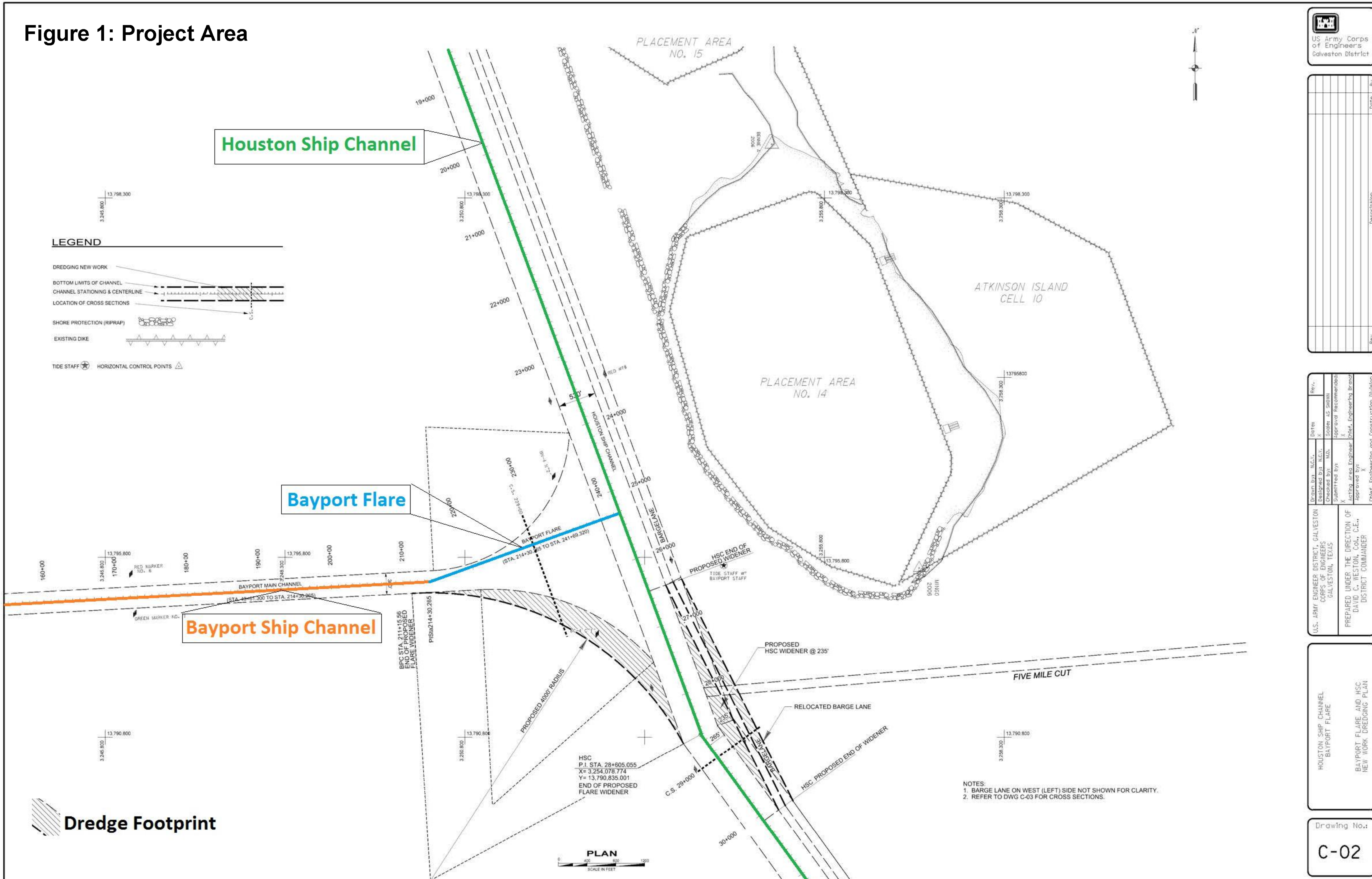
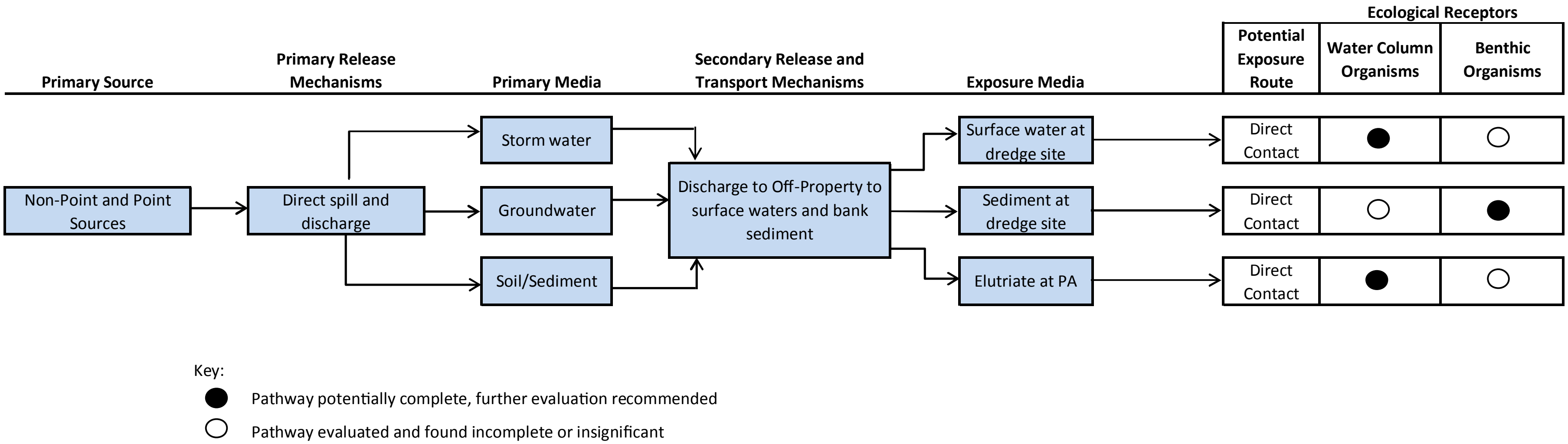


Figure 2: Ecological Conceptual Site Exposure Model
HSC Bend Easing and BSC Flare Widening
Houston, Texas



Tables

Table 1: Scoring Scheme for Causal Criteria
Corrective Actions to Address Design Deficiencies from the HSC Flare at Bayport Ship Channel (BSC)

CRITERION	SCORING SCHEME	
	Result Descriptor	**Score (1)**
Spatial correlation	Strong	+ +
	Moderate	+
	Uncertain	0
	Weak	-
	None	- -
Temporal correlation	Strong	+ +
	Moderately Strong	+
	Uncertain	0
	Weak	-
	None	- -
Biological gradient/strength	Strong and monotonic	+ + +
	Weak or other than monotonic	+
	None	-
	Clear association, but the more stressor, the lower the response	- - -
Plausible mechanism	Actual Evidence	+ +
	Plausible	+
	Not known	0
	Implausible	- - -
Plausible stressor response	Quantitatively Consistent	+ + +
	Concordant	+
	Ambiguous	0
	Inconcordant	- - -
Consistency of association (across sites in the region)	Invariant	+ +
	In many places and times	+
	Present at background frequencies /many exceptions to the association	-
Experimental verification	Experimental Studies	+ + +
	Concordant	0
	Ambiguous	- - -
	Inconcordant	
Specificity of cause	Only possible cause	+ +
	One of a few	+
	One of many	-

Footnotes:
1) In addition to the scores noted, no evidence (NE) might be available relevant to the criterion or the criterion might be not applicable (NA) for the particular case

Table 2: Scoring Lines-of-Evidence (LOE) Using Causal (1) Criteria
Corrective Actions to Address Design Deficiencies from the HSC Flare at Bayport Ship Channel (BSC

AE1: Sustainability of aquatic communities in the vicinity of the project footprint during dredging and within the mixing zone of discharge from the PA

CAUSAL CRITERIA		LINES-OF-EVIDENCE SCORE (2,3)						
			ME2: Intrafrastucture			ME4: COC within or proximate to dredge prism		
No.	Description	ME 1: Geological layers	ME2A: PA-14	ME2B: Industrial	ME3: Ecological Resources	ME4B: Point Sources	ME4C: Predredge Maintenance	ME4D: Predredge New Work
(i)	Spatial Correlation	+	+	- - -	- - -	0	- - -	- - -
(ii)	Temporal Correlation	0	0	- - -	+	0	- - -	- - -
(iii)	Biological Gradient/Strength	NA	NA	NA	NA	NA	NA	NA
(iv)	Plausibility: Mechanism	0	0	0	0	0	- - -	- - -
(v)	Plausibility: Stressor - Response	0	0	0	0	0	- - -	- - -
(vi)	Consistency of Stressor-effect Association	-	-	-	-	-	-	-
(vii)	Experimental Verification	NA	NA	NA	NA	NA	NA	NA
(viii)	Specificity of Cause	0	0	0	0	0	0	0
	ME Strength	◌	◌	◌	◌	◌	◌	◌
	Overall Strength of Evidence (4)	◌	◌		◌	◌		

FOOTNOTES

1) Causation: refers to the overall strength of evidence

2) For explanation of scores, see Table 1. In addition to the scores noted, No Evidence (NE) might be available relevant to the criterion or the criterion might be Not Applicable (NA) for the particular case

3) MEs described more fully in Section 1.5.5. Score assigned based upon local and regional information as appropriate

4) Overall Strength of Evidence

● Strong

○ Moderate

◌ Weak

Table 3: Summary WOE Table With Risk Management Decision (1, 2, 3)
Corrective Actions to Address Design Deficiencies from the HSC Flare at Bayport Ship Channel (BSC

Site Location	ME 1: Geological layers			ME2: Infrastructure						ME3: Ecological Resources		
				ME2A: PA-14			ME2B: Industrial					
	Magnitude	Uncertainty	Causation	Magnitude	Uncertainty	Causation	Magnitude	Uncertainty	Causation	Magnitude	Uncertainty	Causation
Bend Easing	◌	○	◌	◌	○	◌	◌	◌	◌	◌	◌	◌
Flare Widening	◌	○	◌	◌	○	◌	◌	◌	◌	◌	◌	◌

Site Location	ME4: COC within or proximate to dredge prism									Proceed to Risk Mgt (yes/no)? (2)
	ME4A: Point Sources			ME4B: Predredge Maintenance			ME4C: Predredge New Work			
	Magnitude	Uncertainty	Causation	Magnitude	Uncertainty	Causation	Magnitude	Uncertainty	Causation	
Bend Easing	◌	◌	◌	◌	◌	◌	◌	◌	◌	NO
Flare Widening	◌	◌	◌	◌	◌	◌	◌	◌	◌	NO

FOOTNOTES:

1) Definiton of Terms:

Magnitude: refers to the magnitude of response

Uncertainty: related to the magnitude of response category

Causation: refers to the overall strength of evidence(final row of Table 2)

2) Risk Management is defined as inititation of a predredging physical and chemcial testing and evaluation of the dredge prism sediments. The decision to proceed to risk management/sediment testing is yes or no.

3) Key:	●	○	◌
Magnitude	large	moderate	small
Uncertainty	substantial	moderate	low
Causation	strong	moderate	weak

3;8/3/2015