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2 April 2014

Mr. Brian Mueller
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U.S. Environmental Protection Agency (EPA) Region 6
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RE: Screening Level Ecological Risk Assessment for AOC-5
Falcon Refinery Superfund Site
Remedial Investigation/Feasibility Study
EPA Region 6 Remedial Action Contract 2
Contract: EP-W-06-004
Task Order: 0088-RICO-06MC

Dear Mr. Mueller:

EA Engineering, Science, and Technology, Inc. (EA) is enclosing two hard copies and one electronic copy on a compact disk of the Screening Level Ecological Risk Assessment for AOC-5 for the above-referenced Task Order to EPA.

If you have any questions regarding this submittal, please call me at (972) 315-3922.

Sincerely,

Robert M. Owens
Project Manager

RMO/ab

Enclosure

cc: Michael Pheeny, EPA Contracting Officer (letter only)
Rena McClurg, EPA Project Officer (letter only)
Tim Startz, EA Program Manager (letter only)
File

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TRANSMITTAL OF DOCUMENTS FOR ACCEPTANCE BY EPA		DATE: 2 April 2014	TRANSMITTAL NO.: **0015**
TO: **Mr. Brian Mueller** **U.S. Environmental Protection Agency (EPA) Region 6**		FROM: **Mr. Robert Owens** **EA Engineering, Science, and Technology, Inc.**	
SUBTASK NO.	DELIVERABLE	NO. OF COPIES	
7.4	Screening Level Ecological Risk Assessment for AOC-5 Falcon Refinery Superfund Site Remedial Investigation/Feasibility Study	EPA - 1 electronic copy on compact disk and 2 hard copies	
ACCEPTANCE ACTION			
DOCUMENTS FOUND ACCEPTABLE (LIST BY SUBTASK NO.)		NAME/TITLE/SIGNATURE OF REVIEWER DATE	

Screening Level Ecological Risk Assessment for Area of Concern 5 (AOC-5)

Remedial Investigation/Feasibility Study

Falcon Refinery Superfund Site
Ingleside, San Patricio County, Texas
EPA Identification No. TXD086278058

Remedial Action Contract 2 Full Service
Contract: EP-W-06-004
Task Order: 0088-RICO-06MC

Prepared for

U.S. Environmental Protection Agency
Region 6
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LIST OF ACRONYMS AND ABBREVIATIONS

AOC	Area of Concern
ARCS	Assessment and Remediation of Contaminated Sediment
AST	Above ground storage tank
BAF	Bioaccumulation Factor
BCF	Bioconcentration Factor
BTAG	Biological Technical Assistance Group
BRAPF	Baseline Risk Assessment and Problem Formulation
CHPPM	U.S. Army Center for Health Promotion and Preventative Medicine
COPEC	Chemicals of potential concern
CSM	Conceptual site model
EA	EA Engineering, Science, and Technology, Inc.
EPA	U.S. Environmental Protection Agency
EPC	Exposure Point Concentration
ERA	Ecological Risk Assessment
FI	Food Ingestion
FM	Farm-to-market
FS	Feasibility Study
HMW	High molecular weight
HQ	Hazard Quotient
ICW	Intracoastal Waterway
LOAEL	Low Observed Adverse Effect Levels
mg/kg	milligrams per kilogram
mg/L	milligrams per liter
NAWQC	National Ambient Water Quality Criteria
ND	Non-detect
NOAEL	No Observed Adverse Effect Levels
NOAA	National Oceanic and Atmospheric Administration
NORCO	National Oil Recovery Corporation
ORNL	Oak Ridge National Laboratory
PAH	Polynuclear aromatic hydrocarbon
PEL	Probable Effects Level
redox	Reduction and oxidation
RI	Remedial Investigation

LIST OF ACRONYMS AND ABBREVIATIONS (CONTINUED)

Site	Falcon Refinery Superfund Site
SLERA	Screening-Level Ecological Risk Assessment
SQL	Sample Quantitation Level
SVOC	Semivolatile Organic Compound
TAL	Target Analyte List
TCEQ	Texas Commission on Environmental Quality
TEC	Threshold Effects Concentration
TEL	Threshold Effects Level
TRV	Toxicity Reference Value
UCLM	Upper Confidence Level of the Mean
UF	Uptake factor
EPA	U.S. Environmental Protection Agency
VOC	Volatile Organic Compound

1. INTRODUCTION

EA Engineering, Science, and Technology, Inc. (EA) has been authorized by the U.S. Environmental Protection Agency (EPA), under Remedial Action Contract Number EP-W-06-004, Task Order 0088-RICO-06MC, to conduct a Remedial Investigation/Feasibility Study (RI/FS) at the Falcon Refinery Superfund Site (Site). EPA's scope of work includes the preparation of a Screening Level Ecological Risk Assessment (SLERA) for the site. EPA has requested that EA prepare a SLERA for the barge dock area (Area of Concern [AOC] 4) and the Intracoastal Waterway AOC-5) separate from the remaining site. This document provides the results of the SLERA for AOC-5.

1.1 SITE BACKGROUND AND DESCRIPTION

The Site is located 1.7 miles southeast of State Highway 361 on Farm-to-Market (FM) 2725 at the north and south corners of the intersection of FM 2725 and Bishop Road near the City of Ingleside in San Patricio County, Texas (Figure 1). The site occupies approximately 104 acres and consists of a refinery that operated intermittently and has not produced hydrocarbon products in several years. The refinery is currently inactive, except for a crude oil storage operation being conducted by Superior Crude Gathering, Inc. When in operation the refinery had a capacity of 40,000 barrels per day and the primary products consisted of naphtha, jet fuel, kerosene, diesel, and fuel oil. The refinery also historically transferred and stored vinyl acetate, a substance not excluded under the petroleum exclusion.

The Site is divided into the North Site, South Site and current barge dock facility. There are pipelines that connect the North and South Sites with the current and former barge dock facilities. The North Site consisted of nine above ground storage tanks (ASTs), three truck loading racks, associated piping and a transfer pump. The South Site consisted of the main operations of the refinery. This area had a control room, heaters, crude towers, coalesers, boilers, fire water tank, exchangers, cooling towers, desalters, exchangers, compressors, a lab, 24 ASTs, separator, clarifiers, and aeration pond (TRC 2013). The barge dock facility is located on Redfish Bay and was used to load and unload crude oil and refined hydrocarbons via pipelines that connect the dock to the North and South Sites.

The Site was proposed to the National Priorities List on 5 September 2002. The Potentially Responsible Party for the Site, National Oil Recovery Corporation (NORCO), entered into an "Administrative Order on Consent" with the EPA on 9 June 2004, to perform and finance the removal action and RI/FS for the Site.

In 2012, NORCO sold the former Falcon Refinery to Lazarus Texas Refining I, LLC (Lazarus), which operates the former refinery as a crude oil bulk storage and transfer facility. Lazarus is attempting to obtain a notice of no further action for the barge dock facility to obtain a "bridge loan" until additional funding can be obtained (TRC 2013). Lazarus plans to further develop the Site through remedial actions and upgrades.

The Site has been divided into AOCs based upon former use and location (Figure 2). AOC-1 consists of the Former Operational Units and includes the entire North Site and a drum disposal area and metal waste disposal area of the South Site. AOC-2 includes areas of the refinery that were not used for operations or storage and have no record of releases. AOC-3 encompasses the wetlands immediately adjacent to the Site that are bordered by Bay Avenue, Bishop Road, and a dam on the upstream side; wetlands located between Bishop Road, Sunray Road, Bay Avenue and residences along Thayer Avenue; and the wetlands between Sunray Road, residences along FM 2725, Gulf Marine Fabricators, Offshore Specialty Fabricators and the outlet of the wetlands into Redfish Bay. Within AOC-3, there are one active and several abandoned pipelines that lead from the refinery to the barge dock facilities. During June 2006 the abandoned pipelines were cut, the contents of the pipelines were removed and plates were welded on the pipelines. AOC-4 includes the barge docking facility. AOC-4 is approximately 0.5 acres and is located on Redfish Bay. The fenced facility, which is connected to the refinery by pipelines, is used to load and unload barges. Currently only crude oil passes through the docking facility. Historically, refined products were also loaded and unloaded. AOC-5 encompasses the sediments and surface water within the Intracoastal Waterway adjacent to the barge dock facility. AOC-6 includes the neighborhood along Thayer Road, across from the refinery. AOC-7 includes the neighborhood along Bishop Road, across from the North Site.

1.2 SITE INVESTIGATIONS

Phase I sampling was conducted at the Site in 2007 by the potentially responsible parties. EA conducted Phase II investigation activities in accordance with the Field Sampling Plan (EA 2012a) and Quality Assurance Project Plan (EA 2012b) under this task order in 2013.

1.3 AOC-5 BACKGROUND AND DESCRIPTION

AOC-5 includes portions of the Intracoastal Waterway (ICW) near the current and former barge dock facility. The ICW is a major avenue for the commercial transportation of various good along the Texas coast using barge and other smaller boats. Sediment and surface water of the ICW are included in AOC-5. It is not part of the previous Falcon Refinery but is contiguous with the barge dock facility.

2. ECOLOGICAL RISK ASSESSMENT

This section presents the SLERA conducted by EA for AOC-5 at the Site. The purpose of this assessment is to characterize and quantify potential environmental impacts from residual chemicals in sediment and surface water at AOC-5 from Site activities. The assessment was conducted in accordance with EPA guidance for the RI/FS process; specifically the SLERA was conducted in accordance with the process for ecological risk assessments (ERAs) outlined in the document *Ecological Risk Assessment Guidance for Superfund: Process for Designing and Conducting Ecological Risk Assessments* (EPA 1997), other relevant EPA guidance, as well as the Texas Commission on Environmental Quality (TCEQ) guidance *Conducting Ecological Risk Assessments at Remediation Sites in Texas* (TCEQ 2014) and *Texas Surface Water Quality Standards* (TCEQ 2010).

The process for ERA outlined in EPA guidance includes eight steps (EPA 1997, 1998), and this document presents the first three steps of the ERA process (Figure 3). Steps 1 and 2 represent the SLERA. The SLERA uses highly precautionary assumptions regarding exposure and toxicity to develop a Conceptual Site Model (CSM) and identify Chemicals of Potential Ecological Concern (COPECs). The CSM defines complete and significant exposure pathways and identifies assessment and measurement endpoints. The screening level evaluation typically relies on chemical analytical data.

Step 3 of the SLERA process is the Baseline Risk Assessment Problem Formulation (BRAPF). The BRAPF draws from the risk evaluation performed in the SLERA to identify COPECs, exposure pathways, assessment endpoints, and risk questions requiring further consideration. The BRAPF often includes refinement of the screening level risk calculations through use of more realistic or more relevant exposure and toxicity data. The goal of the BRAPF is to provide a clear definition of the ecological risk problems for the Site. This problem formulation forms the basis for either further assessment or, in cases where sufficient data are available, risk management if necessary.

In the case of the Falcon Refinery Superfund Site, a SLERA and BRAPF refinement of risk calculations were performed at relevant sites. Section 2.1 presents the CSM and assessment endpoints. Section 2.2 discusses the data used in the SLERA and presents measurement endpoints for the screening level risk evaluation. Section 2.3 presents the SLERA results and conclusions. Section 2.4 presents the refined risk assessment and methodology and discusses the data and measurement endpoints used. The refined toxicity assessment is defined in Section 2.5, and the refined risk calculation is defined in Section 2.6. Results from the BRAPF for AOC-5 are presented in Section 2.7. The results for all measurement endpoints are combined in a qualitative weight of evidence approach to provide a preliminary risk characterization for each assessment endpoint. Uncertainties associated with the risk assessment are presented in Section 2.8, and results of the risk characterization are considered together in developing the conclusions for the site which are presented in Section 3.0.

Summary of Data Used in the SLERA

Initial field sampling was conducted in 2007/2008 as a result of an EPA approved RI/FS Field Sampling Plan and Quality Insurance Plan for the former refinery, adjacent properties, and background sampling locations (TRC 2013). Analytical data obtained during the sampling was evaluated for ecological exposures, and results indicated that further sampling was necessary to adequately assess certain portions of the Site. Field activities conducted in 2013 as part of the Phase II Field Sampling Plan had objectives relating to this SLERA which included providing data to identify and delineate the extent of COPECs in environmental media, identify potential and complete exposure pathways, and provide data for completion of human health and ERAs as well as the feasibility study. Table 1 presents the samples collected in 2008 and 2013 that were used in this risk assessment.

A total of 13 sediment (0-6 inches below ground surface and surface water samples were collected from AOC-5 in 2008 and 2013 combined. Sediment samples were collected using a ponar sampler or scoop at the same locations, after collection of surface water samples. Sample locations are presented in Figure 4.

The surface water and sediment samples were analyzed for target analyte list (TAL) metals, polynuclear aromatic hydrocarbons (PAHs), semivolatile organic compounds (SVOCs), and volatile organic compounds (VOCs).

Data Reduction and Summary Statistics

This section describes the approach that was followed to evaluate the available analytical data in each medium of concern (e.g., surface soil, sediment, and surface water). The following list summarizes the approach:

- Analytical results with a “R” qualifier (indicating that the data were rejected during the validation process) were not used in the SLERA and BRAPF.

- Analytical results with a “U” or “UJ” qualifier indicate that the analyte was not detected at the sample quantitation level (SQL). These data were considered non-detects (NDs) and were retained in the data set. In the calculation of the 95 percent upper confidence limits of the mean (UCLMs), each ND was assigned a numerical value of one-half its SQL.

- Analytical results with a “J” qualifier indicate that the reported values were estimated because the analyte was detected at a concentration below the SQL or for other reasons. These data were considered detections and were retained in the data set at the measured concentration.

- Analytical results with “D”, “K”, or “L” qualifiers were considered detections and were retained in the data set at the measured concentration.

- Inorganic analytes with “B” or “BJ” qualifiers were retained in the data set at the measured concentration.

- Analytical results for organic analytes with a “B” qualifier (blank-related data) were treated as NDs.

In accordance with EPA (1989) guidance, the following steps were first used to summarize the chemical analytical data for the SLERA:

- Sample data were compared to blank (laboratory, equipment rinse, and field) concentration data. If the chemical concentration detected in a site-related sample was less than 10 times (for common laboratory chemicals) or 5 times (for all other compounds) the concentration detected in the corresponding blank sample, the sample was excluded from the SLERA in accordance with EPA guidance (EPA 1989). The identification and validation of sampling or laboratory artifacts were performed prior to data summarization.

- The maximum concentration of a pair of duplicate or split samples (taken from the same location on the same date) if both parent and duplicate were detected, the maximum nondetect concentration if both parent and duplicate were nondetects, and the detected value if either parent or duplicate were detected, and the other nondetected were used to represent the concentration for that location.

- Frequency of detection was calculated as the number of samples in which the chemical was detected over the total number of samples analyzed (Table 5).

There are a number of uncertainties associated with the chemical analytical data associated with sample coverage and study design. Uncertainties associated with the data used in the SLERA are discussed in Section 2.8.

2.1 ECOLOGICAL CONCEPTUAL SITE MODEL

As part of the CSM, potential sources of chemicals and exposure pathways are characterized for the Site (Figure 5). The model illustrates the pathways through which receptors may be exposed to sources of COPECs. Sources and exposure pathways are discussed further below.

Ecological Setting

The Falcon Refinery Superfund Site consists of a refinery that had the capacity of 40,000 barrels per day with the primary products consisting of naphtha, jet fuel, kerosene, diesel, and fuel oil. The refinery operated intermittently and is currently inactive. The Site encompasses approximately 104 acres in San Patricio County, Texas with portions of the Site (AOC-4 and AOC-5) located along Redfish Bay in the ICW. The property includes piping that leads from the Site to dock facilities at Redfish Bay, where crude oil and hydrocarbons were historically and are currently being transferred between barges and storage tanks to adjacent properties. The current

barge dock facility is fenced and contains several small structures to load and unload crude oil. There have been no known spills or releases, and there are no visible indications of environmental impacts at the barge dock facility.

AOC-5 encompasses the ICW portion of the Site within Redfish Bay. Sediments and surface water were sampled at the Site since it is adjacent to the current and former barge facility. Previous sampling at the Site had not been reviewed due to the significant quantity of barge and industrial traffic in the waterway. Likewise, detections of COPECs at AOC-5 could be attributed to a number of entities along the waterway or traveling through the waterway. For this RI, ten additional sediment and surface water samples were collected within the ICW to better evaluate risks near the barge dock facility.

Threatened and Endangered Species

An important consideration in forming an ecological conceptual model is the presence of endangered, threatened, and rare species on the site. As part of this assessment, the U.S. Fish and Wildlife (USFWS 2014) and the Texas Parks and Wildlife Division (2014a) program databases were searched for species that may utilize AOC-5. Seven endangered and five federally and/or state listed threatened species may exist within the project area:

Endangered

- Whooping crane (*Grus americana*)
- West Indian manatee (*Trichechus manatus*)
- Hawksbill sea turtle (*Eretmochelys imbricata*)
- Kemp's Ridley sea turtle (*Lepidochelys kempii*)
- Leatherback sea turtle (*Dermochelys coriacea*)
- Eskimo curlew (*Numenius borealis*)
- Smalltooth sawfish (*Pristis pectinata*)

Threatened

- Piping plover (*Charadrius melodus*)
- Sooty tern (*Sterna fuscata*)
- Reddish egret (*Egretta rufescens*)
- Wood stork (*Myctena americana*)
- White-face ibis (*Plegadis chihi*).

A more extensive analysis and biological survey would be needed to determine whether or not additional state listed species utilize the Site. It is also possible that bald eagles (*Haliaeetus leucocephalus*) could be associated with the intercoastal habitats. Bald eagles were recently delisted from the federal and state threatened and endangered species lists, and the species is now protected under the Bald and Golden Eagle Protection Act.

Identification of Potential Receptors

Potential receptors evaluated at AOC-5 in the Ecological Risk Assessment (ERA) for the Site are aquatic and benthic (sediment-dwelling) organisms, piscivorous birds, and piscivorous mammals. Potential ecological receptors are shown in the CSM (Figure 5).

Potential Source Areas

Based on the site history, TAL metals, PAHs, SVOCs, and VOCs were analyzed at each AOC. Surface water and sediment samples were obtained at AOC-5. The primary source areas are current and former barge docking facility located along the ICW between AOC-4 and AOC-5 in Redfish Bay.

Fate, Transport, and Media of Concern

A number of fate and transport pathways are expected to influence the transfer of elevated concentrations of COPECs between environmental media in the Site. For AOC-5, runoff and erosion could transport chemicals into sediment or surface water. Similarly, sediment containing chemicals may be eroded and deposited farther downstream. Chemicals carried in surface waters from the Site source areas have the potential to adsorb onto sediment particles. Chemicals may also desorb from the sediment where they are released back into the surface waters. These processes concern ecological receptors in that they allow chemicals from low quality habitats to be redistributed to high quality habitats utilized by wildlife. Bioaccumulation is also a relevant transport pathway. Plants and animals that come in contact with contamination in soil, sediment, or water may uptake chemicals. Dependent upon the chemical and the organism, these chemicals may accumulate in tissue.

It is important to note that all of the transport pathways discussed above are dependent upon factors that influence the forms of chemicals in environmental media and their bioavailability. This is especially important for metals. Metals are present in nature in a wide range of chemical forms. Soluble forms of some metals are highly mobile in soil, sediment, and water, facilitating higher transport rates and making them more bioavailable, meaning that they are taken up more easily by plants and animals. Many of the mineral forms of metals found in naturally occurring rocks and soils are relatively insoluble and are not readily taken up by wildlife. Changes in the chemistry of soil, sediment, or water may make metals more or less soluble, and thus determine their ultimate mobility and bioavailability.

Based on the above discussion of potential habitats, sources, and fate and transport, sediment and surface water were considered the primary media of concern (Figure 5).

Identification of Exposure Pathways

Based on the ecological setting, the EPA Region 6 Ecological Exclusionary Criteria, and the media of concern discussed above, ecological receptors potentially present in the AOC-5 and evaluated in this ERA include aquatic and benthic organisms and piscivorous wildlife (birds and

mammals) (Figure 5). Media of concern and ecological receptors are evaluated to determine potential exposure routes linking the two and to determine which pathways are complete and significant. The sections below identify the major routes of exposure and their applicability to each of these receptor groups.

Aquatic and Benthic Organisms

Aquatic and benthic organisms may be exposed to chemicals in surface water and sediment respectively through direct contact and absorption through the skin and gills. Direct exposure to these media is considered a complete and significant pathway for aquatic and benthic organisms, and therefore relevant for the assessment of AOC-5 sediment and water exposures.

Wildlife (Birds, and Mammals)

The most significant exposure route for wildlife is ingestion of chemicals in contaminated media (EPA 2003). Wildlife may ingest chemicals in environmental media by drinking surface water or by incidentally ingesting soil and sediment while grooming or foraging. As discussed above, chemicals may bioaccumulate in animal tissues. Therefore, wildlife may also ingest chemicals through the animals that they consume as food. Ingestion of chemicals in sediment, surface water, and/or food is considered a complete and potentially significant exposure pathway for wildlife at AOC-5.

Wildlife may be exposed to chemicals in air, sediment, or water via direct contact during foraging or burrowing. Most wildlife have protective outer coverings such as fur, feathers, or scales that prevent or limit the dermal absorption of chemicals from environmental media (CHPPM 2004). EPA guidance identifies that, in most cases, dermal exposures are likely to be less significant than exposures through ingestion and their evaluation involves considerable uncertainty (EPA 2003a, CHPPM 2004). Given that many metals demonstrate relatively low dermal absorption, this exposure route is considered complete but relatively insignificant for wildlife.

Inhalation is a potentially complete pathway for both terrestrial invertebrates and wildlife. These animals may inhale chemicals that have volatilized or that are adsorbed to airborne particulates. EPA guidance indicates that, in general, inhalation pathways are likely to be insignificant compared to ingestion pathways (EPA 2003a).

In summary, ingestion of chemicals in sediment, surface water, and food at AOC-5 are considered complete and significant exposure pathways for assessment in this ERA.

<u>Selection of Representative Receptors</u>

Ecological receptors potentially present at the Site include aquatic and benthic organisms and wildlife (birds, mammals). Selection of representative receptor species is based primarily on several factors: (1) the likelihood of a species to use the Site and the area immediately surrounding the Site, (2) the potential for exposure to site-related contaminants based on the

feeding habits and life history of the organisms/guild represented by the receptor species, (3) the availability of life history and exposure information for the selected receptor species, and (4) the availability of toxicity information for the representative receptor species. Potential representative receptors were evaluated based on these criteria and based on the applicability of available toxicity benchmarks to aquatic and benthic organisms and wildlife at AOC-5. The receptors of concern (and representative receptor species) included in this ERA are:

- Benthic and aquatic organisms (multiple species)
- Piscivorous birds (great blue heron)
- Piscivorous mammals (river otter).

Aquatic Benthic Organisms

Direct exposure to chemicals in sediment represents potential risk to the aquatic benthic community in AOC-5. Additionally, invertebrates serve as a vector of chemical uptake and transport to other invertebrates and vertebrates (e.g., fish, birds) that may feed on them. Because benthic macroinvertebrates are exposed to contaminated sediments and COPECs potentially bioaccumulate in these organisms, higher trophic level organisms (e.g., fish, birds) can be exposed to contamination through the ingestion of larval stages and emerging, adult insects. In addition to benthic macroinvertebrates, aquatic invertebrates can accumulate contaminants from the sediment and surface water column and serve as prey for higher organisms.

No specific aquatic organisms are selected for surface water evaluation; instead, the assessment evaluates the potential for adverse effects to aquatic animal and plant populations. Potential risks to aquatic organisms are evaluated in the ERA for the Site by comparing the maximum and mean chemical concentrations measured in surface water with available toxicity data from the scientific literature as promulgated in water quality standards.

As with aquatic organisms exposed to surface water, the toxicity data being used in the ERA were designed to evaluate the potential for adverse effects to benthic organism populations exposed to sediment containing those contaminants. No individual species were selected for evaluation, and the assessment evaluates the potential for adverse effects to the overall benthic populations. Potential risks to benthic organisms are evaluated in the ERA for the Site by comparing maximum concentrations of the COPECs identified in sediment to applicable toxicity values.

Aquatic Organism-Eating Terrestrial Wildlife

Given that the existence of sediment-bound contaminants and the potential for release of contaminants into the overlying water may result in the pelagic community bioaccumulating contaminants, piscivores (both birds and mammals) may be exposed to contaminants in their diet. In addition, these species may be exposed to contamination through the incidental ingestion

of sediment and surface water that occurs during foraging activities, and through the deliberate ingestion of surface water.

The great blue heron (*Ardea herodias*) was selected as the avian receptor species for evaluating potential adverse effects to birds from the ingestion of aquatic prey at the Site. The great blue heron was selected for evaluation because a large proportion of its diet is comprised of fish and larger aquatic invertebrates.

The river otter (*Lutra canadensis*) was selected as the mammal species for evaluating potential adverse effects to mammals from the ingestion of aquatic prey at the Site. River otters can be found along the eastern shore of the Texas Gulf Coast in marshes, bayous, and brackish inlets (Texas Parks and Wildlife Division 2014b). Since a large proportion of their diet is comprised of fish and larger aquatic invertebrates, the river otter was selected as the representative piscivorous mammal.

2.2 STEPS 1 & 2: SCREENING-LEVEL ECOLOGICAL RISK ASSESSMENT

The first two steps of the 8-step ERA process (Figure 3) constitute the SLERA. The SLERA includes screening-level problem formulation, ecological effects evaluation, exposure estimate, and risk calculation. This section presents the SLERA for the Falcon Refinery Superfund Site and is organized into the following subsections:

- Screening-level problem formulation
- Summary of the SLERA results.

Screening Level Problem Formulation

The screening-level problem formulation includes development of a CSM and assessment and measurement endpoints. Assessment and measurement endpoints are identified for each representative receptor species evaluated at AOC-5 (Table 2). Measurement endpoints are measurable ecological characteristics that are related to the assessment endpoints (EPA 1997). The measurement endpoints are used to assess the potential for effects on the assessment endpoints through their comparison to screening level concentrations or toxicity values.

Measurement and Assessment Endpoints

EPA guidance stresses the importance of ecologically significant endpoints. As discussed by EPA, “Assessment endpoints are explicit expressions of the actual environmental value that is to be protected, operationally defined by an ecological entity and its attributes” (EPA 1998). Failure to select appropriate assessment and measurement endpoints can result in the inability to answer the risk questions central to an ERA. Several criteria are applicable for endpoint selection (Suter 1993; EPA 1998):

1. ***Unambiguous Definition***—Assessment endpoints should indicate a subject and a characteristic of the subject (e.g., fish reproduction).

2. ***Accessibility to Prediction and Measurement***—Assessment endpoints should be reliably predictable from measurements.

3. ***Susceptibility to the Hazardous Agent/Stressor***—Susceptibility of an organism (plant or animal) results from the combination of potential for exposure and the sensitivity to the concentrations of contaminants or other stressors of concern.

4. ***Biological Relevance***—Biological relevance of impacts to an individual organism is determined by the importance of the impact to higher levels of biological organization (e.g., populations or communities).

5. ***Social Relevance and Policy Goals***—Assessment endpoints should be of value to decision-makers and the public. The assessment endpoints should represent effects that would warrant consideration of site remediation or alteration of project plans. Assessment endpoint selection should also include endpoints that may be mandated legally (e.g., protected species).

The ecological assessment endpoints applicable to this site are discussed below:

- Protection of organisms exposed directly or indirectly to sediment to ensure that COPECs in sediment do not have unacceptable adverse effects on organism survival, growth, and reproduction, which may result in adverse effects to the community structure (e.g., diversity or biomass).

- Protection of animals exposed directly or indirectly to surface water to ensure that COPECs in surface water do not have unacceptable adverse effects on organism survival, growth, and reproduction, which may result in adverse effects to the community structure (e.g., diversity or biomass).

These assessment endpoints are general and are refined and revised for sample types warranting evaluation in the refined assessment conducted in Step 3.

The measurement endpoints are measurable ecological characteristics that are related to the assessment endpoints (EPA 1998). Because it is difficult to “measure” assessment endpoints, measurement endpoints were chosen that permit inference regarding the assessment endpoints described above. Measurement endpoints selected for this risk assessment are the following:

1. ***Media Chemistry for Sediment***—The measurement of maximum COPEC concentrations in sediment provides the means, when compared to conservative (based on chronic or no effects levels), ecotoxicological-based screening concentrations, for drawing inferences regarding the assessment endpoint for sediment.

2. ***Media Chemistry for Surface Water***—The measurement of maximum COPEC concentrations in surface water provides the means, when compared to conservative (based on chronic or no effects levels), ecotoxicological-based screening concentrations, for drawing inferences regarding the assessment endpoint for surface water.

Identification of Chemicals of Potential Ecological Concern

COPECs will be selected by comparison of maximum concentrations found in surface soil, marine surface water, and marine sediment to EPA Region 3 and Region 4 ecological risk screening values, which coincide with TCEQ Screening Levels (TCEQ 2014). Maximum concentrations in soil were compared to the lowest value obtained from the EPA Eco-SSLs, or EPA Region 4 screening values for soil which are found at the following links:

- Sediment: TCEQ accessed at http://www.tceq.state.tx.us/assets/public/remediation/eco/0106eragupdate.pdf, Region III Biological Technical Assistance Group (BTAG) Ecological Screening Benchmarks accessed at http://www.epa.gov/reg3hscd/risk/eco/btag/sbv/marsed/screenbench.htm, or at http://www.epa.gov/reg3hscd/risk/eco/btag/sbv/fwsed/screenbench.htm if marine values were not available.

- Surface Water: National Ambient Water Quality Criteria (NAWQC) assessed at http://water.epa.gov/scitech/swguidance/standards/criteria/current/index.cfm, TCEQ Water Quality Standards accessed at http://www.tceq.state.tx.us/waterquality/standards/2010standards.html, or Region III BTAG Ecological Screening Benchmarks (EPA 2003) assessed at http://www.epa.gov/reg3hscd/risk/eco/btag/sbv/fw/screenbench.htm.

The criteria are presented in Table 3.

2.3 SLERA RESULTS

Maximum exposure estimates were compared to media-specific screening-levels. Comparisons for each sample type are presented in Table 4. The results of this risk calculation are used to identify COPECs. The SLERA risk calculation is performed by comparing the maximum exposure concentration to the screening level. When the screening level is greater than the maximum concentration, the potential for adverse effects is considered unlikely. Because of the conservative nature of the SLERA, chemicals with maximum concentrations less than the screening level can be removed from further examination. If the maximum concentration is equal to or greater than the screening leve1, or if a media-specific screening criterion is not available, the chemical is retained as a COPEC and examined further. Inclusion of these chemicals as COPEC does not necessarily indicate that they pose risks; it indicates that the chemicals cannot be definitively eliminated from further consideration. Essential nutrients, although detected in surface soil, sediment, and surface water, are not included in the list of COPECs. Essential nutrients include calcium, magnesium, sodium, and potassium.

The following chemicals exceeded the sediment screening values and were retained as COPEC. Exposure Point Concentrations (EPCs) are shown in Table 4**:**

- Cadmium
- Chromium
- Copper
- Lead
- Nickel
- Zinc
- Total low molecular weight PAHs
- Total high molecular weight (HMW) PAHs
- Carbon disulfide.

The following chemicals were retained as COPECs due to lack of a sediment screening value. Risks from these detected chemicals cannot be determined; therefore, the assessment of risks remains an uncertainty in this ERA and is discussed in Section 2.8 (Uncertainties):

- Aluminum
- Barium
- Beryllium
- Vanadium
- Acetophenone
- Benzaldehyde
- Caprolactum
- Dimethyl phthalate
- 2-Butanone
- Acetone
- Methylene chloride
- Xylenes (m & p)
- Xylenes (o).

The following chemicals exceeded the marine surface water screening values and were retained as COPECs. EPCs are shown in Table 4**:**

- Copper
- Lead
- Zinc.

The following chemicals were retained as COPECs due to lack of marine surface water screening values. Risks from these detected chemicals cannot be determined; therefore, the assessment of risks remains an uncertainty in this ERA and is discussed in Section 2.8 (Uncertainties):

- Aluminum
- Benzaldehyde
- Caprolactum
- 1,3,5-Trimethylbenzene
- n-Propylbenzene.

SLERA Conclusions

The SLERA identified COPECs in sediment and surface water at AOC-5 that require further evaluation. The results of the SLERA represent maximum estimates of risk, and are not necessarily representative of population-wide risks. Therefore, Step 3 of the ERA (the BRAPF) will include a refinement of risk estimates using more site-specific assumptions and information for AOC-5. Risks from chemicals that do not have a screening value could not fully be evaluated and remain an uncertainty. Uncertainties associated with the SLERA are discussed in Section 2.8.

2.4 ECOLOGICAL RISK ASSESSMENT REFINEMENT

The third step in the 8-step ERA process is required only for compounds for which the SLERA (Steps 1 and 2) indicates a need for further ecological risk evaluation. Consistent with ERA guidance (EPA 1997), highly conservative assumptions were used in the SLERA to provide an upper bound estimate of risk to ecological resources. Such an approach meets with the objectives of the SLERA, which are to screen out all chemicals that do not have the potential to adversely affect ecological resources and to maintain chemicals that have potential to cause risks. These conservative assumptions are expected to over-estimate actual levels of risk to most ecological receptors. Consequently, some chemicals that pose negligible risk may be retained as COPEC at the outset of Step 3. The objective of the BRAPF is to determine the scope and goals of the baseline ERA by considering the results of the SLERA with additional site-specific information and alternate, more realistic assumptions in the estimates of risk. The results of this evaluation build upon the risk results presented in the SLERA and are intended to help in making scientific management decisions about the need for further investigation.

Refined Assessment and Measurement Endpoints

The following refined assessment endpoints were defined to reflect the potential impacts of the complete and significant exposure pathways at AOC-5 discussed above:

- Protection of aquatic organism communities (animals) to ensure that COPECs in surface water and sediment do not have unacceptable adverse effects on survival, growth, and reproduction of key aquatic species, which may result in adverse effects to the community structure (e.g., diversity or biomass).

- Protection of piscivorous wildlife to ensure that COPECs that have bioaccumulated in prey tissue do not have unacceptable adverse effects on survival, growth, and reproduction of representative receptor species.

Because assessment endpoints are often defined in terms of ecological characteristics that are difficult to measure (e.g., the health of a population or community), measurement endpoints are selected to provide a quantifiable means of characterizing risks. Measurement endpoints are quantifiable ecological characteristics that are related to each assessment endpoint (EPA 1989). The following refined measurement endpoints were defined to draw inferences regarding the refined assessment endpoints.

1. ***Protection of Sediment Invertebrate Communities—***
    - The measurement of maximum COPEC concentrations in sediment and the calculation of 95 percent UCLM COPEC concentrations in sediment provide the means, when compared to relevant (based on acute or low effects levels) receptor-specific benchmarks, for drawing inferences regarding the first assessment endpoint above.

2. ***Protection of Aquatic Organism Communities—***
    - The measurement of maximum COPEC concentrations in surface water and the calculation of 95 percent UCLM COPEC concentrations in surface water provide the means, when compared to relevant (based on acute or chronic levels) receptor-specific benchmarks, for drawing inferences regarding the first assessment endpoint above.

3. ***Protection of Piscivorous Wildlife—***
    - The measurement of maximum COPEC concentrations in surface water and the calculation of 95 percent UCLM COPEC concentrations in surface water provide the means to model wildlife doses, which can be compared to relevant (based on acute or low effects levels) receptor-specific benchmarks, to draw inferences regarding the second assessment endpoint above.

Benthic Invertebrates

The measurement endpoints for benthic invertebrates include comparison of EPCs to benchmarks called toxicity reference values (TRVs) protective of exposures to sediment. Potential risks to aquatic benthic organisms were evaluated by comparing EPCs in sediment to TRVs for these media. TRVs represent the threshold above which effects are expected and below which either no effect or a low effect is expected. Conservative benchmarks have been selected to ensure that all chemicals that may pose a risk are accurately identified. Comparisons were initially made using maximum EPCs as a precautionary initial screen. Comparisons were then refined using mean and point-by-point concentrations as EPCs. As defined in EPA guidance (EPA 1997), the ratio of a chemical's concentration to its TRV is called a Hazard Quotient (HQ). HQs greater than or equal to 1.0 indicate a potential for unacceptable risk, while

HQs less than 1.0 indicate no potential for unacceptable risk. Results of comparisons will be interpreted in light of the anticipated environmental chemistry of site media and spatial relationships that may affect comparison results and relevance.

Aquatic (Surface Water)

The measurement endpoints for aquatic organisms (e.g. fish, invertebrates and plants) include comparison of EPCs to water quality criteria protective of exposures to surface water. Water quality criteria represent the threshold above which effects are expected and below which either chronic (long-term exposure) or acute (short-term exposure) effects are expected. Conservative benchmarks have been selected to ensure that all chemicals that may pose a risk are accurately identified. Comparisons were initially made using maximum EPCs as a precautionary initial screen. Comparisons were then refined using mean and point-by-point concentrations as EPCs. As discussed above, HQs are used to assess risk. Results of comparisons will be interpreted in light of the anticipated environmental chemistry of site media and spatial relationships that may affect comparison results and relevance.

Wildlife

For wildlife, measurement endpoints are based on the results of food web models that predict the dose of chemicals based on EPCs ingested by wildlife. These doses were compared to TRVs for wildlife. The first measurement endpoint evaluated will be a comparison of doses based on maximum EPCs to no-effects TRVs. Refinement of the models will be conducted using 95 percent UCLM EPCs. As discussed above, HQs greater than or equal to 1.0 indicate a potential for unacceptable risk, while HQs less than 1.0 indicate no potential for unacceptable risk. Results of comparisons will be interpreted in light of factors that include the anticipated environmental chemistry of site media and spatial relationships that may affect comparison results and relevance. A more detailed presentation of measurement endpoints is provided in Table 2.

Refined Exposure Assessment

Many of the measurement endpoints identified in Section 2.2 rely on exposure estimation using chemical analytical data. In some cases, chemical concentrations are used as the exposure estimate, and measured or 95 percent UCLM concentrations are identified as EPCs for comparison to benchmarks. In other cases, chemical concentrations are the EPC inputs for food web models that estimate exposures as ingested doses. The exposure assessment identifies the models and input parameters that were used in benchmark comparisons and food web dose modeling. These parameters include identification of exposure point concentrations, food web model assumptions, and literature-based uptake factors (UFs). These are discussed on a receptor-by-receptor basis.

Exposure Point Concentrations

EPCs are the COPEC concentrations that a receptor is assumed to be exposed to within AOC-5. Two separate EPCs were used in the ERA. The initial measurement endpoint for each receptor consists of a screening level comparison of the maximum case scenario exposure estimate to no-effects benchmarks. Therefore, the maximum concentrations detected in onsite media were used as the EPC in exposure estimation. The maximum EPC is a realistic estimate of hot-spot exposures to organisms that may spend their entire lives in a small area. However, use of the maximum EPCs for assessment of some organisms is conservative and is likely to over-estimate risks because it assumes that individual organisms spend 100 percent of their time inhabiting and feeding from the most contaminated sample location at the site.

Additional measurement endpoints were evaluated based on 95 percent UCLM concentrations found in onsite media. The 95 percent UCLM is a more realistic and yet still conservative value for consideration of the site-wide populations and exposures for mobile receptors, because it assumes an upper-bound estimate of the average exposure across the site. The 95 percent UCLM concentration of a chemical within a given sample data grouping was calculated with the EPA statistical software package ProUCL version 4.0 following EPA guidance (EPA 2002, 2007a). ProUCL was used for calculating the 95 percent UCLMs in this risk assessment, as this program allows the user to calculate distribution-specific UCLMs, as well as UCLMs for data that do not exhibit a specific distribution. If the calculated 95 percent UCLM exceeded the maximum detected concentration, then the maximum concentration was used as the EPC. Where the 95 percent UCLM could not be calculated because of low-detection frequencies, the maximum was used in its place. This creates uncertainties that are discussed further in Section 8; however, it is consistent with the methods utilized in ProUCL version 4.0.

Exposure Modeling for Lower Trophic Level Wildlife

The measurement endpoints for aquatic benthic organisms at AOC-5 include comparison of EPCs to TRVs protective of exposures to environmental media. The use of EPCs to represent exposures for these organisms is discussed further below (Tables 6 to 11).

Benthic Organisms - Chemical concentrations detected in the marine sediment samples were used to evaluate the potential for adverse effects to benthic organisms. Data were compared to literature-based toxicity values for benthic organisms (Table 8). The maximum detected concentrations of chemicals within the site were used in the evaluation of sediment contamination in accordance with EPA guidance (EPA 1997). Although use of the maximum concentration is conservative, it is relevant in the evaluation of potential adverse effects to benthic organisms. If a chemical was not detected at concentrations exceeding the available toxicity value, it was concluded that the chemical is not likely to adversely affect benthic organisms in that area. The mean sediment concentration was also evaluated as an indicator of site-wide risks.

Aquatic (Surface Water) Organisms - Chemical concentrations measured in surface water samples were used to evaluate the potential for adverse effects to aquatic life (Table 9). Data

from AOC-5 were compared to literature-based toxicity values for aquatic life. Both the maximum and mean concentrations of chemicals within AOC-5 were used to evaluate the potential for adverse effects to aquatic life from the presence of chemicals in marine surface water.

Exposure Modeling for Higher Trophic Level Wildlife

Food web dose modeling was used to derive the dose-based exposure estimates for wildlife. This section presents the methods used to quantify the potential exposure of wildlife to chemicals via the ingestion of food, surface water, and sediment. The methods are based on equations presented in EPA (1993) and Sample et al. (1996). The equations and exposure parameters discussed below are consistent with EPA (1997) guidance and standard risk assessment practice.

Chemicals in the exposure media for each receptor were evaluated in the exposure models. Concentrations of these chemicals within other media to which a receptor could be exposed were then also considered for evaluation, whether or not they were COPECs within that media. By using such an approach, concentrations of chemicals within surface water which were not COPECs in surface water, but were COPECs in sediment, were included in the model. Table 6 provides a summary of exposure parameters for the avian and mammalian representative receptor species identified for evaluation. It has been assumed consistent with the ecological exposure factors handbook (EPA 1993) that both the receptor bird (heron) and mammal (otter) consume 100 percent fish in their diet. UFs for fish used in the exposure model is presented in Table 7; food web dose models are presented in Appendix A.

It should be noted that, in general, conservative assumptions were used in the food web models. The objective of the models is to provide an upper bound risk estimate. Accordingly, in almost all cases, actual risks are likely to be overestimated by the models. Uncertainties associated with conservative assumptions and other exposure estimation factors are discussed in Section 2.8.

Two separate EPCs were used in food web dose modeling. The initial measurement endpoint for each bird and mammal receptor consists of a screening level comparison of the maximum case scenario exposure estimate to no-effects benchmarks. Therefore, the maximum concentration detected in on-site media was used as the EPC in exposure estimation for this endpoint. Use of the maximum is highly conservative and is likely to over-estimate risks because it assumes that that wildlife spend 100 percent of their time inhabiting and feeding from the most contaminated sample location at the site.

Therefore, food web modeling for the other wildlife measurement endpoints was based on the 95 percent UCLM concentration in the exposure media. The 95 percent UCLM is a more realistic value for consideration of the site-wide population, because it assumes an upper-bound estimate of the average exposure across the site. As discussed above, the 95 percent UCLM concentration of a chemical within a given sample data grouping was calculated as the 95 percent UCLM derived by the EPA statistical software package ProUCL version 4.0. Where the 95 percent UCLM could not be calculated because of low detection frequencies, the maximum was used in

its stead. Use of the maximum is conservative and produces an exposure estimate that is biased high. This also creates uncertainties that are discussed further in Section 2.8; however, it is consistent with the methods utilized in ProUCL version 4.0.

Ingestion of Chemicals From Abiotic Media

Wildlife at AOC-5 may ingest surface water and sediment while foraging or grooming. Therefore, food web models account for incidental ingestion of surface water and sediment.

The following equation was used to calculate the dose of chemical wildlife would obtain from the ingestion of sediment ($Dose_{sediment}$, in milligram per kilogram [mg/kg]):

$$Dose_{sediment} = Sediment * C_{sediment}$$

where:

$Dose_{sediment}$	=	amount of chemical ingested per day from soil (mg/kg-day)
Sediment	=	sediment ingestion rate (kilograms soil per kilogram body weight per day [kg/kg-day])
$C_{sediment}$	=	chemical concentration in sediment (mg/kg).

Percent sediment ingestion values taken from the scientific literature for the terrestrial wildlife species of concern were multiplied by the food ingestion rates (FI) for these species to estimate sediment ingestion rates. A summary of the percent sediment ingestion rates and food ingestion rates taken from the scientific literature is presented in Table 6.

Exposures to surface water were calculated in a manner similar to those in sediment by multiplying the daily drinking water ingestion rate by the concentrations of chemicals in surface water. The following equation was used to calculate the upper bound dose of chemical that terrestrial wildlife could obtain from the ingestion of surface water:

$$Dose_{sw} = WI * C_{sw}$$

Where:

$Dose_{sw}$	=	amount of chemical ingested per day from surface water (mg/kg bw-d)
WI	=	surface water ingestion rate shown in Table 6 (liters water per kilogram body weight per day [L/kg-day])
C_{sw}	=	maximum chemical concentration in surface water (in milligram per liter [mg/L]).

Ingestion of Chemicals From Food

Food item (fish) concentrations were developed using Bioconcentration Factors (BCFs). Values were selected from defensible, compilation- and consensus-based sources (e.g., EPA 1985a-c,

1986, 1987a-b, 1988, 1999, 2001, 2003b, 2009; ORNL 2009) instead of values from single studies.

The following equation was used to calculate the dose of chemicals that a terrestrial wildlife species could obtain from the ingestion of food (Dose $_{food/prey}$, mg/kg-day):

$$\boxed{Dose_{food/prey} = FI * C_{food/prey}}$$

where:

FI = food ingestion rate (kg/kg-day)
$C_{food/prey}$ = estimated maximum concentration of chemical in food (mg/kg).

A summary of the FI used in the SLERA for each of the terrestrial wildlife species selected for evaluation is presented in Table 7. The following section discusses the equations used to estimate chemical concentrations within each food group ($C_{invert/prey}$).

EPCs in Aquatic Organisms

Fish were selected as representatives of the potential for chemicals to accumulate from surface water into aquatic food items. In the SLERA, fish were used as model prey items to evaluate the potential for adverse effects to piscivorous birds and mammals (as represented by great blue herons and the river otters respectively), because they represent 100 percent of dietary components for these species (EPA 1993). Literature-based water-to-fish UFs or bioaccumulation equations were used to estimate concentrations of COPECs in fish tissue using the following equation:

$$\boxed{C_{fish} = C_{water} * UF}$$

Where:

C_{water} = maximum concentration of COPEC in water (mg/L)
UF = uptake factor for chemicals in fish (unit less).

The maximum concentrations of surface water detected at each site were used as the C_{water} value in the equation. UFs and log K_{ow}s for organic chemicals, and their sources are summarized in Table 7. In the absence of a literature-based bioaccumulation model or UF for a COPEC, an accumulation factor of one was used to estimate chemical concentrations in fish. Use of this default accumulation factor is expected to provide a conservative estimate of accumulation for most chemicals and is expected to overestimate accumulation for non-bioaccumulative compounds.

Total Chemical Ingestion

The total dietary exposure doses ($Dose_{total}$, mg/kg bw-d) for aquatic organism-eating birds (great blue heron) and mammals (river otter) for the evaluated COPECs were determined using the following equation.

$$Dose_{total} = Dose_{food} + Dose_{sed} + Dose_{water}$$

where:

$Dose_{food}$ = amount of chemical ingested per day from food (prey) (mg/kg bw-d)
$Dose_{sed}$ = amount of chemical ingested per day from sediment (mg/kg bw-d)
$Dose_{water}$ = amount of chemical ingested per day from water (mg/kg bw-d).

The total dietary intakes are compared to dietary toxicity values to determine if adverse effects are likely to occur to piscivorous wildlife from the ingestion of COPEC in food, sediment, and surface water.

2.5 REFINED TOXICITY ASSESSMENT

This section derives toxicity values for use in evaluating exposure estimates for each representative receptor selected for evaluation. The TRVs represent concentrations or doses of the chemicals that are protective of the ecological receptors being evaluated. TRVs are compared to EPCs or estimated doses to evaluate each chemical's potential for adverse effects on the receptor in question. The following sections summarize TRVs for each indicator species or community identified for evaluation.

Overview of Bioavailability and Toxicity

The toxicity of chemicals is related to their bioavailability. Organic compounds may form complexes or compounds that bind them to soil and make them chemically inaccessible to ecological receptors. Alternatively, these elements and compounds may be present in forms that are easily dissolved and absorbed, or in forms that tend to bind to biological tissues. It is these forms of easily absorbed chemicals that are most toxic. Most TRVs are based on forms of chemicals that are readily bioavailable.

Metals

For metals, bioavailability is governed largely by formation of metallic compounds, binding to the sediment matrix, and speciation. The compounds and bonds formed by metals are determined by reduction and oxidation (redox) reactions, by the dominant pH in soil and sediment, and by the presence of organic carbon. These factors affect different metals in different ways. Acidity increases the bioavailability of many cationic compounds; such as cadmium, chromium, copper, lead, silver, and zinc, which may become soluble at pH below 5. Some metals, such as aluminum, may also form complexes with iron oxides and hydroxides; this

makes these metals less bioavailable and less mobile. The effect of acidity on other metals is complex; arsenic, for example may form compounds that are less bioavailable under acidic conditions; however, it may also become more bioavailable if arsenic bound to iron hydroxide compounds is released (Bodek et al. 1988).

Redox conditions and pH also determine the speciation of metals. Some metals may exist in different valence states or chemical forms that demonstrate different toxicity and bioavailability. For example, arsenic can be found in nature as As III or As V, with higher toxicity and mobility typically exhibited by As III (EPA 2005a).

Organic Compounds

For organic compounds, the primary factors determining persistence, mobility, and fate are: (1) degradation, (2) volatilization, and (3) binding to soil/sediment. PAHs may degrade over time, resulting in lower concentrations.

Another factor affecting SVOCs (particularly low molecular weight PAHs) and volatile organic carbons (VOCs) is volatilization. Concentrations of these chemicals may decrease in sediment and surface water over time due to transfer to and dispersion in the air. Volatilization may be an important factor in eliminating them from sediment. Expected contributions of these chemicals to air pathways are insignificant.

Perhaps the most important factor affecting fate of organic compounds in sediment is their affinity for binding to fine grained soils and organic matter. Many organic compounds, including PAHs, are hydrophobic and will bind tightly to these sediment particles. This decreases the mobility of these compounds, preventing them from dissolving in the water column. However, while the hydrophobicity of these organic compounds may decrease solubility, it may also increase their uptake into the tissues of biota and the potential for bioaccumulation. Hydrophobic compounds may bioaccumulate and biomagnify in fats and lipids within fish, invertebrates, or wildlife (EPA 2000).

Organism TRVs for Exposure to Sediment

Several sources of toxicity data were used to identify the potential for chemicals in sediment to cause adverse effects to benthic communities (Table 8). Wherever possible, Threshold Effects Levels (TELs) and Probable Effects Levels (PELs) from Long et al. (1995) and MacDonald et al. (1996) were utilized as chronic and acute TRVs, respectively, to determine whether chemicals in the marine sediments are likely to impact benthic organisms. In the absence of the above TRVs, the following values were used: Assessment and Remediation of Contaminated Sediments (ARCS) *Hyalella* TELs for chronic TRVs, and Lowest Effects Levels from Guidelines for the Protection and Management of Aquatic Sediment Quality in Ontario (Persuad 1993) for acute TRVs.

Aquatic Organism TRVs for Exposure to Surface Water

The National Oceanographic and Atmospheric Administration (NOAA) Quick Reference Screening Tables (Buchman 2008) and the TCEQ guidelines were used to assess potential impacts to aquatic species from chemicals in surface water. Marine chronic and acute NAWQC were used as TRVs to evaluate the potential for adverse effects to aquatic life from chemicals measured in the marine surface water samples (Table 9). When the NOAA or TCEQ values were not available, the NAWQC developed by EPA (2012) or the Tier II value from Suter and Tsao (1996) was used as the TRV.

Wildlife TRVs

Chemicals identified as having the potential to adversely affect wildlife species were evaluated using dose-based toxicological benchmarks. Two types of benchmarks were used, each corresponding to a different level of ecological impacts for birds (Table 10) and mammals (Table 11). First, modeled doses were compared to dose-based No Observed Adverse Effect Levels (NOAELs). NOAELs are doses that have been shown to cause no adverse impacts in test species. The NOAELs used in this ERA were derived from studies by Hill (1979), EPA Eco-SSLs (EPA 2005a-h, 2006, 2007b-g, 2008), and by Oak Ridge National Laboratory (Sample et al. 1996). The Oak Ridge National Laboratory NOAELs were generally derived based upon measurements of survival, growth, or reproduction in the laboratory. Values from EPA Eco-SSLs were derived through statistical analyses of results from multiple toxicological studies with multiple endpoints. Because NOAELs are conservative and highly protective, they were used as TRVs in this ERA.

The second set of benchmarks utilized was Lowest Observed Adverse Effects Levels (LOAELs). These are doses at which a very low level of adverse effect was observed on individual test organisms. The severity of effects considered “low level” varies based on the study from which LOAELs are derived; in general, they correspond to minor changes in growth or reproduction. LOAELs are useful because there is considerable uncertainty associated with NOAELs. Because NOAELs are associated with no effects in a test study, it is uncertain whether they are close to or far below the threshold value at which effects would first be observed. LOAELs thus serve to bound the range of NOAELs, and the threshold of toxic effects is considered to lie between the NOAEL and the LOAEL. Therefore, LOAELS were also utilized as TRVs. In some cases, LOAELs were available from studies by Oak Ridge National Laboratory (Sample et al. 1996). When LOAELs were not available from this source or exceeded more reliable NOAELs from EPA Eco-SSL sources, the data provided in EPA Eco-SSL documents was used to derive LOAELs. In all cases, the geometric mean of the bounded LOAELs for growth and reproduction was calculated; this approach is similar to that used for derivation of many Eco-SSL NOAELs.

In general, chemical exposures and toxicity were evaluated on a chemical-by-chemical basis. However, combined effects were evaluated for PAHs. EPA studies show that the PAHs can be grouped into high-molecular weight and low-molecular weight groups and concentrations

summed for comparison to benchmarks (EPA 2007f). Toxicity evaluation using summed PAHs concentrations is performed for invertebrates, birds, and mammals throughout the ERA.

TRVs could not be found for certain chemicals due to a lack of available information in the scientific literature. The uncertainty associated with the lack of TRVs is discussed in Section 2.8.

2.6 REFINED RISK CALCULATION

To calculate a refined estimate of risks, refined estimates of exposure are compared to receptor-specific TRVs. Risk calculation is performed by dividing EPCs by TRVs. As defined in EPA guidance (EPA 1997), the ratio of a chemical's concentration to its TRV is called an HQ. HQs greater than or equal to 1.0 indicate a potential for unacceptable risk, while HQs less than 1.0 indicate no potential for unacceptable risk. Results of comparisons will be interpreted in light of factors that include the anticipated environmental chemistry of site media and spatial relationships that may affect comparison results and relevance.

Refined Risk Characterization

The purpose of the risk characterization is to draw conclusions regarding the potential for risks to each assessment endpoint/representative receptor. This is done using a qualitative weight of evidence approach in which results for each measurement endpoint are considered as lines of evidence. In general, lines of evidence that provide results based on site-specific data applicable at the population level are given the greatest weight. Per EPA guidance (EPA 1997), the focus of the ERA is to protect the ecological values at the site-wide population or community level except where threatened or endangered species are concerned.

Comparisons to Receptor-Based TRVs

Receptor-specific COPEC for the Site were identified through the comparison of receptor-specific exposure estimates to TRVs. As presented in Section 2.5, TRVs are derived from literature-based NOAELs. The HQ, which is a ratio of exposure estimate to TRV is used as a measure of potential toxicity. If the HQ is less than one, then the potential for adverse effects are considered unlikely. If the HQ is equal to or greater than 1.0, then there is a potential for adverse effects to occur. Consistent with ERA guidance (EPA 1997), the models used to quantify the potential exposure to higher trophic level organisms were designed to estimate an upper bound potential for adverse effects to the selected representative receptor species. Therefore, exceedance of a TRV indicates the potential for adverse effects, but does not indicate that an adverse effect is occurring from the chemical (Tannenbaum et al. 2003).

The refinement of the risk calculation compares exposure estimates of the COPECs identified in the first phase to TRVs for each representative receptor species. For benthic and surface water aquatic organisms, the maximum detected chemical concentrations in sediment or surface water are used as exposure estimates respectively.

LOAELs are a valuable indicator of risk because they provide an upper bound to NOAELs. Exceeding a NOAEL-based TRV does not necessarily indicate a risk, because NOAELs, by definition, correspond to no effects and may not be the highest concentration at which no effects occur. LOAELs provide a clear indication of potential effects and a potential for risk; therefore, comparisons to LOAEL-based TRVs provide an important tool for ERA. Comparisons focus on 95 percent UCLM case scenario exposure estimates because they are the most relevant estimates for wildlife populations.

It is important to note that the quality of the TRV can influence the HQ. With metals, for instance, one must consider the bioavailable form of the metal from which the TRV is generated and the bioavailable/toxic form of the metal that is most likely present onsite. Additionally, other literature TRVs are available and may generate different HQs. Uncertainties associated with the selection and use of TRVs are discussed in Section 2.8.

TRVs are not available for all COPECs and, therefore, there is uncertainty associated with the lack of toxicity information for some COPECs. Chemicals that lacked TRVs or had exposure estimates that equaled or exceeded TRVs were considered a COPEC (with the exception of essential nutrients as noted above). Those chemicals that had exposure estimates below TRVs (HQs less than one) were removed from further consideration.

2.7 REFINEMENT AND PROBLEM FORMULATION

The results of the refinement for AOC-5 are presented in Tables 12 through 17.

Benthic Organisms - Sediment

Refined risk calculation and evaluation of qualitative lines of evidence were evaluated to characterize risks to benthic organisms from COPECs in the marine sediment. The following measurement endpoints were evaluated as indicators of risk to benthic organisms:

- Comparison of the chemical concentrations to benchmarks protective of benthic organisms, presented in Table 12, including
    - comparison using maximum EPCs
    - comparison using 95 percent UCLM EPCs
    - comparison of 95 percent UCLM EPCs to LOAEL-based TRVs.

Comparison of maximum concentrations to benchmarks is given the most weight in the weight-of-evidence approach because it is the most conservative indicator of risks at specific locations (e.g., hot spots). Comparison of 95 percent UCLM concentrations to benchmarks is given the second most weight as an indicator of population-wide risks with the understanding that results must be interpreted in light of spatial distribution/frequency of detection.

Measurement Endpoint 1: Comparison of Maximum Chemical Concentrations to Benthic Organism TRVs

The first measurement endpoint evaluated was the comparison of maximum EPCs in sediment to literature-based benchmarks protective of benthic organisms. When maximum EPCs of COPEC were compared to NOAEL-based TRVs, eight chemical concentrations exceeded TRVs for benthic organisms and had an HQ greater than 1.0 (cadmium, chromium, copper, lead, nickel, zinc, total HMW PAHs, and carbon disulfide). This indicates that there is a potential for risk from these chemicals, although this measurement endpoint is highly precautionary because it assumes maximum exposure.

Measurement Endpoint 2: Comparison of 95 Percent UCLM Chemical Concentrations to Benthic Organism NOAEL-Based TRVs

The second measurement endpoint evaluated compared the 95 percent UCLM EPCs in sediment to literature-based benchmarks protective of benthic organisms. A 95 percent UCLM for chromium could not be calculated. When the 95 Percent UCLMs were compared to NOAEL-based TRVs, chemical concentrations of copper, lead, nickel, zinc, total HMW PAHs, and carbon disulfide continued to exceed TRVs for benthic organisms and had an HQ greater than 1.0.

Measurement Endpoint 3: Comparison of 95 Percent UCLM Chemical Concentrations to Benthic Organism LOAEL-Based TRVs

The third measurement endpoint compared the 95 percent UCLM EPCs in sediment to literature-based benchmarks protective of benthic organisms. The LOAEL-based TRVs selected were chosen to provide a more relevant estimate of the potential for risk. When the 95 Percent UCLMs were compared to LOAEL-based TRVs, only lead and nickel continued to exceed TRVs for benthic organisms and had an HQ greater than 1.0. Chromium also exceeded LOAEL-based TRVs, but a 95 percent UCLM could not be calculated so the maximum EPC was used instead.

<u>Aquatic Organisms</u>

As part of the BRAPF, refined risk calculation and evaluation of qualitative lines of evidence were evaluated to characterize risks to aquatic organisms from COPECs in marine surface water. The following measurement endpoints were evaluated as indicators of risk to aquatic organisms:

- Comparison of the chemical concentrations to benchmarks protective of aquatic and benthic organisms, presented in Table 13, including:
    - comparison using maximum EPCs
    - comparison of 95 percent UCLM EPCs
    - comparison of 95 percent UCLM EPCs to Acute TRVs.

Comparison of maximum concentrations to benchmarks is given the most weight in the weight-of-evidence approach because it is the most conservative indicator of risks at specific locations (e.g., hot spots). Comparison of 95 percent UCLM concentrations to benchmarks is given the second most weight as an indicator of population-wide risks with the understanding that results must be interpreted in light of spatial distribution/frequency of detection.

Measurement Endpoint 1: Comparison of Maximum Chemical Concentrations to Aquatic Organism Chronic TRVs

The first measurement endpoint evaluated was the comparison of maximum EPCs in surface water to literature-based benchmarks protective of aquatic organisms. The chronic TRVs selected were chosen to provide a highly conservative estimate of the potential for risk. When maximum EPCs of COPEC were compared to chronic TRVs, three chemical concentrations exceeded TRVs for aquatic organisms and had an HQ greater than 1.0 (copper, lead, and zinc). This indicates that there is a potential for risk from these chemicals, although this measurement endpoint is highly precautionary because it assumes maximum exposure.

Measurement Endpoint 2: Comparison of 95 Percent UCLM Chemical Concentrations to Aquatic Organism Chronic TRVs

The second measurement endpoint evaluated was the comparison of 95 percent UCLM EPCs in surface water to literature-based benchmarks protective of aquatic organisms. A 95 percent UCLM for lead could not be calculated. Yet when the 95 Percent UCLMs of copper and zinc were compared to chronic TRVs, both chemical concentrations continued to exceed TRVs for aquatic organisms and had an HQ greater than 1.0.

Measurement Endpoint 3: Comparison of 95 Percent UCLM Chemical Concentrations to Aquatic Organism Acute TRVs

The third measurement endpoint evaluated was the comparison of 95 percent UCLMs in surface water to literature-based benchmarks protective of aquatic organisms. The acute TRVs selected were chosen to provide a more relevant estimate of the potential for risk. When 95 percent UCLMs of COPEC were compared to acute TRVs, copper and zinc continued to exceed TRVs for aquatic organisms and had an HQ greater than 1.0.

<u>Piscivorous Avian Wildlife</u>

The conceptual model for the site identifies protection of the survival, growth, and reproduction of birds from impacts of COPECs in surface water, sediment and food as an assessment endpoint. The conceptual model identified representative receptors from the piscivore feeding guild for assessment. The following measurement endpoints were evaluated as indicators of risk to birds:

- Screening level comparison of maximum case scenario doses ingested through the food web to NOAEL and LOAEL-based benchmarks protective of birds

- Comparison of 95 percent UCLM case scenario doses ingested through the food web to NOAEL and LOAEL-based benchmarks protective of birds.

Measurement Endpoint 1: Comparison of Maximum Case Scenario Modeled Doses to NOAEL and LOAEL Benchmarks Protective of Birds

The first measurement endpoint evaluated is a screening level comparison of exposure estimates (doses) based on maximum concentrations in sediment and surface water to NOAEL and LOAEL- and literature-based TRVs protective of birds. Dose modeling and comparisons to NOAEL-based literature TRVs using maximum EPCs identified no HQs greater than 1.0 (Table 14); detailed dose calculations are shown in Appendix A, Table A-1. Dose modeling and comparisons to LOAEL-based literature TRVs using maximum EPCs identified no COPECs for piscivorous birds.

Measurement Endpoint 2: Comparison of 95 Percent UCLM Case Scenario Modeled Doses to NOAEL and LOAEL Benchmarks Protective of Birds

The second measurement endpoint evaluated the comparison of ingested doses for birds based on 95 percent UCLM EPCs in sediment and surface water to NOAEL and LOAEL- and literature-based TRVs protective of birds. The comparison to the 95 percent UCLM showed no HQs greater than 1.0 (Table 15); detailed dose calculations are shown in Appendix A, Table A-2.

<u>Piscivorous Mammalian Wildlife</u>

The conceptual model for the site identifies protection of the survival, growth, and reproduction of mammals from impacts of COPECs in sediment, surface water and food as an assessment endpoint. The conceptual model identified representative receptors from the piscivore feeding guild for assessment. The following measurement endpoints were evaluated as indicators of risk to mammals:

- Screening level comparison of maximum case scenario doses ingested through the food web to NOAEL and LOAEL-based benchmarks protective of mammals.
- Comparison of 95 percent UCLM case scenario doses ingested through the food web to NOAEL and LOAEL-based benchmarks protective of mammals.

Measurement Endpoint 1: Comparison of Maximum Case Scenario Modeled Doses to NOAEL and LOAEL Benchmarks Protective of Mammals

The first measurement endpoint evaluated is a screening level comparison of exposure estimates (doses) based on maximum concentrations in surface water to NOAEL and LOAEL-based TRVs protective of mammals. This dose modeling and comparisons identified three chemicals (aluminum, copper, and lead) as having an HQ equaling or exceeding 1.0 (Table 16); detailed dose calculations are shown in Appendix A, Table A-3.

Measurement Endpoint 2: Comparison of 95 Percent UCLM Case Scenario Modeled Doses to NOAEL Benchmarks Protective of Mammals

The second measurement endpoint evaluated is comparison of ingested doses for mammals based on 95 percent UCLM EPCs to NOAEL and LOAEL-based TRVs. The maximum concentration of thallium was used in place of the 95 percent UCLM. However, dose modeling and comparisons using 95 percent UCLM EPCs in comparison to NOAELs continued to identify aluminum and copper, as having an HQ equaling or exceeding 1.0 (Table 17); detailed dose calculations are shown in Appendix A, Table A-4.

Risk Characterization Results for AOC-5

Benthic Organisms - Sediment

COPECs identified in the media-specific screening were assessed for potential risks to benthic organisms. Maximum sediment concentrations of cadmium, chromium, copper, lead, nickel, zinc, total HMW PAHs, and carbon disulfide exceeded NOAELs for benthic organisms and have HQs greater than 1.0. When compared to the 95 percent UCLM values, only cadmium was no longer a COPEC. However, upon further examination of the more relevant LOAELs, chromium, lead, and nickel were the only three chemicals to be identified as potential risks. Chromium was detected at all six locations sampled, but only one sample (FR-222 from the initial sampling) was above the LOAEL-based TRV, and appears to be the driver of the risk to the site. Lead was also detected at all 13 locations sampled, but was only above the LOAEL-based TRV at FR-222 where concentrations were more than one hundred times greater than the next highest concentration. Nickel was detected in 12 of 13 samples, but only one sample (SD5-01 from the 2013 sampling) exceeded the LOAEL-based TRV and appears to be driving the risk. Based on this information, the finding of the SLERA is that chromium and lead are only a concern in the areas near FR-222 and nickel only poses a risk near sample site SD5-01. Because these exceedances are limited to particular sample locations, risks to the populations of benthic organisms throughout the site are low. However, SD5-01 may represent a hot spot.

Aquatic Organisms

COPECs identified in the media-specific screening were assessed for potential risks to aquatic organisms. Maximum and 95 percent UCLM surface water concentrations of copper, lead, and zinc exceeded chronic TRVs for aquatic organisms and had HQs greater than 1.0. However, upon further examination of the more relevant acute TRVs, copper and zinc continued to be identified as potential risk. Copper was detected in all thirteen samples and concentrations exceeded the acute TRVs by 3 to 16 times greater at all locations. The highest concentrations were observed at the three northernmost sample locations (SW5-01, 02, and 03) where levels were 16 times higher than the acute TRV. Sample SW5-09 also had a high concentration of copper (nine times higher than acute-TRV) relative to the surrounding samples. Based on this information, the finding of the SLERA is that copper is likely to pose a risk to aquatic organism populations throughout the site, with particular concern in the northern portion of AOC-5. It is important to note that only total metals data were available for metals, and that the water quality

criteria are based on dissolved metals. It is not uncommon that a large proportion of metals in water is associated with the suspended particulate matter, and that dissolved metals can be much smaller than total metals. Consequently the use of total metals is a conservative measure of risk that may result in a risk overestimate. Further, the detection limits for these analyses were very high (200 µg/L), considerably higher than either the acute or chronic copper and zinc water quality criteria. This represents a large uncertainty in the assignment of risk to aquatic receptors.

Piscivorous Avian Wildlife

COPECs identified by media-specific screening were assessed for potential risks to piscivorous avian wildlife (Tables 14 and 15). Based on these results, the finding of the SLERA is that no COPECs pose a risk to piscivorous avian wildlife.

Piscivorous Mammalian Wildlife

COPECs identified by media-specific screening were assessed for potential risks to piscivorous mammalian wildlife (Tables 16 and 17). The HQs based on comparison of maximum exposure doses of aluminum, copper and lead to NOAEL-based TRVs exceed 1.0. When the 95 percent UCLM was compared to NOAEL-based TRVs, only lead was removed as a potential risk. Aluminum continued to be a concern when the 95 percent UCLM exposure doses were compared to LOAELs. Copper was no longer identified as a COPEC. It is important to note that the aluminum TRV is not based on multiple studies, and may be overly conservative because it does not take into account factors like pH, which at the values shown in marine waters should render aluminum not bioavailable for uptake into fish (and subsequently into the otter).

2.8 UNCERTAINTY EVALUATION

This ERA for the Site incorporates a number of uncertainties associated with the estimates of ecological risk. As directed in the ERA guidance (EPA 1997), a conservative approach was utilized in the ERA to ensure that chemicals eliminated from consideration do not pose risks to ecological receptors. Accordingly, the risks are likely to be overestimated. The main areas of uncertainty associated with the ERA are grouped under the following categories, each of which is discussed in the following subsections:

- Environmental Sampling and Analysis
- Analysis of Chemical Data
- Analysis of Estimated Exposure and Toxicity Data
- Assessment of Risks.

<u>Environmental Sampling and Analysis</u>

Of the potential uncertainties associated with the environmental sampling at the Site, the sample design is likely to have the greatest impact on the evaluation of risks to ecological resources. The sample design was developed based on the available historical information regarding the activities that took place at the site and the apparent health of the ecosystem at the time of

sampling. Focusing the study design to provide analyses for certain chemicals to specific suspected source areas is a valid and accepted means of maintaining a practical and efficient limit on the field effort. However, there is always a possibility that the study design could miss samples where these chemicals are present, or miss other types of chemicals in a specific sample. One limitation to the sample design was the assessment of metals other than cadmium, copper, lead, nickel, and zinc in limited numbers of samples. For example in AOC-5, antimony, selenium, and thallium were only assessed in three sediment samples. Unequal sampling increases the uncertainty of nature and extent of possible contamination. To minimize this possibility and the associated uncertainty, the study design was based on in-depth consideration of site history, potential sources, and fate and transport. Further as discussed above, water quality criteria for metals are based on dissolved values, and only total metal values were provided, resulting in extra conservative analyses. Finally, the detection limits for metals in water were very high, often two orders of magnitude higher than the risk screening values. This introduces a large amount of error in any interpretation of risks to aquatic organisms.

In an effort to address the uncertainties just discussed, and in accordance with the conservative nature of SLERAs, samples were biased to areas of likely contamination in an effort to characterize the areas that were most impacted from historic activities. For example, the food webs assume that the heron and otter obtain all their food from within AOC-5, clearly a highly conservative assumption. With the exception of fixed or limited mobility receptors (e.g., benthic organisms), ecological receptors are unlikely to utilize only those areas of highest contamination, and are more likely to forage over a larger area that includes areas of contamination as well as less contaminated outlying areas.

Analysis of Chemical Data

The maximum concentration of a pair of duplicate or split samples (taken from the same location on the same date) was used to represent the concentration for that location. Selecting the maximum concentration of a chemical detected in duplicate samples for use in the ERAs is a conservative measure and may overestimate risks. The 95 percent UCLM was used as an upper estimate of mean exposures. This exposure scenario is conservative and may also overestimate risks presented in this report.

Chemicals that are not detected in any onsite samples are considered not to be present at the site, because, based on the analytical tools and capabilities at the time of investigation, there is no evidence indicating that these chemicals are present. Risks from these non-detected chemicals cannot be determined; therefore, the assessment of risk from these non-detected chemicals remains an uncertainty in this ERA.

Analysis of Estimated Exposure and Toxicity Data

A major source of uncertainty in the SLERA is associated with the estimation of receptor exposure to COPECs. Generally, the models used to estimate exposures from sediment, surface water and prey were created to represent a worst-case scenario of possible risks to the receptor groups, and thus, many conservative assumptions were incorporated into the models. For

example, bioaccumulation of a chemical in a prey organism was estimated from the maximum detected concentration in surface water. Also, a Bioaccumulation Factor (BAF) of 1.0 was used to estimate chemical concentrations in prey (fish) for which literature-based BAFs were not available. This accumulation factor is expected to provide a conservative estimate of accumulation for all chemicals that are not bioaccumulative. Additionally, for the SLERA the models assume that receptors are exposed to the maximum detected concentration of chemicals over their entire foraging range. This approach is consistent with the objectives of the screening-level assessment, which is to estimate a worst-case scenario under which risks would not be underestimated. It is expected, however, that such a conservative scenario would overestimate risk.

There is uncertainty associated with the lack of formal literature-based TRVs for certain chemicals. There were a number of semivolatile and volatile chemicals detected (Table 5) for which TRVs could not be established or derived for some chemicals because adequate toxicity information could not be found in the scientific literature. Given the absence of methods for estimating risks from exposure to chemicals with no appropriate TRVs, it is not possible to estimate the uncertainty associated with the limitation. It is not possible to indicate if the impacts result in an underestimate or overestimate of potential ecological risks. Presumably, either scenario is possible. Consequently, risks to ecological receptors resulting from exposure to these chemicals without TRVs cannot be quantitatively assessed.

There is also uncertainty associated with toxicological evaluation of essential nutrients including calcium, iron, magnesium, potassium, and sodium. These chemicals are necessary for metabolic processes in organisms and, thus, are considered essential nutrients for wildlife. At naturally occurring concentrations, receptors are able to regulate uptake and metabolism of these elements. However, as with all chemicals, it is possible that nutrients may produce toxic effects at very highly elevated concentrations. These five chemicals do not have screening level concentrations or TRVs, except iron which has screening level concentrations for surface soil and surface water, and TRVs for surface water and sediment. As these metals are essential nutrients, adverse effects to organisms can occur if concentrations are either too low (causing deficiency symptoms) or too high (causing toxic symptoms). However, organisms can adapt to different levels of these metals, although there is little information available regarding concentrations at which adverse effects of either type may be observed. Because screening-level concentrations and TRVs are not available for the essential nutrients, it is not possible to quantitatively assess the potential for risks to ecological receptors from them. However, with the exception of iron, because these nutrients are essential to flora and fauna, these essential nutrients are not maintained as COPEC.

Assessment of Risks

There are uncertainties associated with the assessment of risks in the ERA for the Site. One apparent uncertainty results from the extrapolation of assumptions about the potential for adverse effects from individual organisms to populations. The intent of this ERA, as set forth in the assessment endpoints, is to ultimately evaluate risks to populations. Few methods are available

to extrapolate the potential for adverse effects from the individual level to the population level. It is generally assumed that if there is no potential for direct adverse effects to individual organisms then it is also unlikely for there to be the potential for direct adverse effects to populations. Similarly, it is assumed that if there is the potential for adverse effects to individual organisms there is also the potential for adverse effects to populations. However, it is conservative to assume that potential damage at the individual level will impact the populations in the surrounding ecosystem.

This uncertainty is one of several limitations associated with the use of HQs to determine the potential for risk to ecological receptors. While the HQ is a standard tool in ERAs set forth in EPA guidance (EPA 1997), an article in the scientific literature points out a number of limitations to the use of this method (Tannenbaum et al. 2003). The use of the HQ identifies a potential for risk as opposed to an actual risk, because the HQ result is not a probability. Because the HQ identifies whether a dose or concentrations exceeds a benchmark, it is not a linear or scalable metric. Also, the HQ cannot be used to quantitatively extrapolate between individual and population level effects. Because HQs are based on NOAELs and on the most sensitive species in a media, HQs are often exceeded by concentrations normally found in the environment. All of these limitations should be considered before using HQ-based estimates of the potential for risk to draw conclusions or make decisions based on assessment results.

Another important uncertainty is the limited ability of risk assessment to assess combined and synergistic effects of chemicals. At the site, ecological receptors are exposed to a chemical mixture; however, comparison of individual chemicals to TRVs does not capture the potential for combined effects. Combined and synergistic effects are usually assessed by performing bioassays. As such, risk assessment conclusions have conservatively identified the potential for synergistic effects, and recommended in certain cases the consideration in risk management of all detected chemicals.

In addition, the assessment of risks was primarily based on the comparison of estimated doses to toxicity values from the literature. There are many uncertainties associated with these evaluation tools and thus, with the assessment of risks based upon them.

3. CONCLUSIONS

A conceptual model was developed for the site based on review of site conditions and available data. This model identified that the site provides terrestrial and aquatic habitats. Based on the conceptual model, assessment endpoints were selected to represent the most sensitive of ecological receptors within AOC-5's ecological community. The assessment endpoints included the survival, growth, and reproduction of benthic and aquatic organisms as well as piscivorous birds and mammals.

Assessment endpoints were defined to reflect the potential impacts of complete and significant exposure pathways discussed above and to aid in identifying representative receptor species. These endpoints included the viability of the aquatic invertebrate community as resources for wildlife. Measurement endpoints were selected to provide a quantifiable means of characterizing risks. The measurement endpoints for benthic and aquatic invertebrates included an initial comparison of maximum concentrations to media-specific screening criteria to identify potential COPECs. Maximum and 95 percent UCLM EPCs were then compared to receptor specific benchmarks. The benchmarks selected are highly precautionary and thus provide a conservative assessment of site risks.

For higher trophic level wildlife, maximum concentrations were initially compared to media-specific screening criteria to identify potential COPECs. Additional measurement endpoints were based on the results of food web models that predict the dose of chemicals ingested by wildlife. These doses were then compared to benchmarks. The first measurement endpoint evaluated was a screening level comparison of maximum case scenario doses to no-effects benchmarks. Additional measurement endpoints included comparison of 95 percent UCLM case scenario doses to no-effects and low-effects benchmarks.

To test the measurement endpoints, both site-specific and literature-based information was used to develop exposure and toxicity data and assumptions for use in estimating risks. These tools were used in the data evaluation to test each measurement endpoint as a line of evidence. Lines of evidence were combined in a qualitative weight-of-evidence discussion to determine the potential for risks.

Due to 95 percent UCLM concentrations higher than TRVs and HQs greater or equal to 1.0, the ERA identified a few COPECs for all ecological receptors at AOC-5 that may require additional consideration for risk management. For sediment chromium, lead, and nickel were identified as of concern for benthic invertebrates and their risk appears to be a concern only near one sample location (FR-222 for chromium and lead and SD5-01 for nickel). Copper and zinc pose risk to aquatic organisms throughout the site. Aluminum was found to provide risk to the river otter, however this result may be conservative because the TRV used for this assessment is not strong (based on a single toxicity test), site specific pH has not been considered that may render aluminum not bioavailable, and it has been assumed that the river otter obtains all its prey within AOC-5, which is not likely.

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FIGURES

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N

0 5,000 10,000

Feet

Image Source:
ESRI ArcGIS Online USA Topo Maps layer, 1:100,000 scale, Copyright:© 2011 National Geographic Society, i-cubed

Falcon Refinery Superfund Site
Ingleside, San Patricio County,Texas

Figure 1
Location Map
Ecological Risk Assessment for AOC-5

2014-03-27 R:\Federal\EPA\RAC II\0088-Falcon Refinery RI\FS\GIS\MXDs\AreaMap.mxd EA-Dallas jschwertz

N

0 250 500

Feet

Legend:

Area of Concern Boundary

Active NORCO Pipeline

Above ground

Underground

Abandonded NORCO Pipeline

Above ground

Underground

Outside Operations

Gulf South Pipeline

Boss Pipeline

Gathering Line 2'

Plains Marketing Pipeline

Source: AOC and pipeline locations from TRC, dated, March 10, 2011

Image Source: 2009 Texas Orthoimagery Program, Texas Strategic Mapping Program, TNRIS, 2009

Falcon Refinery Superfund Site
Ingleside, San Patricio County,Texas

Figure 2
Site Map
Ecological Risk Assessment for AOC-5

2014 -03-27 R:\Federal\EPA\RAC II\0088-Falcon Refinery RI\FS\GIS\MXDs\SiteMap.mxd EA-Dallas jschwertz

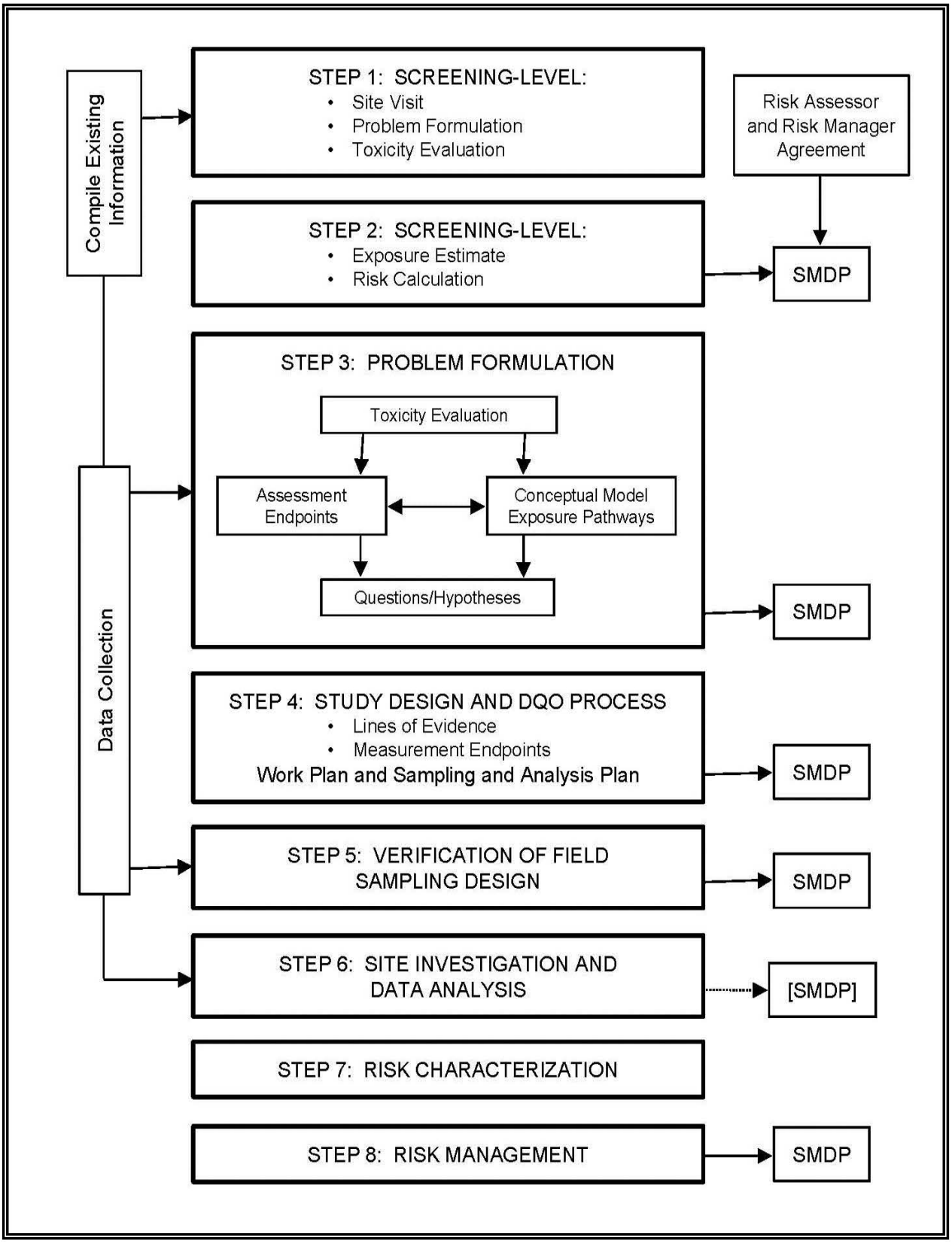


Figure 3. Eight-step Ecological Risk Assessment Process for Superfund (from EPA 1997).

N

0 150 300

Feet

1 inch = 300 feet

Legend:

- 2007/2008 Surface Water and Sediment Samples
- 2013 Surface Water and Sediment Samples
- Area of Concern Boundary

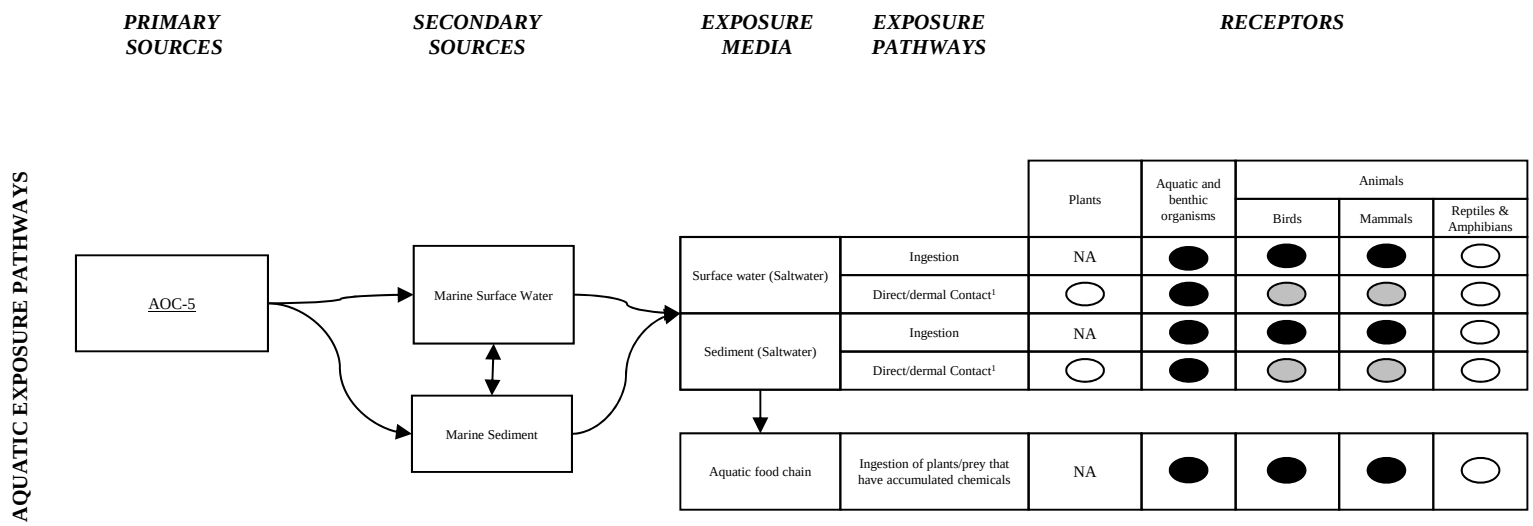
Source: AOC and pipeline locations from TRC, dated, March 10, 2011

Image Source: 2009 Texas Orthoimagery Program, Texas Strategic Mapping Program, TNRIS, 2009

Falcon Refinery Superfund Site
Ingleside, San Patricio County,Texas

Figure 4
AOC-5 Sample Locations
Ecological Risk Assessment for AOC 5

2014-04-01 P:\gisProjects\Falcon\MXDs\RiskMaps\AOC5.mxd EA-Dallas rmullen



- [1]Inhalation and direct contact are identified as complete pathways for higher trophic level wildlife. However, example calculations and information provided in EPA and other exposure modeling guidance demonstrates that these pathways are insignificant compared to ingestion (USEPA 2003a; CHPPM 2004).

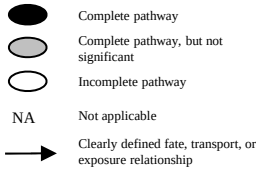


Figure 5. Ecological Conceptual Site Model for Falcon Refinery Superfund Site

TABLES

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Table 1
Samples Used in the Ecological Risk Assessment

Area	Media	Sample Date	Sample ID
AOC-5	Sediment	11-Jan-08	FR-222
		11-Jan-08	FR-224
		11-Jan-08	FR-226
		11-Sep-13	SD5-01-0.0-0.5
		11-Sep-13	SD5-02-0.0-0.5
		11-Sep-13	SD5-03-0.0-0.5
		12-Sep-13	SD5-04-0.0-0.5
		12-Sep-13	SD5-05-0.0-0.5
		12-Sep-13	SD5-06-0.0-0.5
		12-Sep-13	SD5-07-0.0-0.5
		12-Sep-13	SD5-08-0.0-0.5
		12-Sep-13	SD5-09-0.0-0.5
		12-Sep-13	SD5-10-0.0-0.5
	Surface Water	11-Jan-08	FR-220A
		11-Jan-08	FR-223
		11-Jan-08	FR-225
		11-Sep-13	SW5-01
		11-Sep-13	SW5-02
		11-Sep-13	SW5-03
		12-Sep-13	SW5-04
		12-Sep-13	SW5-05
		12-Sep-13	SW5-06
		12-Sep-13	SW5-07
		12-Sep-13	SW5-08
		12-Sep-13	SW5-09
		12-Sep-13	SW5-10

Table 2
Measurement Endpoints for Ecological Risk Assessment

Assessment Endpoint	Measurement Endpoint	On Site-Measurements/Exposure Point Concentrations (EPC)	Evaluation Method	Risk Indicators
Protection of aquatic organisms exposed to COPECs in sediment and surface water from adverse survival, growth and reproductive effects	Initial screening (AOC-5)	• Sediment and surface water concentrations measured at site in past and more recent sampling	• Direct comparison to the NAWQC and Region III ecological screening values to define COPECs	• Chemicals defined as COPECs indicate the potential for risk
	Comparison of sediment and surface water concentrations to benchmarks	• Sediment and surface water concentrations measured at site in past and more recent sampling - SLERA: Maximum Concentrations - Refined BRAPF: Mean Concentrations	• Compare maximum, mean, and individual sediment concentrations against benthic TRVs (consensus based benchmarks from literature-based studies) • Compare maximum, mean, and individual surface water concentrations against aquatic TRVs (water quality standards)	• Exceedence of benchmarks indicates potential for risks • Exceedence of benchmarks and background indicates a more certain potential for risks
Protection of aquatic-feeding birds and mammals, to ensure that ingestion of COPECs in sediment, surface water, and food do not have adverse impacts on survival, growth, and reproduction	Initial screening	• Sediment and surface water concentrations measured at site in past and more recent sampling	• Direct comparison to the Eco-SSL or Region IV ecological screening values to define COPECs	• Chemicals defined as COPECs indicate the potential for risk
	Comparison of modeled food web doses to benchmarks	• Sediment and surface water concentrations measured at site in past and more recent sampling - SLERA: Maximum Concentrations - Refined SLERA & BRAPF: Mean Concentrations • Aquatic food item tissue concentrations modeled using literature-based equations - SLERA: Maximum Concentrations - Refined SLERA & BRAPF: Mean Concentrations • Ingested dose based on literature-based exposure factors and uptake equations - SLERA: Maximum Dose - Refined SLERA & BRAPF: Mean Dose	• Calculate maximum case scenario doses using food web models and compare to no-effects benchmarks • Calculate mean case scenario doses and compare to no- and low-effects benchmarks • Bird dose-based benchmarks from 1) USEPA Eco-SSL 2) ORNL benchmarks (Sample et al., 1998) 3) Additional literatue-based sources as relevant	• Exceedence of benchmarks indicates a potential for risks • Exceedence of low-effects benchmarks indicates a more certain potential for risks

NOTE:
BRAPF: Baseline Risk Assessment Problem Formulation
COPEC: Chemical of Potential Ecological Concern
Eco-SSL: Ecological Soil Screening Levels
NAWQC: National Ambient Water Quality Criteria
ORNL: Oak Ridge National Laboratory
SLERA: Screening Level Ecological Risk Assessment
TRVs: Toxicity Reference Value
USEPA: U.S. Environmental Protection Agency

Table 3
Ecological Screening Benchmarks

Chemical	Soil Criteria (mg/kg)	Soil Criteria Source	Marine Sediment Criteria (mg/kg)	Marine Surface Water Criteria (µg/L)
Metals				
Aluminum	5.00E+01	Region IV	NA	8.70E+01
Antimony	2.70E-01	Mammalian Eco-SSL	2.00E+00	5.00E+02
Arsenic	1.80E+01	Plant Eco-SSL	7.24E+00	1.25E+01
Barium	3.30E+02	Soil Invertebrate Eco-SSL	NA	4.00E+00
Beryllium	2.10E+01	Mammalian Eco-SSL	NA	6.60E-01
Cadmium	3.60E-01	Mammalian Eco-SSL	6.80E-01	1.20E-01
Calcium	NA	--	NA	1.16E+05
Chromium	2.60E+01	Avian Eco-SSL for Cr III	5.23E+01	5.75E+01
Cobalt	1.30E+01	Plant Eco-SSL	5.00E+01	2.30E+01
Copper	2.80E+01	Avian Eco-SSL	1.87E+01	3.10E+00
Iron	2.00E+02	Region IV	2.00E+04	3.00E+02
Lead	1.10E+01	Avian Eco-SSL	3.02E+01	8.10E+00
Magnesium	NA	--	NA	8.20E+04
Manganese	2.20E+02	Plant Eco-SSL	4.60E+02	1.20E+02
Mercury	1.00E-01	Region IV	NA	1.60E-02
Nickel	3.80E+01	Plant Eco-SSL	1.59E+01	8.20E+00
Potassium	NA	--	NA	5.30E+04
Selenium	5.20E-01	Plant Eco-SSL	2.00E+00	7.10E+01
Silver	4.20E+00	Avian Eco-SSL	7.30E-01	2.30E-01
Sodium	NA	--	NA	6.80E+05
Thallium	1.00E+00	Region IV	NA	2.13E+01
Vanadium	7.80E+00	Avian Eco-SSL	NA	2.00E+01
Zinc	4.60E+01	Avian Eco-SSL	1.24E+02	8.10E+01
PAHs				
2-Methylnaphthalene	NA	--	2.02E-02	4.20E+00
Acenaphthene	NA	--	6.71E-03	6.60E+00
Acenaphthylene	NA	--	5.87E-03	NA
Anthracene	NA	--	4.69E-02	1.80E-01
Benzo(a)Anthracene	NA	--	7.48E-02	1.80E-02
Benzo(a)Pyrene	NA	--	8.88E-02	1.50E-02
Benzo(b)Fluoranthene	NA	--	2.72E-02	NA
Benzo(g,h,i)Perylene	NA	--	1.70E-01	NA
Benzo(k)Fluoranthene	NA	--	2.40E-01	NA
Chrysene	NA	--	1.08E-01	NA
Dibenzo(a,h)Anthracene	NA	--	6.22E-03	NA
Fluoranthene	NA	--	1.13E-01	1.60E+00
Fluorene	NA	--	2.12E-02	2.50E+00
Indeno(1,2,3-Cd)Pyrene	NA	--	1.70E-02	NA
Naphthalene	NA	--	3.46E-02	1.40E+00

Table 3
Ecological Screening Benchmarks

Chemical	Soil Criteria (mg/kg)	Soil Criteria Source	Marine Sediment Criteria (mg/kg)	Marine Surface Water Criteria (µg/L)
Phenanthrene	NA	--	8.67E-02	1.50E+00
Pyrene	NA	--	1.53E-01	2.40E-01
Total LMW PAHs	2.90E+01	Soil Invertebrate Eco-SSL	3.12E-01	NA
Total HMW PAHs	1.10E+00	Mammalian Eco-SSL	6.55E-01	NA
Total PAHs	NA	--	4.02E+00	1.68E+03
SVOCs				
1,1'-Biphenyl	6.00E+01	Region IV	1.22E+00	1.40E+01
2-Methylphenol	NA	--	NA	1.02E+03
4-Methylphenol	NA	--	6.70E-01	5.43E+02
Acetophenone	NA	--	NA	NA
Benzaldehyde	NA	--	NA	NA
Benzoic Acid	NA	--	6.50E-01	4.20E+01
Butyl benzyl phthalate	NA	--	1.68E+01	2.94E+01
Bis(2-ethylhexyl)phthalate	NA	--	1.82E-01	1.60E+01
Caprolactum	NA	--	NA	NA
Carbazole	NA	--	NA	NA
Diethyl phthalate	1.00E+02	Region IV	2.18E-01	7.59E+01
Dimethyl phthalate	2.00E+02	Region IV	NA	5.80E+02
Di-N-Butyl phthalate	2.00E+02	Region IV	1.16E+00	3.40E+00
Di-N-octyl Phthalate	NA	--	NA	2.20E+01
Isophorone	NA	--	NA	1.29E+02
Phenol	5.00E-02	Region IV	4.20E-01	5.80E+01
VOCs				
1,1,2,2-Tetrachloroethane	NA	--	2.02E-01	9.02E+01
1,2,4-Trimethlybenzene	NA	--	NA	1.90E+01
1,3,5-Trimethylbenzene	NA	--	NA	NA
2-Butanone	NA	--	NA	1.40E+04
4-Methyl-2-pentanone	NA	--	NA	1.23E+05
Acetone	NA	--	NA	5.64E+05
Benzene	5.00E-02		NA	1.10E+02
Benzaldehyde	1.00E-02	Region IV	NA	NA
Carbon disulfide	NA	--	8.51E-04	9.20E-01
Chloroform	1.00E-03	Region IV	NA	8.15E+02
Chloromethane	NA	--	NA	2.70E+03
Ethylbenzene	5.00E-02	Region IV	3.05E-01	2.50E+01
Isopropylbenzene	NA	--	NA	NA

Table 3
Ecological Screening Benchmarks

Chemical	Soil Criteria (mg/kg)	Soil Criteria Source	Marine Sediment Criteria (mg/kg)	Marine Surface Water Criteria (µg/L)
Methylene chloride	NA	--	NA	2.56E+03
n-Propylbenzene	NA	--	NA	NA
Styrene	1.00E-01	Region IV	7.07E+00	9.10E+02
Tetrachloroethene	1.00E-02	Region IV	1.90E-01	4.50E+01
Toluene	5.00E-02	Region IV	1.09E+00	2.15E+02
Trichloroethene	NA	--	5.70E-01	1.94E+03
Trichloroflouromethane	NA	--	NA	NA
Xylenes (m & p)	NA	--	NA	NA
Xylenes (o)	NA	--	NA	NA
Xylenes (Total)	5.00E-02	Region IV	2.52E-02	1.90E+01

Sources

For surface water criteria:
NAWQC assessed at http://water.epa.gov/scitech/swguidance/standards/criteria/current/index.cfm, TCEQ Water Quality Standards accessed at http://www.tceq.state.tx.us/waterquality/standards/2010standards.html, or Region III BTAG Ecological Screening Benchmarks assessed at http://www.epa.gov/reg3hscd/risk/eco/btag/sbv/fw/screenbench.htm.

For surface sediment criteria :
TCEQ accessed at http://www.tceq.state.tx.us/assets/public/remediation/eco/0106eragupdate.pdf, or Region III BTAG Ecological Screening Benchmarks accessed at http://www.epa.gov/reg3hscd/risk/eco/btag/sbv/marsed/screenbench.htm and http://www.epa.gov/reg3hscd/risk/eco/btag/sbv/fwsed/screenbench.htm.

For surface soil criteria:
The lowest Eco-SSLs of available receptors, accessed at http://www.epa.gov/ecotox/ecossl/, or Region IV Ecological Screening Values, accessed at http://www.epa.gov/region4/superfund/programs/riskassess/ecolbul.html or Region III Ecological Screening Values, assessed at http://www.epa.gov/reg3hscd/risk/eco/btag/sbv/marsed/screenbench.htm, were used if Eco-SSLs were not available.

NOTES:
NA: Screening Value not available
Surface water criteria listed for Chromium is Chromium III.
Surface water criteria listed for Arsenic is Arsenic III.
mg/kg: milligram per kilogram
µg/L: microgram per liter
Eco-SSL: Ecological Soil Screening Levels
LMW PAH: Low molecular weight polynuclear aromatic hydrocarbon
HMW PAH: High molecular weight polynuclear aromatic hydrocarbon

Table 4
Maximum Sediment and Surface Water Detection Comparison to Screening Levels
for AOC-5

Analyte	Marine Sediment				Marine Surface Water (Total)				Selection of Chemicals of Potential Ecological Concern		
	Frequency	Maximum (mg/kg)	Location of the Maximum	Screening Criteria (mg/kg)	Frequency	Maximum (µg/L)	Location of the Maximum	Screening Criteria (µg/L)	Marine Sediment	Marine Surface Water	Marine Aquatic Habitats
Metals											
Aluminum	**6/6**	**1.45E+04**	**SD5-01-0.0-0.5**	**NA**	**10/13**	**7.88E+02**	**SW5-05**	**NA**	**YES**	NO	**YES**
Antimony	0/3	--	--	2.00E+00	3/13	4.90E+00	FR-223	3.00E+01	NO	NO	NO
Arsenic	6/6	7.10E+00	FR-222	9.80E+00	0/10	--	--	7.80E+01	NO	NO	NO
Barium	**6/6**	**2.29E+03**	**FR-226**	**NA**	**3/13**	**5.36E+01**	**FR-225**	**2.00E+02**	**YES**	NO	**YES**
Beryllium	**3/6**	**6.60E-01**	**FR-222**	**NA**	0/10	--	--	1.00E+02	**YES**	NO	**YES**
Cadmium	**12/12**	**1.50E+00**	**SD5-01-0.0-0.5**	**9.90E-01**	0/10	--	--	8.75E+00	**YES**	NO	**YES**
Calcium	3/3	3.48E+04	SD5-01-0.0-0.5	NA	10/10	5.43E+05	SW5-05	NA	NO, Esn. Nut.	NO, Esn. Nut.	NO
Chromium	**6/6**	**2.70E+02**	**FR-222**	**4.34E+01**	2/12	1.80E+00	FR-225, FR-223	2.74E+01	**YES**	NO	**YES**
Cobalt	6/6	7.70E+00	FR-222	5.00E+01	0/10	--	--	1.00E+00	NO	NO	NO
Copper	**13/13**	**1.90E+02**	**SD5-01-0.0-0.5**	**3.16E+01**	**7/10**	**1.12E+02**	**SW5-09**	**3.60E+00**	**YES**	**YES**	**YES**
Iron	6/6	1.29E+04	SD5-01-0.0-0.5	2.00E+04	3/13	1.26E+02	FR-225	5.00E+01	NO	NO	NO
Lead	**13/13**	**1.58E+03**	**FR-222**	**3.58E+01**	**3/13**	**1.19E+01**	**FR-225**	**5.30E+00**	**YES**	**YES**	**YES**
Magnesium	3/3	9.32E+03	SD5-01-0.0-0.5	NA	10/10	1.48E+06	SW5-04, SW5-10,	NA	NO, Esn. Nut.	NO, Esn. Nut.	NO
Manganese	6/6	2.10E+02	SD5-01-0.0-0.5	4.60E+02	8/13	1.22E+01	FR-223, SW5-08	1.00E+02	NO	NO	NO
Mercury	6/6	1.60E-01	FR-222	1.80E-01	0/10	--	--	1.10E+00	NO	NO	NO
Nickel	**12/13**	**2.30E+02**	**SD5-01-0.0-0.5**	**2.27E+01**	0/10	--	--	1.31E+01	**YES**	NO	**YES**
Potassium	3/3	4.83E+03	SD5-01-0.0-0.5	NA	10/10	7.00E+05	SW5-05	NA	NO, Esn. Nut.	NO, Esn. Nut.	NO
Selenium	2/3	5.80E-01	SD5-03-0.0-0.5	2.00E+00	**7/10**	9.13E+01	SW5-08	1.36E+02	NO	NO	NO
Sodium	3/3	2.66E+04	SD5-01-0.0-0.5	NA	10/10	1.28E+07	SW5-05	NA	NO, Esn. Nut.	NO, Esn. Nut.	NO
Thallium	0/3	--	--	NA	**2/12**	4.70E+00	FR-225	1.70E+01	NO	NO	NO
Vanadium	**6/6**	**2.11E+01**	**FR-222**	**NA**	2/12	1.30E+00	FR-223	5.00E+01	**YES**	NO	**YES**
Zinc	**13/13**	**2.60E+02**	**SD5-01-0.0-0.5**	**1.21E+02**	8/13	4.57E+02	SW5-07	8.42E+01	**YES**	**YES**	**YES**
PAHs											
2-Methylnaphthalene	2/10	8.00E-03	SD5-03-0.0-0.5	2.02E-02	2/10	5.90E-02	SW5-09	4.70E+00	NO	NO	NO
Anthracene	**1/11**	**4.40E-01**	**FR-222**	**5.72E-02**	0/10	--	--	1.20E-02	**YES**	NO	**YES**
Benzo(a)Anthracene	**11/11**	**7.10E-01**	**FR-222**	**1.08E-01**	0/10	--	--	1.80E-02	**YES**	NO	**YES**
Benzo(a)Pyrene	**10/11**	**5.11E-01**	**FR-222**	**1.50E-01**	0/10	--	--	1.50E-02	**YES**	NO	**YES**
Benzo(b)Fluoranthene	**11/11**	**9.08E-01**	**FR-222**	**2.72E-02**	0/10	--	--	NA	**YES**	NO	**YES**
Benzo(g,h,i)Perylene	**1/11**	**2.33E-01**	**FR-222**	**1.70E-01**	0/10	--	--	NA	**YES**	NO	**YES**
Benzo(k)Fluoranthene	**9/11**	**3.03E-01**	**FR-222**	**2.40E-01**	0/10	--	--	NA	**YES**	NO	**YES**
Chrysene	**10/11**	**8.95E-01**	**FR-222**	**1.66E-01**	0/10	--	--	NA	**YES**	NO	**YES**
Fluoranthene	**11/11**	**1.78E+00**	**FR-222**	**4.23E-01**	0/10	--	--	4.00E-02	**YES**	NO	**YES**
Fluorene	**1/11**	**2.37E-01**	**FR-222**	**7.74E-02**	0/10	--	--	3.00E+00	**YES**	NO	**YES**
Indeno(1,2,3-Cd)Pyrene	**9/11**	**2.25E-01**	**FR-222**	**1.70E-02**	0/10	--	--	NA	**YES**	NO	**YES**
Naphthalene	0/10	--	--	1.76E-01	2/10	4.80E-02	SW5-09	1.10E+00	NO	NO	NO
Phenanthrene	**8/11**	**3.42E-01**	**FR-222**	**2.04E-01**	3/10	6.50E-02	SW5-02	4.00E-01	**YES**	NO	**YES**
Pyrene	12/12	8.40E-03	FR-222	1.95E-01	0/10	--	--	2.50E-02	NO	NO	NO
Total LMW PAHs	**8/8**	**1.02E+00**	**FR-222**	**7.60E-02**	NT	--	--	NA	**YES**	**YES**	**YES**
Total HMW PAHs	**12/12**	**7.27E+00**	**FR-222**	**1.90E-01**	NT	--	--	NA	**YES**	**YES**	**YES**
Total PAHs	12/12	8.28E+00	FR-222	4.02E+00	3/3	1.55E-01	SW5-09	1.68E+03	YES	NO	YES
SVOCs											
Acetophenone	**1/10**	**5.50E-02**	**SD5-06-0.0-0.5**	**NA**	8/10	1.40E+00	SW5-09, SW5-10	6.60E+00	**YES**	NO	**YES**
Benzaldehyde	**1/10**	**4.30E-02**	**SD5-06-0.0-0.5**	**NA**	**5/10**	**6.90E-01**	**SW5-10**	**NA**	**YES**	**YES**	**YES**
Bis(2-ethylhexyl)phthalate	2/10	1.10E-01	SD5-03-0.0-0.5	1.82E-01	3/12	2.40E+00	FR-220A	1.60E+01	NO	NO	NO
Caprolactum	0/10	--	--	--	**1/10**	**2.90E+00**	**SW5-09**	**NA**	NO	**YES**	**YES**
Dimethyl phthalate	**1/10**	**4.50E-02**	**SD5-02-0.0-0.5**	**NA**	2/10	6.60E-01	SW5-02	5.80E+02	**YES**	NO	**YES**
Phenol	1/10	5.00E-02	SD5-02-0.0-0.5	4.20E-01	0/10	--	--	--	NO	NO	NO
VOCs											
1,2,4-Trimethylbenzene	0/10	--	--	--	3/3	3.70E+00	FR-225	1.90E+01	NO	NO	NO
1,3,5-Trimethylbenzene	NT	--	--	--	**2/2**	**1.00E+00**	**FR-225**	**NA**	NO	**YES**	**YES**
2-Butanone	**1/10**	**6.70E-03**	**SD5-01-0.0-0.5**	**NA**	0/10	--	--	--	**YES**	NO	**YES**
Acetone	**11/13**	**6.43E-02**	**FR-222**	**NA**	9/10	1.80E+00	SW5-09	5.64E+05	**YES**	NO	**YES**
Benzene	0/10	--	--	--	4/10	1.50E+00	FR-225	1.10E+02	NO	NO	NO
Carbon disulfide	**13/13**	**1.40E-02**	**FR-222**	**8.51E-04**	0/10	--	--	--	**YES**	NO	**YES**
Chloromethane	0/10	--	--	--	4/10	1.30E-01	SW5-04, SW5-01	2.70E+03	NO	NO	NO
Ethylbenzene	1/10	1.70E-03	SD5-01-0.0-0.5	3.05E-01	2/12	1.10E+00	FR-225	2.50E+01	NO	NO	NO
Methylene chloride	**1/11**	**3.60E-03**	**FR-226**	**NA**	0/10	--	--	--	**YES**	NO	**YES**
n-Propylbenzene	NT	--	--	--	**1/1**	**5.50E-01**	**FR-220A**	**NA**	NO	**YES**	**YES**
Tetrochloroethene	1/10	8.70E-04	SD5-01-0.0-0.5	1.90E-01	0/10	--	--	--	NO	NO	NO
Toluene	1/10	8.60E-04	SD5-01-0.0-0.5	--	3/13	6.30E+00	FR-225	2.15E+02	NO	NO	NO
Xylenes (m & p)	**3/10**	**1.50E-02**	**SD5-01-0.0-0.5**	**NA**	NT	--	--	--	**YES**	NO	**YES**
Xylenes (o)	**1/10**	**4.90E-03**	**SD5-01-0.0-0.5**	**NA**	NT	--	--	--	**YES**	NO	**YES**
Xylenes (Total)	NT	--	--	--	2/2	5.70E+00	FR-225	1.90E+01	NO	NO	NO

NOTES:
NA: Screening Value not available
ND: Not detected
NT: Not tested
Eco-SSL: Ecological Soil Screening Levels
LMW PAH: Low molecular weight polynuclear aromatic hydrocarbon
Esn. Nut.: Essential nutrient
HMW PAH: High molecular weight polynuclear aromatic hydrocarbon
UCL: Upper confidence level

Table 5
Frequency of Detection and Exposure Point Concentrations
for AOC-5

Analyte	Surface Water Accessible for Drinking by Wildlife (Total Concentrations)			Marine Sediment			Marine Surface Water (Total Concentration)		
	Frequency	Maximum (mg/L)	95% UCL Mean (mg/L)	Frequency	Maximum (mg/kg)	95% UCL Mean (mg/kg)	Frequency	Maximum (µg/L)	95% UCL Mean (µg/L)
Metals									
Aluminum	10/13	7.88E-01	6.42E-01	6/6	1.45E+04	1.28E+04	10/13	7.88E+02	6.42E+02
Barium	3/13	5.36E-02	5.36E-02	6/6	2.29E+03	2.29E+03	3/13	5.36E+01	5.36E+01
Beryllium	0/10	--	--	3/6	6.60E-01	6.60E-01	0/10	--	--
Cadmium	0/10	--	--	12/12	1.50E+00	7.84E-01	0/10	--	--
Chromium	2/12	1.80E-03	1.80E-03	6/6	2.70E+02	2.70E+02	2/12	1.80E+00	1.80E+00
Copper	7/10	1.12E-01	7.54E-02	13/13	1.90E+02	8.17E+01	7/10	1.12E+02	7.54E+01
Lead	3/13	1.19E-02	1.19E-02	13/13	1.58E+03	1.33E+03	3/13	1.19E+01	1.19E+01
Nickel	0/10	--	--	12/13	2.30E+02	1.30E+02	0/10	--	--
Selenium	7/10	9.13E-02	8.40E-02	NO COPC	NO COPC	NO COPC	NO COPC	NO COPC	NO COPC
Thallium	NO COPC	NO COPC	NO COPC	NO COPC	NO COPC	NO COPC	NO COPC	NO COPC	NO COPC
Vanadium	2/12	1.30E-03	1.30E-03	6/6	2.11E+01	1.76E+01	2/12	1.30E+00	1.30E+00
Zinc	8/13	4.57E-01	4.57E-01	13/13	2.60E+02	1.22E+02	8/13	4.57E+02	4.57E+02
PAHs									
Total LMW PAHs	NT	--	--	8/8	1.02E+00	1.02E+00	NT	--	--
Total HMW PAHs	NT	--	--	12/12	7.27E+00	3.34E+00	NT	--	--
SVOCs									
Acetophenone	8/10	1.40E-03	1.15E-03	1/10	5.50E-02	5.50E-02	8/10	1.40E+00	1.15E+00
Benzaldehyde	5/10	6.90E-04	6.73E-04	1/10	4.30E-02	4.30E-02	5/10	6.90E-01	6.73E-01
Caprolactum	1/10	2.90E-03	2.90E-03	0/10	--	--	1/10	2.90E+00	2.90E+00
Dimethyl phthalate	2/10	6.60E-04	0.00E+00	1/10	4.50E-02	4.50E-02	2/10	6.60E-01	6.60E-01
VOCs									
1,3,5-Trimethylbenzene	2/2	1.00E-03	1.00E-03	NT	--	--	2/2	1.00E+00	1.00E+00
2-Butanone	0/10	--	--	1/10	6.70E-03	6.70E-03	0/10	--	--
Acetone	9/10	1.80E-03	1.52E-03	11/13	6.43E-02	3.45E-02	9/10	1.80E+00	1.52E+00
Carbon disulfide	0/10	--	--	13/13	1.40E-02	6.01E-03	0/10	--	--
Methylene chloride	0/10	--	--	1/11	3.60E-03	3.60E-03	0/10	--	--
n-Propylbenzene	1/1	5.50E-04	5.50E-04	NT	--	--	1/1	5.50E-01	5.50E-01
Xylenes (m & p)	NT	--	--	3/10	1.50E-02	1.50E-02	NT	--	--
Xylenes (o)	NT	--	--	1/10	4.90E-03	4.90E-03	NT	--	--

NOTES:
NT: Not tested
mg/kg: milligram per kilogram
µg/L: microgram per liter
LMW PAH: Low molecular weight polynuclear aromatic hydrocarbon
HMW PAH: High molecular weight polynuclear aromatic hydrocarbon
UCL: Upper confidence level

Table 6
Wildlife Exposure Factors for the Ecological Risk Assessment at AOC-5

Exposure Parameter	Value	Units	Notes
GREAT BLUE HERON			
Body Weight	2.229	kg	CHPPM, 2004
Food Ingestion Rate	0.0450	kg dry wt./kg-day	CHPPM, 2004, converted assuming 75% prey moisture (CHPPM 2004)
Food Ingestion Rate	0.18	kg wet wt./kg-day	CHPPM, 2004
Incidental Sediment Ingestion Rate	2.00%	% of total mass of diet	Sample and Suter, 1994
Water Ingestion Rate	0.045	L/kg-day	CHPPM, 2004
RIVER OTTER			
Body Weight	7.400	kg	USEPA 1993 (value is average of male and female weights, 8.13 and 6.73, respectively)
Food Ingestion Rate	0.1600	kg dry wt./kg-day	CHPPM, 2004
Food Ingestion Rate	0.64	kg wet wt./kg-day	CHPPM, 2004, converted assuming 75% prey moisture (CHPPM 2004)
Incidental Sediment Ingestion Rate	2.00%	% of total mass of diet	As a default, ingestion rate is assumed to be 2%
Water Ingestion Rate	0.081	L/kg-day	USEPA 1993

NOTE:
It is assumed (consistent with Exposure Factors Handbood, USEPA 1993) that the heron and otter consume 100% fish.
kg: kilogram
kg dry wt./kg-day: kilogram of dry weight food per kilogram of body weight per day
kg wet wt./kg-day: kilogram of wet weight food per kilogram of body weight per day
dry wt.: dry weight
L/kg-day: liter of water per kilogram of body weight per day
USEPA: U.S. Environmental Protection Agency
CHPPM: U.S. Army Center for Health Promotion and Preventative Medicine

Table 7
Uptake Models Relating Concentrations in Surface Water to Concentrations in Fish

Chemical	Food Item (Fish) Uptake		
	Uptake Model[A, B, C]	BAF/Equation (mg/L dry wt. to mg/kg dry wt.)	Source
Metals			
Aluminum	Uptake Factor	2.70E+00	From Table C-5 - USEPA 1999
Antimony	Uptake Factor	1.00E+00	Based on bluegill in Table 5 - USEPA 1988
Arsenic	Uptake Factor	4.00E+00	Based on bluegill in Table 5 - USEPA 1985a
Barium	Uptake Factor	4.00E+00	BCF from http://rais.ornl.gov/cgi-bin/tox/TOX_select?select=chem
Beryllium	Uptake Factor	6.20E+01	From Table C-5 - USEPA 1999
Cadmium	Uptake Factor	5.90E+01	Based on bluegill in Table 5 - USEPA 2001
Calcium	Uptake Factor	1.00E+00	Default
Chromium	Uptake Factor	2.00E+02	BCF from http://rais.ornl.gov/cgi-bin/tox/TOX_select?select=chem
Cobalt	Uptake Factor	1.00E+00	Default
Copper	Uptake Factor	4.64E+02	Based on fathead minnow in Table 5 - USEPA 2003b
Iron	Uptake Factor	1.00E+00	Default
Lead	Uptake Factor	4.50E+01	Based on bluegill in Table 5 - USEPA 1985b
Magnesium	Uptake Factor	1.00E+00	Default
Manganese	Uptake Factor	4.00E+02	BCF from http://rais.ornl.gov/cgi-bin/tox/TOX_select?select=chem
Mercury	Uptake Factor	1.80E+03	Based on rainbow trout in Table 5 - USEPA 1985c
Nickel	Uptake Factor	2.70E+01	Based on rainbow trout/fathead minnow in Table 5 - USEPA 1986
Potassium	Uptake Factor	1.00E+00	Default
Selenium	Uptake Factor	2.42E+02	Based on bluegill in Table 5 - USEPA 1987a
Silver	Uptake Factor	8.77E+01	From Table C-5 - USEPA 1999
Sodium	Uptake Factor	1.00E+00	Default
Thallium	Uptake Factor	1.00E+03	BCF from http://rais.ornl.gov/cgi-bin/tox/TOX_select?select=chem
Vanadium	Uptake Factor	1.00E+00	Default
Zinc	Uptake Factor	1.30E+01	Based on mummichog in Table 5 - USEPA 1987b
PAHs			
2-Methylnaphthalene	Uptake Factor	1.86E+02	Regression from BCFWIN Program
Acenaphthene	Uptake Factor	1.79E+02	Regression from BCFWIN Program
Acenaphthylene	Uptake Factor	2.14E+02	Regression from BCFWIN Program
Anthracene	Uptake Factor	5.37E+02	Regression from BCFWIN Program
Benzo(a)Anthracene	Uptake Factor	5.50E+03	Regression from BCFWIN Program
Benzo(a)Pyrene	Uptake Factor	1.05E+04	Regression from BCFWIN Program
Benzo(b)Fluoranthene	Uptake Factor	5.62E+03	Regression from BCFWIN Program
Benzo(g,h,i)Perylene	Uptake Factor	2.57E+04	Regression from BCFWIN Program
Benzo(k)Fluoranthene	Uptake Factor	1.00E+04	Regression from BCFWIN Program
Chrysene	Uptake Factor	5.89E+03	Regression from BCFWIN Program
Dibenzo(a,h)Anthracene	Uptake Factor	2.19E+04	Regression from BCFWIN Program
Fluoranthene	Uptake Factor	1.86E+03	Regression from BCFWIN Program
Fluorene	Uptake Factor	2.66E+02	Regression from BCFWIN Program
Indeno(1,2,3-Cd)Pyrene	Uptake Factor	2.88E+04	Regression from BCFWIN Program
Naphthalene	Uptake Factor	6.92E+01	Regression from BCFWIN Program
Phenanthrene	Uptake Factor	5.37E+02	Regression from BCFWIN Program
Pyrene	Uptake Factor	1.15E+03	Regression from BCFWIN Program
Total LMW PAHs	NA	--	--
Total HMW PAHs	NA	--	--

NOTES:
A - Equation types:
Uptake Factor:
B - USEPA 2009, Uptake factor for organics derived using the BCF Win/BCFBAF Program from USEPA
http://www.epa.gov/oppt/exposure/pubs/episuitedl.htm
C - Uptake factor for inorganics from the following sources:
ORNL 2009, BCF from http://rais.ornl.gov/cgi-bin/tox/TOX_select?select=chem
ORNL 2009, BCF from http://rais.ornl.gov/cgi-bin/tools/TOX_search
USEPA 1999, Table C-5
USEPA 1988, Table 5 (bluegill)
USEPA 1985a, Table 5
USEPA 1985b, Table 5
USEPA 1985c, Table 5
mg/L dry wt: milligram per liter dry weight
NA: Uptake Model not available
mg/kg dry wt: milligram per kilogram of dry weight
UF: Uptake Factor
BCF: Bioconcentration Factor
BAF: Bioaccumulation Factor
USEPA: U.S. Environmental Protection Agency

Table 8
Sediment Toxicity Reference Values for Benthic Organism Exposures

Chemical	Sediment TRV (mg/kg dry wt.)	Sediment LOAEL-based TRV (mg/kg dry wt.)	Source
Metals			
Aluminum	NA	NA	---
Antimony	2.00E+00	NA	Value is LEL from Persaud et al. 1993
Arsenic	7.24E+00	8.20E+00	MacDonald et al. 1996
Barium	NA	NA	---
Beryllium	NA	NA	---
Cadmium	6.80E-01	1.40E+00	MacDonald et al. 1996
Calcium	NA	NA	---
Chromium	5.23E+01	1.41E+02	MacDonald et al. 1996
Cobalt	NA	NA	---
Copper	1.87E+01	9.40E+01	MacDonald et al. 1996
Iron	2.00E+04	NA	Value is TEL from MacDonald et al. 1996
Lead	3.02E+01	9.40E+01	MacDonald et al. 1996
Magnesium	NA	NA	---
Manganese	4.60E+02	NA	Value is TEL from MacDonald et al. 1996
Mercury	NA	1.50E-01	MacDonald et al. 1996
Nickel	1.59E+01	2.99E+01	MacDonald et al. 1996
Potassium	NA	NA	---
Selenium	NA	NA	---
Silver	7.30E-01	1.00E+00	MacDonald et al. 1996
Sodium	NA	NA	---
Thallium	NA	NA	---
Vanadium	NA	NA	---
Zinc	1.24E+02	1.50E+02	MacDonald et al. 1996
PAHs			
Total LMW PAHs	1.60E+00	5.52E-01	MacDonald et al. 1996
Total HMW PAHs	1.60E+00	1.70E+00	MacDonald et al. 1996
VOCs			
Carbon disulfide	8.50E-04	NA	Value is SQB calculated from Tier II secondary chronic value (Jones et al. 1997) assuming 1% OC

NOTES:
NA = TRV not available
mg/kg dry wt: miligram per kilogram of dry weight
USEPA: U.S. Environmental Protection Agency
LMW PAH: Low molecular weight polynuclear aromatic hydrocarbon
HMW PAH: High molecular weight polynuclear aromatic hydrocarbon
TEC: Threshold Effect Concentration
TEL: Threshold Effect Level
LEL: Lowest Effect Level
LOAEL: Lowest Observed Adverse Effect Level

Table 9
Surface Water Toxicity Reference Values for Marine Aquatic Organism Exposures

Chemical	Chronic TRV (ug/L)	Acute TRV (ug/L)	Source for Marine Surface Water TRVs
Metals			
Aluminum	NA	NA	---
Antimony	3.00E+01	8.80E+01	NAWQC value from Suter and Tsao 1996
Arsenic	7.80E+01	1.49E+02	TCEQ 2010
Barium	2.00E+02	1.00E+03	Buchman 2008
Beryllium	1.00E+02	1.50E+03	Buchman 2008
Cadmium	8.75E+00	4.00E+01	TCEQ 2010
Calcium	NA	NA	---
Chromium	2.74E+01	5.70E+02	Chronic from Buchman 2008, Acute from NAWQC (USEPA 2012)
Cobalt	1.00E+00	NA	Buchman 2008
Copper	3.60E+00	1.35E+01	TCEQ 2010
Iron	5.00E+01	3.00E+02	Buchman 2008
Lead	5.30E+00	1.33E+02	TCEQ 2010
Magnesium	NA	NA	---
Manganese	1.00E+02	NA	Buchman 2008
Mercury	1.10E+00	2.10E+00	TCEQ 2010
Nickel	1.31E+01	1.18E+02	TCEQ 2010
Potassium	NA	NA	---
Selenium	1.36E+02	5.64E+02	TCEQ 2010
Silver	1.90E+00	2.00E+00	TCEQ 2010
Sodium	NA	NA	---
Thallium	1.70E+01	2.13E+03	Buchman 2008
Vanadium	5.00E+01	NA	Buchman 2008
Zinc	8.42E+01	9.27E+01	TCEQ 2010
PAHs			
Total LMW PAHs	NA	3.00E+02	Buchman 2008
Total HMW PAHs	NA	3.00E+02	Buchman 2008
VOCs			
Carbon disulfide	9.20E-01		Tier II value from Suter and Tsao 1996

NOTES:
NAWQC: National Ambient Water Quality Criteria.
TCEQ: Texan Commission on Environmental Quality
NA = TRV not available
USEPA: U.S. Environmental Protection Agency
µg/L: micrograms per liter
TRV: Toxicity Reference Values

Table 10
Dose-based Toxicity Reference Values for Birds

Chemical	Avian NOAEL (mg/kg-bw day)	Avian NOAEL Source and Notes	Avian LOAEL (mg/kg-bw day)	Avian LOAEL Source and Notes
Metals				
Aluminum	1.10E+02	Sample et al. 1996	NA	---
Antimony	5.10E+00	USEPA 2005h	1.28E+01	Sample et al. 1996
Arsenic	2.24E+00	USEPA 2005a	7.40E+00	Sample et al. 1996
Barium	2.08E+01	Sample et al. 1996	4.17E+01	Sample et al. 1996
Beryllium	NA	---	NA	---
Cadmium	1.45E+00	USEPA 2005b	2.00E+01	Sample et al. 1996
Calcium	NA	---	NA	---
Chromium	2.66E+00	Eco-SSL (trivalent) 2008	5.00E+00	Sample et al. 1996
Cobalt	7.61E+00	USEPA 2005g	2.67E+01	Derived from Data in USEPA 2005g
Copper	4.05E+00	USEPA 2007b	6.17E+01	Sample et al. 1996
Iron	NA	---	NA	---
Lead	1.63E+00	USEPA 2005c	1.13E+01	Sample et al. 1996
Magnesium	NA	---	NA	---
Manganese	9.97E+02	Sample et al. 1996	NA	---
Mercury	4.50E-01	Sample et al. 1996	9.00E-01	Sample et al. 1996
Nickel	7.74E+01	Sample et al. 1996	1.07E+02	Sample et al. 1996
Potassium	NA	---	NA	---
Selenium	5.00E-01	Sample et al. 1996	1.00E+00	Sample et al. 1996
Silver	2.02E+00	USEPA 2006	6.05E+01	Derived from Data in USEPA 2006
Sodium	NA	---	NA	---
Thallium	3.50E-01	Derived	NA	---
Vanadium	3.44E-01	USEPA 2005d	6.88E-01	Hill 1979 (study from Eco-SSL used to derive NOAEL)
Zinc	6.61E+01	USEPA 2007e	1.31E+02	Sample et al. 1996
PAHs				
Total LMW PAHs	3.37E+00	Sample et al. 1996	3.37E+01	Sample et al. 1996
Total HMW PAHs	3.37E+00	Sample et al. 1996	3.37E+01	Sample et al. 1996
VOCs				
Carbon disulfide	NA	---	NA	---

NOTES:
NA = TRV not available
mg/kg dry wt: milligram per kilogram of dry weight
USEPA: U.S. Environmental Protection Agency
LMW PAH: Low molecular weight polynuclear aromatic hydrocarbon
HMW PAH: High molecular weight polynuclear aromatic hydrocarbon
Eco-SSL: Ecological Soil Screening Levels
NOAEL: No Observed Adverse Effect Level
LOAEL: Lowest Observed Adverse Effect Level

Table 11
Dose-based Toxicity Reference Values for Mammals

Chemical	Mammalian NOAEL (mg/kg-bw day)	Mammalian NOAEL Source and Notes	Mammalian LOAEL (mg/kg-bw day)	Mammalian LOAEL Source and Notes
Metals				
Aluminum	1.93E+00	Sample et al. 1996	1.93E+01	Sample et al. 1996
Antimony	5.90E-02	USEPA 2005h	1.25E+00	Sample et al. 1996
Arsenic	1.04E+00	USEPA 2005a	1.26E+00	Sample et al. 1996
Barium	5.18E+01	USEPA 2005e	4.36E+02	Derived from Data in USEPA 2005e
Beryllium	5.32E-01	USEPA 2005f	NA	---
Cadmium	7.70E-01	USEPA 2005b	1.00E+01	Sample et al. 1996
Calcium	NA	---	NA	---
Chromium	2.40E+00	Eco-SSL (trivalent) 2008	1.31E+01	Sample et al. 1996
Cobalt	7.33E+00	USEPA 2005g	1.18E+02	Derived from Data in USEPA 2005g
Copper	5.60E+00	USEPA 2007b	1.54E+01	Sample et al. 1996
Iron	NA	---	NA	---
Lead	4.70E+00	USEPA 2005c	8.00E+01	Sample et al. 1996
Magnesium	NA	---	NA	---
Manganese	5.15E+01	USEPA 2007c	2.84E+02	Sample et al. 1996
Mercury	1.32E+01	Sample et al. 1996	NA	---
Nickel	1.70E+00	USEPA 2007d	8.00E+01	Sample et al. 1996
Potassium	NA	---	NA	---
Selenium	1.43E-01	USEPA 2007g	3.30E-01	Sample et al. 1996
Silver	6.02E+00	USEPA 2006	1.16E+02	Derived from Data in USEPA 2006
Sodium	NA	---	NA	---
Thallium	7.40E-03	Sample et al. 1996	7.40E-02	Sample et al. 1996
Vanadium	4.16E+00	USEPA 2005d	8.31E+00	Sanchez et al. 1991 (study from Eco-SSL used to derive NOAEL)
Zinc	7.54E+01	USEPA 2007e	3.20E+02	Sample et al. 1996
PAHs				
Total LMW PAHs	6.56E+01	USEPA 2007f	4.34E+02	Derived from data in USEPA 2007f
Total HMW PAHs	6.15E-01	USEPA 2007f	3.07E+00	Derived from data in USEPA 2007f
VOCs				
Carbon disulfide	2.64E+01	Sample et al. 1996	2.64E+02	Sample et al. 1996

NOTES:
NA = TRV not available
mg/kg dry wt: milligram per kilogram of dry weight
USEPA: U.S. Environmental Protection Agency
LMW PAH: Low molecular weight polynuclear aromatic hydrocarbon
HMW PAH: High molecular weight polynuclear aromatic hydrocarbon
Eco-SSL: Ecological Soil Screening Levels
NOAEL: No Observed Adverse Effect Level
LOAEL: Lowest Observed Adverse Effect Level

Table 12

Comparison of Exposure Point Concentrations (EPCs) in Sediment to Benthic Organisms Toxicity Reference Values for AOC-5

Chemical	Sediment Toxicity Reference Value (mg/kg)	Maximum Exposure Point Concentration (mg/kg dry wt)	Hazard Quotient for Maximum EPC	95% UCL Mean Exposure Point Concentration (mg/kg dry wt)	Hazard Quotient for 95% UCL Mean EPC	LOAEL-based TRV (mg/kg)	Hazard Quotient for 95% UCL Mean Compared to LOAEL-based TRV
Metals							
Aluminum	NA	1.45E+04	--	1.28E+04	--	7.88E+02	--
Barium	NA	2.29E+03	--	2.29E+03	--	NA	--
Beryllium	NA	6.60E-01	--	6.60E-01	--	NA	--
Cadmium	9.90E-01	1.50E+00	**1.5**	7.84E-01	0.79	4.90E+01	0.016
Chromium	4.34E+01	2.70E+02	**6.2**	2.70E+02	**6.2**	1.11E+02	**2.4**
Copper	3.16E+01	1.90E+02	**6.0**	8.17E+01	**2.6**	1.49E+02	0.55
Lead	3.58E+01	1.58E+03	**44**	1.33E+03	**37**	1.28E+02	**10**
Nickel	2.27E+01	2.30E+02	**10**	1.30E+02	**5.7**	4.86E+01	**2.7**
Selenium	NA	NO COPC	--	NO COPC	--	NA	--
Thallium	NA	NO COPC	--	NO COPC	--	NA	--
Vanadium	NA	2.11E+01	--	1.76E+01	--	NA	--
Zinc	1.21E+02	2.60E+02	**2.1**	1.22E+02	**1.0**	4.59E+02	0.26
PAHs							
Total LMW PAHs	1.60E+00	1.02E+00	0.64	1.02E+00	0.64	NA	--
Total HMW PAHs	1.60E+00	7.27E+00	**4.5**	3.34E+00	**2.1**	NA	--
VOCs							
Carbon disulfide	8.51E-04	1.40E-02	**16**	6.01E-03	**7.1**	NA	--

NOTES:
mg/kg: milligram per kilogram
UCL: Upper confidence level
EPC: Exposure point concentrations
mg/kg dry wt: miligram per kilogram of dry weight
HMW PAH: High molecular weight polynuclear aromatic hydrocarbon
LMW PAH: Low molecular weight polynuclear aromatic hydrocarbon
LOAEL: Low Observed Adverse Effect Levels
TRV: Toxicity Reference Value

Table 13
Comparison of Exposure Point Concentrations (EPCs) in Marine Surface Water to Aquatic Organism Toxicity for AOC-5

Chemical	Chronic TRV (µg/L)	Total Concentrations					
		Maximum EPC (µg/L)	HQ for Maximum EPC	95% UCL Mean EPC (µg/L)	HQ for 95% UCL Mean EPC	Acute TRV (µg/L)	HQ for 95% UCL Mean Compared to Acute TRV
Metals							
Copper	3.60E+00	1.12E+02	**31**	7.54E+01	**2.09E+01**	1.35E+01	**5.6**
Lead	5.30E+00	1.19E+01	**2.2**	1.19E+01	**2.25E+00**	1.33E+02	0.09
Zinc	8.42E+01	4.57E+02	**5.4**	4.57E+02	**5.43E+00**	9.27E+01	**4.9**

NOTES:
µg/L: microgram per liter
UCL: Upper confidence level
EPC: Exposure point concentrations
HQ: Hazard Quotient
TRV: Toxicity Reference Value

Table 14
Maximum Modeled Doses to Birds Compared to Avian Toxicity Reference Values for AOC-5

Chemical	Avian TRVs (mg/kg-bw day)		Maximum Case Scenario HQs Based on Comparison of Doses to NOAELs	Maximum Case Scenario HQs Based on Comparison of Doses to LOAELs
	NOAEL	LOAEL	Piscivorous Birds	Piscivorous Birds
Metals				
Aluminum	1.10E+02	NA	1.20E-01	--
Barium	2.08E+01	4.17E+01	9.97E-02	4.97E-02
Cadmium	1.45E+00	2.00E+01	9.31E-04	6.75E-05
Chromium	2.66E+00	5.00E+00	9.75E-02	5.19E-02
Copper	4.05E+00	6.17E+01	6.21E-01	4.08E-02
Lead	1.63E+00	1.13E+01	8.88E-01	1.28E-01
Nickel	7.74E+01	1.07E+02	2.67E-03	1.93E-03
Vanadium	3.44E-01	6.88E-01	5.55E-02	2.78E-02
Zinc	6.61E+01	1.31E+02	7.90E-03	3.98E-03
PAHs				
Total LMW PAHs	3.37E+00	3.37E+01	1.21E-03	1.21E-04
Total HMW PAHs	3.37E+00	3.37E+01	1.01E-03	1.01E-04

NOTES:
TRV: Toxicity Reference Value
NA: Screening Value not available
mg/kg-bw day: milligram of food per kilogram of body weight per day
NOAEL: No Observed Adverse Effect Levels
LOAEL: Low Observed Adverse Effect Levels
LMW PAH: Low molecular weight polynuclear aromatic hydrocarbon
HMW PAH: High molecular weight polynuclear aromatic hydrocarbon

Table 15
95% UCL Mean Modeled Doses to Birds Compared to Avian Toxicity Reference Values for AOC-5

Chemical	Avian TRVs (mg/kg-bw day)		95% UCL Mean Case Scenario HQs Based on Comparison of Doses to NOAELs	95% UCL Mean Case Scenario HQs Based on Comparison of Doses to LOAELs
	NOAEL	LOAEL	Piscivorous Birds	Piscivorous Birds
Metals				
Aluminum	1.10E+02	NA	1.06E-01	--
Barium	2.08E+01	4.17E+01	9.97E-02	4.97E-02
Cadmium	1.45E+00	2.00E+01	4.87E-04	3.53E-05
Chromium	2.66E+00	5.00E+00	9.75E-02	5.19E-02
Copper	4.05E+00	6.17E+01	4.08E-01	2.68E-02
Lead	1.63E+00	1.13E+01	7.51E-01	1.08E-01
Nickel	7.74E+01	1.07E+02	1.51E-03	1.09E-03
Vanadium	3.44E-01	6.88E-01	4.65E-02	2.32E-02
Zinc	6.61E+01	1.31E+02	6.01E-03	3.03E-03
PAHs				
Total LMW PAHs	3.37E+00	3.37E+01	1.18E-03	1.18E-04
Total HMW PAHs	3.37E+00	3.37E+01	6.29E-04	6.29E-05

NOTES:
TRV: Toxicity Reference Value
NA: Screening Value not available
mg/kg-bw day: milligram of food per kilogram of body weight per day
UCL: Upper confidence level
HQ: Hazard Quotient
NOAEL: No Observed Adverse Effect Levels
LOAEL: Low Observed Adverse Effect Levels
LMW PAH: Low molecular weight polynuclear aromatic hydrocarbon
HMW PAH: High molecular weight polynuclear aromatic hydrocarbon

Table 16
Maximum Modeled Doses to Mammals Compared to Mammalian Toxicity Reference Values for AOC-5

Chemical	Mammalian TRVs (mg/kg-bw day)		Maximum Case Scenario HQs Based on Comparison of Doses to NOAELs	Maximum Case Scenario HQs Based on Comparison of Doses to LOAELs
	NOAEL	LOAEL	Piscivorous Mammals	Piscivorous Mammals
Metals				
Aluminum	1.93E+00	1.93E+01	**2.43E+01**	**2.43E+00**
Barium	5.18E+01	4.36E+02	1.42E-01	1.69E-02
Beryllium	5.32E-01	NA	3.97E-03	--
Cadmium	7.70E-01	1.00E+01	6.23E-03	4.80E-04
Chromium	2.40E+00	1.31E+01	3.84E-01	7.01E-02
Copper	5.60E+00	1.54E+01	**1.59E+00**	5.80E-01
Lead	4.70E+00	8.00E+01	**1.09E+00**	6.43E-02
Nickel	1.70E+00	8.00E+01	4.33E-01	9.20E-03
Vanadium	4.16E+00	8.31E+00	1.63E-02	8.16E-03
Zinc	7.54E+01	3.20E+02	2.41E-02	5.69E-03
PAHs				
Total LMW PAHs	6.56E+01	4.34E+02	2.22E-04	3.35E-05
Total HMW PAHs	6.15E-01	3.07E+00	1.97E-02	3.95E-03

NOTES:
TRV: Toxicity Reference Value
mg/kg-bw day: milligram of food per kilogram of body weight per day
NOAEL: No Observed Adverse Effect Levels
LOAEL: Low Observed Adverse Effect Levels
LMW PAH: Low molecular weight polynuclear aromatic hydrocarbon
HMW PAH: High molecular weight polynuclear aromatic hydrocarbon

Table 17
95% UCL Mean Modeled Doses to Mammals Compared to Mammalian Toxicity Reference Values for AOC-5

Chemical	Mammalian TRVs (mg/kg-bw day)		95% UCL Mean Case Scenario HQs Based on Comparison of Doses to NOAELs	95% UCL Mean Case Scenario HQs Based on Comparison of Doses to LOAELs
	NOAEL	LOAEL	Piscivorous Mammals	Piscivorous Mammals
Metals				
Aluminum	1.93E+00	1.93E+01	**2.14E+01**	**2.14E+00**
Barium	5.18E+01	4.36E+02	1.42E-01	1.69E-02
Beryllium	5.32E-01	NA	3.97E-03	--
Cadmium	7.70E-01	1.00E+01	3.26E-03	2.51E-04
Chromium	2.40E+00	1.31E+01	3.84E-01	7.01E-02
Copper	5.60E+00	1.54E+01	**1.05E+00**	3.81E-01
Lead	4.70E+00	8.00E+01	9.25E-01	5.44E-02
Nickel	1.70E+00	8.00E+01	2.45E-01	5.20E-03
Vanadium	4.16E+00	8.31E+00	1.36E-02	6.83E-03
Zinc	7.54E+01	3.20E+02	1.83E-02	4.30E-03
PAHs				
Total LMW PAHs	6.56E+01	4.34E+02	2.16E-04	3.27E-05
Total HMW PAHs	6.15E-01	3.07E+00	1.23E-02	2.46E-03

NOTES:
TRV: Toxicity Reference Value
mg/kg-bw day: milligram of food per kilogram of body weight per day
UCL: Upper confidence level
HQ: Hazard Quotient
NOAEL: No Observed Adverse Effect Levels
LOAEL: Low Observed Adverse Effect Levels
LMW PAH: Low molecular weight polynuclear aromatic hydrocarbon
HMW PAH: High molecular weight polynuclear aromatic hydrocarbon

APPENDIX A

Food Web Calculations

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Table A-1
Wildlife Exposure Modeling of Maximum Doses to Piscivorous Birds (Great Blue Heron) from Media for AOC-5

Exposure Parameters

Soil Ingestion Rate (kg dry wt./kg bw-day):	9.00E-04
Food Ingestion Rate (kg dry wt./kg bw-day):	4.50E-02
Water Ingestion Rate (L/kg bw-day):	4.50E-02

Chemical	Maximum Sediment Concentration (mg/kg dry wt.)	Maximum Water Concentration (mg/L)	Food Item (Fish) Uptake		Maximum Case Scenario Doses			
			BAF/Equation (mg/L dry wt. to mg/kg dry wt.)	Maximum Food Item Tissue Concentration (mg/kg dry wt.)	Dose from Sediment (mg/kg bw-day)	Dose from Food (mg/kg bw-day)	Dose from Water (mg/kg bw-day)	Total Dose (mg/kg bw-day)
Metals								
Aluminum	1.45E+04	7.88E-01	2.70E+00	2.13E+00	1.31E+01	9.57E-02	3.55E-02	1.32E+01
Barium	2.29E+03	5.36E-02	4.00E+00	2.14E-01	2.06E+00	9.65E-03	2.41E-03	2.07E+00
Beryllium	6.60E-01	--	6.20E+01	0.00E+00	5.94E-04	0.00E+00	0.00E+00	5.94E-04
Cadmium	1.50E+00	--	5.90E+01	0.00E+00	1.35E-03	0.00E+00	0.00E+00	1.35E-03
Chromium	2.70E+02	1.80E-03	2.00E+02	3.60E-01	2.43E-01	1.62E-02	8.10E-05	2.59E-01
Copper	1.90E+02	1.12E-01	4.64E+02	5.20E+01	1.71E-01	2.34E+00	5.04E-03	2.51E+00
Lead	1.58E+03	1.19E-02	4.50E+01	5.36E-01	1.42E+00	2.41E-02	5.36E-04	1.45E+00
Nickel	2.30E+02	--	2.70E+01	0.00E+00	2.07E-01	0.00E+00	0.00E+00	2.07E-01
Selenium	NO COPC	9.13E-02	2.42E+02	2.21E+01	0.00E+00	9.94E-01	4.11E-03	9.98E-01
Thallium	NO COPC	NO COPC	1.00E+03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Vanadium	2.11E+01	1.30E-03	1.00E+00	1.30E-03	1.90E-02	5.85E-05	5.85E-05	1.91E-02
Zinc	2.60E+02	4.57E-01	1.30E+01	5.94E+00	2.34E-01	2.67E-01	2.06E-02	5.22E-01
PAHs								
Total LMW PAHs	1.02E+00	--	--	0.00E+00	2.52E-03	1.57E-03	2.93E-06	4.09E-03
Total HMW PAHs	7.27E+00	--	--	0.00E+00	3.41E-03	0.00E+00	0.00E+00	3.41E-03

NOTES:
mg/kg bw-day: milligram of food per kilogram of body weight per day
kg: kilogram
L/kg bw-day: liters per kilogram of body weight per day
mg/kg dry wt.: milligram per kilogram of dry weight
mg/L: milligram per liter
HMW PAH: High molecular weight polynuclear aromatic hydrocarbon
LMW PAH: Low molecular weight polynuclear aromatic hydrocarbon

Table A-2
Wildlife Exposure Modeling of 95% UCL Mean Doses to Piscivorous Birds (Great Blue Heron) from Media for AOC-5

Exposure Parameters

Soil Ingestion Rate (kg dry wt./kg bw-day):	9.00E-04	kg/kg-day
Food Ingestion Rate (kg dry wt./kg bw-day):	4.50E-02	kg/kg-day
Water Ingestion Rate (L/kg bw-day):	4.50E-02	L/kg-day

Chemical	95% UCL Mean Sediment Concentration (mg/kg dry wt.)	95% UCL Mean Water Concentration (mg/L)	Food Item (Fish) Uptake		95% UCL Mean Case Scenario Doses			
			BAF/Equation (mg/L dry wt. to mg/kg dry wt.)	95% UCL Mean Food Item Tissue Concentration (mg/kg dry wt.)	Dose from Sediment (mg/kg bw-day)	Dose from Food (mg/kg bw-day)	Dose from Water (mg/kg bw-day)	Total Dose (mg/kg bw-day)
Metals								
Aluminum	1.28E+04	6.42E-01	2.70E+00	1.73E+00	1.15E+01	7.80E-02	2.89E-02	1.16E+01
Barium	2.29E+03	5.36E-02	4.00E+00	2.14E-01	2.06E+00	9.65E-03	2.41E-03	2.07E+00
Beryllium	6.60E-01	--	6.20E+01	0.00E+00	5.94E-04	0.00E+00	0.00E+00	5.94E-04
Cadmium	7.84E-01	--	5.90E+01	0.00E+00	7.06E-04	0.00E+00	0.00E+00	7.06E-04
Chromium	2.70E+02	1.80E-03	2.00E+02	3.60E-01	2.43E-01	1.62E-02	8.10E-05	2.59E-01
Copper	8.17E+01	7.54E-02	4.64E+02	3.50E+01	7.35E-02	1.57E+00	3.39E-03	1.65E+00
Lead	1.33E+03	1.19E-02	4.50E+01	5.36E-01	1.20E+00	2.41E-02	5.36E-04	1.22E+00
Nickel	1.30E+02	--	2.70E+01	0.00E+00	1.17E-01	0.00E+00	0.00E+00	1.17E-01
Selenium	NO COPC	8.40E-02	2.42E+02	2.03E+01	0.00E+00	9.14E-01	3.78E-03	9.18E-01
Thallium	NO COPC	NO COPC	1.00E+03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Vanadium	1.76E+01	1.30E-03	1.00E+00	1.30E-03	1.59E-02	5.85E-05	5.85E-05	1.60E-02
Zinc	1.22E+02	4.57E-01	1.30E+01	5.94E+00	1.09E-01	2.67E-01	2.06E-02	3.97E-01
PAHs								
Total LMW PAHs	1.02E+00	--	--	0.00E+00	2.42E-03	1.57E-03	2.93E-06	3.99E-03
Total HMW PAHs	3.34E+00	--	--	0.00E+00	2.12E-03	0.00E+00	0.00E+00	2.12E-03

NOTES:
mg/kg bw-day: milligram of food per kilogram of body weight per day
kg: kilogram
L/kg bw-day: liters per kilogram of body weight per day
mg/kg dry wt.: milligram per kilogram of dry weight
mg/L: milligram per liter
HMW PAH: High molecular weight polynuclear aromatic hydrocarbon
LMW PAH: Low molecular weight polynuclear aromatic hydrocarbon
UCL: Upper confidence level

Table A-3
Wildlife Exposure Modeling of Maximum Doses to Piscivorous Mammals (River Otter) from Media for AOC-5

Exposure Parameters

Soil Ingestion Rate (kg dry wt./kg bw-day):	3.20E-03
Food Ingestion Rate (kg dry wt./kg bw-day):	1.60E-01
Water Ingestion Rate (L/kg bw-day):	8.10E-02

Chemical	Maximum Sediment Concentration (mg/kg dry wt.)	Maximum Water Concentration (mg/L)	Food Item (Fish) Uptake		Maximum Case Scenario Doses			
			BAF/Equation (mg/L dry wt. to mg/kg dry wt.)	Maximum Food Item Tissue Concentration (mg/kg dry wt.)	Dose from Sediment (mg/kg bw-day)	Dose from Food (mg/kg bw-day)	Dose from Water (mg/kg bw-day)	Total Dose (mg/kg bw-day)
Metals								
Aluminum	1.45E+04	7.88E-01	2.70E+00	2.13E+00	4.64E+01	3.40E-01	6.38E-02	4.68E+01
Barium	2.29E+03	5.36E-02	4.00E+00	2.14E-01	7.33E+00	3.43E-02	4.34E-03	7.37E+00
Beryllium	6.60E-01	--	6.20E+01	0.00E+00	2.11E-03	0.00E+00	0.00E+00	2.11E-03
Cadmium	1.50E+00	--	5.90E+01	0.00E+00	4.80E-03	0.00E+00	0.00E+00	4.80E-03
Chromium	2.70E+02	1.80E-03	2.00E+02	3.60E-01	8.64E-01	5.76E-02	1.46E-04	9.22E-01
Copper	1.90E+02	1.12E-01	4.64E+02	5.20E+01	6.08E-01	8.31E+00	9.07E-03	8.93E+00
Lead	1.58E+03	1.19E-02	4.50E+01	5.36E-01	5.06E+00	8.57E-02	9.64E-04	5.14E+00
Nickel	2.30E+02	--	2.70E+01	0.00E+00	7.36E-01	0.00E+00	0.00E+00	7.36E-01
Selenium	NO COPC	9.13E-02	2.42E+02	2.21E+01	0.00E+00	3.54E+00	7.40E-03	3.54E+00
Thallium	NO COPC	NO COPC	1.00E+03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Vanadium	2.11E+01	1.30E-03	1.00E+00	1.30E-03	6.75E-02	2.08E-04	1.05E-04	6.78E-02
Zinc	2.60E+02	4.57E-01	1.30E+01	5.94E+00	8.32E-01	9.51E-01	3.70E-02	1.82E+00
PAHs								
Total LMW PAHs	1.02E+00	--	--	3.49E-02	8.96E-03	5.59E-03	5.27E-06	1.45E-02
Total HMW PAHs	7.27E+00	--	--	0.00E+00	1.21E-02	0.00E+00	0.00E+00	1.21E-02

NOTES:
mg/kg bw-day: milligram of food per kilogram of body weight per day
kg: kilogram
L/kg bw-day: liters per kilogram of body weight per day
mg/kg dry wt.: milligram per kilogram of dry weight
mg/L: milligram per liter
HMW PAH: High molecular weight polynuclear aromatic hydrocarbon
LMW PAH: Low molecular weight polynuclear aromatic hydrocarbon

Table A-4
Wildlife Exposure Modeling of 95% UCL Mean Doses to Piscivorous Mammals (River Otter) from Media for AOC-5

Exposure Parameters

Soil Ingestion Rate (kg dry wt./kg bw-day):	3.20E-03
Food Ingestion Rate (kg dry wt./kg bw-day):	1.60E-01
Water Ingestion Rate (L/kg bw-day):	8.10E-02

Chemical	95% UCL Mean Sediment Concentration (mg/kg dry wt.)	95% UCL Mean Water Concentration (mg/L)	Food Item (Fish) Uptake		95% UCL Mean Case Scenario Doses			
			BAF/Equation (mg/L dry wt. to mg/kg dry wt.)	95% UCL Mean Food Item Tissue Concentration (mg/kg dry wt.)	Dose from Sediment (mg/kg bw-day)	Dose from Food (mg/kg bw-day)	Dose from Water (mg/kg bw-day)	Total Dose (mg/kg bw-day)
Metals								
Aluminum	1.28E+04	6.42E-01	2.70E+00	1.73E+00	4.10E+01	2.77E-01	5.20E-02	4.14E+01
Barium	2.29E+03	5.36E-02	4.00E+00	2.14E-01	7.33E+00	3.43E-02	4.34E-03	7.37E+00
Beryllium	6.60E-01	--	6.20E+01	0.00E+00	2.11E-03	0.00E+00	0.00E+00	2.11E-03
Cadmium	7.84E-01	--	5.90E+01	0.00E+00	2.51E-03	0.00E+00	0.00E+00	2.51E-03
Chromium	2.70E+02	1.80E-03	2.00E+02	3.60E-01	8.64E-01	5.76E-02	1.46E-04	9.22E-01
Copper	8.17E+01	7.54E-02	4.64E+02	3.50E+01	2.62E-01	5.60E+00	6.11E-03	5.87E+00
Lead	1.33E+03	1.19E-02	4.50E+01	5.36E-01	4.26E+00	8.57E-02	9.64E-04	4.35E+00
Nickel	1.30E+02	--	2.70E+01	0.00E+00	4.16E-01	0.00E+00	0.00E+00	4.16E-01
Selenium	NO COPC	8.40E-02	2.42E+02	2.03E+01	0.00E+00	3.25E+00	6.80E-03	3.26E+00
Thallium	NO COPC	NO COPC	1.00E+03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Vanadium	1.76E+01	1.30E-03	1.00E+00	1.30E-03	5.64E-02	2.08E-04	1.05E-04	5.68E-02
Zinc	1.22E+02	4.57E-01	1.30E+01	5.94E+00	3.89E-01	9.51E-01	3.70E-02	1.38E+00
PAHs								
Total LMW PAHs	1.02E+00	--	--	3.49E-02	8.60E-03	5.59E-03	5.27E-06	1.42E-02
Total HMW PAHs	3.34E+00	--	--	0.00E+00	7.54E-03	0.00E+00	0.00E+00	7.54E-03

NOTES:
mg/kg bw-day: milligram of food per kilogram of body weight per day
kg: kilogram
L/kg bw-day: liters per kilogram of body weight per day
mg/kg dry wt.: milligram per kilogram of dry weight
mg/L: milligram per liter
HMW PAH: High molecular weight polynuclear aromatic hydrocarbon
LMW PAH: Low molecular weight polynuclear aromatic hydrocarbon
UCL: Upper confidence level