Screening Level Ecological Risk Assessment for Area of Concern 4 (AOC-4)

Remedial Investigation/Feasibility Study

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LIST OF ACRONYMS AND ABBREVIATIONS

AOC	Area of Concern
AST	Above ground storage tank
BAF	Bioaccumulation Factor
BCF	Bioconcentration Factors
BRAPF	Baseline Risk Assessment Problem Formulation
BW	Body weight
CHPPM	U.S. Army Center for Health Promotion and Preventative Medicine
COPEC	Chemicals of Potential Ecological Concern
CSM	Conceptual Site Model
d	Day
EA	EA Engineering, Science, and Technology, Inc.
Eco-SSL	Ecological Soil Screening Level
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
kg	Kilogram
Lazarus	Lazarus Texas Refining I, LLC
LMW	Low molecular weight
LOAEL	Low Observed Adverse Effect Levels
mg/kg	Milligrams per kilogram
mg/L	Milligrams per liter
ND	Non-detect
NOAEL	No Observed Adverse Effect Levels
NORCO	National Oil Recovery Corporation

LIST OF ACRONYMS AND ABBREVIATIONS (CONTINUED)

ORNL	Oak Ridge National Laboratory
PAH	Polynuclear aromatic hydrocarbon
PRG	Preliminary Remediation Goal
PRP	Potentially Responsible Party
RI	Remedial Investigation
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
TPWD	Texas Parks and Wildlife Division
TRV	Toxicity reference value
UCLM	Upper confidence level of the mean
UF	Uptake factor
UPL	Upper prediction limit
USFWS	U.S. Fish and Wildlife Service
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 (ICW; aka AOC-5) separate from the remaining Site. This document provides the results of the SLERA for AOC-4. The SLERA for AOC-5 is completed as a second document.

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. The refinery is currently inactive and has not produced hydrocarbon products in several years 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 (AOC-4) is located on Redfish Bay (AOC-5) 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 which are part 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 1.6 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 ICW 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

Initial field sampling was conducted in 2007 in accordance with an EPA approved RI/FS Field Sampling Plan and Quality Assurance 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. EA conducted Phase II investigation activities in accordance with the Final Field Sampling Plan (EA 2013) and Quality Assurance Project Plan (EA 2012) under this Task Order in 2013. The data table for AOC-4 is presented in Appendix A.

1.3 AOC-4 BACKGROUND AND DESCRIPTION

AOC-4 is the current barge docking facility which occupies approximately 1.6 acres adjacent to the ICW. The fenced facility is connected to the refinery by pipelines and is used to load and unload barges. It was reported that only crude oil passed through the docking facility. However, refined products historically were loaded and unloaded at this docking facility. There have been no reported releases associated with this AOC. However, analytical results indicate that a release or releases have occurred. Although there is no indication from the boring cores that fill material is present at the Site, historical aerial photos show that the area generally consisted of wetlands in the 1950s. It is likely that the elevation of the Site was raised with fill material for its industrial purpose and also because of the potential for flooding and hurricanes in the area.

2. ECOLOGICAL RISK ASSESSMENT

This section presents the SLERA conducted by EA for AOC-4 at the Site. The purpose of this assessment is to characterize and quantify potential environmental impacts from residual chemicals in soil at AOC-4 from Site activities. The assessment was conducted in accordance with EPA guidance for the RI/FS process; specifically the ecological risk assessment (ERA) was conducted in accordance with the process for 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 AOC-4. 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-4 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.

2.1 SUMMARY OF DATA USED IN THE SLERA

Initial field sampling was conducted in 2007 in accordance with an EPA approved RI/FS Field Sampling Plan and Quality Assurance 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 2013 that were used in this risk assessment.

A total of six surface soil samples were collected from AOC-4 in 2013 as shown in Figure 4. For the purposes of the ERA, surface soil is defined as the top 0 to 6 inches below ground surface. This is considered the zone of greatest potential exposure for ecological receptors. The soil was analyzed for target analyte list (TAL) metals, polynuclear aromatic hydrocarbons (PAHs), semivolatile organic compounds (SVOCs), and volatile organic compounds (VOCs).

Investigation of soil for the Site included collection and analysis of samples from 10 locations representative of background conditions. These locations were selected to be beyond the suspected influence of the Falcon Refinery Site. Background data are evaluated in the BRAPF to aid in risk management decisions. Details regarding background sampling can be found in the Field Sampling Plan for the investigation effort (EA 2013).

2.1.1 Data Reduction and Summary Statistics

This section describes the approach that was followed to evaluate the available analytical data in the medium of concern (surface soil). 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 treated as a ND. 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 non-detect concentration if both parent and duplicate were non-detects, and the detected value if either parent or duplicate were detected, and the other non-detected 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.

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 2.5.

2.2 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.

2.2.1 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 reported spills or releases, and there are no visible indications of environmental impacts at the barge dock facility.

2.2.2 Vegetation and Physical Habitat

The barge dock facility (AOC-4) consists of approximately 1.6 acres. The barge dock facility is fenced, contains several small structures, and is comprised primarily of compacted silty sand and gravel. AOC-4 borders AOC-5 (evaluated separately) which includes the ICW; other than the ICW, no additional sensitive environmental areas exist within 500 feet of AOC-4.

Based on aerial photographs and direct observation during site visits, AOC-4 is mostly barren of vegetation with scattered patches of herbaceous vegetation interspersed among the roads and storage areas. Plant species consist primarily of disturbance-tolerant grasses and forbs. As such, AOC4 is expected to provide relatively poor, isolated habitat for wildlife.

Site visits have identified that soils at the Site are disturbed and compacted due to vehicle traffic and storage. Soil survey data (CSRL 2014) indicates that local soils consist of former dredged material, with some areas consisting of moderately alkaline massive clays while other areas consist of moderately alkaline fine sands. Based on this information and the soil boring at location MW-17, AOC-4 consists of moderately alkaline compacted silty sand and gravel. This substrate's compacted structure presents physical and nutritional challenges to colonization and establishment of plant and soil invertebrate communities. Given the proximity of the ICW and potential for flooding during hurricanes, salinity may play a natural role in limiting plant growth and diversity. Thus AOC-4 is likely to provide relatively poor habitat for plants and invertebrates.

Restoration of the Site to higher quality habitat faces challenges unrelated to chemical concentrations in soil. Although there are no restrictions or institutional control documenting that the property will remain industrial for future use, the Deed No. 615663 has a section called "Assumption of Obligations" and states that the "Falcon Refinery" has been designated by the EPA as a Superfund Site, and is subject to remediation and clean-up in connection with two (2) Administrative Orders On Consent. Existing soil is compacted and disturbed; should restoration occur at the Site, it would require major physical changes to the substrate such as mixing, addition of organic matter, or re-grading.

2.2.3 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 Service (USFWS 2014a) and the Texas Parks and Wildlife Division (TPWD 2014a) program databases were searched for species that may utilize AOC-4 and the adjacent wetlands

and waterways. Two endangered and five federally and/or state listed threatened species may exist near the project area but would primarily utilize the aquatic habitat of AOC-5:

Endangered Species

Whooping crane (*Grus americana*)—*Federally Endangered, State Endangered*
Whooping cranes migrate through the area and are not residential. They typically feed in shallow water on fish, crustaceans, and other small marine animals, although they occasionally forage in fields (USFWS 2014b). Whooping cranes are not expected to utilize AOC-4, as none of these habitats are present.

Eskimo curlew (*Numenius borealis*)—*Federally Endangered, State Endangered*
Eskimo curlew migrate from the Arctic tundra to South America and only temporality utilize grassland habitat in Texas (TPWD 2014b). Since AOC-4 has no grassland habitat, it is not expected that the Eskimo curlew will utilize the Site.

Threatened Species

Piping plover (*Charadrius melodus*)—*Federally Threatened, State Threatened*
Piping plovers are commonly found along sandy shorelines where they utilize the habitat for nesting and forage on small marine organisms (TPWD 2014c). They are not expected to use AOC-4 due to lack of suitable habitat.

Sooty tern (*Sterna fuscata*)—*State Threatened*
The Sooty tern is a rare shorebird not commonly found along the east coast of Texas (TPWD 2014d). Due to their rarity and requirements for shore habitats and foraging grounds, Sooty terns are not expected to be found at AOC-4.

Reddish egret (*Egretta rufescens*)—*State Threatened*
Reddish egrets are shorebirds that nest on the ground near bushes or on oyster shell beaches and they forage in brackish, marine, or freshwater habitats (TPWD 2014e). Reddish egrets are not expected to utilize AOC-4.

Wood stork (*Myctena americana*)—*State Threatened*
Wood stork is a highly migratory species that utilizes shore habitat for foraging (TPWD 2014d). There have been no recent listings of wood stork in San Patricio County, and are therefore not expected to be present at AOC-4.

White-face ibis (*Plegadis chihi*)—*State Threatened*
White-face ibis overwinters in warm climates and some are also permanent residents of the Texas east coast. They are most common in marshes, swamps, and riverine habitats with emergent vegetation (TPWD 2014 f). Since AOC-4 does not contain any suitable habitat, White-face ibis are not expected to utilize AOC-4.

Although it is not likely for any of these listed species to utilize AOC-4 due to the lack of habitat and adequate prey species, a more extensive analysis and biological survey would be needed to determine whether or not additional state listed species utilize the Site.

2.2.4 Potential Source Areas

The primary source area is the barge docking facility. 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. There have been no reported releases associated with this AOC, however, analytical results indicated that a release or releases have occurred in the past. Based on the Site history, TAL metals, PAHs, SVOCs, and VOCs were analyzed in the soils at AOC-4.

2.2.5 Fate, Transport, and Media of Concern

A number of fate and transport pathways are expected to influence the transfer of COPECs between environmental media in the Site. Chemicals in surface soil at AOC-4 may have been transferred vertically to subsurface soil by leaching beyond the zone of exposure for ecological receptors, or horizontally to soil further from the source. Given the tendency for some of the COPECs at the Site (metals and PAHs) to bind to soil, horizontal transport is expected to be limited. The Site also consists of heavily compacted soils and has minimal changes in elevation.

The Site is at risk of flooding from hurricanes. Given the highly compact nature of the soil and the sea wall bordering Redfish Bay, it is unlikely that substantive amounts of COPECs in soil would migrate via storm runoff to the ICW during large storm events. The marine site AOC-5 is being evaluated separately.

It is important to note that transport pathways 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. Metals such as barium, copper, chromium, lead, nickel, vanadium, zinc, and others are more soluble in acidic or highly alkaline environments, and less soluble in circum-neutral or moderately alkaline environments. Soil surveys for the area around AOC-4 (CSRL 2014) indicate that soils tend to be moderately alkaline; therefore, many metals are expected to be less mobile and less bioavailable.

2.2.6 Identification of Media of Concern & Potential Receptors of Concern

Based on the above discussion of potential habitats, sources, and fate and transport, surface soil was considered the primary medium of concern (Figure 5). Potential receptors evaluated at AOC-4 in the SLERA for the Site include plants, soil invertebrates, amphibians and reptiles, birds, and small mammals. Potential ecological receptors are shown in the CSM (Figure 5).

Identification of Exposure Pathways

Based on the ecological setting and media of concern discussed above, ecological receptors potentially present in AOC-4 include plants, terrestrial invertebrates, wildlife (birds and mammals), and reptiles and amphibians (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.

Terrestrial Plants and Invertebrates

Terrestrial plants and invertebrates may be exposed to environmental media through direct contact. Plants may absorb chemicals from surface and subsurface soil via their roots. They may also absorb chemicals from air or airborne particles through their leaves, although the waxy surfaces of leaves limit this exposure. Terrestrial invertebrates may be exposed to chemicals in soil through direct contact and chemicals may be absorbed from soil through the skin. Because the most organic matter is found in the top 0 to 6 inches, plant and invertebrate exposures are expected to occur primarily in surface soil. Therefore, exposure pathways linking plants and soil invertebrates to surface soil are complete and therefore relevant for assessment.

Wildlife (Birds, and Mammals)

The most significant exposure route for wildlife is ingestion of chemicals in contaminated media (EPA 2003a). Wildlife may ingest chemicals in environmental media by incidentally ingesting soil 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-4.

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 surface soil and food at AOC-4 are considered complete and significant exposure pathways for assessment in this SLERA.

Selection of Representative Receptors

Ecological receptors that could possibly utilize the Site include plants, terrestrial invertebrates, and wildlife (reptiles, amphibians, 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 plants, soil invertebrates, and wildlife at AOC-4. The receptors of concern (and representative receptor species) included in this SLERA are:

- Terrestrial plants (multiple species)
- Soil invertebrates (earthworm)
- Insectivorous birds (American robin)
- Insectivorous mammals (northern short-tailed shrew)
- Amphibians and reptiles (multiple species).

Terrestrial Plants

Based on the general nature of available plant toxicity data, no specific plant species are selected for evaluation. Instead, the assessment evaluates the potential for adverse effects to herbaceous plant populations.

Terrestrial Invertebrates

Earthworms were selected as the receptor species for evaluating the potential for adverse effects to soil invertebrates for several reasons. Earthworms have direct contact with soil and are sensitive to chemicals in soil, relative to other soil invertebrates. Furthermore, earthworms serve an important ecological role in the aeration of soils and cycling of nutrients and are an important food source for some soil invertebrate-eating species (e.g., robins and shrews). Lastly, toxicity data for earthworms are available in scientific literature.

Wildlife

AOC-4 is an industrialized 0.5 acre site that is not expected to support a large diversity of terrestrial wildlife species. With the lack of suitable habitat and the presence of physical barriers for large predators, only smaller insectivorous species of birds and mammals were identified as potentially affected species.

While the risk assessments make conclusions concerning the potential for adverse effects to individual organisms, the objective is to be protective of the populations that may use AOC-4. However, few methods are available to extrapolate the potential for adverse effects from the

individual level to the population level. Therefore, it was 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 was assumed that if there is the potential for adverse effects to individual organisms, then there is also the potential for adverse effects to populations. The following sections provide a summary of the avian and mammalian representative receptor species identified for evaluation.

Invertebrate-Eating Wildlife

The American robin (*Turdus migratorius*) was selected as the invertebrate-eating avian species for evaluation, because a significant portion of its diet is comprised of earthworms and consequently, this species would have a higher rate of incidental ingestion of surface soil than an insect-eating bird species. The American robin also has an average home range of 1 to 2 acres (Young 1951, Pitts 1984).

The short-tailed shrew (*Blarina brevicauda*) was selected as the invertebrate-eating mammal species for evaluation because it feeds largely on soil invertebrates. Thus, it not only would be potentially exposed through prey items, but also would have a relatively high rate of incidental ingestion of soil while foraging. Furthermore, it has a small home range (0.07-4.4 acres) (EPA 1993) and thus could conceivably consume all of its diet from on-site.

In addition to the ingestion of chemicals in food items, the inadvertent ingestion of chemicals in surface soil was considered for the above species.

Amphibians and Reptiles

The assessment of risks to amphibians and reptiles is limited by the lack of sufficient literature-based exposure and toxicity information. Also, there are currently no assessment methods for evaluating these receptors. The habitat at AOC-4 will most likely not support amphibian and reptile populations. Because potential risks to these receptors cannot be quantitatively dismissed, the amphibian and reptile receptor endpoints will be carried forward through the SLERA.

2.3 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.

2.3.1 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-4 (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.

2.3.2 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 surface soil to ensure that COPECs in surface soil 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. ***Chemistry for Surface Soil***—The measurement of maximum COPEC concentrations in surface soil 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 soil.

2.3.3 Identification of Chemicals of Potential Ecological Concern

COPECs are selected by comparison of maximum concentrations found in surface soil 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 Ecological Soil Screening Levels (Eco-SSLs), or EPA Region 4 screening values for soil which are found at the following links:

- Surface Soil—the lowest value obtained from the Eco-SSLs of available receptors from:

    1. EPA Eco-SSLs accessed at http://www.epa.gov/ecotox/ecossl

    2. Region 4 Ecological Screening Values, accessed at http://www.epa.gov/region4/superfund/programs/riskassess/ecolbul.html, or

    3. TCEQ—Table 3.4, accessed at http://www.tceq.texas.gov/assets/public/remediation/trrp/rg263-draft.pdf

The criteria are presented in Table 3. Potential ecological risks associated with aluminum and iron in surface soils are identified based on pH. Aluminum and iron in surface soil can be identified as COPECs only at sites where the soil pH is less than 5.0 (EPA 2003a). The pH values for soils were not available for AOC-4, however soil pH is typically higher than 5.0, and considering the findings of CSRL (2014) that soils are moderately alkaline (pH > 7), neither metal was identified as a COPEC in surface soil samples during the initial screening.

2.4 SLERA RESULTS

Maximum exposure estimates were compared to media-specific screening levels and are shown 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, only 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 COPECs 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 are not included in the list of COPECs. Essential nutrients include calcium, magnesium, sodium, and potassium.

The following chemicals exceed the surface soil screening value and were identified as COPECs. The Exposure Point Concentrations (EPCs) for these COPECs are shown in Table 4.

- Barium
- Cadmium
- Chromium
- Copper
- Lead
- Manganese
- Mercury
- Vanadium
- Zinc
- Total high molecular weight (HMW) PAHs.

The following SVOCs and VOCs were retained as COPECs due to lack of soil screening values. Risks from these detected chemicals cannot be determined and are typically discussed in the uncertainty evaluation of the ERA.

- Acetophenone
- Benzaldehyde
- Bis(2-ethylhexyl)phthalate
- Carbazole
- 2-Butanone
- Isopropylbenzene
- Trichlorofluoromethane
- Xylenes (m & p)
- Xylenes (o).

2.4.1 SLERA Conclusions

The SLERA identified COPECs in soil at AOC-4 that require further evaluation (Table 5). 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) includes a refinement of risk estimates using more site-specific assumptions and information for AOC-4.

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.

2.5 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 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.

2.5.1 Refined Assessment and Measurement Endpoints

The following refined assessment endpoints were defined (Table 2) to reflect the potential impacts of the complete and significant exposure pathways at AOC-4 discussed above:

- Protection of terrestrial plant communities to ensure that COPEC in surface soils do not have unacceptable adverse effects on survival, growth, and reproduction of key plant species, which may result in adverse effects to the community structure.

- Protection of invertebrate communities to ensure that COPEC in surface soils do not have unacceptable adverse effects on survival, growth, and reproduction of key invertebrate species, which may result in adverse effects to the community structure, i.e., diversity or biomass.

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

- Protection of reptiles and amphibians to ensure that COPEC in soils do not have unacceptable adverse effects on survival, growth, and reproduction of key 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 Terrestrial Plant Communities*—**The measurement of maximum COPEC concentrations in surface soil and the calculation of 95 percent UCLM COPEC concentrations in surface soil provide the means, when compared to relevant receptor-specific benchmarks, for drawing inferences regarding the first assessment endpoint above.

2. ***Protection of Invertebrate Communities*—**The measurement of maximum COPEC concentrations in soil and the calculation of 95 percent UCLM COPEC concentrations in soil provide the means, when compared to relevant receptor-specific benchmarks, for drawing inferences regarding the second assessment endpoint above.

3. ***Protection of Terrestrial Wildlife*—**The measurement of maximum COPEC concentrations in soil and the calculation of 95 percent UCLM COPEC concentrations in soil provide the means to model wildlife doses, which can be compared to relevant receptor-specific benchmarks, to draw inferences regarding the fifth assessment endpoint above.

4. ***Protection of Reptiles and Amphibians*—**The assessment of risks to amphibians and reptiles is limited by the lack of sufficient literature-based exposure and toxicity information. Also, there are currently no assessment methods for evaluating these receptors.

Plants and Invertebrates

The measurement endpoints for plants and soil invertebrates include comparison of EPCs to benchmarks called toxicity reference values (TRVs) protective of exposures to soil. Potential risks to plants and soil invertebrates were evaluated by comparing EPCs in soil to TRVs for these media. TRVs represent the threshold above which effects are expected and below which no 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.

Exposure estimates are not developed for amphibians or reptiles, because a quantitative measurement endpoint for this ecological resource cannot be identified. Literature and database resources were examined for exposure and toxicity information that could be used to

quantitatively evaluate risks to amphibians and reptiles. Despite searches of the EPA ECOTOX database, Canadian-based Reptile and Amphibian Toxicology Literature database, and other various literature sources, inadequate data are available for a quantitative evaluation. Therefore, the potentials for risks to amphibians and reptiles will be maintained as an uncertainty throughout this ERA (see Section 2.8: Uncertainties).

Wildlife

For wildlife, measurement endpoints are based on the results of food web models that predict the dose of chemicals ingested by wildlife. These doses will be 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. More detailed presentation of measurement endpoints is provided in Table 2.

2.5.2 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 the calculated 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. 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-4. Two separate EPCs were used in the ERA (Table 5). 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 soils. Given the small area of AOC-4, high confidence was attributed to the

relevance of using 95 percent UCLMs as EPCs. 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 2002b, 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 terrestrial plants and soil invertebrates at AOC-4 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 16).

Terrestrial Plants—Chemical concentrations measured in the soil of the Site were used to evaluate the potential for adverse effects to terrestrial plants. Consistent with EPA guidance (EPA 1997), the maximum detected concentration was used as the initial EPC in comparisons against benchmarks protective of plants. In addition, the chemical concentrations at each sample location were used as sample-specific EPCs in comparisons to benchmarks (Table 8); the results of these sample-specific comparisons were used to calculate site-wide frequencies of exceedance. Finally, a conservative estimate of the 95 percent UCLM concentration was evaluated as an EPC in comparisons to indicate the potential for population-wide impacts.

Terrestrial Invertebrates—Chemical concentrations measured in the soil at AOC-4 were used to evaluate the potential for adverse effects to terrestrial soil invertebrates. Consistent with EPA guidance (EPA 1997), the maximum detected concentration was used as the initial EPC in comparisons against benchmarks protective of soil invertebrates (Table 8). In addition, the chemical concentrations at each sample location were used as sample-specific EPCs in comparisons to benchmarks; the results of these sample-specific comparisons were used to calculate site-wide frequencies of exceedance. Finally, a conservative estimate of the 95 percent UCLM concentration was evaluated as an EPC in comparisons to indicate the potential for population-wide impacts.

Exposure Modeling for Higher Trophic Level Wildlife

Food web 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 and surface soil. 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. Table 6 provides uptake factors for invertebrates used in the exposure models. Table 7 provides a summary of exposure parameters for the avian and mammalian representative receptor species identified for evaluation, and food web models are presented in Appendix B.

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 Observed Adverse Effect Levels (NOAELs) 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 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 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.

Ingestion of Chemicals From Abiotic Media

Wildlife at AOC-4 may ingest soil while foraging or grooming. Therefore, food web models account for incidental ingestion of soil.

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

$$\boxed{Dose_{soil} = Soil * C_{soil}}$$

Where:

$Dose_{soil}$ = Amount of chemical ingested per day from soil (mg/kg-day)

Soil	=	Soil ingestion rate (kilograms soil per kilogram body weight per day [kg/kg-day])
C_{soil}	=	Chemical concentration in surface soil (mg/kg).

Percent soil 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 soil ingestion rates. A summary of the percent soil ingestion rates and food ingestion rates taken from the scientific literature is presented in Table 7.

Ingestion of Chemicals From Food

Food item (soil invertebrates) concentrations were developed using Bioaccumulation Factors (BAFs)/Bioconcentration Factors (BCFs). In general, values were selected from defensible, compilation- and consensus-based sources or sources which include validated models (i.e., Sample et al. 1998a; Beyer and Stafford 1993; ORNL 2009) instead of values from single studies. First preference was given to regression equations derived from paired field- or laboratory-based measurements. Second preference was given to ratio-derived BAFs developed based on paired data of tissue concentrations compared to media concentrations, unless validation studies showed these to be preferable to regressions. Examples of regression and ratio BAF development can be found in Sample et al. (1998b). Third preference was given to modeled equilibrium partitioning-derived BAFs based on physical or chemical characteristics. If no values could be identified, a BAF or BCF of 1 was selected.

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}).

EPCs in Soil Invertebrates

Concentrations were derived from literature-based uptake factors (UF) for uptake in earthworms (Table 6). When literature-based uptake factors for soil invertebrates were not available for the detected chemicals, tissue concentrations were derived using a default BAF of 1. Dry weight tissue concentration was calculated by multiplying the dry weight soil times the uptake factor or, where a regression was used, by entering the dry weight soil concentration into the equation. The 95 percent UCLM case scenario tissue concentrations were calculated using the 95 percent UCLM dry weight soil concentration. Where conversion to wet weight values was required, soil invertebrates were considered to contain 75 percent moisture as a default (CHPPM 2004).

$$C_{benthos} = C_{soil} * UF$$

Where:

C_{soil} = Concentration of COPEC in soil (mg/kg);
UF = Uptake factor for chemicals in sediment (unit less).

Total Chemical Ingestion

The total dietary exposure doses ($Dose_{total}$, mg/kg body weight [bw]-day [d]) for small insectivorous birds (American robin) and insectivorous mammals (northern short-tailed shrew) for the evaluated COPEC were determined using the following equation.

$$Dose_{total} = Dose_{food} + Dose_{soil}$$

Where:

$Dose_{food}$ = Amount of chemical ingested per day from food (prey) (mg/kg bw-d);
$Dose_{soil}$ = Amount of chemical ingested per day from soil (mg/kg bw-d).

The total dietary intakes are compared to dietary toxicity values to determine if adverse effects are likely to occur to insectivorous wildlife from the ingestion of COPEC in food and soil.

2.6 REFINED TOXICITY ASSESSMENT

This section derives toxicity values for use in evaluating exposure estimates for each representative receptor reference values 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.

2.6.1 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 soil 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. Toxicological benchmarks such as those provided in EPA Eco-SSLs are developed based on moderately bioavailable forms of metals; these benchmarks may overestimate toxicity for less bioavailable forms, or underestimate toxicity for more bioavailable forms. Acidity increases the bioavailability of many cationic metals, such as barium, chromium, copper, lead, vanadium, and zinc, which may become more soluble at pH below 5. Soil surveys for the area around AOC-4 (CSRL 2014) indicate that soils tend to be moderately alkaline; therefore, many metals are expected to be less mobile and less bioavailable. 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. PAHs may degrade over time, resulting in lower concentrations.

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

Perhaps the most important factor affecting fate of organic compounds in soil 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 soil 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). Soils at the Site tend to consist of fine sands with a low percentage of organic matter; therefore, binding to soil is not expected to be a significant factor affecting bioavailability of organics.

2.6.2 Plant TRVs for Exposure to Soil

To assess the potential for chemicals to adversely affect terrestrial plants, soil concentrations were compared to soil TRVs protective of plants (Table 8) (EPA 2005 a-h; EPA 2006; EPA 2007 b-g). TRVs from studies by Efroymson et al. (1997a) were established at a level associated with a 20 percent reduction in growth or other measured toxicological endpoints. This level is consistent with other screening level benchmarks for SLERA and the current regulatory approach. Because few toxicity values have been developed for organic chemicals, surrogate organic chemical TRVs were used for the evaluation of potential adverse effects to plants, as applicable; surrogates are identified in Table 8.

2.6.3 Soil Invertebrate TRVs for Exposure to Soil

To assess the potential for inorganic and organic chemicals to adversely affect soil invertebrates, soil concentrations were compared to TRVs protective of soil invertebrates (Table 8) (Efroymson et al. 1997b; EPA 2005 a-h; EPA 2007 b-g). TRVs protective of worms were used to assess the potential for inorganic and organic chemicals to adversely affect worms (Efroymson et al. 1997b). TRVs from studies by Efroymson et al. (1997b) were established at a level associated with a 20 percent mortality or other measured toxicological endpoint for earthworms. This level is consistent with other screening level benchmarks for SLERA and the current regulatory approach. Because few toxicity values have been developed for organic chemicals, surrogate organic chemical TRVs were used for the evaluation of potential adverse effects to soil invertebrates, as applicable (Table 8).

2.6.4 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 9) and mammals (Table 10). First, modeled doses were compared to dose-based 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 the lowest concentrations at which adverse effects are 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 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 HMW and LMW groups and concentrations summed for comparison to benchmarks (EPA 2007f). Toxicity evaluation using summed PAH 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.

2.7 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.

2.7.1 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.

2.7.2 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 were selected from the literature. 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 plant and soil invertebrates, the maximum detected chemical concentrations in soil 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 mobile 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). Those chemicals that had exposure estimates below TRVs (HQs less than 1.0) were removed from further consideration.

2.7.3 Additional Factors for Consideration at AOC-4

Additional lines of evidence were considered when creating the qualitative weight of evidence approach for this SLERA. For each receptor, the following characteristics were factored into the risk characterization:

- Evaluation of site-specific factors affecting chemical bioavailability and toxicity by examining pH and soil characteristics as they may affect relevance of toxicity benchmarks;
- Habitat quality and area use examined in light of representative receptor habitat requirements and habitat use patterns;
- Factors affecting future land use and changes to site substrates;
- Frequency of detection, exceedance, and spatial distribution;
- Comparison to background concentrations.

Background Data

Background data are not used to eliminate COPECs from consideration in this SLERA. However, per EPA guidance, cleanup does not focus on COPECs with concentrations that are consistent with regional background (EPA 2002). Therefore, background data specific to the project are used as comparison criteria as part of a weight of evidence approach to inform risk management. The upper prediction limits (UPLs) were calculated for background data using ProUCL (Version 4.0) and compared to the maximum and 95 percent UCLMs (Table 17).

Background concentrations were only available for metals. The following COPECs demonstrated a maximum detected concentration that exceeded the 95% UPL background concentration:

- Cadmium
- Copper
- Mercury
- Vanadium.

The following COPECs did not have a maximum detected concentration that exceeded the 95% UPL background concentration:

- Barium
- Chromium

- Lead
- Manganese
- Zinc.

These comparisons to background are discussed as a factor relevant to risk management at the end of the risk characterization for each receptor.

2.8 REFINEMENT AND PROBLEM FORMULATION

The results of comparisons performed for the SLERA refinement for AOC-4 are presented in Tables 11 through 17.

2.8.1 Terrestrial Plants

The conceptual model for AOC-4 soil identifies protection of terrestrial plant survival, growth, and reproduction from impacts of COPECs in soil as an assessment endpoint. The following measurement endpoints were evaluated as indicators of risk to terrestrial plants (Table 11):

- Comparison of the chemical concentrations to benchmarks protective of plants including
    - Comparison using maximum EPCs and
    - Comparison of 95 percent UCLM EPCs.

Comparison of maximum concentrations to benchmarks is typically given the most weight in the weight of evidence approach because it is the most precautionary indicator of risks at specific locations (i.e. hotspots). However, due to the small size and nature of the disturbed habitat at AOC-4, comparison of the 95 percent UCLM concentrations to benchmarks had the strongest weight of evidence as an indicator of population-wide risks in this refinement of the SLERA.

Measurement Endpoint 1: Comparison of Maximum Soil Concentrations to TRVs Protective of Plants

The first measurement endpoint evaluated was the screening-level comparison of maximum chemical concentrations in soil to literature-based TRVs protective of plants. When maximum EPCs of COPECs were compared to TRVs, concentrations of six metals (barium, chromium, manganese, mercury, vanadium, and zinc) exceed TRVs protective of plants grown in soil (Table 11).

Measurement Endpoint 2: Comparison of 95 Percent UCLM Soil Concentrations to TRVs Protective of Plants

Comparison of 95 percent UCLM chemical concentrations in soil to plant TRVs was considered as a second measurement endpoint. Chromium did not have a calculated 95 percent UCLM, so the maximum concentration was utilized as the 95 percent UCLM. When the 95 percent UCLM

EPCs were compared to TRVs, an HQ greater than 1.0 remained for barium, chromium, mercury, vanadium, and zinc (Table 11). Several chemicals did not have NOAEL-based TRVs available and the uncertainty associated with the lack of TRVs is discussed in Section 2.8.

Additional Factors Relevant to Risk Characterization for Plants

A number of site-specific factors are relevant to interpretation of results of chemical comparisons and overall risk characterization for terrestrial plants. Additional factors were evaluated relevant to barium, chromium, mercury, vanadium, and zinc, the chemicals for which 95 percent UCLM exceed TRVs. Evaluation of the factors identified in Section 2.7.3, include the following:

- **Site-specific bioavailability and toxicity—**Soil surveys for the area around AOC-4 (CSRL 2014) indicate that soils tend to be moderately alkaline. Barium, chromium, vanadium, and zinc all demonstrate lower toxicity in moderately alkaline soils. Benchmarks for plants are derived from studies focused on moderately to highly bioavailable concentrations of metals. Therefore, toxicity associated with these metals is likely to be over-estimated.

- **Habitat quality**—As discussed in the CSM, soils at the Site consist of compacted silty sands in an environment periodically subjected to inundation in saline water. Compacted sand provides a poor substrate for plant growth, and saline environments limit plant diversity to species highly tolerant of free metal ions. As such, factors other than elevated concentrations of metals are likely to limit plant establishment and growth, and species diversity at the Site.

- **Future land use—**Based on the Site setting, future land use is likely to remain industrial. Should attempts be made to restore vegetative communities, major physical changes to the Site's substrates would be required to mitigate the effects of compaction, salinity, and low organic matter content. These changes would likely pose a much greater influence on plant growth and reproduction than the elevated metal concentrations identified at the Site.

- **Frequency of detection and spatial distribution—**For barium, mercury, vanadium, and zinc, risks are driven by a single high concentration at SO4-01 (809 mg/kg barium, 1.5 mg/kg for mercury, 21.3 mg/kg for vanadium, and 560 mg/kg for zinc) compared to the plant NOAEL of 500, 0.3, 2.0, and 160 mg/kg, respectively. These concentrations are at least two times higher than the next closest value. Because these exceedances are limited to a single location, risks to the populations of plants at the Site are low. Chromium exceeded the plant TRV by 2 to 17 times in all 6 samples; however, 4 of the detected concentrations were estimated below the laboratory reporting limits and a 95 percent ULCM could not be calculated.

- **Background concentrations—**AOC-4 maximum detected concentrations of barium, chromium, and zinc did not exceed the 95% UPL background concentrations, and therefore unlikely to warrant consideration in risk management

Risk Characterization for Terrestrial Plants

When 95 percent UCLM are compared to TRVs protective of terrestrial plants, barium, chromium, mercury, vanadium, and zinc are found in exceedance. However, a number of factors identify that the potential for risk from these metals is low for AOC-4. Specifically, metal bioavailability and toxicity are likely over-estimated; site habitats are subject to non-chemical factors that already limit plant growth and diversity, and would require extensive alteration to support higher quality habitat; and exceedances are limited in spatial distribution. Moreover, three of the five metals are consistent with background concentrations and would not warrant risk management.

2.8.2 Soil Invertebrates

As part of the BRAPF, refined risk calculation and evaluation of qualitative lines of evidence were evaluated to characterize risks to soil invertebrates from COPEC in soil. The following measurement endpoints were evaluated as indicators of risk to benthic organisms.

- Comparison of the chemical concentrations to benchmarks protective of soil invertebrates, presented in Table 12, including
    - Comparison using maximum EPCs and
    - Comparison of 95 percent UCLM EPCs.

Comparison of maximum concentrations to benchmarks is typically given the most weight in the weight of evidence approach because it is the most precautionary indicator of risks at specific locations (i.e. hotspots). However, due to the small size and nature of the disturbed habitat at AOC-4, comparison of the 95 percent UCLM concentrations to benchmarks had the strongest weight of evidence as an indicator of population-wide risks.

Measurement Endpoint 1: Comparison of Maximum Chemical Concentrations to Soil Invertebrate TRVs

The first measurement endpoint evaluated was the comparison of maximum EPCs in surface soil to literature-based benchmarks protective of soil invertebrates. The NOAEL-based TRVs selected were chosen to provide a highly conservative estimate of the potential for risk. When maximum EPCs of COPEC were compared to NOAEL-based TRVs, four metal concentrations exceeded TRVs for soil invertebrates (barium, chromium, mercury, and zinc) and had an HQ greater than or equal to 1.0. Results for this measurement endpoint indicate that there is a potential for risk from these chemicals, although this measurement endpoint is highly precautionary because it assumes maximum exposure. Several chemicals did not have NOAEL-

based TRVs available and the uncertainty associated with the lack of TRVs is discussed in Section 2.8.

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

The second measurement endpoint evaluated was the comparison of 95 percent UCLM EPCs in soil to literature-based benchmarks protective of soil invertebrates. Only barium, mercury, and zinc had a calculated 95 percent UCLM, whereas the maximum concentration had to be used for chromium due to the guidelines outlined in Section 2.4. When the 95 percent UCLM EPCs of barium, mercury, and zinc were compared to TRVs, an HQ greater than 1.0 remained.

Additional Factors Relevant to Risk Characterization for Soil Invertebrates

A number of site-specific factors are relevant to interpretation of results of chemical comparisons and overall risk characterization for soil invertebrates. Additional factors were evaluated relevant to barium, chromium, mercury, and zinc, the chemicals for which 95 percent UCLM exceed TRVs. Evaluation of the factors identified in Section 2.7.3, include the following:

- **Site-specific bioavailability and toxicity—**Soil surveys for the area around AOC-4 (CSRL 2014) indicate that soils tend to be moderately alkaline. Barium, chromium, and zinc all demonstrate lower toxicity in moderately alkaline soils. Benchmarks for soil invertebrates are derived from studies focused on moderately to highly bioavailable concentrations of metals. Therefore, toxicity associated with these metals is likely to be over-estimated.

- **Habitat quality**—As discussed in the CSM, soils at the Site consist of compacted silty sands in an environment periodically subjected to inundation in saline water. Compacted sand provides a poor habitat for more sensitive soil invertebrates such as worms as do saline environments. This limits soil invertebrate diversity to species highly tolerant of free metal ions and compacted substrates. As such, factors other than elevated concentrations of metals are likely to limit soil invertebrate diversity and abundance at the Site.

- **Future land use**—Based on the Site setting, future land use is likely to remain industrial. Should attempts be made to restore native communities, major physical changes to the Site's substrates would be required to mitigate the effects of compaction, salinity, and low organic matter content. These changes would likely pose a much greater influence on soil invertebrate communities than the elevated metal concentrations identified at the Site.

- **Frequency of detection and spatial distribution**—For barium, mercury, and zinc, risks are driven by a single high concentration at SO4-01 (809 mg/kg barium, 1.5 mg/kg for mercury, and 560 mg/kg for zinc) compared to the soil invertebrate

NOAEL of 330, 0.1, and 120 mg/kg, respectively. These concentrations are at least two times higher than the next closest value. Because these exceedances are limited to a single location, risks to the populations of soil invertebrates at the Site are low. Chromium exceeded the soil invertebrate TRV by 5 to 44 times in all 6 samples.

- **Background concentrations**—AOC-4 maximum detected concentrations of barium, chromium, and zinc did not exceed the 95% UPL background concentrations, and therefore unlikely to warrant consideration in risk management

Risk Characterization for Soil Invertebrates

When 95 percent UCLM are compared to TRVs protective of terrestrial plants, barium, chromium, mercury, and zinc are found in exceedance. However, a number of factors modify concern for the potential for risk from these metals for AOC-4. In specific, metal bioavailability and toxicity are likely over-estimated; site habitats are subject to non-chemical factors that already limit soil invertebrate abundance and diversity, and would require extensive alteration to support higher quality habitat; and exceedances for some chemicals are limited in spatial distribution. Moreover, three of the four metals are consistent with background concentrations and would not warrant risk management.

2.8.3 Terrestrial Avian Wildlife

The conceptual model for the Site identifies protection of the survival, growth, and reproduction of birds from impacts of COPECs in soil and food as an assessment endpoint. The conceptual model identified representative receptors from the insectivore feeding guild (American robin) 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 HQ for each chemical is calculated based on the comparison of the dose from maximum concentrations in soil to the NOAEL and the LOAEL (dose modeling presented in Appendix B). Dose modeling and comparisons to NOAEL-based literature TRVs using maximum EPCs identified six metals (barium, cadmium, copper, lead, vanadium, and zinc) as having an HQ equaling or exceeding 1.0 for insectivorous birds (Table 13).

Dose modeling and comparisons to LOAEL-based literature TRVs using maximum EPCs identified three metals as having an HQ equaling or exceeding 1.0 for insectivorous birds (barium, vanadium, and zinc) (Table 13).

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 soil to NOAEL and LOAEL and literature-based TRVs protective of birds. Only barium, lead, vanadium, and zinc had a calculated 95 percent UCLM, whereas the maximum concentrations had to be used for cadmium due to low frequency of detection. When the 95 percent UCLM EPCs were compared to NOAELs, an HQ greater than 1.0 remained for barium, lead, vanadium and zinc for insectivorous birds (Table 14). When compared of LOAELs, vanadium and zinc continued to have an HQ greater than 1.0 for insectivorous birds (Table 14).

Additional Factors Relevant to Risk Characterization for Avian Wildlife

A number of site-specific factors are relevant to interpretation of results of chemical comparisons and overall risk characterization for avian wildlife. Additional factors were evaluated relevant to vanadium and zinc, the chemicals for which 95 percent UCLM exceed TRVs. Evaluation of the factors identified in Section 2.7.3, include the following:

- **Site-specific bioavailability and toxicity**—Soil surveys for the area around AOC-4 (CSRL 2014) indicate that soils tend to be moderately alkaline. Vanadium and zinc demonstrate lower bioavailability and toxicity in moderately alkaline soils. Uptake factors and benchmarks for birds are derived from studies focused on moderately to highly bioavailable concentrations of metals. Therefore, bioavailability and toxicity associated with these metals is likely to be over-estimated.

- **Habitat quality**—As discussed in the CSM, the Site provides poor quality habitat for wildlife, with little vegetation and few resources to support prey items such as soil invertebrates. The American robin has an average home range of 1 to 2 acres, and with the small size of AOC-4 and lack of suitable habitat for soil invertebrates, the robin is likely to forage outside of Site, and AOC-4 is likely to provide habitat for a very small population of birds.

- **Future land use—**Based on the Site setting, future land use is likely to remain industrial. Should attempts be made to restore higher quality habitat, major physical changes to the Site's substrates would be required that would greatly alter exposure concentrations.

- **Frequency of detection and spatial distribution—**Vanadium concentrations exceeded LOAELs in all six samples. Zinc concentrations exceeded LOAELs at three of the six sample locations by a factor of 1 to 4.

- **Background concentrations—**The AOC-4 maximum detected concentration of zinc did not exceed the 95% UPL background concentrations, and is therefore unlikely to warrant consideration in risk management.

Risk Characterization for Avian Wildlife

When 95 percent UCLM are compared to NOAELs protective of avian receptors, barium, lead, vanadium, and zinc are found in exceedance. When 95 percent UCLM are compared to LOAELs protective of avian receptors, vanadium and zinc are found in exceedance. However, a number of factors identify that the potential for risk from these metals is minimal for AOC-4. In specific, metal bioavailability and toxicity is likely over-estimated; site habitats are subject to non-chemical factors that limit their use by birds as a resource, and would require extensive alteration to support higher quality habitat; and exceedances are limited in spatial distribution. Moreover, concentrations of one of the two metals identified are consistent with background concentrations and would not warrant risk management.

2.8.4 Terrestrial Mammalian Wildlife

The conceptual model for the Site identifies protection of the survival, growth, and reproduction of mammals from impacts of COPECs in soil and food as an assessment endpoint. The conceptual model identified representative receptors from the insectivore feeding guild (shrew) 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 HQ for each chemical is calculated based on the comparison of the dose from maximum concentrations in soil to the NOAEL and LOAEL (dose modeling is presented in Appendix B). Dose modeling and comparisons to NOAEL-based literature TRVs using maximum EPCs identified two chemicals (cadmium and zinc) as having an HQ equaling or exceeding 1.0 (Table 15).

Dose modeling and comparisons to LOAEL-based literature TRVs using maximum EPCs identified no COPECs as having an HQ equaling or exceeding 1.0 (Table 15).

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

The second measurement endpoint evaluated the comparison of ingested doses for mammals based on 95 percent UCLM EPCs to NOAEL and LOAEL-based TRVs. The HQ for each chemical is calculated based on the comparison of the dose from 95 percent UCLM concentrations in soil to the NOAEL and LOAEL. Zinc had a calculated 95 percent UCLM, whereas the maximum concentration was used for the cadmium due to low frequency of detection. An HQ greater than 1.0 remained for zinc during the comparisons of the 95 percent UCLM to NOAELs for insectivores, but did not remain a concern when compared to LOAELs (Table 16).

Additional Factors Relevant to Risk Characterization for Mammalian Wildlife

A number of site-specific factors are relevant to interpretation of results of chemical comparisons and overall risk characterization for mammalian wildlife. Additional factors were evaluated relevant to zinc, the chemical for which 95 percent UCLM exceeded TRVs. Evaluation of the factors identified in Section 2.7.3, include the following:

- **Site-specific bioavailability and toxicity—**Soil surveys for the area around AOC-4 (CSRL 2014) indicate that soils tend to be moderately alkaline. Zinc demonstrates lower bioavailability and toxicity in moderately alkaline soils. Uptake factors and benchmarks for mammals are derived from studies focused on moderately to highly bioavailable concentrations of metals. Therefore, bioavailability and toxicity associated with zinc is likely to be over-estimated.

- **Habitat quality**—As discussed in the CSM, the Site provides poor quality habitat for wildlife, with little vegetation and few resources to support prey items such as soil invertebrates. The shrew has an average home range of 0.7 to 4.4 acres, and with the small size of AOC-4 and lack of suitable habitat for soil invertebrates, the shrew is likely to forage outside of the Site, and AOC-4 is likely to provide habitat for a very small population of mammals.

- **Future land use—**Based on the Site setting, future land use is likely to remain industrial. Should attempts be made to restore higher quality habitat, major physical changes to the Site's substrates would be required that would greatly alter exposure concentrations.

- **Background concentrations**—The AOC-4 maximum detected concentration of zinc did not exceed the 95% UPL background concentrations, and is therefore unlikely to warrant consideration in risk management.

Risk Characterization for Mammalian Wildlife

When 95 percent UCLM are compared to NOAELs protective of mammalian receptors, cadmium and zinc are found in exceedance. When 95 percent UCLM are compared to LOAELs protective of mammalian receptors, no chemicals are found in exceedance. However, a number of factors identify that the potential for risk from these metals is minimal for AOC-4. In specific, metal bioavailability and toxicity is likely over-estimated; site habitats are subject to non-chemical factors that limit their use by mammals as a resource, and would require extensive alteration to support higher quality habitat; and exceedances are limited in spatial distribution. Moreover, concentrations of one of the two metals identified are consistent with background concentrations and would not warrant risk management.

2.9 UNCERTAINTY EVALUATION

This ERA for AOC-4 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 AOC-4, 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. 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 America robin and shrew obtain all their food from within AOC-4, 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 soil 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 soil. Also, a BAF of 1.0 was used to estimate chemical concentrations in prey (soil invertebrates) 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. As these metals are essential nutrients, adverse effects on 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, because these nutrients are essential to flora and fauna, these essential nutrients are not maintained as COPECs.

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 may provide limited terrestrial habitats. Based on the conceptual model, assessment endpoints were selected to represent the most sensitive of ecological receptors within AOC-4's ecological community. The assessment endpoints included the survival, growth, and reproduction of plants, soil invertebrates, insectivorous birds, and insectivorous 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 soil invertebrate community as resources for wildlife. Measurement endpoints were selected to provide a quantifiable means of characterizing risks. The measurement endpoints for plant and soil 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. Due to the small size and nature of the disturbed habitat at AOC-4, comparison of the 95 percent UCLM concentrations to TRVs and LOAELs was given the strongest weight of evidence.

Maximum concentrations were initially compared to media-specific screening criteria to identify potential COPECs. For higher trophic level wildlife, 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 NOAELs and LOAELs.

To test the measurement endpoints, both site-specific and literature-based information were 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. Additional considerations specific to AOC-4 were also taken into consideration, such as the size of the Site, the current use, and the home range of wildlife receptors. Lines of evidence were combined in a qualitative weight-of-evidence discussion to determine the potential for risks. Several metals had 95 percent UCLM concentrations higher than TRVs and LOAEL HQs greater or equal to 1.0 for the receptors. Exceedances include:

- **Terrestrial plants**—When 95 percent UCLM are compared to TRVs protective of terrestrial plants, barium, chromium, mercury, vanadium, and zinc are found in exceedance.

- **Soil invertebrates**—When 95 percent UCLM are compared to TRVs protective of soil invertebrates, barium, chromium, mercury, and zinc are found in exceedance.

- **Avian wildlife**—When 95 percent UCLM are compared to NOAELs protective of avian receptors, barium, cadmium, copper, lead, vanadium, and zinc are found in exceedance. When 95 percent UCLM are compared to LOAELs protective of avian receptors, vanadium and zinc are found in exceedance.

- **Mammalian wildlife**—When 95 percent UCLM are compared to NOAELs protective of mammalian receptors, zinc is found in exceedance. When 95 percent UCLM are compared to LOAELs protective of mammalian receptors, no chemicals are found in exceedance.

However, a number of factors identify that the potential for risk from these metals is minimal for AOC-4. Specifically, metal bioavailability and toxicity is likely over-estimated; site habitats are subject to non-chemical factors that limit habitat quality and would require extensive alteration to support higher quality habitat; and exceedances are limited in spatial distribution. Moreover, the maximum detected concentrations of barium, chromium, lead, and zinc did not exceed the 95% UPL background concentrations and would not warrant risk management.

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FIGURES

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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-4

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Feet

Legend:

- Area of Concern 4 Boundary
- 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-4

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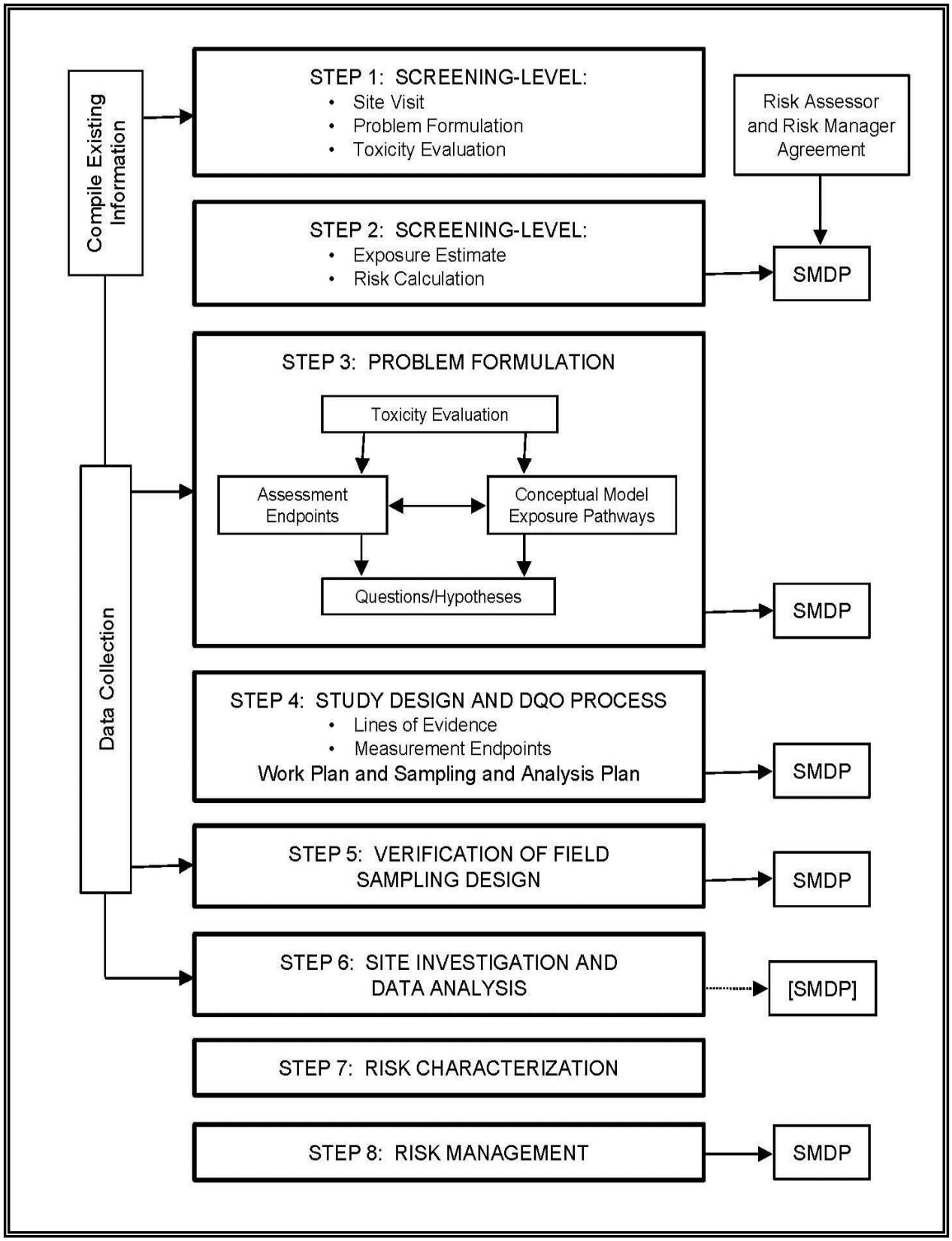

SMDP = Scientific Management Decision Points

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

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Legend:

- Monitoring Well Location (2013)
- Soil Sample Location (2013)
- Area of Concern 4 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-4 Sample Locations
Ecological Risk Assessment for AOC-4

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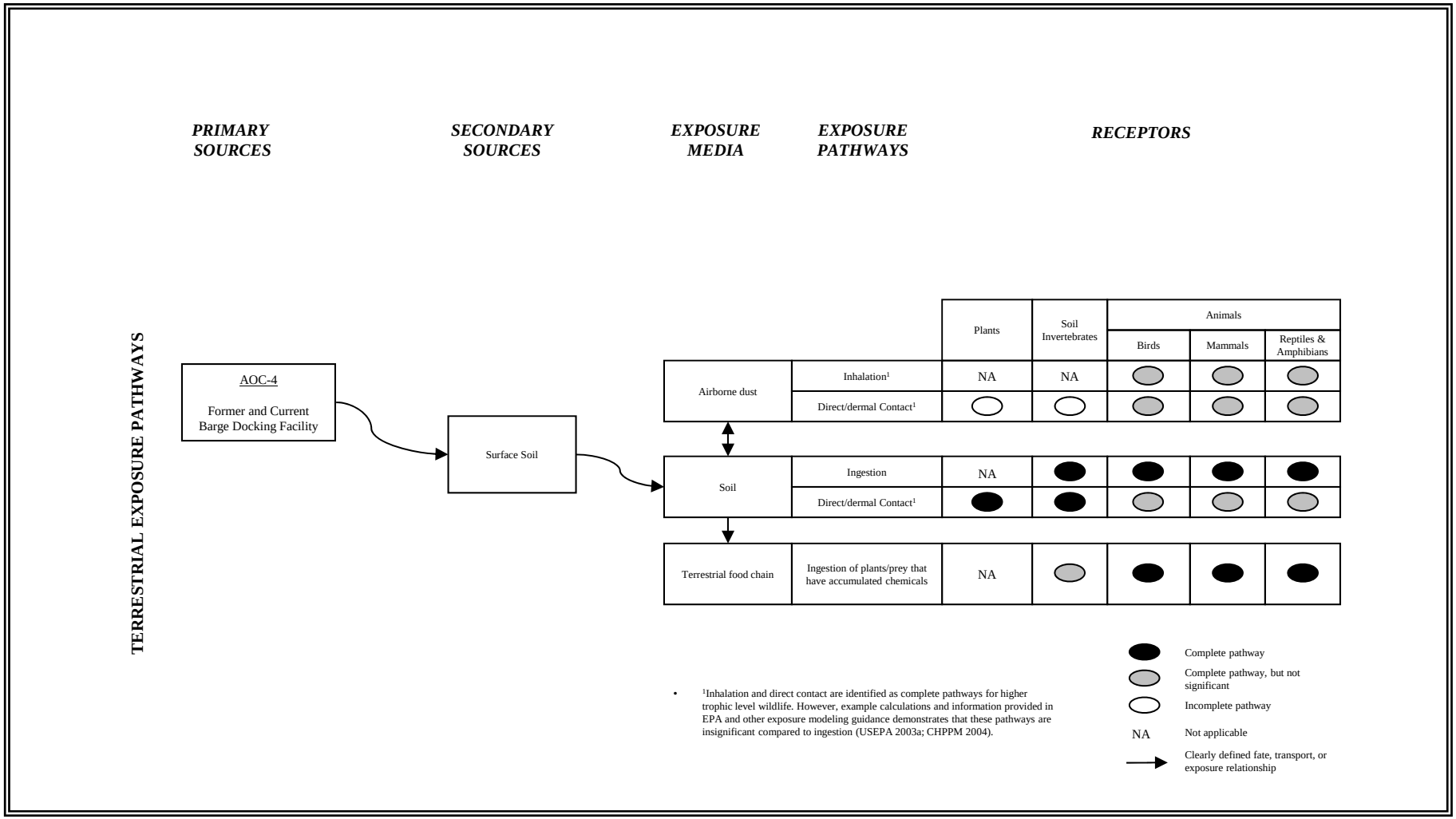

Figure 5. Ecological Conceptual Site Model for Falcon Refinery Superfund Site

TABLES

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Table 1
Samples Used in the Ecological Risk Assessment

Area	Media	Sample Date	Sample ID
AOC-4	Surface Soil	10-Sep-13	MW-17-0.0-0.5
		10-Sep-13	SO4-01-0.0-0.5
		10-Sep-13	SO4-02-0.0-0.5
		10-Sep-13	SO4-03-0.0-0.5
		10-Sep-13	SO4-04-0.0-0.5
		10-Sep-13	SO4-05-0.0-0.5

NOTE:
AOC = Area of Concern

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 terrestrial plants and surface soil invertebrates exposed to COPECs in surface soil from adverse survival, growth and reproductive effects	Initial screening	• Surface soil concentrations measured at site during 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 surface soil concentrations to benchmarks	• Surface soil concentrations measured at site during recent sampling - SLERA: Maximum Concentrations - Refined BRAPF: Mean Concentrations	• Direct comparison of maximum surface soil concentrations to plant benchmarks (TRVs) • Direct comparison of maximum surface soil concentrations to invertebrate benchmarks (TRVs) • Direct comparison of mean surface soil concentrations and individual concentrations to invertebrate benchmarks • Invertebrate benchmarks from EPA Eco-SSLs; ORNL benchmarks (Efroymson et al., 1997b)	• Exceedence of benchmarks indicates potential for risks
Protection of terrestrial mammals and birds to ensure that ingestion of COPCs in surface soil and food do not have unacceptable impacts on survival, growth, and reproduction	Initial screening	• Surface soil concentrations measured at site during recent sampling	• Direct comparison to the Eco-SSL or Region IV ecological screening values to define COPECs	• Chemicals defined as COEPCs indicate the potential for risk
	Comparison of modeled food web doses to benchmarks	• Surface soil concentrations measured at site during recent sampling - 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 • Mammal and bird dose-based benchmarks from 1) USEPA EcoSSL 2) ORNL benchmarks (Sample et al., 1998b) 3) Additional literature-based sources as relevant	• Exceedence of benchmarks indicates a potential for risks
	Qualitative evaluation of habitat	• Species lists and observations from previous habitat surveys • Observations of vegetation community distribution from aerial photographs	• Presence of signs of stress, such as bare areas	• Presence of signs of stress indicates potential impacts/risks
Protection of reptiles and amphibians to ensure that ingestion of COEPCs in surface soil and food do not have unacceptable impacts on survival, growth, and reproduction	Comparison of modeled food web doses to benchmarks	• EPCs evaluated for other receptors	• Evaluate whether other wildlife receptors are at risk and consider results as surrogate for reptiles and amphibians.	• Risks from COPECs to other receptors indicate that there may be a risk to reptiles and amphibians from the same COEPCs

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
TRV = Toxicity Reference Value
EPA = U.S. Environmental Protection Agency

Table 3
Ecological Screening Benchmarks

Chemical	Soil Criteria (mg/kg)	Soil Criteria Source
Metals		
Aluminum	5.00E+01	Region 4, Retain only if soil pH < 5.5 (TCEQ)
Antimony	2.70E-01	Mammalian Eco-SSL
Arsenic	1.80E+01	Plant Eco-SSL
Barium	3.30E+02	Soil Invertebrate Eco-SSL
Beryllium	1.00E+01	TCEQ Plant Eco-SSL
Cadmium	3.60E-01	Mammalian Eco-SSL
Calcium	NA	--
Chromium	4.00E-01	TCEQ Plant Eco-SSL
Cobalt	1.30E+01	Plant Eco-SSL
Copper	2.80E+01	Avian Eco-SSL
Iron	2.00E+02	Region 4
Lead	1.10E+01	Avian Eco-SSL
Magnesium	NA	--
Manganese	2.20E+02	Plant Eco-SSL
Mercury	1.00E-01	TCEQ Soil Invertebrate Eco-SSL
Nickel	3.80E+01	Plant Eco-SSL
Potassium	NA	--
Selenium	5.20E-01	Plant Eco-SSL
Silver	4.20E+00	Avian Eco-SSL
Sodium	NA	--
Thallium	1.00E+00	TCEQ Plant Eco-SSL
Vanadium	2.00E+00	TCEQ Plant Eco-SSL
Zinc	4.60E+01	Avian Eco-SSL
Polynuclear Aromatic Hydrocarbons		
2-Methylnaphthalene	NA	--
Acenaphthene	2.00E+01	TCEQ Plant Eco-SSL
Acenaphthylene	NA	--
Anthracene	NA	--
Benzo(a)Anthracene	NA	--
Benzo(a)Pyrene	NA	--
Benzo(b)Fluoranthene	NA	--
Benzo(g,h,i)Perylene	NA	--
Benzo(k)Fluoranthene	NA	--
Chrysene	NA	--
Dibenzo(a,h)Anthracene	NA	--
Fluoranthene	NA	--
Fluorene	3.00E+01	TCEQ Soil Invertebrate Eco-SSL
Indeno(1,2,3-Cd)Pyrene	NA	--
Naphthalene	NA	--
Phenanthrene	NA	--
Pyrene	NA	--
Total LMW PAHs	2.90E+01	Soil Invertebrate Eco-SSL
Total HMW PAHs	1.10E+00	Mammalian Eco-SSL
Semivolatile Organic Compounds		
	6.00E+01	TCEQ Plant Eco-SSL
2-Methylphenol	NA	--
4-Methylphenol	NA	--
Acetophenone	NA	--
Benzaldehyde	NA	--
Benzoic Acid	NA	--
Butyl benzyl phthalate	NA	--
Bis(2-ethylhexyl)phthalate	NA	--
Caprolactum	NA	--
Carbazole	NA	--

Table 3
Ecological Screening Benchmarks

Chemical	Soil Criteria (mg/kg)	Soil Criteria Source
Diethyl phthalate	1.00E+02	TCEQ Plant Eco-SSL
Dimethyl phthalate	2.00E+02	TCEQ Soil Invertebrate Eco-SSL
Di-N-Butyl phthalate	2.00E+02	TCEQ Plant Eco-SSL
Di-N-octyl Phthalate	NA	--
Isophorone	NA	--
Phenol	5.00E-02	Region 4
Volatile Organic Compounds		
1,1,2,2-Tetrachloroethane	NA	--
1,2,4-Trimethlybenzene	NA	--
1,3,5-Trimethylbenzene	NA	--
2-Butanone	NA	--
4-Methyl-2-pentanone	NA	--
Acetone	NA	--
Benzene	5.00E-02	Region 4
Benzaldehyde	1.00E-02	Region 4
Carbon disulfide	NA	--
Chloroform	1.00E-03	Region 4
Chloromethane	NA	--
Ethylbenzene	5.00E-02	Region 4
Isopropylbenzene	NA	--
Methylene chloride	NA	--
n-Propylbenzene	NA	--
Styrene	1.00E-01	Region 4
Tetrachloroethene	1.00E-02	Region 4
Toluene	5.00E-02	Region 4
Trichloroethene	NA	--
Trichloroflouromethane	NA	--
Xylenes (m & p)	NA	--
Xylenes (o)	NA	--
Xylenes (Total)	5.00E-02	Region 4

Sources: The lowest Eco-SSL available from one of the following:

(1) Texas Commision on Environmental Quality (TCEQ) - Table 3.4, accessed at *http://www.tceq.texas.gov/assets/public/remediation/trrp/rg263-draft.pdf*

(2) EPA Eco-SSLs, accessed at *http://www.epa.gov/ecotox/ecossl*

(3) EPA Region 4 Ecological Screening Values, accessed at *http://www.epa.gov/region4/superfund/programs/riskassess/ecolbul.html*

NOTE:
Eco-SSL = Ecological Soil Screening Levels
EPA = U.S. Environmental Protection Agency
HMW PAH = High molecular weight polynuclear aromatic hydrocarbon
LMW PAH = Low molecular weight polynuclear aromatic hydrocarbon
mg/kg = Milligram per kilogram
NA = Screening value not available

Table 4
Maximum Soil Detection Comparison to Screening Levels
for AOC-4

Analyte	Surface Soil				Selection of Chemical of Potential Ecological Concern
	Frequency of Detection	Maximum (mg/kg)	Location of Maximum	Screening Criteria (mg/kg)*	Terrestrial Habitats
Metals					
Aluminum	6/6	1.70E+04	SO4-01-0.0-0.5	pH < 5.5	NO
Arsenic	6//6	5.70E+00	SO4-01-0.0-0.5	1.80E+01	NO
Barium	**6/6**	**8.09E+02**	**SO4-01-0.0-0.5**	**3.30E+02**	**YES**
Cadmium	**1/6**	**9.00E-01**	**SO4-01-0.0-0.5**	**3.60E-01**	**YES**
Calcium	6/6	2.64E+05	SO4-03-0.0-0.5	NA	NO, Esn. Nut.
Chromium	**6/6**	**1.76E+01**	**SO4-04-0.0-0.5**	**4.00E-01**	**YES**
Cobalt	6/6	3.80E+00	SO4-01-0.0-0.5	1.30E+01	NO
Copper	**6/6**	**3.98E+01**	**SO4-04-0.0-0.5**	**2.80E+01**	**YES**
Iron	6/6	1.30E+04	SO4-01-0.0-0.5	pH < 5.5	NO
Lead	**6/6**	**4.30E+01**	**SO4-01-0.0-0.5**	**1.10E+01**	**YES**
Magnesium	6/6	6.01E+03	SO4-01-0.0-0.5	NA	NO, Esn. Nut.
Manganese	**6/6**	**2.59E+02**	**SO4-01-0.0-0.5**	**2.20E+02**	**YES**
Mercury	**6/6**	**1.50E+00**	**SO4-01-0.0-0.5**	**1.00E-01**	**YES**
Nickel	6/6	1.85E+01	SO4-01-0.0-0.5	3.80E+01	NO
Potassium	6/6	4.00E+03	SO4-01-0.0-0.5	NA	NO, Esn. Nut.
Sodium	5/6	4.23E+03	MW-17-0.0-0.5	NA	NO, Esn. Nut.
Vanadium	**6/6**	**2.13E+01**	**SO4-01-0.0-0.5**	**2.00E+00**	**YES**
Zinc	**6/6**	**5.60E+02**	**SO4-01-0.0-0.5**	**4.60E+01**	**YES**
Polynuclear Aromatic Hydrocarbons					
Acenaphthene	3/6	3.20E-02	SO4-04-0.0-0.5	2.00E+01	NO
Acenaphthylene	4/6	6.10E-02	SO4-04-0.0-0.5	NA	Use Total LMW
Anthracene	5/6	6.50E-02	SO4-04-0.0-0.5	NA	Use Total LMW
Benzo(a)Anthracene	6/6	5.90E-01	MW-17-0.0-0.5	NA	Use Total HMW
Benzo(a)Pyrene	6/6	5.09E-01	MW-17-0.0-0.5	NA	Use Total HMW
Benzo(b)Fluoranthene	6/6	8.20E-01	MW-17-0.0-0.5	NA	Use Total HMW
Benzo(g,h,i)Perylene	6/6	2.19E-01	SO4-04-0.0-0.5 MW-17-0.0-0.5	NA	Use Total HMW
Benzo(k)Fluoranthene	6/6	2.70E-01	SO4-04-0.0-0.5	NA	Use Total HMW
Chrysene	6/6	6.00E-01	MW-17-0.0-0.5	NA	Use Total HMW
Dibenzo(a,h)Anthracene	5/6	7.60E-02	MW-17-0.0-0.5	NA	Use Total HMW
Fluoranthene	6/6	1.40E+00	MW-17-0.0-0.5	NA	Use Total LMW
Fluorene	2/6	1.50E-02	MW-17-0.0-0.5	3.00E+01	NO
Indeno(1,2,3-Cd)Pyrene	6/6	3.50E-01	SO4-04-0.0-0.5 MW-17-0.0-0.5	NA	Use Total HMW
Phenanthrene	6/6	3.50E-01	MW-17-0.0-0.5	NA	Use Total LMW
Pyrene	6/6	1.10E+00	MW-17-0.0-0.5	NA	Use Total HMW
Total LMW PAHs	6/6	4.49E-01	MW-17-0.0-0.5	2.90E+01	NO
Total HMW PAHs	**6/6**	**5.87E+00**	**MW-17-0.0-0.5**	**1.10E+00**	**YES**
Semivolatile Organic Compounds					
Acetophenone	**1/6**	**6.20E-02**	**SO4-05-0.0-0.5**	**NA**	**YES**
Benzaldehyde	**1/6**	**6.60E-02**	**SO4-05-0.0-0.5**	**NA**	**YES**
Bis(2-ethylhexyl)phthalate	**2/6**	**2.20E-01**	**SO4-04-0.0-0.5**	**NA**	**YES**
Carbazole	**1/6**	**1.90E-02**	**SO4-05-0.0-0.5**	**NA**	**YES**
Dimethyl phthalate	2/6	1.50E-01	SO4-04-0.0-0.5	2.00E+02	NO
Phenol	1/6	3.30E-02	SO4-05-0.0-0.5	5.00E-02	NO
Volatile Organic Compounds					
2-Butanone	**1/6**	**1.40E-02**	**SO4-01-0.0-0.5**	**NA**	**YES**
Ethylbenzene	1/6	3.70E-03	SO4-01-0.0-0.5	5.00E-02	NO
Isopropylbenzene	**1/6**	**3.30E-04**	**SO4-01-0.0-0.5**	**NA**	**YES**
Tetrachloroethene	1/6	1.20E-03	SO4-01-0.0-0.5	1.00E-02	NO
Trichloroflouromethane	**4/6**	**5.00E-04**	**SO4-01-0.0-0.5**	**NA**	**YES**
Xylenes (m & p)	**2/6**	**3.50E-02**	**SO4-01-0.0-0.5**	**NA**	**YES**
Xylenes (o)	**1/6**	**1.20E-02**	**SO4-01-0.0-0.5**	**NA**	**YES**

NOTE:
* See Table 3
Esn. Nut. = Essential nutrient
HMW PAH = High molecular weight polynuclear aromatic hydrocarbon
LMW PAH = Low molecular weight polynuclear aromatic hydrocarbon
mg/kg = Miligram per kilogram
NA = Screening value not available

Table 5
Frequency of Detection and Exposure Point Concentrations
for AOC-4

Analyte	Surface Soil		
	Frequency	Maximum (mg/kg)	95% UCL Mean (mg/kg)
Metals			
Barium	6/6	8.09E+02	5.32E+02
Cadmium	1/6	9.00E-01	9.00E-01
Chromium	6/6	1.76E+01	1.76E+01
Copper	6/6	3.98E+01	3.98E+01
Lead	6/6	4.30E+01	3.98E+01
Manganese	6/6	2.59E+02	1.85E+02
Mercury	6/6	1.50E+00	1.18E+00
Vanadium	6/6	2.13E+01	1.83E+01
Zinc	6/6	5.60E+02	4.33E+02
Polynuclear Aromatic Hydrocarbons			
Total HMW PAHs	6/6	5.87E+00	4.34E+00
Semivolatile Organic Compounds			
Acetophenone	1/6	6.20E-02	6.20E-02
Benzaldehyde	1/6	6.60E-02	6.60E-02
Bis(2-ethylhexyl)phthalate	2/6	2.20E-01	2.20E-01
Carbazole	1/6	1.90E-02	1.90E-02
Volatile Organic Compounds			
2-Butanone	1/6	1.40E-02	1.40E-02
Isopropylbenzene	1/6	3.30E-04	3.30E-04
Trichloroflouromethane	4/6	5.00E-04	4.40E-04
Xylenes (m & p)	2/6	3.50E-02	3.50E-02
Xylenes (o)	1/6	1.20E-02	1.20E-02

NOTE:
HMW PAH = High molecular weight polynuclear aromatic hydrocarbon
LMW PAH = Low molecular weight polynuclear aromatic hydrocarbon
mg/kg = Milligram per kilogram
UCL = Upper confidence level

Table 6
Uptake Models Relating Concentrations in Soil to Concentrations in Soil Invertebrates

Chemical	Food Item (Worm) Uptake		
	Uptake Model[A, B, C]	BAF/Equation (mg/kg dry wt. to mg/kg dry wt.)	Source
Metals			
Aluminum	Uptake Factor	1.18E-01	90% UF, Sample et al 1998a
Antimony	Uptake Factor	1.00E+00	Default
Arsenic	Log Linear	ln(dry worm conc, mg/kg) = (-1.421+0.706*ln(soil conc))	Sample et al. 1998a
Barium	Uptake Factor	1.60E-01	90% UF, Sample et al 1998a
Beryllium	Uptake Factor	1.18E+00	90% UF, Sample et al 1998a
Cadmium	Log Linear	ln(dry worm conc, mg/kg) = (2.114+0.795*ln(soil conc))	Sample et al. 1998a
Calcium	Uptake Factor	1.00E+00	Default
Chromium	Log Linear	ln(dry worm conc, mg/kg) = (2.481+-0.067*ln(soil conc))	Sample et al. 1998a
Cobalt	Uptake Factor	2.91E-01	90% UF, Sample et al 1998a
Copper	Log Linear	ln(dry worm conc, mg/kg) = (1.675+0.264*ln(soil conc))	Sample et al. 1998a
Iron	Uptake Factor	7.80E-02	90% UF, Sample et al 1998a
Lead	Log Linear	ln(dry worm conc, mg/kg) = (-0.218+0.807*ln(soil conc))	Sample et al. 1998a
Magnesium	Uptake Factor	5.30E-01	90% UF, Sample et al 1998a
Manganese	Log Linear	ln(dry worm conc, mg/kg) = (-0.809+0.682*ln(soil conc))	Default
Mercury	Log Linear	ln(dry worm conc, mg/kg) = (-0.684+0.118*ln(soil conc))	Sample et al. 1998a
Nickel	Log Linear	ln(dry worm conc, mg/kg) = (3.677-0.26*ln(soil conc))	Sample et al. 1998a
Potassium	Uptake Factor	1.00E+00	Default
Selenium	Log Linear	ln(dry worm conc, mg/kg) = (-0.075+0.733*ln(soil conc))	Sample et al. 1998a
Silver	Uptake Factor	1.53E+01	90% UF, Sample et al 1998a
Sodium	Uptake Factor	1.00E+00	Default
Thallium	Uptake Factor	1.00E+00	Default
Vanadium	Uptake Factor	8.80E-01	90% UF, Sample et al 1998a
Zinc	Log Linear	ln(dry worm conc, mg/kg) = (4.449+0.328*ln(soil conc))	Sample et al. 1998a
PAHs			
2-Methylnaphthalene	Uptake Factor	2.00E-01	Beyer and Stafford 1993
Acenaphthene	Uptake Factor	3.00E-01	Beyer and Stafford 1993
Acenaphthylene	Uptake Factor	2.20E-01	Beyer and Stafford 1993
Anthracene	Uptake Factor	3.20E-01	Beyer and Stafford 1993
Benzo(a)Anthracene	Uptake Factor	2.70E-01	Beyer and Stafford 1993
Benzo(a)Pyrene	Uptake Factor	3.40E-01	Beyer and Stafford 1993
Benzo(b)Fluoranthene	Uptake Factor	2.10E-01	Beyer and Stafford 1993
Benzo(g,h,i)Perylene	Uptake Factor	1.50E-01	Beyer and Stafford 1993
Benzo(k)Fluoranthene	Uptake Factor	2.10E-01	Beyer and Stafford 1993
Chrysene	Uptake Factor	4.40E-01	Beyer and Stafford 1993
Dibenzo(a,h)Anthracene	Uptake Factor	4.90E-01	Beyer and Stafford 1993
Fluoranthene	Uptake Factor	3.70E-01	Beyer and Stafford 1993
Fluorene	Uptake Factor	2.00E-01	Beyer and Stafford 1993
Indeno(1,2,3-Cd)Pyrene	Uptake Factor	4.10E-01	Beyer and Stafford 1993
Naphthalene	Uptake Factor	2.10E-01	Beyer and Stafford 1993
Phenanthrene	Uptake Factor	2.80E-01	Beyer and Stafford 1993
Pyrene	Uptake Factor	3.90E-01	Beyer and Stafford 1993
Total LMW PAHs	NA	--	--
Total HMW PAHs	NA	--	--
SVOCs			
Acetophenone	Uptake Factor	1.00E+00	Default
Benzaldehyde	Uptake Factor	1.00E+00	Default
Bis(2-ethylhexyl)phthalate	Uptake Factor	1.00E+00	Default
Carbazole	Uptake Factor	1.00E+00	Default
VOCs			
2-Butanone	Uptake Factor	1.00E+00	Default
Isopropylbenzene	NA	--	--
Trichlorofluoromethane	Uptake Factor	1.00E+00	Default
Xylenes (m & p)	Uptake Factor	1.00E+00	Default
Xylenes (o)	Uptake Factor	1.00E+00	Default

A - The default uptake factor for chemicals were no information was available was assumed to be 1.
B - Equation types:
Uptake Factor: [ConcBio] = m x [ConcSoil]
Log linear: [ConcBio] = 10b*[ConcSoil]m
C - Uptake factor derived using
ln(earthworm) = B0 + B1(ln(soil concentration))
B0 = Constituent-specific intercept based on tissue type
B1 = Constituent-specific slope based on tissue type
Data for B0 and B1 are presented in Sample, et. al 1998a, Table 12, pg. 33.
NOTE:
mg/kg = Milligram per kilogram
mg/kg dry wt = Milligram per kilogram of dry weight
NA = Uptake Model not available

Table 7
Wildlife Exposure Factors for the Ecological Risk Assessment at AOC-4

Exposure Parameter	Value	Units	Notes
AMERICAN ROBIN			
Body Weight	0.077	kg	Value from Dunning (1984)
Food Ingestion Rate	0.22	kg dry wt./kg-day	EPA 1993, converted assuming 75% prey moisture (CHPPM 2004)
Food Ingestion Rate	0.89	kg wet wt./kg-day	EPA 1993
Incidental Soil Ingestion Rate	10.50%	% of total mass of diet	Value base on woodcock, Sample and Suter, 1994
Water Ingestion Rate	0.14	L/kg-day	EPA 1993
NORTHERN SHORT-TAILED SHREW			
Body Weight	0.015	kg	Values from Sample et al. (1996)
Food Ingestion Rate	0.16	kg dry wt./kg-day	EPA 1993, converted assuming 75% prey moisture (CHPPM 2004)
Food Ingestion Rate	0.62	kg wet wt./kg-day	EPA 1993
Incidental Soil Ingestion Rate	13.00%	% of total mass of diet	Sample and Suter, 1994
Water Ingestion Rate	0.22	L/kg-day	EPA 1993

NOTE:
CHPPM = U.S. Army Center for Health Promotion and Preventative Medicine
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
L/kg-day = Liter of water per kilogram of body weight per day
USEPA = U.S. Environmental Protection Agency

Table 8
Soil Toxicity Reference Values for Plants and Soil Invertebrates

Chemical	Plant Toxicity Reference Value (mg/kg dry wt)	Toxicity Reference Value Source and Notes	Earthworm Toxicity Reference Value (mg/kg dry wt)	Toxicity Reference Value Source and Notes
Metals				
Aluminum	5.00E+01	Efroymson et al. 1997a	NA	---
Antimony	5.00E+00	Efroymson et al. 1997a	7.80E+01	EPA 2005h
Arsenic	1.80E+01	EPA 2005b	6.00E+01	Efroymson et al. 1997b
Barium	5.00E+02	Efroymson et al. 1997a	3.30E+02	EPA 2005e
Beryllium	1.00E+01	Efroymson et al. 1997a	4.00E+01	EPA 2005f
Cadmium	3.20E+01	EPA 2005b	1.40E+02	EPA 2005b
Calcium	NA	---	NA	---
Chromium	1.00E+00	Efroymson et al. 1997a	4.00E-01	Efroymson et al. 1997b
Cobalt	1.30E+01	EPA 2005g	NA	---
Copper	7.00E+01	EPA 2007b	8.00E+01	EPA 2007b
Iron	NA	---	NA	---
Lead	1.20E+02	EPA 2005c	1.70E+03	EPA 2005c
Magnesium	NA	---	NA	---
Manganese	2.20E+02	EPA 2007c	4.50E+02	EPA 2007c
Mercury	3.00E-01	Efroymson et al. 1997a	1.00E-01	Efroymson et al. 1997b
Nickel	3.80E+01	EPA 2007d	2.80E+02	EPA 2007e
Potassium	NA	---	NA	---
Selenium	5.20E-01	EPA 2007g	4.10E+00	EPA 2007g
Silver	5.60E+02	EPA 2006	NA	---
Sodium	NA	---	NA	---
Thallium	1.00E+00	Efroymson et al. 1997a	NA	---
Vanadium	2.00E+00	Efroymson et al. 1997a	NA	---
Zinc	1.60E+02	EPA 2007e	1.20E+02	EPA 2007e
Polynuclear Aromatic Hydrocarbons				
Total LMW PAHs	2.00E+01	Efroymson et al. 1997a, value for acenaphthene	2.90E+01	EPA 2007f
Total HMW PAHs	2.00E+01	Efroymson et al. 1997a, value for acenaphthene	1.80E+01	EPA 2007f
Semivolatile Organic Compounds				
Acetophenone	NA	---	NA	---
Benzaldehyde	NA	---	NA	---
Bis(2-ethylhexyl)phthalate	1.00E+02	Efroymson et al. 1997a, value for diethyl phthalate	2.00E+02	Efroymson et al. 1997b, value for dimethyl phthalate
Carbazole	NA	---	NA	---
Volatile Organic Compounds				
2-Butanone	NA	---	NA	---
Isopropylbenzene	NA	---	NA	---
Trichloroflouromethane	NA	---	NA	---
Xylenes (m & p)	NA	---	NA	---
Xylenes (o)	NA	---	NA	---

NOTE:
EPA = U.S. Environmental Protection Agency
HMW PAH = High molecular weight polynuclear aromatic hydrocarbon
LMW PAH = Low molecular weight polynuclear aromatic hydrocarbon
mg/kg dry wt = Milligram per kilogram of dry weight
NA = Toxicity reference value not available

Table 9
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	EPA 2005h	1.28E+01	Sample et al. 1996
Arsenic	2.24E+00	EPA 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	EPA 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	EPA 2005g	2.67E+01	Derived from Data in EPA 2005g
Copper	4.05E+00	EPA 2007b	6.17E+01	Sample et al. 1996
Iron	NA	---	NA	---
Lead	1.63E+00	EPA 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	EPA 2006	6.05E+01	Derived from Data in USEPA 2006
Sodium	NA	---	NA	---
Thallium	3.50E-01	Derived	NA	---
Vanadium	3.44E-01	EPA 2005d	6.88E-01	Hill 1979 (study from Eco-SSL used to derive NOAEL)
Zinc	6.61E+01	EPA 2007e	1.31E+02	Sample et al. 1996
Polynuclear Aromatic Hydrocarbons				
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
Semivolatile Organic Compounds				
Acetophenone	NA	---	NA	---
Benzaldehyde	NA	---	NA	---
Bis(2-ethylhexyl)phthalate	1.10E+00	Sample et al. 1996	NA	---
Carbazole	NA	---	NA	---
Volatile Organic Compounds				
2-Butanone	NA	---	NA	---
Isopropylbenzene	NA	---	NA	---
Trichloroflouromethane	NA	---	NA	---
Xylenes (m & p)	NA	---	NA	---
Xylenes (o)	NA	---	NA	---

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

Table 10
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	EPA 2005h	1.25E+00	Sample et al. 1996
Arsenic	1.04E+00	EPA 2005a	1.26E+00	Sample et al. 1996
Barium	5.18E+01	EPA 2005e	4.36E+02	Derived from Data in EPA 2005e
Beryllium	5.32E-01	EPA 2005f	NA	---
Cadmium	7.70E-01	EPA 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	EPA 2005g	1.18E+02	Derived from Data in EPA 2005g
Copper	5.60E+00	EPA 2007b	1.54E+01	Sample et al. 1996
Iron	NA	---	NA	---
Lead	4.70E+00	EPA 2005c	8.00E+01	Sample et al. 1996
Magnesium	NA	---	NA	---
Manganese	5.15E+01	EPA 2007c	2.84E+02	Sample et al. 1996
Mercury	1.32E+01	Sample et al. 1996	NA	---
Nickel	1.70E+00	EPA 2007d	8.00E+01	Sample et al. 1996
Potassium	NA	---	NA	---
Selenium	1.43E-01	EPA 2007g	3.30E-01	Sample et al. 1996
Silver	6.02E+00	EPA 2006	1.16E+02	Derived from Data in EPA 2006
Sodium	NA	---	NA	---
Thallium	7.40E-03	Sample et al. 1996	7.40E-02	Sample et al. 1996
Vanadium	4.16E+00	EPA 2005d	8.31E+00	Sanchez et al. 1991 (study from Eco-SSL used to derive NOAEL)
Zinc	7.54E+01	EPA 2007f	3.20E+02	Sample et al. 1996
Polynuclear Aromatic Hydrocarbons				
Total LMW PAHs	6.56E+01	EPA 2007f	4.34E+02	Derived from data in EPA 2007f
Total HMW PAHs	6.15E-01	EPA 2007f	3.07E+00	Derived from data in EPA 2007f
Semivolatile Organic Compounds				
Acetophenone	NA	---	NA	---
Benzaldehyde	NA	---	NA	---
Bis(2-ethylhexyl)phthalate	1.83E+01	Sample et al. 1996	1.83E+02	Sample et al. 1996
Carbazole	NA	---	NA	---
Volatile Organic Compounds				
2-Butanone	1.77E+03	Sample et al. 1996	4.57E+03	Sample et al. 1996
Isopropylbenzene	NA	---	NA	---
Trichloroflouromethane	NA	---	NA	---
Xylenes (m & p)	NA	---	NA	---
Xylenes (o)	NA	---	NA	---

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

Table 11
Comparison of Exposure Point Concentrations (EPCs) in Soil to Plant Toxicity Reference Values for AOC-4

Chemical	Plant Toxicity Reference Value (mg/kg dry wt)	Terrestrial Plants (Surface Soil)			
		Maximum EPC (mg/kg dry wt)	Hazard Quotient for Maximum EPC	95% UCL Mean EPC (mg/kg dry wt)	Hazard Quotient for 95% UCL Mean EPC
Metals					
Barium	5.00E+02	8.09E+02	**1.62E+00**	5.32E+02	**1.06E+00**
Cadmium	3.20E+01	9.00E-01	2.81E-02	9.00E-01	2.81E-02
Chromium	1.00E+00	1.76E+01	**1.76E+01**	1.76E+01	**1.76E+01**
Copper	7.00E+01	3.98E+01	5.69E-01	3.98E+01	5.69E-01
Lead	1.20E+02	4.30E+01	3.58E-01	3.98E+01	3.32E-01
Manganese	2.20E+02	2.59E+02	**1.18E+00**	1.85E+02	8.39E-01
Mercury	3.00E-01	1.50E+00	**5.00E+00**	1.18E+00	**3.92E+00**
Vanadium	2.00E+00	2.13E+01	**1.07E+01**	1.83E+01	**9.14E+00**
Zinc	1.60E+02	5.60E+02	**3.50E+00**	4.33E+02	**2.71E+00**
Polynuclear Aromatic Hydrocarbons					
Total HMW PAHs	2.00E+01	5.87E+00	2.93E-01	4.34E+00	2.17E-01
SVOCs					
Acetophenone	NA	6.20E-02	--	6.20E-02	--
Benzaldehyde	NA	6.60E-02	--	6.60E-02	--
Bis(2-ethylhexyl)phthalate	1.00E+02	2.20E-01	2.20E-03	2.20E-01	2.20E-03
Carbazole	NA	1.90E-02	--	1.90E-02	--
VOCs					
2-Butanone	NA	1.40E-02	--	1.40E-02	--
Isopropylbenzene	NA	3.30E-04	--	3.30E-04	--
Trichloroflouromethane	NA	5.00E-04	--	4.40E-04	--
Xylenes (m & p)	NA	3.50E-02	--	3.50E-02	--
Xylenes (o)	NA	1.20E-02	--	1.20E-02	--

NOTE:
EPC = Exposure point concentrations
HMW PAH = High molecular weight polynuclear aromatic hydrocarbon
mg/kg dry wt = Milligram per kilogram of dry weight
UCL = Upper confidence level

Table 12
Comparison of Exposure Point Concentrations (EPCs) in Soil to Soil Invertebrate Toxicity Reference Values for AOC-4

Chemical	Invertebrate Toxicity Reference Value (mg/kg dry wt)	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
Metals					
Barium	3.30E+02	8.09E+02	**2.45E+00**	5.32E+02	**1.61E+00**
Cadmium	1.40E+02	9.00E-01	6.43E-03	9.00E-01	6.43E-03
Chromium	4.00E-01	1.76E+01	**4.40E+01**	1.76E+01	**4.40E+01**
Copper	8.00E+01	3.98E+01	4.98E-01	3.98E+01	4.98E-01
Lead	1.70E+03	4.30E+01	2.53E-02	3.98E+01	2.34E-02
Manganese	4.50E+02	2.59E+02	5.76E-01	1.85E+02	4.10E-01
Mercury	1.00E-01	1.50E+00	**1.50E+01**	1.18E+00	**1.18E+01**
Vanadium	NA	2.13E+01	--	1.83E+01	--
Zinc	1.20E+02	5.60E+02	**4.67E+00**	4.33E+02	**3.61E+00**
Polynuclear Aromatic Hydrocarbons					
Total HMW PAHs	1.80E+01	5.87E+00	3.26E-01	4.34E+00	2.41E-01
Semivolatile Organic Compounds					
Acetophenone	NA	6.20E-02	--	6.20E-02	--
Benzaldehyde	NA	6.60E-02	--	6.60E-02	--
Bis(2-ethylhexyl)phthalate	2.00E+02	2.20E-01	1.10E-03	2.20E-01	1.10E-03
Carbazole	NA	1.90E-02	--	1.90E-02	--
Volatile Organic Compounds					
2-Butanone	NA	1.40E-02	--	1.40E-02	--
Isopropylbenzene	NA	3.30E-04	--	3.30E-04	--
Trichloroflouromethane	NA	5.00E-04	--	4.40E-04	--
Xylenes (m & p)	NA	3.50E-02	--	3.50E-02	--
Xylenes (o)	NA	1.20E-02	--	1.20E-02	--

NOTE:
EPC = Exposure point concentrations
HMW PAH = High molecular weight polynuclear aromatic hydrocarbon
mg/kg dry wt = Milligram per kilogram of dry weight
NA = Reference value not available
UCL = Upper confidence level

Table 13
Maximum Modeled Doses to Birds Compared to Avian Toxicity Reference Values for AOC-4

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	Insectivorous Birds	Insectivorous Birds
Metals				
Barium	2.08E+01	4.17E+01	**2.29E+00**	**1.14E+00**
Cadmium	1.45E+00	2.00E+01	**1.18E+00**	8.58E-02
Chromium	2.66E+00	5.00E+00	9.80E-01	5.21E-01
Copper	4.05E+00	6.17E+01	**1.01E+00**	6.60E-02
Lead	1.63E+00	1.13E+01	**2.90E+00**	4.18E-01
Manganese	9.97E+02	NA	1.05E-02	--
Mercury	4.50E-01	9.00E-01	3.40E-01	1.70E-01
Vanadium	3.44E-01	6.88E-01	**1.36E+01**	**6.79E+00**
Zinc	6.61E+01	1.31E+02	**2.49E+00**	**1.26E+00**
Polynuclear Aromatic Hydrocarbons				
Total HMW PAHs	3.37E+00	3.37E+01	1.28E-01	1.28E-02
Semivolatile Organic Compounds				
Acetophenone	NA	NA	--	--
Benzaldehyde	NA	NA	--	--
Bis(2-ethylhexyl)phthalate	1.10E+00	NA	4.92E-02	--
Carbazole	NA	NA	--	--
Volatile Organic Compounds				
2-Butanone	NA	NA	--	--
Isopropylbenzene	NA	NA	--	--
Trichloroflouromethane	NA	NA	--	--
Xylenes (m & p)	NA	NA	--	--
Xylenes (o)	NA	NA	--	--

NOTE:
HQ = Hazard Quotient
HMW PAH = High molecular weight polynuclear aromatic hydrocarbon
LOAEL = Low Observed Adverse Effect Levels
mg/kg-bw day = Milligram of food per kilogram of body weight per day
NOAEL = No Observed Adverse Effect Levels
TRV = Toxicity reference value

Table 14
95% UCL Mean Modeled Doses to Birds Compared to Avian Toxicity Reference Values for AOC-4

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	Insectivorous Birds	Insectivorous Birds
Metals				
Barium	2.08E+01	4.17E+01	**1.51E+00**	7.52E-01
Cadmium	1.45E+00	2.00E+01	**1.18E+00**	8.58E-02
Chromium	2.66E+00	5.00E+00	9.80E-01	5.21E-01
Copper	4.05E+00	6.17E+01	**1.01E+00**	6.60E-02
Lead	1.63E+00	1.13E+01	**2.72E+00**	3.92E-01
Manganese	9.97E+02	NA	7.82E-03	--
Mercury	4.50E-01	9.00E-01	3.15E-01	1.58E-01
Vanadium	3.44E-01	6.88E-01	**1.16E+01**	**5.82E+00**
Zinc	6.61E+01	1.31E+02	**2.26E+00**	**1.14E+00**
Polynuclear Aromatic Hydrocarbons				
Total HMW PAHs	3.37E+00	3.37E+01	1.15E-01	1.15E-02
Semivolatile Organic Compounds				
Acetophenone	NA	NA	--	--
Benzaldehyde	NA	NA	--	--
Bis(2-ethylhexyl)phthalate	1.10E+00	NA	4.92E-02	--
Carbazole	NA	NA	--	--
Volatile Organic Compounds				
2-Butanone	NA	NA	--	--
Isopropylbenzene	NA	NA	--	--
Trichloroflouromethane	NA	NA	--	--
Xylenes (m & p)	NA	NA	--	--
Xylenes (o)	NA	NA	--	--

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

Table 15
Maximum Modeled Doses to Mammals Compared to Mammalian Toxicity Reference Values
for AOC-4

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	Insectivorous Mammals	Insectivorous Mammals
Metals				
Barium	5.18E+01	4.36E+02	7.02E-01	8.34E-02
Cadmium	7.70E-01	1.00E+01	**1.56E+00**	1.20E-01
Chromium	2.40E+00	1.31E+01	7.85E-01	1.43E-01
Copper	5.60E+00	1.54E+01	5.34E-01	1.94E-01
Lead	4.70E+00	8.00E+01	7.36E-01	4.32E-02
Manganese	5.15E+01	2.84E+02	1.61E-01	2.91E-02
Mercury	1.32E+01	NA	8.51E-03	--
Vanadium	4.16E+00	8.31E+00	8.02E-01	4.01E-01
Zinc	7.54E+01	3.20E+02	**1.55E+00**	3.65E-01
Polynuclear Aromatic Hydrocarbons				
Total HMW PAHs	6.15E-01	3.07E+00	5.18E-01	1.04E-01
Semivolatile Organic Compounds				
Acetophenone	1.60E+02	NA	6.79E-05	--
Benzaldehyde	NA	NA	--	--
Bis(2-ethylhexyl)phthalate	1.83E+01	1.83E+02	2.11E-03	2.11E-04
Carbazole	NA	NA	--	--
Volatile Organic Compounds				
2-Butanone	1.77E+03	4.57E+03	1.38E-06	5.36E-07
Isopropylbenzene	NA	NA	--	--
Trichloroflouromethane	NA	NA	--	--
Xylenes (m & p)	NA	NA	--	--
Xylenes (o)	NA	NA	--	--

NOTE:
HMW PAH = High molecular weight polynuclear aromatic hydrocarbon
HQ = Hazard Quotient
LOAEL = Low Observed Adverse Effect Levels
mg/kg-bw day = Milligram of food per kilogram of body weight per day
NOAEL = No Observed Adverse Effect Levels
TRV = Toxicity Reference Value

Table 16
95% UCL Mean Modeled Doses to Mammals Compared to Mammalian Toxicity Reference Values for AOC-4

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	Insectivorous Mammals	Insectivorous Mammals
Metals				
Barium	5.18E+01	4.36E+02	4.61E-01	5.48E-02
Cadmium	7.70E-01	1.00E+01	**1.56E+00**	1.20E-01
Chromium	2.40E+00	1.31E+01	7.85E-01	1.43E-01
Copper	5.60E+00	1.54E+01	5.34E-01	1.94E-01
Lead	4.70E+00	8.00E+01	6.90E-01	4.05E-02
Manganese	5.15E+01	2.84E+02	1.19E-01	2.16E-02
Mercury	1.32E+01	NA	7.83E-03	--
Vanadium	4.16E+00	8.31E+00	6.88E-01	3.44E-01
Zinc	7.54E+01	3.20E+02	**1.40E+00**	3.31E-01
Polynuclear Aromatic Hydrocarbons				
Total HMW PAHs	6.15E-01	3.07E+00	4.66E-01	9.34E-02
Semivolatile Organic Compounds				
Acetophenone	1.60E+02	NA	6.79E-05	--
Benzaldehyde	NA	NA	--	--
Bis(2-ethylhexyl)phthalate	1.83E+01	1.83E+02	2.11E-03	2.11E-04
Carbazole	NA	NA	--	--
Volatile Organic Compounds				
2-Butanone	1.77E+03	4.57E+03		
Isopropylbenzene	NA	NA		
Trichloroflouromethane	NA	NA		
Xylenes (m & p)	NA	NA		
Xylenes (o)	NA	NA		

NOTE:
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
HMW PAH = High molecular weight polynuclear aromatic hydrocarbon

Table 17

Frequency of Detection and Exposure Point Concentrations in Comparison to Background Data for AOC-4

Analyte	Surface Soil				
	Frequency of Detections	Maximum Detected Concentration (mg/kg)	95% UCL Mean (mg/kg)	Background 95% UPL (mg/kg)	Exceeds Background 95% UPL (mg/kg)
Metals					
Barium	7/7	8.09E+02	5.32E+02	1.19E+03	No
Cadmium	**2/7**	**9.00E-01**	**9.00E-01**	**6.80E-01**	**Yes**
Chromium	7/7	1.76E+01	1.76E+01	6.15E+01	No
Copper	**7/7**	**3.98E+01**	**3.98E+01**	**2.84E+01**	**Yes**
Lead	7/7	4.30E+01	3.98E+01	5.02E+01	No
Manganese	7/7	2.59E+02	1.85E+02	3.27E+02	No
Mercury	**7/7**	**1.50E+00**	**1.18E+00**	**2.10E-02**	**Yes**
Vanadium	**7/7**	**2.13E+01**	**1.83E+01**	**1.93E+01**	**Yes**
Zinc	7/7	5.60E+02	4.33E+02	3.63E+03	No

NOTE:
mg/kg = Milligram per kilogram
UCL = Upper confidence level
UPL = Upper prediction limit

APPENDIX A

AOC-4 Data Table

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TABLE A-1
SURFACE SOIL DATA

	Sample Name:	MW-17-0.0-0.5	SO4-01-0.0-0.5	SO4-01-0.0-0.5 Dup	SO4-02-0.0-0.5	SO4-03-0.0-0.5	SO4-04-0.0-0.5	SO4-04-0.0-0.5 Dup	SO4-05-0.0-0.5
	Parent Sample Name:			SO4-01-0.0-0.5				SO4-04-0.0-0.5	
	Sample Depth:	0.0-0.5	0.0-0.5	0.0-0.5	0.0-0.5	0.0-0.5	0.0-0.5	0.0-0.5	0.0-0.5
	Date Sampled:	9/10/2013	9/10/2013	9/10/2013	9/10/2013	9/10/2013	9/10/2013	9/10/2013	9/10/2013
Chemical Name	**Unit**								
INORGANICS									
Aluminum	mg/kg	2430	13300	17000	2000	2210	3930	3920	3450
Antimony	mg/kg	0.83 UJ	1 UJ	1.3 UJ	1.2 UJ	1.1 UJ	1.1 UJ	0.79 UJ	0.93 UJ
Arsenic	mg/kg	2	5.7	5.4	0.94	1.2	1.4	2	1.6 J
Barium	mg/kg	325	727	809	81.4	113	360	352	174
Beryllium	mg/kg	0.41 U	0.51 U	0.66 U	0.58 U	0.55 U	0.54 U	0.4 U	0.46 U
Cadmium	mg/kg	0.41 U	0.71	0.9	0.58 U	0.55 U	0.54 U	0.4 U	0.46 U
Calcium	mg/kg	180000	199000	184000	21700	264000	48300	56200	87700
Chromium	mg/kg	4.4 J	16.2 J	14.3 J	2	4.3	4.9 J	17.6 J	4 J
Cobalt	mg/kg	0.89	3.6	3.8	0.72	1.5	1.1	1.7	0.85 J
Copper	mg/kg	5.1	37.9	23.8	2.8	5.8	10.4	39.8	5 J
Iron	mg/kg	3770	11500	13000	2250 J	2620 J	4940	5160	7060
Lead	mg/kg	13.1	31.1	43	12.9	11.6	8.6	7.9	12.2
Magnesium	mg/kg	2470	5660	6010	1160	2370	1880	1860	1820
Manganese	mg/kg	108 J	259 J	250 J	65	137	89.7 J	97.8 J	106 J
Mercury	mg/kg	0.47	1.5	0.97	0.24	0.43	0.27	0.2	0.13
Nickel	mg/kg	2.6	18.5	11.1	1.7	2.3	3.1	13	2.6 J
Potassium	mg/kg	852	3340	4000	605	804	753	854	840
Selenium	mg/kg	2.1 U	2.5 U	3.3 U	2.9 U	2.7 U	2.7 U	2 U	2.3 U
Silver	mg/kg	0.41 U	0.51 U	0.66 U	0.58 U	0.55 U	0.54 U	0.4 U	0.46 U
Sodium	mg/kg	4230	1280	1460	449 U	2380	549	625	979
Thallium	mg/kg	0.41 U	0.51 U	0.66 U	0.58 U	0.55 U	0.54 U	0.4 U	0.46 U
Vanadium	mg/kg	5.5 J	17.5 J	21.3 J	3.4	6.5	6.8 J	4.7 J	5.1 J
Zinc	mg/kg	121	560	478	99.6	231	135	105	71.8
POLYNUCLEAR AROMATIC HYDROCARBONS									
2-Methylnaphthalene	ug/kg	36 U	46 U	22 U	7.7 U	57 U	73 U	74 U	72 U
Acenaphthene	ug/kg	21 LJ	46 U	22 U	5.1 LJ	57 U	73 U	32 LJ	72 U
Acenaphthylene	ug/kg	36 U	46 U	13 LJ	7.3 LJ	28 LJ	61 LJ	74 U	72 U
Anthracene	ug/kg	63	46 U	13 LJ	16	36 LJ	65 LJ	63 LJ	72 U
Benzo(a)anthracene	ug/kg	590	81	54	63	100	290	490	100
Benzo(a)pyrene	ug/kg	500	99	71	53	160	360	450	82
Benzo(b)fluoranthene	ug/kg	820	210	150	100	260	570	800	150
Benzo(g,h,i)perylene	ug/kg	210	66	52	22	150	200	210	34 LJ
Benzo(k)fluoranthene	ug/kg	220	55	43	28	72	160	270	43 LJ
Chrysene	ug/kg	600	120	90	70	190	290	520	100
Dibenz(a,h)anthracene	ug/kg	76	22 LJ	16 LJ	10	53 LJ	64 LJ	75	72 U
Fluoranthene	ug/kg	1400	180	98	160	250	430	950	210
Fluorene	ug/kg	15 LJ	46 U	22 U	3.7 LJ	57 U	73 U	74 U	72 U
Indeno(1,2,3-cd)pyrene	ug/kg	350	110	82	50	150	320	350	70 LJ
Naphthalene	ug/kg	36 U	46 U	22 U	7.7 U	57 U	73 U	74 U	72 U
Phenanthrene	ug/kg	350	43 LJ	26	49	89	170	230	92
Pyrene	ug/kg	1100	140	90	120	190	380	690	150
SEMIVOLATILE ORGANIC COMPOUNDS									
1,1-Biphenyl	ug/kg	920 U	1200 U	1100 U	400 U	980 U	940 U	950 U	190 U
1,2,4,5-Tetrachlorobenzene	ug/kg	920 U	1200 U	1100 U	400 U	980 U	940 U	950 U	190 U
2,3,4,6-Tetrachlorophenol	ug/kg	920 U	1200 U	1100 U	400 U	980 U	940 U	950 U	190 U
2,4,5-Trichlorophenol	ug/kg	920 U	1200 U	1100 U	400 U	980 U	940 U	950 U	190 U
2,4,6-Trichlorophenol	ug/kg	920 U	1200 U	1100 U	400 U	980 U	940 U	950 U	190 U
2,4-Dichlorophenol	ug/kg	920 U	1200 U	1100 U	400 U	980 U	940 U	950 U	190 U
2,4-Dimethylphenol	ug/kg	920 U	1200 U	1100 U	400 U	980 U	940 U	950 U	190 U
2,4-Dinitrophenol	ug/kg	1800 U	2300 U	2200 U	770 U	1900 U	1800 U	1800 U	360 U

	Sample Name:	MW-17-0.0-0.5	SO4-01-0.0-0.5	SO4-01-0.0-0.5 Dup	SO4-02-0.0-0.5	SO4-03-0.0-0.5	SO4-04-0.0-0.5	SO4-04-0.0-0.5 Dup	SO4-05-0.0-0.5
	Parent Sample Name:			SO4-01-0.0-0.5				SO4-04-0.0-0.5	
	Sample Depth:	0.0-0.5	0.0-0.5	0.0-0.5	0.0-0.5	0.0-0.5	0.0-0.5	0.0-0.5	0.0-0.5
	Date Sampled:	9/10/2013	9/10/2013	9/10/2013	9/10/2013	9/10/2013	9/10/2013	9/10/2013	9/10/2013
Chemical Name	**Unit**								
SEMIVOLATILE ORGANIC COMPOUNDS									
2,4-Dinitrotoluene	ug/kg	920 U	1200 U	1100 U	400 U	980 U	940 U	950 U	190 U
2,6-Dinitrotoluene	ug/kg	920 U	1200 U	1100 U	400 U	980 U	940 U	950 U	190 U
2-Chloronaphthalene	ug/kg	920 U	1200 U	1100 U	400 U	980 U	940 U	950 U	190 U
2-Chlorophenol	ug/kg	920 U	1200 U	1100 U	400 U	980 U	940 U	950 U	190 U
2-Methylphenol	ug/kg	920 U	1200 U	1100 U	400 U	980 U	940 U	950 U	190 U
2-Nitroaniline	ug/kg	1800 U	2300 U	2200 U	770 U	1900 U	1800 U	1800 U	360 U
2-Nitrophenol	ug/kg	920 U	1200 U	1100 U	400 U	980 U	940 U	950 U	190 U
3,3-Dichlorobenzidine	ug/kg	920 U	1200 U	1100 U	400 U	980 U	940 U	950 U	190 U
3-Nitroaniline	ug/kg	1800 U	2300 U	2200 U	770 U	1900 U	1800 U	1800 U	360 U
4,6-Dinitro-2-methylphenol	ug/kg	1800 U	2300 U	2200 U	770 U	1900 U	1800 U	1800 U	360 U
4-Bromophenyl phenyl ether	ug/kg	920 U	1200 U	1100 U	400 U	980 U	940 U	950 U	190 U
4-Chloro-3-methylphenol	ug/kg	920 U	1200 U	1100 U	400 U	980 U	940 U	950 U	190 U
4-Chloroaniline	ug/kg	920 U	1200 U	1100 U	400 U	980 U	940 U	950 U	190 U
4-Chlorophenyl phenyl ether	ug/kg	920 U	1200 U	1100 U	400 U	980 U	940 U	950 U	190 U
4-Methylphenol	ug/kg	920 U	1200 U	1100 U	400 U	980 U	940 U	950 U	190 U
4-Nitroaniline	ug/kg	1800 U	2300 U	2200 U	770 U	1900 U	1800 U	1800 U	360 U
4-Nitrophenol	ug/kg	1800 U	2300 U	2200 U	770 U	1900 U	1800 U	1800 U	360 U
Acetophenone	ug/kg	920 U	1200 U	1100 U	400 U	980 U	940 U	950 U	62 LJ
Atrazine	ug/kg	920 U	1200 U	1100 U	400 U	980 U	940 U	950 U	190 U
Benzaldehyde	ug/kg	920 U	1200 U	1100 U	400 U	980 U	940 U	950 U	66 LJ
Bis(2-chloroethoxy)methane	ug/kg	920 U	1200 U	1100 U	400 U	980 U	940 U	950 U	190 U
Bis(2-chloroethyl)ether	ug/kg	920 U	1200 U	1100 U	400 U	980 U	940 U	950 U	190 U
Bis(2-chloroisopropyl) ether	ug/kg	920 U	1200 U	1100 U	400 U	980 U	940 U	950 U	190 U
Bis(2-ethylhexyl) phthalate	ug/kg	920 U	1200 U	1100 U	400 U	980 U	220 LJ	130 LJ	94 LJ
Butyl benzyl phthalate	ug/kg	920 U	1200 U	1100 U	400 U	980 U	940 U	950 U	190 U
Caprolactum	ug/kg	920 U	1200 U	1100 U	400 U	980 U	940 U	950 U	190 U
Carbazole	ug/kg	920 U	1200 U	1100 U	400 U	980 U	940 U	950 U	19 LJ
Dibenzofuran	ug/kg	920 U	1200 U	1100 U	400 U	980 U	940 U	950 U	190 U
Diethyl phthalate	ug/kg	920 U	1200 U	1100 U	400 U	980 U	940 U	950 U	190 U
Dimethyl phthalate	ug/kg	920 U	1200 U	1100 U	400 U	980 U	150 LJ	950 U	20 LJ
Di-n-butyl phthalate	ug/kg	920 U	1200 U	1100 U	400 U	980 U	940 U	950 U	190 U
Di-n-octyl phthalate	ug/kg	920 U	1200 U	1100 U	400 U	980 U	940 U	950 U	190 U
Hexachlorobenzene	ug/kg	920 U	1200 U	1100 U	400 U	980 U	940 U	950 U	190 U
Hexachlorobutadiene	ug/kg	920 U	1200 U	1100 U	400 U	980 U	940 U	950 U	190 U
Hexachlorocyclopentadiene	ug/kg	920 U	1200 U	1100 U	400 U	980 U	940 U	950 U	190 U
Hexachloroethane	ug/kg	920 U	1200 U	1100 U	400 U	980 U	940 U	950 U	190 U
Isophorone	ug/kg	920 U	1200 U	1100 U	400 U	980 U	940 U	950 U	190 U
Nitrobenzene	ug/kg	920 U	1200 U	1100 U	400 U	980 U	940 U	950 U	190 U
N-Nitrosodi-n-propylamine	ug/kg	920 U	1200 U	1100 U	400 U	980 U	940 U	950 U	190 U
N-Nitrosodiphenylamine	ug/kg	920 U	1200 U	1100 U	400 U	980 U	940 U	950 U	190 U
Pentachlorophenol	ug/kg	73 U	94 U	45 U	16 U	120 U	150 U	150 U	150 U
Phenol	ug/kg	920 U	1200 U	1100 U	400 U	980 U	940 U	950 U	33 LJ
VOLATILE ORGANIC COMPOUNDS									
1,1,1-Trichloroethane	ug/kg	5.3 U	7.9 U	8.7 U	5.1 U	4.9 U	5.9 U	5.9 U	5.6 U
1,1,2,2-Tetrachloroethane	ug/kg	5.3 U	7.9 U	8.7 U	5.1 U	4.9 U	5.9 U	5.9 U	5.6 U
1,1,2-Trichloro-1,2,2-trifluoroethane	ug/kg	5.3 U	7.9 U	8.7 U	5.1 U	4.9 U	5.9 U	5.9 U	5.6 U
1,1,2-Trichloroethane	ug/kg	5.3 U	7.9 U	8.7 U	5.1 U	4.9 U	5.9 U	5.9 U	5.6 U
1,1-Dichloroethane	ug/kg	5.3 U	7.9 U	8.7 U	5.1 U	4.9 U	5.9 U	5.9 U	5.6 U
1,1-Dichloroethene	ug/kg	5.3 U	7.9 U	8.7 U	5.1 U	4.9 U	5.9 U	5.9 U	5.6 U
1,2,3-Trichlorobenzene	ug/kg	5.3 U	R	R	5.1 U	4.9 U	5.9 U	5.9 U	5.6 U
1,2,4-Trichlorobenzene	ug/kg	5.3 U	R	R	5.1 U	4.9 U	5.9 U	5.9 U	5.6 U
1,2-Dibromo-3-chloropropane (DBCP)	ug/kg	5.3 U	R	R	5.1 U	4.9 U	5.9 U	5.9 U	5.6 U
1,2-Dibromoethane (Ethylene dibromide [EDB])	ug/kg	5.3 U	7.9 U	8.7 U	5.1 U	4.9 U	5.9 U	5.9 U	5.6 U

	Sample Name:	MW-17-0.0-0.5	SO4-01-0.0-0.5	SO4-01-0.0-0.5 Dup	SO4-02-0.0-0.5	SO4-03-0.0-0.5	SO4-04-0.0-0.5	SO4-04-0.0-0.5 Dup	SO4-05-0.0-0.5
	Parent Sample Name:			SO4-01-0.0-0.5				SO4-04-0.0-0.5	
	Sample Depth:	0.0-0.5	0.0-0.5	0.0-0.5	0.0-0.5	0.0-0.5	0.0-0.5	0.0-0.5	0.0-0.5
	Date Sampled:	9/10/2013	9/10/2013	9/10/2013	9/10/2013	9/10/2013	9/10/2013	9/10/2013	9/10/2013
Chemical Name	**Unit**								
VOLATILE ORGANIC COMPOUNDS									
1,2-Dichlorobenzene	ug/kg	5.3 U	R	R	5.1 U	4.9 U	5.9 U	5.9 U	5.6 U
1,2-Dichloroethane	ug/kg	5.3 U	7.9 U	8.7 U	5.1 U	4.9 U	5.9 U	5.9 U	5.6 U
1,2-Dichloroethene (cis)	ug/kg	5.3 U	7.9 U	8.7 U	5.1 U	4.9 U	5.9 U	5.9 U	5.6 U
1,2-Dichloroethene (trans)	ug/kg	5.3 U	7.9 U	8.7 U	5.1 U	4.9 U	5.9 U	5.9 U	5.6 U
1,2-Dichloropropane	ug/kg	5.3 U	7.9 U	8.7 U	5.1 U	4.9 U	5.9 U	5.9 U	5.6 U
1,3-Dichlorobenzene	ug/kg	5.3 U	R	R	5.1 U	4.9 U	5.9 U	5.9 U	5.6 U
1,3-Dichloropropene (cis)	ug/kg	5.3 U	7.9 U	8.7 U	5.1 U	4.9 U	5.9 U	5.9 U	5.6 U
1,3-Dichloropropene (trans)	ug/kg	5.3 U	7.9 U	8.7 U	5.1 U	4.9 U	5.9 U	5.9 U	5.6 U
1,4-Dichlorobenzene	ug/kg	5.3 U	R	R	5.1 U	4.9 U	5.9 U	5.9 U	5.6 U
1,4-Dioxane	ug/kg	110 UJv	160 UJv	170 UJv	100 UJV	97 UJV	120 UJv	120 UJv	110 UJv
2-Butanone (Methyl ethyl ketone)	ug/kg	11 U	14 LJ	17 U	10 U	9.7 U	12 U	12 U	11 U
2-Hexanone	ug/kg	11 U	16 U	17 U	10 U	9.7 U	12 U	12 U	11 U
4-Methyl-2-pentanone (Methyl isobutyl ketone [MIBK])	ug/kg	11 U	16 U	17 U	10 U	9.7 U	12 U	12 U	11 U
Acetone	ug/kg	11 U	16 U	17 U	10 U	9.7 U	12 U	12 U	11 U
Benzene	ug/kg	5.3 U	7.9 U	8.7 U	5.1 U	4.9 U	5.9 U	5.9 U	5.6 U
Bromochloromethane	ug/kg	5.3 U	7.9 U	8.7 U	5.1 U	4.9 U	5.9 U	5.9 U	5.6 U
Bromodichloromethane	ug/kg	5.3 U	7.9 U	8.7 U	5.1 U	4.9 U	5.9 U	5.9 U	5.6 U
Bromoform	ug/kg	5.3 U	R	R	5.1 U	4.9 U	5.9 U	5.9 U	5.6 U
Bromomethane (Methyl bromide)	ug/kg	5.3 U	7.9 U	8.7 U	5.1 U	4.9 U	5.9 U	5.9 U	5.6 U
Carbon disulfide	ug/kg	5.3 U	7.9 U	8.7 U	5.1 U	4.9 U	5.9 U	5.9 U	5.6 U
Carbon tetrachloride	ug/kg	5.3 U	7.9 U	8.7 U	5.1 U	4.9 U	5.9 U	5.9 U	5.6 U
Chlorobenzene	ug/kg	5.3 U	7.9 U	8.7 U	5.1 U	4.9 U	5.9 U	5.9 U	5.6 U
Chloroethane (Ethyl chloride)	ug/kg	5.3 U	7.9 U	8.7 U	5.1 U	4.9 U	5.9 U	5.9 U	5.6 U
Chloroform	ug/kg	5.3 U	7.9 U	8.7 U	5.1 U	4.9 U	5.9 U	5.9 U	5.6 U
Chloromethane (Methyl chloride)	ug/kg	5.3 U	7.9 U	8.7 U	5.1 U	4.9 U	5.9 U	5.9 U	5.6 U
Cyclohexane	ug/kg	5.3 U	7.9 U	8.7 U	5.1 U	4.9 U	5.9 U	5.9 U	5.6 U
Dibromochloromethane (Chlorodibromomethane)	ug/kg	5.3 U	7.9 U	8.7 U	5.1 U	4.9 U	5.9 U	5.9 U	5.6 U
Dichlorodifluoromethane	ug/kg	5.3 U	7.9 U	8.7 U	5.1 U	4.9 U	5.9 U	5.9 U	5.6 U
Ethylbenzene	ug/kg	5.3 U	3.7 LJ	1.6 LJ	5.1 U	4.9 U	5.9 U	5.9 U	5.6 U
Isopropylbenzene (Cumene)	ug/kg	5.3 U	0.33 LJ	8.7 U	5.1 U	4.9 U	5.9 U	5.9 U	5.6 U
m- & p-Xylenes	ug/kg	0.15 LJ	35 J	14	5.1 U	4.9 U	5.9 U	5.9 U	5.6 U
Methyl acetate	ug/kg	5.3 U	7.9 U	8.7 U	5.1 U	4.9 U	5.9 U	5.9 U	5.6 U
Methylcyclohexane	ug/kg	5.3 U	7.9 U	8.7 U	5.1 U	4.9 U	5.9 U	5.9 U	5.6 U
Methylene chloride	ug/kg	5.3 U	7.9 U	8.7 U	5.1 U	4.9 U	5.9 U	5.9 U	5.6 U
Methyl-tertiary-butyl ether (MtBE)	ug/kg	5.3 U	7.9 U	8.7 U	5.1 U	4.9 U	5.9 U	5.9 U	5.6 U
o-Xylene	ug/kg	5.3 U	12	4.2 LJ	5.1 U	4.9 U	5.9 U	5.9 U	5.6 U
Styrene	ug/kg	5.3 U	7.9 U	8.7 U	5.1 U	4.9 U	5.9 U	5.9 U	5.6 U
Tetrachloroethene (PCE)	ug/kg	5.3 U	7.9 U	8.7 U	5.1 U	4.9 U	5.9 U	5.9 U	5.6 U
Toluene	ug/kg	5.3 U	7.9 U	8.7 U	5.1 U	4.9 U	5.9 U	5.9 U	5.6 U
Trichloroethene (TCE)	ug/kg	5.3 U	1.2 LJ	8.7 U	5.1 U	4.9 U	5.9 U	5.9 U	5.6 U
Trichlorofluoromethane	ug/kg	0.25 LJ	0.5 LJ	0.48 LJ	5.1 U	4.9 U	0.27 LJ	0.18 LJ	0.23 LJ
Vinyl chloride	ug/kg	5.3 U	7.9 U	8.7 U	5.1 U	4.9 U	5.9 U	5.9 U	5.6 U

NOTE:
mg/kg = Milligram per kilogram
ug/kg = Microgram per kilogram

Qualifiers:
J = Indicates an estimated value
L = Result is biased low
R = Result is unusable
U = Not detected

APPENDIX B

Food Web Calculations

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Table B-1
Wildlife Exposure Modeling of Maximum Doses to Insectivorous Birds (American Robin) from Media for AOC-4

Exposure Parameters

Soil Ingestion Rate (kg dry wt./kg bw-day):	2.34E-02	kg/kg-day
Food Ingestion Rate (kg dry wt./kg bw-day):	2.23E-01	kg/kg-day

Chemical	Maximum Soil Concentration (mg/kg dry wt.)	Food Item (Insect/Worm) Uptake		Maximum Case Scenario Doses		
		BAF/Equation (mg/kg dry wt. to mg/kg dry wt.)	Maximum Food Item Tissue Concentration (mg/kg dry wt.)	Dose from Soil (mg/kg bw-day)	Dose from Food (mg/kg bw-day)	Total Dose (mg/kg bw-day)
Metals						
Barium	8.09E+02	1.60E-01	1.29E+02	1.89E+01	2.88E+01	4.77E+01
Cadmium	9.00E-01	ln(dry worm conc, mg/kg) = (2.114+0.795*ln(soil conc))	7.62E+00	2.10E-02	1.69E+00	1.72E+00
Chromium	1.76E+01	ln(dry worm conc, mg/kg) = (2.481+-0.067*ln(soil conc))	9.86E+00	4.11E-01	2.19E+00	2.61E+00
Copper	3.98E+01	ln(dry worm conc, mg/kg) = (1.675+0.264*ln(soil conc))	1.41E+01	9.30E-01	3.14E+00	4.07E+00
Lead	4.30E+01	ln(dry worm conc, mg/kg) = (-0.218+0.807*ln(soil conc))	1.67E+01	1.00E+00	3.72E+00	4.73E+00
Manganese	2.59E+02	ln(dry worm conc, mg/kg) = (-0.809+0.682*ln(soil conc))	1.97E+01	6.05E+00	4.38E+00	1.04E+01
Mercury	1.50E+00	ln(dry worm conc, mg/kg) = (-0.684+0.118*ln(soil conc))	5.29E-01	3.50E-02	1.18E-01	1.53E-01
Vanadium	2.13E+01	8.80E-01	1.87E+01	4.98E-01	4.17E+00	4.67E+00
Zinc	5.60E+02	ln(dry worm conc, mg/kg) = (4.449+0.328*ln(soil conc))	6.82E+02	1.31E+01	1.52E+02	1.65E+02
Polynuclear Aromatic Hydrocarbons						
Total HMW PAHs	5.87E+00	--	1.47E+00	1.06E-01	3.27E-01	4.33E-01
Semivolatile Organic Compounds						
Acetophenone	6.20E-02	1.00E+00	6.20E-02	1.45E-03	1.38E-02	1.52E-02
Benzaldehyde	6.60E-02	1.00E+00	6.60E-02	1.54E-03	1.47E-02	1.62E-02
Bis(2-ethylhexyl)phthalate	2.20E-01	1.00E+00	2.20E-01	5.14E-03	4.90E-02	5.41E-02
Carbazole	1.90E-02	1.00E+00	1.90E-02	4.44E-04	4.23E-03	4.67E-03
Volatile Organic Compounds						
2-Butanone	1.40E-02	1.00E+00	1.40E-02	3.27E-04	3.12E-03	3.44E-03
Trichloroflouromethane	5.00E-04	1.00E+00	5.00E-04	1.17E-05	1.11E-04	1.23E-04
Xylenes (m & p)	3.50E-02	1.00E+00	3.50E-02	8.18E-04	7.79E-03	8.61E-03
Xylenes (o)	1.20E-02	1.00E+00	1.20E-02	2.80E-04	2.67E-03	2.95E-03

NOTE:
BAF = Bioacculation Factor
HMW PAH = High molecular weight polynuclear aromatic hydrocarbon
kg = Kilogram
L/kg bw-day = Liters per kilogram of body weight per day
mg/kg bw-day = Milligram of food per kilogram of body weight per day
mg/kg dry wt. = Milligram per kilogram of dry weight
mg/L = Milligram per liter

Table B-2
Wildlife Exposure Modeling of 95% UCL Mean Doses to Insectivorous Birds (American Robin) from Media for AOC-4

Exposure Parameters

Soil Ingestion Rate (kg dry wt./kg bw-day):	2.34E-02	kg/kg-day
Food Ingestion Rate (kg dry wt./kg bw-day):	2.23E-01	kg/kg-day

Chemical	95% UCL Mean Soil Concentration (mg/kg dry wt.)	Food Item (Insect/Worm) Uptake		95% UCL Mean Case Scenario Doses		
		BAF/Equation (mg/kg dry wt. to mg/kg dry wt.)	95% UCL Mean Food Item Tissue Concentration (mg/kg dry wt.)	Dose from Soil (mg/kg bw-day)	Dose from Food (mg/kg bw-day)	Total Dose (mg/kg bw-day)
Metals						
Barium	5.32E+02	1.60E-01	8.50E+01	1.24E+01	1.89E+01	3.13E+01
Cadmium	9.00E-01	ln(dry worm conc, mg/kg) = (2.114+0.795*ln(soil conc))	7.62E+00	2.10E-02	1.69E+00	1.72E+00
Chromium	1.76E+01	ln(dry worm conc, mg/kg) = (2.481+-0.067*ln(soil conc))	9.86E+00	4.11E-01	2.19E+00	2.61E+00
Copper	3.98E+01	ln(dry worm conc, mg/kg) = (1.675+0.264*ln(soil conc))	1.41E+01	9.30E-01	3.14E+00	4.07E+00
Lead	3.98E+01	ln(dry worm conc, mg/kg) = (-0.218+0.807*ln(soil conc))	1.57E+01	9.31E-01	3.50E+00	4.43E+00
Manganese	1.85E+02	ln(dry worm conc, mg/kg) = (-0.809+0.682*ln(soil conc))	1.56E+01	4.31E+00	3.48E+00	7.79E+00
Mercury	1.18E+00	ln(dry worm conc, mg/kg) = (-0.684+0.118*ln(soil conc))	5.14E-01	2.75E-02	1.14E-01	1.42E-01
Vanadium	1.83E+01	8.80E-01	1.61E+01	4.27E-01	3.58E+00	4.01E+00
Zinc	4.33E+02	ln(dry worm conc, mg/kg) = (4.449+0.328*ln(soil conc))	6.27E+02	1.01E+01	1.39E+02	1.50E+02
Polynuclear Aromatic Hydrocarbons						
Total HMW PAHs	4.34E+00	--	1.32E+00	9.59E-02	2.93E-01	3.89E-01
Semivolatile Organic Compounds						
Acetophenone	6.20E-02	1.00E+00	6.20E-02	1.45E-03	1.38E-02	1.52E-02
Benzaldehyde	6.60E-02	1.00E+00	6.60E-02	1.54E-03	1.47E-02	1.62E-02
Bis(2-ethylhexyl)phthalate	2.20E-01	1.00E+00	2.20E-01	5.14E-03	4.90E-02	5.41E-02
Carbazole	1.90E-02	1.00E+00	1.90E-02	4.44E-04	4.23E-03	4.67E-03
Volatile Organic Compounds						
2-Butanone	1.40E-02	1.00E+00	1.40E-02	3.27E-04	3.12E-03	3.44E-03
Trichloroflouromethane	4.40E-04	1.00E+00	4.40E-04	1.03E-05	9.78E-05	1.08E-04
Xylenes (m & p)	3.50E-02	1.00E+00	3.50E-02	8.18E-04	7.79E-03	8.61E-03
Xylenes (o)	1.20E-02	1.00E+00	1.20E-02	2.80E-04	2.67E-03	2.95E-03

NOTE:
BAF = Bioacculation Factor
HMW PAH = High molecular weight polynuclear aromatic hydrocarbon
kg = Kilogram
L/kg bw-day = Liters per kilogram of body weight per day
mg/kg bw-day = Milligram of food per kilogram of body weight per day
mg/kg dry wt. = Milligram per kilogram of dry weight
mg/L = Milligram per liter
UCL = Upper confidence level

Table B-3
Wildlife Exposure Modeling of Maximum Doses to Insectivorous Mammals (Northern Short-Tailed Shrew) from Media for AOC-4

Exposure Parameters

Soil Ingestion Rate (kg dry wt./kg bw-day):	2.02E-02	kg/kg-day
Food Ingestion Rate (kg dry wt./kg bw-day):	1.55E-01	kg/kg-day

Chemical	Maximum Soil Concentration (mg/kg dry wt.)	Food Item (Insect/Worm) Uptake		Maximum Case Scenario Doses		
		BAF/Equation (mg/kg dry wt. to mg/kg dry wt.)	Maximum Food Item Tissue Concentration (mg/kg dry wt.)	Dose from Soil (mg/kg bw-day)	Dose from Food (mg/kg bw-day)	Total Dose (mg/kg bw-day)
Metals						
Barium	8.09E+02	1.60E-01	1.29E+02	1.63E+01	2.01E+01	3.64E+01
Cadmium	9.00E-01	ln(dry worm conc, mg/kg) = (2.114+0.795*ln(soil conc))	7.62E+00	1.81E-02	1.18E+00	1.20E+00
Chromium	1.76E+01	ln(dry worm conc, mg/kg) = (2.481+-0.067*ln(soil conc))	9.86E+00	3.55E-01	1.53E+00	1.88E+00
Copper	3.98E+01	ln(dry worm conc, mg/kg) = (1.675+0.264*ln(soil conc))	1.41E+01	8.02E-01	2.19E+00	2.99E+00
Lead	4.30E+01	ln(dry worm conc, mg/kg) = (-0.218+0.807*ln(soil conc))	1.67E+01	8.66E-01	2.59E+00	3.46E+00
Manganese	2.59E+02	ln(dry worm conc, mg/kg) = (-0.809+0.682*ln(soil conc))	1.97E+01	5.22E+00	3.05E+00	8.27E+00
Mercury	1.50E+00	ln(dry worm conc, mg/kg) = (-0.684+0.118*ln(soil conc))	5.29E-01	3.02E-02	8.20E-02	1.12E-01
Vanadium	2.13E+01	8.80E-01	1.87E+01	4.29E-01	2.91E+00	3.33E+00
Zinc	5.60E+02	ln(dry worm conc, mg/kg) = (4.449+0.328*ln(soil conc))	6.82E+02	1.13E+01	1.06E+02	1.17E+02
Polynuclear Aromatic Hydrocarbons						
Total HMW PAHs	5.87E+00	--	1.47E+00	9.14E-02	2.28E-01	3.19E-01
Semivolatile Organic Compounds						
Acetophenone	6.20E-02	1.00E+00	6.20E-02	1.25E-03	9.61E-03	1.09E-02
Benzaldehyde	6.60E-02	1.00E+00	6.60E-02	1.33E-03	1.02E-02	1.16E-02
Bis(2-ethylhexyl)phthalate	2.20E-01	1.00E+00	2.20E-01	4.43E-03	3.41E-02	3.85E-02
Carbazole	1.90E-02	1.00E+00	1.90E-02	3.83E-04	2.95E-03	3.33E-03
Volatile Organic Compounds						
2-Butanone	1.40E-02	1.00E+00	1.40E-02	2.82E-04	2.17E-03	2.45E-03
Trichloroflouromethane	5.00E-04	1.00E+00	5.00E-04	1.01E-05	7.75E-05	8.76E-05
Xylenes (m & p)	3.50E-02	1.00E+00	3.50E-02	7.05E-04	5.43E-03	6.13E-03
Xylenes (o)	1.20E-02	1.00E+00	1.20E-02	2.42E-04	1.86E-03	2.10E-03

NOTE:
BAF = Bioacculation Factor
HMW PAH = High molecular weight polynuclear aromatic hydrocarbon
kg = Kilogram
L/kg bw-day = Liters per kilogram of body weight per day
mg/kg bw-day = Milligram of food per kilogram of body weight per day
mg/kg dry wt. = Milligram per kilogram of dry weight
mg/L = Milligram per liter

Table B-4
Wildlife Exposure Modeling of 95% UCL Mean Doses to Insectivorous Mammals (Northern Short-Tailed Shrew) from Media for AOC-4

Exposure Parameters

Soil Ingestion Rate (kg dry wt./kg bw-day):	2.02E-02	kg/kg-day
Food Ingestion Rate (kg dry wt./kg bw-day):	1.55E-01	kg/kg-day

Chemical	95% UCL Mean Soil Concentration (mg/kg dry wt.)	Food Item (Insect/Worm) Uptake		95% UCL Mean Case Scenario Doses		
		BAF/Equation (mg/kg dry wt. to mg/kg dry wt.)	95% UCL Mean Food Item Tissue Concentration (mg/kg dry wt.)	Dose from Soil (mg/kg bw-day)	Dose from Food (mg/kg bw-day)	Total Dose (mg/kg bw-day)
Metals						
Barium	5.32E+02	1.60E-01	8.50E+01	1.07E+01	1.32E+01	2.39E+01
Cadmium	9.00E-01	ln(dry worm conc, mg/kg) = (2.114+0.795*ln(soil conc))	7.62E+00	1.81E-02	1.18E+00	1.20E+00
Chromium	1.76E+01	ln(dry worm conc, mg/kg) = (2.481+-0.067*ln(soil conc))	9.86E+00	3.55E-01	1.53E+00	1.88E+00
Copper	3.98E+01	ln(dry worm conc, mg/kg) = (1.675+0.264*ln(soil conc))	1.41E+01	8.02E-01	2.19E+00	2.99E+00
Lead	3.98E+01	ln(dry worm conc, mg/kg) = (-0.218+0.807*ln(soil conc))	1.57E+01	8.03E-01	2.44E+00	3.24E+00
Manganese	1.85E+02	ln(dry worm conc, mg/kg) = (-0.809+0.682*ln(soil conc))	1.56E+01	3.72E+00	2.42E+00	6.14E+00
Mercury	1.18E+00	ln(dry worm conc, mg/kg) = (-0.684+0.118*ln(soil conc))	5.14E-01	2.37E-02	7.97E-02	1.03E-01
Vanadium	1.83E+01	8.80E-01	1.61E+01	3.68E-01	2.49E+00	2.86E+00
Zinc	4.33E+02	ln(dry worm conc, mg/kg) = (4.449+0.328*ln(soil conc))	6.27E+02	8.72E+00	9.71E+01	1.06E+02
Polynuclear Aromatic Hydrocarbons						
Total HMW PAHs	4.34E+00	--	1.32E+00	8.27E-02	2.04E-01	2.87E-01
Semivolatile Organic Compounds						
Acetophenone	6.20E-02	1.00E+00	6.20E-02	1.25E-03	9.61E-03	1.09E-02
Benzaldehyde	6.60E-02	1.00E+00	6.60E-02	1.33E-03	1.02E-02	1.16E-02
Bis(2-ethylhexyl)phthalate	2.20E-01	1.00E+00	2.20E-01	4.43E-03	3.41E-02	3.85E-02
Carbazole	1.90E-02	1.00E+00	1.90E-02	3.83E-04	2.95E-03	3.33E-03
Volatile Organic Compounds						
2-Butanone	1.40E-02	1.00E+00	1.40E-02	2.82E-04	2.17E-03	2.45E-03
Trichloroflouromethane	4.40E-04	1.00E+00	4.40E-04	8.86E-06	6.81E-05	7.70E-05
Xylenes (m & p)	3.50E-02	1.00E+00	3.50E-02	7.05E-04	5.43E-03	6.13E-03
Xylenes (o)	1.20E-02	1.00E+00	1.20E-02	2.42E-04	1.86E-03	2.10E-03

NOTE:
BAF = Bioacculation Factor
HMW PAH = High molecular weight polynuclear aromatic hydrocarbon
kg = Kilogram
L/kg bw-day = Liters per kilogram of body weight per day
mg/kg bw-day = Milligram of food per kilogram of body weight per day
mg/kg dry wt. = Milligram per kilogram of dry weight
mg/L = Milligram per liter
UCL: Upper confidence level