BASELINE RISK ASSESSMENT REPORT
for the
NIAGARA FALLS STORAGE SITE

***Prepared for*:**
U.S. Army Corps of Engineers
Buffalo District

***Prepared by*:**
Science Applications International Corporation
4700 Lakehurst Court, Suite 110
Dublin, Ohio 43017

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ABBREVIATIONS AND ACRONYMS

ABS	Absorption Factor
ADD	Average Daily Dose
AEC	Atomic Energy Commission
ANOVA	Analysis of Variance
ARAR	Applicable or Relevant and Appropriate Requirement
aSRC	ANOVA Site-Related Constituent
ATSDR	Agency for Toxic Substances Disease Registry
AUF	Area Use Factor
BAF	Bioaccumulation Factor
BCF	Bioconcentration Factor for media-specific and receptor class-specific purposes
BCG	Biota Concentration Guide
BERA	Baseline Ecological Risk Assessment
BNI	Bechtel National, Incorporated
BRA	Baseline Risk Assessment
Cal EPA	California Environmental Protection Agency
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
COPC	Chemical of Potential Concern
COC	Chemical of Concern
CSF	Cancer Slope Factor
CSM	Conceptual Site Model
CTE	Central Tendency Exposure
CX	Center for Expertise
+D	Daughter decay products from radioactive isotopes measured at the site
DAD	Daily Absorbed Dose
DAF	Dilution Attenuation Factor
DOE	Department of Energy
DSR	Dose to Source Ratio
DV	Recommended Daily Value
ECSM	Ecological Conceptual Site Model
EPA	Environmental Protection Agency
EPC	Exposure Point Concentration
ERAGS	Ecological Risk Assessment Guidance for Superfund
ESV	Ecological Screening Value for media-specific purposes
EU	Exposure Unit
FS	Feasibility Study
FUSRAP	Formerly Utilized Sites Remedial Action Program
GI	Gastrointestinal Absorption Factor
HEAST	Health Effects Assessment Summary Tables
HELP	Hydrologic Evaluation of Landfill Performance model
HGL	HydroGeoLogic, Inc.
HHRA	Human Health Risk Assessment
HI	Hazard Index
HQ	Hazard Quotient
HRS	Hazard Ranking System
IEUBK	Integrated Exposure Uptake Biokinetic Model
ILCR	Incremental Lifetime Cancer Risk
IRIS	Integrated Risk Information System

ABBREVIATIONS AND ACRONYMS (continued)

IWCS	Interim Waste Containment Structure
KAPL	Knolls Atomic Power Laboratory
LCS	Laboratory Control Sample
LLC	Limited Liability Company
LOAEL	Lowest Observed Adverse Effects Level
LOOW	Lake Ontario Ordnance Works
MCL	Maximum Contaminant Level
mCOPC	Migration Chemical of Potential Concern
MED	Manhattan Engineer District
MRL	Minimal Risk Levels
mSRC	Migration Site-Related Constituent
NAWQC	National Ambient Water Quality Criteria
NCP	National Oil and Hazardous Substances Pollution Contingency Plan
NOAEL	No Observed Adverse Effects Level
NFA	No Further Action
NFSS	Niagara Falls Storage Site
NTS	Nuclear Technology Services
NWI	National Wetland Inventory
NYCRR	New York Codes, Rules and Regulations
NYSDEC	New York State Department of Environmental Conservation
OME	Ontario Ministry of the Environment
PAH	Polycyclic Aromatic Hydrocarbon
PCB	Polychlorinated Biphenyl
PPRTV	Provisional Peer Reviewed Toxicity Values
PRG	Preliminary Remediation Goal
pSRCs	Preliminary Site-Related Constituents
QA	Quality Assurance
QAPP	Quality Assurance Project Plan
QC	Quality Control
RAGS	Risk Assessment Guidance for Superfund
RBC	Risk Based Concentration
RCRA	Resource Conservation and Recovery Act
RESRAD	Residual Radioactivity Code Version 6.2
RfC	Reference Concentration
RfD	Reference Dose
RI	Remedial Investigation
RME	Reasonable Maximum Exposure
ROC	Radionuclide of Concern
ROPC	Radionuclide of Potential Concern
RSR	Risk to Source Ratio
SAIC	Science Applications International Corporation
SERA	Screening-Level Ecological Risk Assessment
SMDP	Scientific Management Decision Point
SPv	Soil-to-Plant Bioconcentration Factor for Vegetative Parts
SRC	Site-Related Constituents
STSC	Superfund Health Risk Technical Support Center
SVOC	Semi-volatile Organic Compound

ABBREVIATIONS AND ACRONYMS (continued)

TAGM	Technical and Administrative Guidance Memorandum
T&E	Threatened & Endangered
TIC	Tentatively Identified Compound
TNT	Trinitrotoluene
TOGS	Technical and Operational Guidance Series
TRV	Toxicity Reference Value for receptor-specific uses
TRW	Toxicity Reference Workgroup
UCL	Upper Confidence Limit
UTL	Upper Tolerance Limit
USACE	U.S. Army Corps of Engineers
UWBZ	Upper Water Bearing Zone
VOC	Volatile Organic Compound
WOE	Weight-of-Evidence
WSDE	Washington State Department of Ecology

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Metric Conversion Chart

To Convert to Metric			To Convert From Metric		
If You Know	Multiply By	To Get	If You Know	Multiply By	To Get
Length					
inches	2.54	centimeters	centimeters	0.3937	inches
feet	30.48	centimeters	centimeters	0.0328	feet
feet	0.3048	meters	meters	3.281	feet
yards	0.9144	meters	meters	1.0936	yards
miles	1.60934	kilometers	kilometers	0.6214	miles
Area					
square inches	6.4516	square centimeters	square centimeters	0.155	square inches
square feet	0.092903	square meters	square meters	10.7639	square feet
square yards	0.8361	square meters	square meters	1.196	square yards
acres	0.40469	hectares	hectares	2.471	acres
square miles	2.58999	square kilometers	square kilometers	0.3861	square miles
Volume					
fluid ounces	29.574	milliliters	milliliters	0.0338	fluid ounces
gallons	3.7854	liters	liters	0.26417	gallons
gallons	0.00378	cubic meters	cubic meters	264.55	gallons
cubic feet	0.028317	cubic meters	cubic meters	35.315	cubic feet
cubic yards	0.76455	cubic meters	cubic meters	1.038	cubic yards
Weight					
ounces	28.3495	grams	grams	0.03527	ounces
pounds	0.4536	kilograms	kilograms	2.2046	pounds
Temperature					
Fahrenheit	Subtract 32 then multiply by 5/9ths	Celsius	Celsius	Multiply by 9/5ths then add 32	Fahrenheit
Radiation					
picocurie	0.037	becquerel	becquerel	27.027027	picocuries
curie	3.70E+10	becquerel	becquerel	2.703E-11	curies
rem	0.01	sievert	sievert	100	rem
RAD	0.01	Gray	Gray	100	RADs

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EXECUTIVE SUMMARY

ES.1 Introduction

The Niagara Falls Storage Site (NFSS) baseline risk assessment (BRA) is composed of a human health risk assessment (HHRA) and a screening-level ecological risk assessment (SERA). The BRA evaluates current and potential future risks to human health and the environment from site contamination. This assessment is limited to hypothetical on-site exposures. The purpose of the BRA is to provide the United States Army Corps of Engineers (USACE), the regulatory agencies and other stakeholders with a decision-making tool for use in determining the need for further investigation or site cleanup based upon present site conditions. The modeled receptors do not live at the site; therefore, their presence at the site is "hypothetical", meaning that they may or may not occupy the site in the future. The modeled exposures for these receptors are based on EPA-approved models and parameters such that a reasonable estimate of the risk to these receptors can be calculated. The mathematical models were based on guidance documents prepared by the regulatory agencies. These models are recommended as a reasonable means to provide a conservative estimate of the effect of chemicals of concern (COCs) and radionuclides of concern (ROCs) on human receptors.

Investigation of NFSS is authorized under the Formerly Utilized Sites Remedial Action Program (FUSRAP). FUSRAP was initiated in 1974 to identify, investigate, and cleanup or otherwise control sites throughout the United States that became contaminated during the nation's early atomic energy program. Many of the sites became contaminated during activities of private contractors under contract to the Manhattan Engineer District (MED) and/or the Atomic Energy Commission (AEC). Since 1997, USACE has had responsibility for the administration and execution of FUSRAP. USACE is required to comply with the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) when conducting FUSRAP cleanup work. Procedures for implementing response actions pursuant to CERCLA are identified in the National Oil and Hazardous Substances Pollution Contingency Plan (NCP) which is codified at 40 Code of Federal Regulations (CFR) Part 300 (EPA 1990). The BRA evaluates potential risks at the site using a conservative methodology to ensure that the mandate to protect human health and the environment given in the NCP is achieved.

Both United States Environmental Protection Agency (EPA) and USACE guidance documents were used to prepare this BRA. It relies on modeled risk estimates for representative receptors that may be exposed to chemical and radiological constituents at the site. The risk estimates are not based on observed impacts to actual people, plants, or animals at the site, nor are they based on measured levels of chemicals within the tissues of these potential receptors. The risk estimates are developed using mathematical models as opposed to actual observed or measured effects. Therefore, these risk estimates should be used only within the CERCLA framework for which they are intended and not for any other purpose such as wildlife management or the development of health advisories.

The BRA evaluates both chemical and radiological constituents. The HHRA for chemical constituents is conducted according to the methodology presented by the EPA in the *Risk Assessment Guidance for Superfund* (RAGS) (EPA 1989) and other guidance documents (see references in Section 6.0). The HHRA for radiological constituents is conducted in accordance with RAGS using the residual radioactivity (RESRAD) computer code Version 6.2. The SERA follows RAGS and associated guidance for chemical constituents. For radiological constituents,

the SERA follows *A Graded Approach for Evaluating Radiation Doses to Aquatic and Terrestrial Biota* (DOE 2002).

ES.2 General Site Description

The NFSS is located at 1397 Pletcher Road in Lewiston, NY. The 191-acre site is a remnant of a larger Lake Ontario Ordnance Works (LOOW) site used by the wartime MED. The NFSS and adjacent LOOW properties were developed for the production of trinitrotoluene (TNT) during World War II. However, TNT production never reached full capacity and the site became an interim storage facility, first receiving radioactive wastes and residues in 1944. Interim remedial actions addressed radioactive residues stored at various locations on the site and widespread contaminated soil on-site. In addition, these actions addressed on-site and off-site drainage areas that had been contaminated from migration of radioactive materials. During the remedial actions, conducted from 1982 to 1986, approximately 183,000 m^3 of residues and wastes were consolidated in a diked containment area known as the interim waste containment structure (IWCS). The 10-acre engineered IWCS, located in the southwest corner of the site, was covered with an interim facility cap.

The HHRA and SERA both evaluate the entire NFSS property. Any residual radioactivity or chemical constituents presently existing in media outside the IWCS is evaluated as part of this BRA. In addition, the IWCS is evaluated in its present state. The risk from potential opening (either intentional or accidental) of the IWCS is being evaluated separately as part of the NFSS Feasibility Study (FS). Therefore, risk resulting from a breach is not quantified in this BRA. It is understood that the IWCS is only an interim remedial action, and therefore, an FS is already underway to determine a permanent solution for waste in the IWCS. In addition, the future existence and stability of the IWCS subjected to various failure events also is being evaluated separately as part of the FS. It is assumed that a breach of the cap would result in an unacceptable risk to human health and the environment.

Three buildings remain on-site, one of which is abandoned and is scheduled to be demolished. The remainder of the site is currently a combination of abandoned structures such as tank cradles and building foundations, open fields, and wooded areas all surrounded by a 7-ft security fence. It is bounded to the east, north, and south by privately owned operating landfills.

NFSS is divided into 17 exposure units (EU) for purposes of quantifying risks in this BRA. EUs 1 through 14 are terrestrial (also referred to as physical) EUs. Soil is evaluated in each of these 14 EUs. EU 15 is the Central Ditch (including the South 16, South 35 and Modern Ditches) and EU 16 is the site pipelines. These EUs include soil (0-10 ft), surface soil (0-0.5 ft), sediment, and surface water. For defining environmental media within EUs, sediments are operationally defined as being in ditches that are submerged (wet) for at least six months of the year (i.e., 50 percent of the year). Areas submerged for less than 50 percent of the year are defined as soil areas. Only EUs 5, 9, 15, 16, and 17 contain surface water and sediment. EU 17 is a sitewide unit for all media and data. EU 18 contains off-site areas where background samples were collected, but no risk was quantified for this EU.

ES.3 HHRA Overview

The HHRA evaluates risk to representative on-site human receptor populations either currently exposed to site-related constituents (SRCs) or reasonably anticipated to be exposed in the future. Under the current land use scenario, on-site receptors include adult and adolescent trespassers and maintenance workers. It is conceivable that future land use could include industrial use or, as an

extreme case, residential development or use for subsistence farming. Therefore, the future on-site receptors include construction workers, maintenance workers, industrial workers, adult and adolescent recreational visitors, adult and child residents, and adult and child subsistence farmers. It is assumed that only current and future maintenance workers will be exposed at the surface of the IWCS. It is also assumed that all other receptors will be exposed to non-IWCS areas. It should be noted that the subsistence farmer land use scenario was evaluated in the HHRA as an overly conservative worst case. This scenario is highly unlikely due to the proximity of the site to surrounding landfills and the poor yield and quality of on-site groundwater resources.

In order to determine which chemicals and radionuclides need to be retained in this BRA for full quantitative risk analysis, a series of screening steps was used to evaluate environmental data collected during the Remedial Investigation (RI). Site data for all detected constituents are first compared to background concentrations to determine which constituents exceed background levels. Constituents that exceed background levels are referred to as site-related constituents (SRCs). SRCs are then subjected to additional screening steps, including a comparison to conservative risk-based concentrations, to determine which constituents warrant quantitative risk evaluation. These constituents are referred to as chemicals of potential concern (COPCs) or radionuclides of potential concern (ROPCs).

Quantitative risk characterizations are performed for COPCs/ROPCs in EUs 1 through 17. Groundwater contamination is evaluated in three EUs. EU 17 is a site-wide unit and includes all groundwater data. However, volatile organic compounds (VOCs) in groundwater are localized in two EUs, EU 4 and EU 13. Therefore, groundwater COPCs/ROPCs are identified for EUs 4, 13, and 17. A qualitative discussion of potential future off-site risks from migration of existing contaminants, based on groundwater modeling is evaluated briefly.

Human health risk estimates for all potential scenarios and pathways are presented in Appendices A and B for COPCs and ROPCs, respectively. These risk estimates are summarized in Section 5.4 by EU. Reasonable maximum exposure (RME) risk estimates are presented first followed by central tendency exposure (CTE) risk estimates. For purposes of the results presentation, COCs/ROCs are defined based on total risk by medium and then by COPC/ROPC-specific risk. Cancer risk must exceed 1×10^{-4} in a specific medium for any COCs/ROCs to be identified. When medium-specific risk exceeds 1×10^{-4}, any individual COPC/ROPC posing 1×10^{-5} risk, or greater, is identified as a COC/ROC. ROCs also are identified based on exceedance of a 25 mrem/yr dose. Non-cancer hazard index (HI) values for any medium must be greater than 1 for any non-cancer COCs to be identified in this results discussion. When medium-specific HI exceeds 1, individual COPCs with an HI greater than 1 are identified as COCs. When medium-specific risks exceed 1×10^{-4} and/or HI greater than 1, but no COPC/ROPC-specific risks exceed 1×10^{-5} or noncancer hazard quotient (HQ) greater than 1, then the COPC/ROPC contributing the greatest cancer risk/HQ is discussed in the risk summary. A summary of reasonable maximum exposure COCs and ROCs as identified by the HHRA by EU is provided in Table ES.1.

The chemical HHRA identifies polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), several pesticides, and various metals as COCs in soil. Soil COCs are not present in EUs 1, 3, 5, 6, 7, 9 and 10 even under the most conservative scenario, the subsistence farmer. No COCs are identified in sediment or surface water in on-site surface water bodies (i.e., ditches and wetlands). PCBs and lead are COCs in the pipelines. Groundwater COCs pose very high cancer risk (e.g., in excess of 1×10^{-2}), but the VOCs driving risk are mostly limited in extent to EUs 4 and 13. Other groundwater COCs are metals and one semi-volatile organic compound (SVOC), bis(2-ethylhexyl)phthalate.

The radiological HHRA concludes that risks from ROPCs exceed 1 x 10^{-4} and dose estimates exceed 25 mrem/yr from exposure to soil, surface soil, and groundwater in all EUs across the site. All risk and dose estimates for sediment are below criteria and no ROPCs are identified for surface water. For radionuclides, the daughter decay products from radioactive isotopes measured at the site are noted as "+D". Ra-226 and Pb-210 dominate radiological risk and dose estimates primarily through plant ingestion for gardening receptors and through external gamma exposure for all other receptors. Groundwater ROCs include Cs-137, Pb-210, Ra-226+D, Ra-228+D, Th-228+D, Th-230, Th-232, U-234, U-235+D, and U-238+D. All ROPCs except Sr-90 are identified as ROCs for some receptor/medium combination.

Based on groundwater modeling, little to no additional future risk to off-site receptors beyond what is present due to current groundwater contamination is expected. Model results show little lateral migration of existing VOC, SVOC, and metal contaminants. While leaching of contaminants from the IWCS is predicted, the leached contaminants do not reach the site boundary. Uranium contamination currently in the upper water-bearing zone (UWBZ) in EUs 1 and 11 exceeding the upper tolerance limits (UTLs) is predicted to move off-site over the 1,000-year evaluation period; however, radionuclide concentrations are not expected to increase significantly in the plumes and are not expected to move far beyond the site boundary.

ES.4 SERA Overview

The scope of the SERA is to determine the potential for adverse ecological impacts resulting from exposure to chemicals and radionuclides present from past AEC/MED activities at the site. The SERA provides information to scientists and managers for the first scientific management/decision point (SMDP) to enable them to decide whether ecological risks at the site are negligible, further information and evaluation are necessary to better define potential ecological risks at the site, or mitigation should be done without further evaluation. Further evaluation required by the SMDP, if any, would be provided in another document.

The SERA uses available site analyte concentrations in soil, sediment, and surface water from the NFSS. Risks to ecological receptors are evaluated by performing a multi-step screen (also known as a graded approach for radionuclides) that identifies EUs and media where specific analyte concentrations are above values that are deemed safe for one or more receptors. The SERA also identifies receptors that are particularly at risk. The results also provide information about the relative magnitude of risk from different analytes. For the SERA, future risks are assumed to be the same as current risks presented here; however, for some chemicals, this may be overly conservative due to degradation. The approaches and methods that are used are summarized below.

The problem formulation for the SERA includes two levels of screening: a general screening followed by a site-specific analysis. These screens are applied to COPCs and ROPCs. Briefly, the general screening compares the maximum detected concentration of COPCs against screening benchmarks and ROPCs against generic biota concentration guides (BCGs) developed by the United States Department of Energy (DOE) (DOE 2002). The site-specific analysis uses site-specific information to calculate HQs for chemical constituents, and site-specific BCGs for radionuclides to evaluate whether EUs or receptors can be eliminated from further analysis due to negligible risk.

The NFSS landscape consists of predominately low-lying land or terrestrial habitats and water or aquatic habitats. Terrestrial habitats include maintained turf/mowed grass (about 90 acres); sedges, reeds, rushes, and cattails (about 16 acres); and mixtures of various forests, e.g., ash-elm-

maple, mixed upland hardwoods, (about 85 acres). Wildlife species include white-tailed deer, rabbits, raccoons, groundhogs and other rodents as well as hawks, herons, pheasants, doves, and other birds. Other terrestrial organisms like reptiles and amphibians are also present. Aquatic habitats drain poorly among the various man-made ditches and there is only one perennially flowing ditch. This limits the types and numbers of aquatic organisms that can and do live at NFSS. In fact, there are only four EUs where sediment and surface water are present. The SERA evaluates the same EUs as the HHRA except EU 16 (pipelines), which is not evaluated.

The methods emphasize a screening level approach to both exposure and risk characterization. Each is done in a series of steps of increasing geographical and exposure specificity for both chemicals and radionuclides. For chemicals, a site-wide screen of maximum concentrations identifies the SRCs for further EU-specific evaluation. For chemicals, there are two EU-specific steps where reasonable maximum exposure (RME) concentrations are compared to ecological screening values (ESVs) to develop HQs. For radionuclides, a site-wide screen of maximum concentrations was used to determine whether further analysis was required. EU-specific steps followed in which concentrations were compared to BCGs to develop overall radiation doses.

For radionuclides, all 16 of the 16 EUs evaluated, including the NFSS site-wide EU 17, were eliminated by application of the various site-wide and EU-specific screens

For chemicals, none of the 15 soil EUs or the sixteenth NFSS-wide EU 17 could be dismissed because one or more chemicals were present at sufficiently high concentrations to produce a hazard quotient (HQ) greater than one. For example, cadmium, chromium, copper, selenium, and total uranium had HQs >1 at most every EU. At some EUs, fewer metals and no SVOCs had HQs >1, while at other EUs there were SVOCs with HQs >1. Thus, a simple pattern can emerge from the results. Briefly, there are six EUs where only metals define the sources of chemical risk to the various receptors (EUs 1, 3, 6, 7, 9, and 14). Three EUs (5, 10, and 13) have metals and one SVOC [benzo(b)fluoranthene] with HQs >1. Six EUs have many metals and SVOCs (EUs 2, 4, 8, 11, 12, and 17) with HQs>1. There are four sediment and surface water EUs, one of them being the NFSS site-wide EU. The results show them to be in two categories: EUs 5, 15, and 17 have many metals with HQs >1 (and EU 5 has two SVOCs with HQs >1), and EU 9 has only one metal with a HQ >1.

ES.5 Conclusions

The HHRA identifies COCs and ROCs in soil and groundwater exceeding 1×10^{-4} and/or HI of 1 across NFSS. Generally, radiological contaminants are more widespread than chemical contaminants. ROCs were identified in all 14 physical EUs, whereas COCs were identified in 7 of the 14 physical EUs. ROCs and COCs are present in surface soils and at various depths with most of the contamination limited to the top two feet of soil. COCs also are present in the pipelines. Groundwater COCs and ROCs were limited to the upper water bearing zone. Additional conclusions regarding risks from radiological and chemical contamination at NFSS are presented in the conclusions section of the RI Report (SAIC 2007)

The SERA results are intended to facilitate decision-making relative to the protection of the habitats and ecological receptors at NFSS. Given that it is a screening level process, it may not be conclusive regarding remedial actions. However, risk managers may use the SERA information in conjunction with the HHRA to determine if (1) a weight-of-evidence (WOE) evaluation of the screening results should be carried out, (2) a definitive Baseline Ecological Risk Assessment should be performed (BERA), and (3) the screening level information is sufficient to identify remedial actions for the site.

The WOE assessment, (Option 1 above) evaluates the technical information common to risk assessments in the context of broader topics such as significance of ecological resources, human-dominated land use, and trade-offs for chemical risk and physical or remedial risk. Eight WOE elements are developed to weigh the NFSS SERA quantitative results and other evidence. Each evaluation or weighing is presented in a logical order. Together, the WOE elements provide a holistic view and understanding of the ecological risk situation at NFSS. The outcome of this assessment is the recommendation for no further action (NFA) for the relatively productive habitats, vegetation, and wildlife at NFSS.

1.0 INTRODUCTION

This baseline risk assessment (BRA) report accompanies the remedial investigation (RI) report for the Niagara Falls Storage Site (NFSS). Together the RI and BRA reports contain the results of the NFSS investigation. These reports will be used to prepare a feasibility study (FS). The BRA is composed of a human health risk assessment (HHRA) and a screening-level ecological risk assessment (SERA). The BRA evaluates current and potential future risks to human health and the environment from site contamination.

The investigation of NFSS is authorized under the Formerly Utilized Sites Remedial Action Program (FUSRAP). FUSRAP was initiated in 1974 to identify, investigate, and cleanup or otherwise control sites throughout the United States that became contaminated during the nation's early atomic energy program. Many of the sites became contaminated during activities of private contractors under contract to the Manhattan Engineer District (MED) and/or the Atomic Energy Commission (AEC).

The United States Department of Energy (DOE) and its predecessor organizations, the AEC and the Energy Research and Development Agency, were responsible for FUSRAP from its inception until October 1997, when the Energy and Water Development Appropriations Act for Fiscal Year 1998, PL 105-62, transferred responsibility for the administration and execution of FUSRAP from DOE to the United States Army Corps of Engineers (USACE).

The Energy and Water Development Appropriations Act for Fiscal Year 2000, PL 106-60 requires that USACE comply with the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) when conducting FUSRAP cleanup work. Therefore, USACE is conducting FUSRAP investigations and cleanups in accordance with CERCLA and its principal implementing regulation, the National Oil and Hazardous Substances Pollution Contingency Plan (NCP) which is codified at 40 CFR Part 300 (EPA 1990).

In the RI/FS process, the RI is conducted to characterize the site and determine the nature and extent of contamination. The BRA is performed utilizing information from the RI to assess current and future risks to human health and the environment from site contamination. In some cases, the BRA is submitted as part of the RI report. Even though the NFSS RI report (SAIC 2007) and BRA were prepared as separate documents, the RI report incorporates results from this BRA report and the Groundwater Flow and Contaminant Transport Modeling Report (HGL 2007) to provide recommendations for media needing further evaluation in the FS. The FS will then evaluated remedial action objectives for the site and will evaluated remedial alternatives for those areas requiring cleanup.

The purpose of this BRA is to provide USACE, the regulatory agencies, and other stakeholders with a decision-making tool for use in determining the need for further investigation or site cleanup based upon present site conditions. The regulatory mandate from the NCP (EPA 1990) is to protect human health and the environment. The BRA evaluates potential risks at the site using a conservative methodology to ensure that this mandate is achieved.

The U.S. EPA and USACE guidance used to prepare this BRA relies on modeled risk estimates for representative receptors that may be exposed to chemical and radiological constituents at the site. The risk estimates are not based on observed impacts to actual people, plants, or animals at the site, nor are they based on measured levels of chemicals within the tissues of these potential

receptors. The risk estimates are developed using mathematical models as opposed to actual observed or measured effects. Therefore, these risk estimates should be used only within the CERCLA framework for which they are intended and not for any other purpose such as wildlife management or the development of health advisories.

1.1 STRATEGY AND OBJECTIVES

The purpose of this BRA is to provide an analysis of baseline human health risks and a screening-level assessment of ecological risk associated with NFSS. The specific objectives of this BRA are as follows:

- Estimate potential human health risks and environmental impacts associated with the NFSS if no further remedial action occurs.

- Identify areas that do not pose unacceptable risks to human health or the environment, and thus require no further action (NFA).

- Develop lists of chemicals of potential concern (COPCs) and radionuclides of potential concern (ROPCs) for contaminants on-site that are the most significant in terms of percent contribution to total risk and extent of contamination in all areas where unacceptable risks to human health or the environment are identified. Significant COPCs and ROPCs are labeled as chemicals of concern (COCs) and radionuclides of concern (ROCs).

- Provide baseline risks for the NFA alternative in the FS that are used to evaluate risk reduction for each proposed alternative. For purposes of the BRA, it is assumed that maintenance of the interim waste containment structure (IWCS) and the associated chemical and radiological surveillance sampling will continue under the NFA alternative.

- Develop risk-based concentrations and radionuclide action levels for the identified COCs/ROCs to provide a basis of preliminary cleanup goals for use in decision-making during the FS. This focuses on future remedy selection for COCs/ROCs that are the significant contributors to human and ecological health risks.

The HHRA and the SERA are conducted according to the methodology presented by the EPA in the *Risk Assessment Guidance for Superfund* (EPA 1989) and other guidance documents. The BRA evaluates both chemical and radiological constituents. The term "chemical" is used throughout the report to refer to non-radiological constituents. Evaluations of chemical and radiological constituents are conducted separately. The HHRA for radiological constituents presented in Section 3 is conducted using the Residual Radioactivity (RESRAD) computer code Version 6.2. The SERA for radiological constituents contained within Section 4 follows guidance in *A Graded Approach for Evaluating Radiation Doses to Aquatic and Terrestrial Biota* (DOE 2002), which is consistent with CERCLA guidance.

The HHRA and SERA both evaluate the entire 191-acre NFSS property. The NFSS was used during World War II for trinitrotoluene (TNT) production and subsequently used for storage of radioactive residues. Interim actions conducted in the 1980s, and an additional action in 1991, consolidated approximately 183,000 m^3 of residues and wastes into a diked containment area known as the IWCS. In this BRA, the 10-acre IWCS is evaluated in its present state. Any

residual radioactivity or chemical constituents presently existing in media outside of the IWCS are evaluated as part of this BRA. The risk from potential opening (either intentional or accidental) of the IWCS is being evaluated separately as part of the FS. Therefore, risk resulting from a breach is not quantified in this BRA. It is understood that the IWCS is only an interim remedial action, and therefore, an FS is already underway to determine a permanent solution for waste in the IWCS. In addition, the future existence and stability of the IWCS subjected to various failure events also is being evaluated separately as part of the FS. It is assumed that a breach of the cap will result in an unacceptable risk to human health and the environment.

1.2 SITE DESCRIPTION AND HISTORY

The NFSS is located at 1397 Pletcher Road in Lewiston, NY (Figure 1.1). The 191-acre site is a remnant of a larger Lake Ontario Ordnance Works (LOOW) site used by the wartime MED. The NFSS and adjacent LOOW properties were developed for the production of TNT during World War II. However, TNT production never reached full capacity and the site became an interim storage facility, first receiving radioactive wastes and residues in 1944 (BNI 1990). In 1953, the former steam plant was modified and used to separate boron-10 between 1953 and 1959, and again between 1965 and 1971. Site operations were put on standby in 1971 and activities at NFSS were limited to storage and remediation of radioactive residues and wastes.

For the purposes of this report, the term "residues" applies to radioactive materials that resulted from the processing of uranium ores and contain elevated concentrations of radium, uranium and thorium isotopes. The term "waste" applies to all other contaminated soils and materials.

A variety of environmental cleanup activities have been conducted at the site, prior to USACE's current investigation. Consolidation and removal of surface debris and off-site shipment of waste occurred during the first period of site operations. In 1972, the DOE excavated contaminated material (soils, sediment, and rubble) from off-site areas and placed the material on a storage pile containing R-10 residues. In 1981, the DOE excavated contaminated soil from an area just east of the NFSS and placed it back within the NFSS boundaries (Bechtel 1986). Then in 1982, cleanup activities were accelerated and an interim remedial action plan was developed under the direction of the DOE.

Interim remedial actions addressed radioactive residues stored at various locations on the site and widespread contaminated soil on-site. In addition, these actions addressed on-site and off-site drainage areas that had been contaminated from migration of radioactive materials. During the interim actions conducted from 1982 to 1986, approximately 183,000 m^3 of residues and wastes were consolidated in a diked containment area known as the IWCS. The 10-acre engineered IWCS, located in the southwest corner of the site, was covered with an interim facility cap. A more detailed site description and site history can be found in Section 2.3 of the RI report.

Only three buildings remain on the site. The currently unused Building 401 initially was used for steam production, was later used for boron production, and finally was used for storage of radioactively contaminated materials and equipment. The smaller Building 429 is currently used as office space and for maintenance activities. The Hittman building currently houses maintenance equipment. The entire site is surrounded by a 7-foot high security fence.

The site is bordered by CWM Chemical Services, Limited Liability Company (LLC). (a privately owned hazardous waste landfill) on the north and by Modern Landfill (a privately owned

municipal landfill) to the east and south. Niagara Mohawk Power Corporation owns property to the west of the site and other land to the south is privately held.

1.3 REPORT ORGANIZATION

The BRA is organized into seven sections. Each section is described below.

Section 1 – Introduction: discusses the purpose of the BRA, presents a brief site description and history, and describes the organization of the report.

Section 2 – Baseline Human Health Chemical Risk Assessment: presents the characterization of human health risks from exposure to chemical constituents at NFSS.

Section 3 – Baseline Human Health Radiological Risk Assessment: presents the characterization of human health risks from exposure to radiological constituents at NFSS.

Section 4 – Screening-Level Ecological Risk Assessment: presents the characterization of risks to ecological receptors from exposure to chemical and radiological constituents at NFSS.

Section 5 – Baseline Risk Assessment Summary: summarizes, by exposure unit (EU), the results of the HHRAs and the SERA. In addition, the results of the site-wide (EU 17) assessment are summarized.

Section 6 – References: presents references cited throughout the report.

2.0 BASELINE HUMAN HEALTH CHEMICAL RISK ASSESSMENT

The HHRA for chemical constituents was conducted in accordance with methods presented in the *Risk Assessment Guidance for Superfund, Volume I: Human Health Evaluation Manual, (Part A)* (RAGS) (EPA 1989). Sources of additional specific methodologies are cited throughout the report. The HHRA follows the five-step process recommended by RAGS, as follows:

- Section 2.1 (Data Collection and Evaluation) provides the criteria used to evaluate and screen the NFSS site data and select COPCs that are evaluated in the HHRA;

- Section 2.2 (Exposure Assessment) defines the exposure setting, the conceptual site model (CSM), exposure concentrations, and pathway-specific intakes;

- Section 2.3 (Toxicity Assessment) presents the methodology and guidance used to identify appropriate quantitative indicators of toxicity;

- Section 2.4 (Risk Characterization) presents the methodology used to integrate the exposure and toxicity assessments in the risk characterization for COPCs and the results of the risk characterization; and

- Section 2.5 (Uncertainty Analysis) outlines the criteria and guidance used to evaluate the uncertainties associated with the chemical HHRA.

Detailed results tables for the COPC screens and risk calculations for each pathway, medium, and EU are presented in Appendix A. Section 2.0 presents the HHRA for chemical constituents. The HHRA for radionuclides is presented in Section 3.0.

2.1 DATA COLLECTION AND EVALUATION

Data collection and evaluation involves gathering and analyzing the site data relevant to the risk assessment and identifying the chemical constituents present at the site that are the focus of the risk assessment process. Section 2.1.1 summarizes the environmental data that have been collected during the RI used to perform the BRA. Section 2.1.2 discusses how these data are evaluated for use in the BRA.

2.1.1 Data Collection

The NFSS BRA database consists of analytical results for samples collected from June 30, 1998 through October 7, 2003. The database consists of analytical results for 954 soil samples, 238 groundwater samples, 115 sediment samples, and 98 surface water samples. Site samples were collected across all of the 191-acre NFSS. Human receptors typically are exposed in areas much smaller than 191 acres; therefore, NFSS was divided into smaller areas for purposes of quantifying exposures to human receptors. The areas are termed “exposure units” or EUs. Seventeen on-site EUs are evaluated in this HHRA. EUs 1-16 are subsections of the NFSS while EU 17 represents a site-wide unit. EU 18 refers to the off-site areas where background samples were collected. Section 2.2.2.2 describes the EUs in detail.

2.1.2 Selection of Chemicals of Potential Concern

Data were collected, verified, and validated according to the field sampling plan (Maxim Technologies 1999 and 2000a) and quality assurance project plan (QAPP) (Maxim Technologies 2000b). These data were reviewed and screened to identify site-related constituents (SRCs). The following sections summarize the process used to select the COPCs carried through the BRA. COPCs are screened for each EU by environmental medium. Figure 2.1 is a graphical depiction of the COPC selection process.

The COPC selection criteria discussed below are applied to the detected chemical constituents by EU and by media. Environmental media sampled during the RI include soil (0-10 ft), surface soil (0-0.5 ft), surface water, sediment, groundwater, pipeline material (sludge /sediment and water), and road cores (asphalt/concrete). All media are evaluated in this BRA except those that will be addressed in the FS using non-risk-based disposal criteria. The COPC identification tables (Appendix A, Tables A.3 and A.4) provide information on the magnitude of chemical detection at the site and present the rationale for selection of the COPCs. The same COPCs are utilized for current and future exposures. Essential human nutrients are not presented in the screening tables.

Data reported as "dissolved" has been retained in the database for potential discussion in the risk assessment document, but will not be used in calculations during the risk assessment.

2.1.2.1 Data Quality Evaluation

Prior to the first COPC screening step, the data are evaluated for use in the BRA. The data review methods are described below.

Data Review

In order to ensure the quality of the chemical data collected and analyzed in the RI, several techniques were used to monitor the usability and acceptability of the data. The data review process was conducted in three phases. The first phase, conducted to monitor completeness, correctness, and consistency of the data, involved a review of the laboratory-generated electronic files containing analytic results by the RI Contractor, Maxim Technologies, Inc. The second phase included a further review of the data for accuracy by Science Applications International Corporation (SAIC) to ensure the data met EPA functional guidelines and that assigned data qualifiers were appropriate. The final phase included validation of a subset of the overall number of samples collected in the RI. This validation step was conducted during the different stages of the RI by different contractors. In the first subset (samples collected between November 1999 and January 2000), radiological data validation was conducted by Nuclear Technologies Services (NTS), Inc. (Roswell, Georgia). In the second subset (samples collected between August 2000 and January 2001), chemical and radiological data validation was conducted by the USACE Engineer Research and Development Center Environmental Laboratory (Omaha, Nebraska). In the third subset (samples collected between May 2001 and October 2003), chemical validation was conducted by Integrate, Inc. (Baton Rouge, Louisiana) and radiological validation was conducted by NTS, Inc. (Roswell, Georgia). Data was transferred between contractors using traditional paper report format (hard copy format) and as computer files (electronic data).

Phase 1

Maxim Technologies, Inc. conducted a completeness and accuracy review of 100% of the hard copy data packages (items 1, 2, and 3) and 15% of the laboratory-generated electronic files (item 4) including the following items/sections.

1. Completeness Check (Hard Copy Review)
    - Project Cover Sheet
    - Table of Contents
    - Case Narrative
    - Chain-of-Custody
    - Method Information/Data Check by Lab (per fraction)
    - Analytical Results (per fraction)
    - Laboratory Quality Assurance/Quality Control (QA/QC) Data
    - Instrument QC (Calibration Date)
    - Raw Data (run logs, instrument output, preparation logs)

    Missing data sections in the primary laboratory reports were documented and forwarded to the laboratory for review, comment, and revision, as needed.

2. Inconsistency/Error Screening (Hard Copy Review)
    The following sections of the hard copy were checked for inconsistencies and errors. Any inconsistency or error detected during the screening was documented and forwarded to the laboratory for response and correction, as needed.
    - Chain-of-Custody
    - Analyses Requested
    - Sample Handling
    - Sample IDs
    - Cooler Receipt Forms
    - Holding Times/Preservation

3. QA/QC Review (Hard Copy Review)
    The QA/QC data was evaluated to determine compliance with the QAPP. The review included documentation verification of non-conformances and assessment of laboratory designated data qualifiers. The following data were evaluated.
    - Laboratory Control Sample (LCS)/(LCS Duplicate) Data
    - Method Blank Data
    - Surrogate Recovery Data
    - Laboratory Duplicate Data

    This data review process ensured that all the necessary and appropriate information was included in the data packages for final data review and validation, as required.

4. Completeness Check (Laboratory-Generated Electronic Files Review)
    All laboratory-generated electronic files containing analytical results were reviewed in their entirety for completeness to ensure all sample data were included. Following the completeness review, approximately 15% of the data entries were verified for correctness. All specified field entries associated with the designated review sample records were verified for correctness based upon the hard copy results. If discrepancies were detected during this part of the review process, additional samples were designated for a correctness check.

Phase 2

Maxim Technologies, Inc. transferred the analytical lab results into an Access database. SAIC then conducted data verification on 100% of the data that further evaluated the completeness and accuracy of the data. The objective of this assessment was to ensure the data met EPA functional guidelines. Completeness of the database was also reviewed to ensure all reporting limits were identified, as necessary. The following reviews were conducted in this phase.

1. Evaluation of Method Blank Contamination
   Organic results were qualified with a "B" by the laboratory in cases where the method blank contained reportable concentrations of target compounds. Those results in the database that were potentially affected by laboratory contamination were identified and those data were compared to the target compound concentrations reported in the method blanks. Target compounds prominent in the list were those typically considered by EPA to be suspected laboratory contaminants. Volatile organic compounds (VOCs) included acetone and methylene chloride and for semi-volatile organic compounds (SVOCs) any phthalate may be a contaminant although bis(2-ethylhexyl)phthalate tended to show up the most.

   The method blank results were compared to the "B" flagged results in the database. This was accomplished by application of the EPA 5x/10x rule. In this data evaluation guidance, the reviewer is instructed to set compound specific action levels by multiplying the observed blank contamination by a factor of either 5 or 10 times. The observed blank contamination is multiplied by a factor of 10 for all common laboratory contaminants (methylene chloride, acetone, and common phthalates). All other VOC and SVOC blank contaminants are multiplied by a factor of 5. The action levels were set and compared to the target compound concentrations reported as "B" flagged results. The evaluation criterion was that the reported sample concentration could not be lower than the action levels derived from the blank contamination data. Where they were lower, the affected database results were qualified with a "U" during the verification process. These results were considered non-detect because they were suspected laboratory contaminant artifacts, and therefore, not representative of site media conditions. The "U" flags were placed in the database field named "data_qual" and have been evaluated as non-detects in this risk assessment.

2. Evaluation of QC Blank Contamination
   One source water blank from 1998 was evaluated. The same verification process was used as stated above for method blank contamination. Metals fall under the EPA 5x rule. However, since the laboratory does not qualify these results, the field QC results were paired with their associated investigative samples. In this case, the 1998 source water blank was applied to the data from 1998, but not to any other data. For all NFSS database years (1999-2003), no other field blanks, rinsate blanks, or trip blanks were taken.

3. Evaluation of Radiochemical Uncertainties
   Reported radiochemical results must be greater than their associated uncertainties in order to be valid. As part of the data verification process, all radiochemical results were reviewed with respect to their uncertainties. During the verification process some reported results were found to be less than their associated uncertainties. These results were qualified as "U" and were treated as non-detects in this risk assessment.

Based on these reviews, any inconsistency was documented and the database was changed accordingly.

Phase 3

Through contracting and in-house resources, USACE validated a subset of analytical data from various stages of the RI to substantiate its usability. Since the validated data is representative of all samples collected for the RI, it supports the RI conducted by the USACE (Buffalo District).

Chemical (non-radiological) and radiological analytical results were validated by the following: U.S. Army Engineer Research and Development Center Environmental Laboratory (Omaha, NE), Integrate, Inc. (Baton Rouge, LA), and NTS, Inc. (Roswell, GA).

The number of samples submitted for data validation totaled 55, and consisted of soil, sediment, surface water, and groundwater. In order to encompass the various areas at the NFSS site involved in the RI, a balanced approach was utilized to select samples for validation.

U.S.EPA National Functional Guidelines for Organic Data Review and Inorganic Data Review were followed to the extent appropriate for review of the analytical data produced by SW-846 methods. Items reviewed include the case narrative, analytical results reports, chain of custody, extraction and digestion logs, run logs, instrument tuning and performance, initial calibration responses, continuing calibration responses, internal standard areas, raw data quantitation reports and chromatograms for field and quality control (QC) samples (including the method blank, LCSs, matrix spike/matrix spike duplicate, and laboratory duplicates - metals only), surrogate and spike recoveries, technical holding times, target compound identification, calculations of concentration and reporting limits, and tentatively identified compounds (TICs). Review of explosives data was performed using similar requirements of other methods. Radiological data was reviewed following the Westinghouse Hanford Company validation procedures to the greatest extent possible (document WHC-SD-EN-SPP-001, Rev.1). Radiological data validation procedures include the evaluation of all batch QC including method blanks, LCSs, laboratory duplicate, matrix spike and matrix spike duplicates, evaluation of calibration checks, and standard preparation information.

As mentioned earlier, all data was 100% verified independently by SAIC (Dublin, OH). The appropriate sections of SAIC's Quality Assurance (QA) Technical Procedure (SAIC 2004) for validation were utilized for radiological and non-radiological analyses. SAIC verification and USACE validation summaries were compared. Similar findings confirmed that the verification is in alignment with the validation, furthering the acceptability of this data for its intended use.

2.1.2.2 Background Characterization

A major step in assessing site data is to distinguish between chemical constituents that are likely related to past material or waste handling and/or disposal practices at the site and those that may be naturally occurring or ubiquitously distributed in the environment (i.e., background levels). As part of the RI field investigation, samples of various environmental media were collected at background or up-gradient locations. Background sample locations were selected to match the geology of the areas of concern. The methods used for sample collection and the rationale for sample locations and analyte selection are discussed in the RI report and Section 4.2 of *Report of Results for Phase II Remedial Investigation of the Former Lake Ontario Ordnance Works*, (EA Engineering, Science and Technology 2002). Due to industrial use of adjacent property, the

background analyte list included organics and radionuclides that may be present due to activities unrelated to NFSS.

The calculation of a background value for each analyte within each medium requires the establishment of a background data set for each medium including groundwater, sediment, soil (0–10 ft), surface soil (0 - 0.5 ft) and surface water (EPA 2001a). The data for each analyte within each sample medium are reviewed to determine the total number of samples analyzed and the number of analyses resulting in a detection of an analyte. Prior to performing calculations using the medium-specific background data sets, the data set was evaluated for outliers using a simple inter-quartile test (Iglewicz and Hoaglin, 1993) that determined a limit above which a sample value may be considered a potential outlier. The equation used to determine this limit is as follows:

$$L=Q3+3(Q3-Q1)$$

where:

Q1= first quartile of the data
Q3= third quartile of the data
L= the limit above which a sample value may be considered a potential outlier.

A factor of three was applied to the difference between the third quartile and the first quartile in the above equation for conservatism so that only the extreme outliers would be rejected.

Any background sample value that exceeded this calculated limit was considered a potential outlier. Potential outliers were further reviewed to determine if there were any technical reason(s) for removing the data from the background data set (e.g. impacts from site activities, or laboratory and transcription errors). The evaluation of potential outliers in the NFSS background data resulted in the following conclusions.

- Some of the background sample values in the NFSS RI medium-specific background data sets are slightly greater than the upper limit specified by the outlier test. A sufficient number of samples were available to determine that the data were simply high values in the medium-specific background data sets and not outliers.

- Because the detection limits for an analyte within a given medium vary, many of the potential outliers represent detection limits that are relatively greater in value than other analytical results for that parameter. However, the presence of a significant number of non-detected results for non-radiological parameters in the medium-specific background data sets tends to skew the quartile values, resulting in low values for the outlier limits. This is due to the fact that non-detected results are evaluated using ½ the detection limit, while detected results are evaluated using the value at which they are reported. In such cases, a greater possibility exists for the identification of potential outliers.

- The NFSS RI background data set was reviewed to determine if any background values exceeded the acceptable risk-based screening values. Background values that exceeded risk-based screening values may be identified as potential outliers. However, no background values in the NFSS RI medium-specific background data sets exceeded the risk screening values. Potential outliers in the medium-specific background data sets that are less than risk-based screening levels do not affect evaluation of site risk. However, potential outliers in the medium-specific background data sets can affect the

identification of SRCs because SRCs are determined using background values, not risk screening values. The presence of potential outliers in the medium-specific background data sets can result in fewer SRCs being identified for any given medium because the background concentrations used to screen SRCs may be biased high. The determination of SRCs is further discussed in Section 2.1.2.3.

- Manganese oxides and hydroxides naturally occur in the mineral (solid) phase under oxidizing conditions. Manganese minerals are commonly associated with iron oxides and hydroxides, which are also solids under oxidizing conditions. Under anaerobic (reducing) conditions, such as in low-lying swampy areas, both manganese and iron are reduced to more soluble forms, resulting in higher dissolved phase concentrations. Once in the dissolved phase, iron and manganese may precipitate as new oxygenated water mixes with the soluble metals. The precipitation of these metals under aerobic conditions to form concretions high in iron and manganese is a common occurrence in soils. The soil conditions at NFSS are conducive for generating such concretions.

  The background UTL for manganese in soils at the NFSS is 6,650 mg/kg, which represents the maximum value of manganese detected in NFSS background soil samples. This sample was not considered an outlier because it is believed to represent the presence of iron/manganese concretions that are typically found in soils at the NFSS. As a result, all other detections of manganese in soil were found to be below the background UTL and were not further investigated as SRCs, even though manganese concentrations in NFSS soils are observed to be up to thousands of parts per million. Total and dissolved concentrations of manganese in sitewide groundwater are less than 80 parts per million (ppm). The concentrations of manganese and iron in groundwater are most likely related to the naturally occurring concentrations of these metals in NFSS soils and not from operations conducted at the NFSS. However, to provide a conservative evaluation of human health risk, manganese was identified as a COC in sitewide groundwater (EU 17), and in groundwater in EUs 4 and 13.

- An outlier for selenium was identified in the surface soil sample collected from background location BKGD-12. BKGD-12 is located on property owned by a hunting and gaming club. Selenium dioxide is used to "blue" gunmetal, and selenium is used in various copper alloys that could be associated with ammunition (NLM 2002). Selenium is a common contaminant at ammunition facilities. Because selenium could be a result of the current land use, the selenium concentration reported in the surface soil sample collected at BKGD-12 was considered an outlier and was not included in the surface soil background data set.

- Lead and arsenic were identified as outliers in the surface soil sample collected at background location BKGD-17 because these metals are likely to be a result of historical land use. Lead arsenate, used historically as a pesticide and herbicide, was employed extensively on apple orchards to control the codling moth (NLM 2002; NJDEP 1999). Lead arsenate was also used for control of agricultural pests in vegetable fields and other fruit orchards, as well as golf courses and turf farms (NJDEP 1999). Application of lead arsenate on apple and peach crops was recommended by the New Jersey Agricultural Experiment Station, and these recommendations continued until 1967 when the use of other pesticides (primarily organochlorine pesticides) became established (NJDE, 1999). BKGD-17 is apparently adjacent to an old fruit orchard, where lead arsenate would have been used as a pesticide. Consequently, lead and arsenic concentrations reported in the surface soil at BKGD-17 were excluded from the surface soil background data set.

Additionally, an Integrated Exposure Uptake Biokinetic Model (IEUBK) guideline value of 400 mg/kg is being used as the risk screening level for lead in soil and sediment. This guideline is greater than any potential outlier values for lead in soil and sediment, therefore, the presence of potential outliers in the soil and sediment background data sets has no effect on the risk evaluation of site data.

- Lead is a potential outlier in groundwater and surface water. Outliers are present in groundwater and surface water at concentrations of 5.99 µg/L and 11 µg/L, respectively. However, both of these concentrations are less than the Maximum Contaminant Level (MCL) for lead (15 µg/L), which is being used as the risk screening level in groundwater and surface water. Therefore, the presence of potential outliers for lead in the groundwater and surface water background data sets has no effect on the risk evaluation of site data, and no outliers for lead were removed from the groundwater and surface water background data sets.

- Groundwater data from two background monitoring wells (PZ-21S and PZ-25S) were determined to contain outliers and thus, all groundwater results from these two wells were removed from the background data set. These two wells are located near a rail bed on the Modern Landfill property. Although analyte concentrations from these wells were below MCLs, data from these wells were removed from the background data set due to noticeably high total and dissolved isotopic uranium values derived from ballast leaching and nearby disturbed soil. These two samples have unusually high concentrations of uranium isotopes and have uranium isotopic ratios indicating that they may have been impacted by site contaminants (Rhodes et al. 2006).

- A few background sample results, particularly those for metals collected in groundwater, may reflect the quality of the water migrating on-site from the Modern Landfill located to the south and east of the NFSS. Despite potential outliers in these results, the risk screening values are much higher than the outlier values and therefore, the potential outliers do not present a risk concern and were not removed from the background data set.

- Potential outliers exist in groundwater samples for alpha and beta radiation. The MCL, rather than a background concentration, is being used as the risk screening value for alpha and beta radiation in groundwater. Because concentrations of alpha and beta radiation in the background groundwater data set are less than the MCL, the presence of potential outliers for these two parameters in the background data set has no effect on the risk evaluation of site data. Thus, no outliers for alpha and beta were removed from the groundwater background data set.

- Outliers were identified for alpha radiation, beta radiation, total uranium, uranium-234, uranium-235, and uranium-238 in samples collected from background surface water locations SWBKGD-3 and SWBKGD-7. These constituents were removed from the surface water background data set, from these locations, based on outlier testing and elevated radiological concentrations for total uranium and uranium isotopes.

- Potential outliers exist in sediment samples for radium-226, thorium-230 and uranium-234. These radionuclides are present in sediment at concentrations that slightly exceed the calculated outlier limit. The potential outliers are present in samples collected at background locations SDBKGD-2 and SDBKGD-3. SDBKGD-2 is located in the West

Ditch south of the IWCS and SDBKGD-3 is located in the ditch adjacent to the West Patrol Road in the northwestern corner of the NFSS, next to EU 1. Upon further evaluation of these data, it was determined that these potential outliers are not likely the result of activities conducted at the NFSS; therefore, the data were not removed from the background data set.

For the purpose of calculating background, non-detects are set to a concentration of one-half the detection limit for non-radiological data. Radiological data evaluated as non-detected results are represented using the reported activities. Note that for radionuclides the measured values were used even if they were below the specified lower limit of detection.

A standard 95% Upper Tolerance Limit (UTL) is calculated for data that are normally distributed, and a lognormal UTL is calculated for log-transformed data. The maximum detected concentration is used as a surrogate for the UTL for data that are neither normal nor lognormal. In addition, the maximum detected concentration is used as a surrogate UTL for any analyte with less than three sample results. Background concentrations were not established for any analyte not detected in background samples.

The result of these calculations is a set of background values represented by either the UTL or maximum detected concentration of each analyte for each sample medium. These values are used in comparisons to background concentrations for SRC and COPC determinations. A summary of the background data and calculated UTLs is presented in Table 2.1.

The State of New York defines surface soil as 0 – 2 inches below the vegetation root system to assess chemical risk and 0 - 6 inches below ground surface to assess radiological risk. In this BRA, surface soil is defined as 0 – 6 inches below ground surface and includes the root zone excluded in the State of New York definition. Therefore, there is the possibility of including slightly more soil in the BRA definition. The slight difference between the BRA definition and the State of New York definition is not expected to have any significant impact on the identification of COPCs and the calculation of exposure point concentrations (EPCs).

2.1.2.3 Determination of Site-Related Constituents

SRCs are determined using a series of statistical comparisons and weight-of-evidence factors. Because of problems inherent in applying a single statistical tool to data sets that have different characteristics, multiple types of evidence are considered to determine whether a chemical is site-related or naturally occurring. Chemicals and radionuclides retained after this screen are considered SRCs. The SRC screening results are presented in Appendix A, Table A.1. The final list of SRCs is presented in Table A.2.

The first procedure in the SRC identification consists of two statistical comparisons of site data to background data. First, the maximum detected site concentration for each analyte in each sample medium is compared to background. This comparison is done on an EU basis and a sitewide basis. Analytes in site data that exceed background concentrations are flagged as preliminary SRCs (pSRCs) in Table A.1. Following the initial comparison to background concentrations, a comparison of the distributions for the site data and the background data is performed for analytes that have sufficient data from site sampling (n=8), and that have detectable background concentrations. Analysis of variance (ANOVA) testing is used to determine whether the means of two populations are significantly different. If both datasets are normally distributed (or log-normally distributed) then a standard ANOVA is performed. If the two datasets have dissimilar distributions or are non-parametric, a non-parametric ANOVA is performed using the Wilcoxon

Rank Sum statistical method. Determination of data distributions in conjunction with the use of the ANOVA and Wilcoxon Rank Sum methods allows for a more statistically rigorous comparison of the site and background data.

The final determination of an SRC involves a logical evaluation process. This process includes the calculation of a "weight-of-evidence" percentage. The weight-of-evidence percentage is determined by the following equation:

$$\text{Weight-of-Evidence} = \frac{\left|\text{maximum detected concentration - UTL}\right|}{\text{UTL}} \times 100$$

The weight-of-evidence percentage is used when statistical evaluations yield differing outcomes or to support the statistical evaluation when only one evaluation could be performed on the data set. The weight-of-evidence percentage is only calculated if the pSRC indicates that the analyte is an SRC. Calculation of the weight-of-evidence percentage is not based on the relationship between the pSRC evaluation results and the ANOVA SRC (aSRC) evaluation results.

The cases for which an analyte is identified as an SRC are described below. Evaluation codes (e.g., YES:2 or NO:0) listed at the end of each bulleted text correspond to footnotes included on Table A.1.

The analyte is identified as a final SRC if:

- both the pSRC and aSRC agree that the analyte is an SRC, even if the weight-of-evidence is less than 1.1 (Yes:2);
- the pSRC is not confirmed by the ANOVA, but the weight-of-evidence is greater than 1.1 (Yes);
- there is no ANOVA, but the pSRC indicates that some site data are above background (i.e., the analyte is an SRC), and the weight-of-evidence is greater than 1.1 (Yes); and
- the ANOVA indicates that the analyte is an SRC although the pSRC does not agree, and the mean of the RI data is greater than the mean of the background data (Yes:1).

Additionally, an analyte is not considered a final SRC if:

- the pSRC is not confirmed by the ANOVA, and the weight-of-evidence is less than 1.1 (No:3);
- both the pSRC and ANOVA agree that the analyte is not an SRC (No:2);
- the ANOVA indicates that the analyte is an SRC although the pSRC evaluation does not agree, and the mean of the RI data is less than mean of the background data (No:4); and
- there are less than 5% detectable results for that analyte in a given medium (No:0). Chemicals that are detected infrequently (e.g. less then 5%) may be artifacts in the data due to sampling, analytical, or other problems and may not be related to site activities or

disposal practices (EPA 1989). These chemicals are not included in the risk assessment. However, they are retained if process knowledge suggested that the data might represent a hot spot.

Exhibit 2.1, provided below, summarizes the evaluation cases used for determination of an SRC.

Exhibit 2.1. SRC Evaluations

pSRC	aSRC	WoE	Final SRC?
Yes	Yes	NA	Yes
Yes	No	>1.1	Yes
Yes	NA	>1.1	Yes
No	Yes	RI Mean>Bkg Mean	Yes
Yes	No	<1.1	No
No	No	NA	No
No	Yes	RI Mean<Bkg Mean	No
No	NA	<5% detects	No

2.1.2.4 Essential Nutrients

Ubiquitous elements that are present at low concentrations and are essential human nutrients are eliminated as COPCs for the BRA. Essential human nutrients include iron, magnesium, calcium, potassium, and sodium. These chemicals are toxic only at very high doses and are considered human nutrients essential to a well-balanced diet. For these reasons, they typically are not considered hazardous to humans. However, at high concentrations they could pose a significant risk. Therefore, for this BRA, if the EPC for an essential nutrient exceeds twice the background concentration for that nutrient, then the nutrient is identified as a COPC and is addressed in the risk characterization (Section 2.4).

2.1.2.5 Risk-based Screening

Once SRCs are determined, a risk-based screening step is conducted to eliminate SRCs that pose negligible risk. While the New York State Department of Environmental Conservation (NYSDEC) and U.S. EPA each have published risk-based concentrations (e.g. technical and administrative guidance memorandum (TAGM), technical and operational guidance series (TOGS), and preliminary remedial goals (PRGs)), none of the receptor scenarios used to calculate these concentrations include all the exposure pathways evaluated in this HHRA (NYSDEC 1994 and 1998). Therefore, their use in risk-based screening may not be sufficiently conservative. Therefore, site-specific PRGs were developed for screening NFSS data.

These PRGs are based on the most conservative human receptor evaluated in this HHRA, the subsistence farmer. The subsistence farmer receptor includes both adult and child receptors. The PRGs are calculated using the same exposure equations and parameters used to calculate carcinogenic and non-carcinogenic risk (see Section 2.2). However, instead of solving for risk, the equations are used to solve for a chemical concentration that corresponds to an acceptable risk. Multiple COPCs were detected in each of the EUs. Consequently, risk-based PRGs are based on either a noncarcinogenic hazard quotient (HQ) of 0.1 or a cancer risk of 10^{-6}, whichever is lower. In addition, the lower of the adult and child PRGs is used. Since the target risk level for non-carcinogenic screening criteria is 1.0, if more than one non-carcinogenic COPC is present, screening chemicals present at the screening value may allow for cumulative risk levels that

exceed the target level of one. Since the screening criteria are calculated for a carcinogenic risk of 10^{-6} and the NCP provides a range of 10^{-4} to 10^{-6} for carcinogenic risk, screening COPCs by the whole PRG value is conservative.

There are no EPA-approved toxicity criteria for lead; therefore, no risk-based PRGs could be developed for screening NFSS lead results. The EPA Office of Solid Waste and Emergency Response *Interim Soil Lead Guidance* (EPA 1994a) established a screening value for lead in soil of 400 mg/kg. EPA's more recent: *Lead; Identification of Dangerous Levels of Lead,* 66 Fed. Reg. 1206, January 5, 2001 also establishes standards for lead in residential soil. This rule establishes the following standards for bare residential soil: a hazard standard of 400 mg/kg by weight in play areas based on the play area bare soil sample and an average of 1200 mg/kg in bare soil in the remainder of the yard based on an average of all other samples collected. (40 CFR § 745.65(c)). When screening NFSS data, the 400 mg/kg standard is used. The 0.1 factor is not applied to the screening value for lead in soil because the lead screening value is calculated using a different method, as described in Section 2.2. The lead drinking water action level of 0.015 mg/L is used for screening groundwater data.

Environmental media at NFSS include soil, groundwater, sediment and surface water. For human receptors, exposures to soil and groundwater are more significant (i.e., there is a greater intake of COPCs) than exposures to sediment and surface water. As an additional conservative screening measure, soil PRGs are used to screen both soil and sediment SRCs. In addition, groundwater PRGs are used to screen both groundwater and surface water SRCs. PRGs used to screen NFSS data are contained in Appendix A Table A.3 for COPCs and Appendix B, Table B.1 for ROPCs.

The maximum detected concentration of each SRC in each EU is compared to the appropriate PRG. When the maximum detected concentration exceeds the PRG, the SRC is identified as a COPC. COPCs are carried into the next step of the HHRA that involves quantifying risks from exposure to COPCs.

2.1.2.6 Summary of COPCs

Table A.3 in Appendix A presents the COPC screening process and identifies which SRCs are COPCs. COPCs are present in all EUs and in all media. COPCs include polychlorinated biphenyls (PCBs), pesticides, polycyclic aromatic hydrocarbons (PAHs) and other SVOCs, VOCs, high explosives, and metals.

Groundwater contamination is evaluated in three EUs. EU 17 is a site-wide unit and includes all groundwater data. However, VOC contaminants in groundwater are localized in two EUs, EU 4 and EU 13. Therefore, groundwater COPCs are identified for EU 17, but also for EUs 4 and 13. Limited groundwater sampling was performed in EU 13. A few significant detections of VOCs occurred in EU 13; however, they were screened out as SRCs due to frequency of detection being less than 5%. These high concentrations warrant further evaluation; therefore, all VOCs detected in EU 13 groundwater are considered COPCs regardless of frequency of detection. These VOCs include 1,1-dichloroethene, 2-butanone, acetone, chloromethane, cis-1,2-dichloroethene, methylene chloride, tetrachloroethene, trans-1,2-dichloroethene, and trichloroethene.

2.2 EXPOSURE ASSESSMENT

The exposure assessment evaluates potential exposure to COPCs for all receptor populations reasonably anticipated to be exposed to COPCs. The exposure assessment is performed in three steps. First the exposure setting is characterized using available site-specific information. A summary of the exposure setting is presented in Section 2.2.1. Second, a CSM, identifying potentially complete exposure pathways between chemical sources and potential receptors, is developed. This is accomplished by the following:

1. identifying current and potential future on-site and off-site receptors;

2. identifying media through which chemicals may come in contact with receptors, including soils, groundwater, sediment and surface water, and air; and

3. identifying the routes of exposure or pathways through which the receptors may be exposed (i.e. ingestion, dermal contact, and inhalation).

A detailed discussion of the CSM including site EUs is presented in Section 2.2.2.

In the third step of the exposure assessment, dose or intake of COPCs for each receptor resulting from contact with contaminated media are calculated. The general equations used to quantify exposure to contaminated media at the NFSS are presented in Section 2.2.3. Potential risks are quantified for all identified receptors using conservative (90-95th percentile) or reasonable maximum exposure (RME) scenario exposure assumptions. Receptors whose potential risks exceeded a hazard index (HI) of 0.1 or a cancer risk of 10^{-6} are also evaluated using median or central tendency exposure (CTE) assumptions. The general equations used to quantify exposure to contaminated media at the NFSS are presented in Section 2.2.3.

2.2.1 Characterization of Exposure Setting

The NFSS is located on the Ontario Plain approximately 3.5 miles east of the Niagara River and 4.0 miles south of Lake Ontario in the Central Lowland Physiographic Province. The Ontario Plain is generally level with a general north to northwestward slope. With the exception of the IWCS, the NFSS is relatively level with elevations ranging from 315 feet AMSL to 321 feet AMSL (Englert and Hinnefeld 1981, BNI 1987, National Lead Company 1979).

2.2.1.1 Regional Geology

The subsurface at the NFSS consists of thick clay deposits overlying dense coarse-grained glaciofluvial sediments that directly contact shale bedrock. Lenses of sand occur in the clay deposits. These units are described in detail in the groundwater modeling report (HGL 2007).

Regional groundwater flow is toward the northwest, mimicking the erosional surface of the underlying bedrock strata (BNI 1994). The bedrock dips to the south but its topography dips northwesterly. Two zones of groundwater have been identified at the NFSS. The upper water-bearing zone occurs chiefly in lenses contained in the clay deposits. Bedrock and a sand and gravel unit located above the bedrock constitute the lower water-bearing zone. Neither of these zones is considered a significant source of groundwater, due to low well yield and/or a high degree of mineralization. Groundwater is rarely used as a potable water supply on, or near NFSS; however, it is considered a potential potable water source for purposes of this HHRA. Despite

low yields and a high degree of mineralization, a recent well survey supplied by the Niagara County Health Department indicates that 6 potable wells are in use in the vicinity of the NFSS, one of which is a sole source well (Niagara County DOH 2006).

The NFSS is nearly level to gently sloping and soils are predominantly poorly drained to very poorly drained. Landform manipulation on the site has been performed to provide surface drainage through a series of ditches. Three main south-to-north ditch systems drain the site. The primary ditch draining the site is the Central Ditch. The Central Ditch flows south-to-north from off-site through the site to the west of Campbell Road immediately east of the IWCS. Most of the site eventually drains to the Central Ditch. The Central Ditch is entrenched to a depth of over 10 feet through most of the site. The West Ditch flows along the western boundary of the NFSS and receives drainage from the west side of the IWCS as well as drainage from off-site. A third ditch flows along the east side of the site. It receives drainage from Modern Landfill to the east of the site and drainage from the eastern third of the site. These ditches and other smaller on-site ditches are discussed in more detail in the SERA (see Section 4.2.1.2).

2.2.1.2 Meteorology

Niagara County and the NFSS have a humid, continental climate moderated by Lakes Erie and Ontario. The monthly average temperature ranges from 26º F to 76º F and the average annual precipitation is 37.5 inches. The wind in the area is predominantly from the west-southwest.

2.2.1.3 Surrounding Land Use

CWM Chemical Service, Inc., a hazardous waste landfill, borders the NFSS to the north and Modern Landfill, Inc., a solid waste disposal facility, borders the NFSS to the east. Modern Landfill also owns some of the property directly south of the site. The Niagara Mohawk Power Corporation owns and uses the property adjoining the west border of the site as a power transmission corridor. The village of Lewiston owns property adjoining the northwestern portion of the site (BNI 1994). A commercial farm is located south of the site and is bordered by Pletcher and Harold Roads. A commercial greenhouse is operated just south of the site at the southwest corner of Pletcher and Harold Roads. Several residences are located further south on Harold Road. A KOA campground is located southwest of the site with its entrance on Pletcher Road. All of the aforementioned properties were once part of the original LOOW. Several residences are located on Pletcher Road approximately one-half mile west-southwest of the site.

2.2.1.4 Grounds Maintenance

At the NFSS, grounds maintenance focuses on the IWCS. Grounds maintenance consists of maintaining the grass at IWCS per the NFSS Turf Management Program and inspection for ruts, depressions, non-grassed areas and other indications as to the soundness of the structure. The grounds maintenance includes, but is not limited to the following:

- Mowing the IWCS structure;
- Fertilization;
- Pesticide treatment;

- Repairing holes, depressions, and non-grassed areas. A typical repair of the IWCS consists of an area 2" wide, 6' long and 6" deep; and

- Dethatching, removing leaves, twigs, and aeration.

Mowing the grounds around IWCS, wellheads and various other areas, including weed and grass trimming is a regular part of the grounds maintenance activity. Work includes brush hogging the fields around the IWCS, access to and around wellheads, road edges, and mowing along the entrance road from Pletcher Road. This activity needs to be done several times a year in order to provide access and prevent over-growth of the roadways.

At other locations on the NFSS, away from the IWCS, tree and bush trimming activity is required to remove overhanging branches and brush from fence lines, roads and other areas that require access. This item is performed on an "as needed" basis in order to comply with any of the other maintenance items. Various other grounds maintenance general activities are performed as needed on the NFSS, including watering the IWCS, snow removal, and road and fence repairs.

Numerous other activities that are not part of the regular grounds maintenance may be performed by qualified personnel as needed, including: utilities maintenance/repairs in radiologically restricted areas, rigging and load-out of equipment, equipment repairs, monitoring well maintenance, and groundwater monitoring.

2.2.2 Conceptual Site Model

The CSM for the HHRA was developed considering a range of current and future receptors, and available site characterization data. Section 2.2.2.1 discusses the range of receptors and why they were selected. The CSM helps identify and visually organize potential exposure pathways and receptors and identifies those pathways that are complete (major or minor) or incomplete. The elements of the CSM are:

- Contamination mechanism (i.e., the origin of contamination),
- Source media (i.e., originally contaminated media),
- Potential transportation mechanisms (e.g., leaching),
- Exposure media (e.g., surface soil, biota, etc.),
- Exposure routes (e.g., inhalation, ingestion, etc.), and
- Potential receptors (e.g., industrial worker, resident, etc.).

Receptors may be exposed to chemicals by direct contact with contaminated source media or as the result of chemical migration away from the source into other media. The source media for the NFSS are surface soils (assumed to be 0 – 6 inches below ground surface) which were contaminated through the transport and storage of waste materials to and within the site boundaries. It is probable that initial chemical releases were restricted to surface soils, with various transport mechanisms leading to subsequent contamination of other environmental media such as subsurface soil (6 inches to 10 feet below ground surface), biota, surface water, sediment, and groundwater. Ten feet below ground surface is generally accepted as the excavation depth needed to construct a home with a basement.

Exposure routes that incorporate constituent migration from a source to a secondary medium (subsurface soil, biota, surface water, sediment, and groundwater) or to an off-site receptor are

identified as indirect contact pathways. Chemical release mechanisms and transport pathways include the following as well as others:

- airborne release of volatiles and fugitive dust containing organic substances, metals, and/or radionuclides;
- uptake and bioaccumulation by flora and fauna (into the food chain);
- leaching of constituents from soil to groundwater; and
- release of contaminated soil particulates to storm water run-off (sediments and surface water).

The BRA evaluates risk to current on-site and future hypothetical on-site receptors only. The protection of off-site receptors from radiological constituents is addressed by the annual environmental surveillance program. In addition, the NFSS groundwater model examines the potential for movement of contaminants off-site.

2.2.2.1 Human Receptors

All of the exposure pathways, receptors, media, and scenarios that may be evaluated in the NFSS HHRA are presented in Figures 2.2 and 2.3. Figure 2.2 is a graphical depiction of the CSM for non-IWCS EUs. This CSM includes both current and future exposure. Figure 2.3 is a graphical depiction of the CSM for the IWCS under current land use. Future exposures to the IWCS are being addressed in the FS. The HHRA evaluates risks from exposures to both chemical (Section 2) and radiological (Section 3) constituents. In both cases, the same receptors are evaluated; therefore, this discussion applies to both the chemical and radiological HHRAs.

Complete pathways are evaluated either quantitatively or qualitatively. For quantitative evaluations of chemicals, exposures are estimated using standard exposure equations and site-specific or standard default parameter values identified for various exposure conditions (EPA 1989, EPA 1992a, EPA 1992b, and EPA 1997a). For quantitative evaluations of radionuclides, exposures are estimated using the RESRAD model (ANL 2001a) and, to the extent possible, the same parameter values identified for chemical analyses. The same exposure parameters were used for both chemical and radiological HHRAs; however, the RESRAD model uses some additional parameters that the chemical risk equations do not include. RESRAD default values are used when standard default or site-specific parameter values are not available. The equations, parameter values, and references used to calculate chemical risks are presented in the following sections. Section 3 presents similar information for radiological risks. For qualitative evaluations of chemicals, relative risk is discussed based on toxicity and/or carcinogenic potential of the site constituents.

The HHRA evaluates the risk to a range of on-site human receptor populations that are currently exposed to SRCS or reasonably anticipated to be exposed to SRCs. Three buildings remain on-site, one of which is abandoned and is scheduled to be demolished. The remainder of the site is currently a combination of abandoned structures such as tank cradles and building foundations, open fields, and wooded areas all surrounded by a 7-ft security fence. It is bounded to the east and north by operating landfills. Under the current land use scenario, on-site receptors include adult and adolescent trespassers and maintenance workers. It is conceivable that future land use could include industrial or, as an extreme case, subsistence farming. Therefore, future on-site

receptors include construction workers, maintenance workers, industrial workers, adult and adolescent recreational visitors, adult and child residents, and adult and child subsistence farmers. All current and potential future receptors are described in more detail in the following paragraphs (also see Figures 2.2 and 2.3). It is assumed that only the current and future maintenance workers will be exposed on the surface of the IWCS. It is also assumed that all other receptors will be exposed to non-IWCS areas.

Maintenance Worker

The site is currently maintained as a government-owned facility. Maintenance activities include mowing, site inspections, and general maintenance of security barriers. These or similar activities will continue indefinitely for the IWCS (as long as it is present) even if the site is transformed into an industrial or residential area. For other areas at NFSS, continued maintenance also is a possible future use scenario. It is assumed that these workers could be exposed to contaminated surface soil and surface water/sediment while on-site including exposures on the surface of the IWCS. Exposure to surface water/sediment would occur during routine ditch maintenance. Specifically, exposure pathways for a maintenance worker include:

- inhalation of volatiles from surface soil, surface water, and sediment;
- inhalation of fugitive dust from surface soil and dry sediment;
- dermal contact with surface soil and surface water/sediment;
- incidental ingestion of surface soil, surface water, and sediment; and
- external gamma exposure to surface soil and sediment evaluated in the radiological HHRA.

The maintenance worker's water supply is from an off-site (uncontaminated) source. The maintenance worker is assumed to be an adult and is considered under both current and future land use scenarios. Exposure assumptions for the maintenance worker are similar to the future industrial worker (see below).

Trespassers/Recreational Receptors

Deer and other game animals are known to exist within the fenced boundary of NFSS and there have been anecdotal accounts of hunters trespassing on the site while hunting local game. Under current land use, the receptors are called trespassers. Future land use could permit hunting on-site; therefore, the receptors are called recreational visitors under the future use scenario. Exposure pathways and parameters are the same regardless of current or future land use. It is assumed that these receptors could be exposed to contaminated surface soil and surface water/sediment while on-site and could consume contaminated meat from site-impacted game. Fish consumption is not considered a complete exposure pathway because NFSS does not contain bodies of water capable of supporting game fish populations. Specifically, exposure pathways for a trespasser/recreational visitor include:

- inhalation of volatiles from surface soil, surface water, and sediment;
- inhalation of fugitive dust from surface soil and dry sediment;
- dermal contact with surface soil and surface water/sediment;
- incidental ingestion of surface soil and sediment;
- external gamma exposure to surface soil and sediment; and
- consumption of meat from impacted game.

Two age groups are considered including an adult and a 7-16 year old adolescent. The 7–16 age range is used to span 10 years after the 0–6 years of childhood. For purposes of exposure assessment, an individual who is more is than 16 years old is assumed to be an adult. Both the adult and adolescent receptors are considered under current and future land use scenarios.

Construction Worker

Future land use scenarios include the development of NFSS for industrial or residential use. There are currently no habitable structures on the site, there is no useable utility infrastructure, and there is inadequate vehicle access. Therefore, construction workers likely represent the first group of receptors that could be exposed if the site is developed for industrial or residential use. It is assumed that these workers could be exposed to contaminated surface soil, subsurface soil (below the top 6 inches), surface water/sediment, and upper groundwater while on-site. The construction worker also accounts for exposures typical of landfill workers. Specifically, exposure pathways for a construction worker include:

- inhalation of volatiles from surface soil, subsurface soil, surface water, upper ground water, and sediment;
- inhalation of fugitive dust from surface soil, subsurface soil, and dry sediment;
- dermal contact with soil (surface and subsurface), sediment (including pipe sludge), and water (surface and upper groundwater);
- incidental ingestion of soil, surface water, sediment, and upper groundwater; and
- external gamma exposure to soil and sediment.

The construction worker is assumed to be an adult and is considered only under future land use scenarios. The construction worker is the only receptor assumed to be exposed to materials (sludge and water) in inactive pipelines at NFSS. The construction worker would be exposed to these materials during future pipeline removal. Exposures to pipeline sludge and water are quantified in the same manner as exposures to sediment and surface water.

Industrial Worker

Future land use scenarios include the development of NFSS for industrial use. This scenario could include the construction of office space or warehouses that would be occupied by full-time employees (i.e., industrial workers). It is assumed that these workers could be exposed to contaminated surface soil and surface water/sediment while on-site. Specifically, exposure pathways for an industrial worker include:

- inhalation of volatiles from surface soil, surface water, and sediment;
- inhalation of fugitive dust from surface soil and dry sediment;
- dermal contact with surface soil and surface water/sediment;
- incidental ingestion of surface soil surface water, and sediment; and
- external gamma exposure to surface soil and sediment.

The industrial worker is assumed to be an adult and is considered only under future land use scenarios.

Residents

In spite of the proximity to two operating landfills, future land use scenarios include the development of NFSS for residential use because there are currently residents within approximately 2,500 feet of the front entrance to the site. It is assumed that residents could be exposed to contaminated surface soil, surface water/sediment, impacted homegrown produce (i.e., from a garden), and upper and lower groundwater while on-site. Specifically, exposure pathways for a resident include:

- inhalation of volatiles from surface soil, subsurface soil, surface water, upper and lower groundwater, and sediment;
- inhalation of fugitive dust from surface soil, subsurface soil, and dry sediment;
- dermal contact with surface soil, surface water/sediment, and upper and lower groundwater;
- incidental ingestion of surface soil, subsurface soil, surface water, and, sediment;
- intentional ingestion of home-grown produce, and upper and lower groundwater; and
- external gamma exposure to surface soil, subsurface soil, and sediment.

Two age groups are considered including an adult and a 0-6 year old child. Both the adult and child residential receptors are considered only under future land use scenarios.

Subsistence Farmer

The subsistence farming scenario is considered as the most conservative future use scenario for NFSS. This scenario is conceivable given the site contains large open fields and wooded areas, but is unlikely given the proximity to two operating landfills and a cultural trend away from subsistence farming. However, there is a farm located just south of NFSS and there are many farms/orchards in Niagara County. The subsistence farming scenario includes the development of a working farm with livestock for meat and dairy products plus cultivated land for grains, fruits, and vegetables. It is assumed that a subsistence farmer could be exposed to contaminated surface soil, surface water/sediment, impacted homegrown produce, impacted meat and dairy products, and upper and lower groundwater while on-site. Fish consumption is not considered a complete exposure pathway because NFSS does not contain bodies of water capable of supporting game fish populations. Irrigation with surface water or groundwater is not included because the regional climate provides adequate rainfall in most years. Specifically, exposure pathways for a subsistence farmer include:

- inhalation of volatiles from surface soil, subsurface soil, surface water, upper and lower groundwater, and sediment;

- inhalation of fugitive dust from surface soil, subsurface soil, and dry sediment;

- dermal contact with surface soil, surface water/sediment, and upper and lower groundwater;

- incidental ingestion of surface soil, subsurface soil, surface water, and sediment;

- intentional ingestion of home-grown produce, beef, poultry, and dairy products, and upper and lower groundwater; and

- external gamma exposure to surface soil, subsurface soil, and sediment.

Two age groups are considered including an adult and a 0-6 year old child. Both the adult and child subsistence farmer receptors are considered only under future land use scenarios.

2.2.2.2 Exposure Units

The site is divided into 18 separate EUs, or areas over which a receptor is likely to average his or her exposure, for the BRA. The EUs for NFSS are defined based on administrative considerations and available data. Each is explained below.

Administrative Considerations

Administrative considerations for EUs are factors unrelated to site data, such as:

- Adequate representation of potential site exposures in terms of receptor behavior,

- The potential for future release of specific properties for re-use (e.g., sale of property to adjacent landfills),

- Consistency with previous divisions of the site as identified in prior site investigations,

- Consistency with historical use of specific areas at NFSS,

- Consistency with operable unit definitions for the FS,

- Conformity for use in both the HHRA and SERA and

- Relative size of each EU.

Data Considerations

Regarding the data, there are several issues to consider. There must be sufficient sample points within each EU to conduct the BRA and the actual analytical results are important factors used to define EUs. For example, EUs should be defined such that distinct areas of contamination are not split (i.e., diluted) between two or more EUs. In addition, the data needs to be organized spatially

to address the potential for off-site influences (e.g., contamination originating from adjacent landfills).

Definition of EUs

The 18 EUs are shown on Figures 2.4, 2.5, and 2.6 and are listed below. Note that for the purpose of defining environmental media within EUs, sediments are operationally defined as being in ditches that are submerged (wet) for at least six months of the year (i.e., 50 percent of the year). Areas submerged for less than 50 percent of the year are defined as soil areas. Thus, whether a ditch is wet at least 50 percent of the year dictates the types of media to which receptors in a given EU are exposed. Areas wet at least 50 percent of the year are shown in Figure 2.5. Only EUs 5, 9, 15, 16, and 17 contain surface water and sediment. Surface water and sediment in EU 9 was evaluated only for radiological constituents.

Groundwater contamination is evaluated in three EUs. EU 17 is a site-wide unit and includes all groundwater data. However, VOC contaminants in groundwater are localized in two EUs, EU 4 and EU 13. Therefore, groundwater COPCs are identified for EU 17, but also for EUs 4 and 13.

- EU 1 contains soil in the northwest corner of NFSS, referred to as the Baker-Smith Area. The Baker-Smith Area consisted of a storehouse, pipe shop, welding shop, and machine shop where potentially hazardous materials may have been used. Prior to their demolition, radioactive residues were stored in these buildings. This included storage of Knolls Atomic Power Laboratory (KAPL) Waste (Aerospace Corp. 1982). The EU is currently overgrown with shrubs and trees with some open areas around the former building areas. EU 1 is approximately 6.9 acres.

- EU 2 contains soil in the area immediately east of EU 1. This area is not known to have contained buildings or process equipment during the time when operations were ongoing at the site. The EU is bordered to the west by the Baker-Smith Area, to the north by the NFSS property boundary, to the east by the New Naval Waste Area (EU 3), and to the south by O Street. The historical activities in the eastern portion of EU 2 are associated with the New Naval Waste Area (EU 3) and former Acidification Area (EU 4), but EU 2 is now separated from these areas by a fence. The Central Ditch flows north through the center of EU 2. Young upland forest covers most of the area. Maintained turf grass is present in some areas. EU 2 is approximately 17.6 acres.

- EU 3 contains soil in the western portion of the former Acidification Area, EU 4. This area differs from the rest of Acidification Area in that it is also known as the New Navy Waste Area. Records indicate that waste from the Navy Mathieson area was placed here. Currently, young shrubs and trees cover the area. EU 3 is approximately 4.7 acres.

- EU 4 contains soil in the former Acidification Area. This area was used as the acidification and acid storage location for the TNT production plant. Several aboveground tanks storing various acids (nitric and sulfuric) and other potentially hazardous materials were located in this area and were used in the 1940s when the LOOW produced TNT. Tank cradles and concrete slabs are still present. Possible fuel oil storage and TNT mix storage may have occurred in this area. Temporary storage locations and constructed vaults for storage of pure uranium, thorium, and radium billets, ingots, bars, and rods reportedly existed in the former acidification area. The area is

presently overgrown with young upland forest shrubs and trees. EU 4 is approximately 13.9 acres.

- EU 5 contains soil, surface water, and sediment in the area east of the former Acidification Area. CWM Chemical Services, LLC Landfill is located to the north and Modern Landfill is located to the south. EU 6 is located to the east. EU 5 did not contain any buildings during site operations; however, the pipeline that transported radioactive residues from the former Building 434 in the EU 6 area to the IWCS ran through EU 5. This pipeline was monitored during the transfer of K-65 residues and no leaks were reported. Currently EU 5 contains mostly young upland forest. CWM East Ditch Outfall, N Street South Pond, and O Street North Pond are semi-permanently flooded wetland areas. Sediment and surface water in these wetlands are included in EU 5. EU 5 is approximately 16.1 acres.

- EU 6 contains soil in the far northeastern corner of NFSS. CWM Chemical Services, LLC. Landfill is located to the north and Modern Landfill is located to the south. EU 6 formerly contained Building 434, the K-65 silo (the former Cooling Water Storage Tower). The central portion of EU 6, where Building 434 previously was located, is covered by maintained turf grass. Young shrubs and trees are present around the perimeter. EU 6 is approximately 13.3 acres.

- EU 7 contains soil in the area north of the IWCS and south of O Street, including the Organic Burial Area where cut vegetation was previously disposed. Currently, EU 7 is covered by maintained turf grass. EU 7 is approximately 13.2 acres.

- EU 8 contains soil in the former shops area. This area once contained a parking garage, an equipment maintenance garage and repair shop, material shed, general storehouse, combined shops, millwright shop, and riggers shop. None of these buildings remain although some concrete building foundations are still present. Radioactive residues were stored in several of the former buildings in this EU. Corroded uranium billets were cut into smaller sections in the riggers shop. Vegetation in EU 8 is predominantly young, scrubby wet forest (ash, elm, and maple) with some reeds and cattails in ditch areas. EU 8 is approximately 18.9 acres.

- EU 9 includes soil in the off-site Niagara Mohawk property adjacent to the western border of NFSS. Contaminants may have been released to this area during past site operations and construction of the IWCS. The West Ditch flows south to north through the entire length of EU 9. Old-field vegetation is present underneath the power line. Reeds fill most of the West Ditch. The northernmost reach of the West Ditch within EU 9 contains sediment that is submerged more than 50 percent of the year. EU 9 is approximately 5.7 acres.

- EU 10 contains the IWCS and adjacent soil, surface water, and sediment. The IWCS contains the radioactive residues, radioactive wastes from prior decontamination efforts at both NFSS and vicinity properties, building rubble, drummed radioactive tar-like waste, foundations from buildings 409, 411, 413, and 414, and other construction debris. The cap covering the IWCS was initially completed in 1986. Additional material was placed on top of the existing IWCS cap in 1991 and an additional cap layer was placed to entomb the material. A network of groundwater monitoring wells surrounds the IWCS. Except for vegetation in the ditches, all of EU 10 including the IWCS is covered by

maintained turf grass. EPCs were developed for residual constituents found in media outside or in the vicinity of the IWCS. EU 10 is approximately 25.7 acres.

- EU 11 is located between the IWCS and Building 401. The two other remaining buildings, Building 429 and the Hittman Building, are located in EU 11. Campbell Street, the main site access road, runs north and south through EU 11. The site water treatment system previously was located in this area. Maintained turf grass now covers the area. EU 11 is approximately 19.2 acres.

- EU 12 includes soil in the area north and east of Building 401. Modern Landfill borders the EU to the east. No buildings were previously located in this area. Young, wet forest now covers most of the area. EU 12 is approximately 10.2 acres.

- EU 13 contains soil in the Building 401 area. Building 401 was initially a coal-fired boiler house used to supply steam to the TNT production facility located to the north of NFSS. Subsequent renovations of the building in 1953 converted the building into a boron-10 isotope separation plant. Later it stored KAPL Waste. Building 401 is now a dilapidated structure and is scheduled to be decontaminated and demolished. Vegetation in EU 13 is primarily maintained turf grass. EU 13 is approximately 3.5 acres.

- EU 14 contains soil in the area south and southeast of Building 401. This area is not known to have contained buildings or process equipment during the time when operations were ongoing at the site. The EU is bordered to the east by Modern Landfill and to the south by the NFSS property boundary. Modern Ditch and the South 31 Ditch flow through this EU. Young wet forest covers most of the area. The western portion contains maintained turf grass. The ditches are filled with reeds. EU 14 is approximately 14.3 acres.

- EU 15 contains surface water and sediment in the main ditch system including Central Ditch, South 16 Ditch, South 31 Ditch, and Modern Ditch (see Figure 2.5). This ditch system drains most of the central portion of NFSS and receives runoff from Modern Landfill. The Central Ditch exits the site to the north in EU 2. Surface water is present in these ditches more than 50 percent of the year. The Central Ditch contains flowing water year-round. Reeds and cattails are frequently present in all these ditches.

- EU 16 contains on-site pipelines used in former site operations. These pipelines include acid lines, water lines, sanitary sewers, and storm sewers. The locations of pipelines are shown of Figure 2.6. Evaluation of direct exposures to material (sludge and water) in pipelines is limited to future construction workers who may be exposed to this material during pipeline removal.

- EU 17 is a site-wide EU and includes all areas and media within the property boundary of NFSS and the adjacent Niagara Mohawk Property (EU 9). This includes all soil, sediment, surface water, and pipeline material in EUs 1 through 16. In addition it contains site-wide groundwater, including both the upper and lower water bearing zones. For purposes of future exposure, the lower water-bearing zone is assumed to be the source of drinking water; however, due to the potential for connectivity between the two water-bearing zones, all NFSS groundwater data are used to generate exposure concentrations. EU 17 is approximately 191 acres.

- EU 18 contains off-site areas where background samples were collected. No risks were quantified for this EU.

Although larger than an individual home parcel, the on-site EUs are of a reasonable size for many of the receptors that will be considered in the BRA such as maintenance/industrial workers, recreational visitors, subsistence farmers, and many of the ecological receptors. In addition to risk evaluations for each EU, a site-wide risk evaluation will be performed for each human receptor utilizing the complete site data set.

2.2.3 Quantification of Exposure Concentration and Pathway-Specific Intakes

2.2.3.1 Exposure Point Concentrations

In order to quantify exposure to each receptor, an EPC, or the estimate of the constituent concentration a receptor is likely to come in contact with over the duration of exposure, is calculated. EPCs are calculated on an EU-specific basis. Additionally, site-wide EPCs are calculated for use in the site-wide assessment (EU 17). For both the CTE and the RME scenarios, EPCs for soil, sediment, surface water, and groundwater are determined by calculating the 95% upper confidence limit (UCL) of the mean following the procedures presented in EPA's 2002a *Calculating Upper Confidence Limits for Exposure Point Concentrations at Hazardous Waste Sites* (OSWER 9285.6-10) (EPA 2002a).

A normal UCL is calculated for normally distributed data. A number of UCL calculation approaches are used for lognormal data (using log transformed data) based on the skewness of the data and the number of samples. The Land statistic is used for lognormal data with a skewness of 0.1 or less. Chebyshev 95%, 97.5% and 99% UCLs determined using the minimum variance unbiased estimators of the mean and variance are calculated for varying levels of skewness and sample numbers. Regular Chebyshev 95%, 97.5%, and 99% UCLs determined using the standard mean and variance are calculated on untransformed, non-parametric data. A regular Chebyshev 99% UCL is calculated for low sample numbers and high skewness sets of data. The assignment of the UCLs to the data follows provisions in the ProUCL user guide (EPA 2004c). EPA issued the ProUCL program to assist in the determination of UCLs following the methodology in their 2002a guidance. The UCL is used as the EPC except in cases where the maximum detected value is less than the EPC. In these cases, the maximum detected value is used as the EPC not the 95% UCL.

EPCs are used to estimate the intake of each COPC by individual receptors via all pathways and media identified in the CSM. Intake is a measure of exposure expressed as the concentration of a constituent that has come in contact (e.g. ingestion, inhalation, dermal, etc.) with a receptor per unit body weight per unit of time [milligram per kilogram day (mg/kg-d)]. With the exception of groundwater, current and future EPCs are the same. Estimation of future groundwater EPCs is described in Section 2.2.3.2.

Chemical Concentrations in Food

There are no direct measurements of chemical concentrations in food produced on-site; therefore, EPCs for these media must be estimated.

Homegrown Produce and Animal Forage

Chemical concentrations in homegrown produce and forage for animals are calculated using factors for uptake from soil into the edible portion of plants. The soil EPC is used as the starting concentration for estimating chemical concentration in produce and forage. For the chemicals and conditions at NFSS, root uptake is expected to be the primary mechanism for transfer of soil contaminants to plants.

According to EPA (1999a), the wet weight plant concentration due to root uptake (Pr) is estimated as:

$$Pr = Cs \times (BCF)r \times 0.12$$

where:

Cs = dry weight concentration of contaminant in soil (mg/kg soil)
BCFr = plant-soil bioconcentration factor (BCF)(unitless)
12 = dry weight to wet weight conversion factor (unitless).

EPA (1999a) ascribes credit for the approach to Travis and Arms (1988).

The concentration in edible portions of plants through root uptake from soil is a function of the chemical-specific soil concentration and chemical-specific plant bioconcentration factors (BCFr). BCFr is equivalent to the soil-to-plant bioconcentration factor, or SPv used to determine plant uptake in the screening ecological risk assessment (see Section 4.3.5.1). The same values are used for homegrown produce.

For most organic COPCs, SPvs are calculated using an equation developed by Travis and Arms (1988).

$$\log(SPv) = 1.588 - 0.578 \times \log(K_{ow})$$

where:

SPv = soil-to-plant bioconcentration factor (kg dry soil/kg plant or g dry soil/g plant)
K_{ow} = octanol-water partitioning coefficient (unitless).

Values of $\log(K_{ow})$ are given in Table 2.2.

SPvs for inorganic COPCs are taken from several sources, including EPA's *Soil Screening Guidance* (EPA 1996b), DOE uptake models (DOE 1998a), EPA guidance for hazardous waste combustion (EPA 1999c), Washington State Department of Ecology (WSDE) Toxics Cleanup Program Table 749-5 (WSDE 2003), and Baes et al. (1984) and are provided in Table 4.2.

Chemical concentrations in animal products (beef, poultry, deer, milk) are calculated from chemical concentrations in soil and feed, and chemical-specific bioconcentration factors as shown in the equations below (EPA 1998a). Chemical concentrations in animal products are only calculated for chemicals with log K_{ow} values greater than four (4). Generally, there is minimal bioaccumulation at log K_{ow} of four (4) and below (EPA 1998a).

Beef

The following equation (EPA 1998a) calculates the concentration of a COPC in beef from cattle that ingest contaminated plant and soil material.

$$A_{beef} = \left[\left(F_f \cdot Qp_f \cdot P_f\right) + Qs_{soil(beef)} \cdot Cs \cdot Bs\right] \cdot Ba_{beef} \cdot MF$$

where:

A_{beef}	=	Concentration of COPC in beef (mg/kg).
F_f	=	Fraction of forage grown on contaminated soil and ingested by the animal (unitless).
Qp_f	=	Quantity of forage ingested by the animal per day (kg/day). Qp_1 = 8.8 kg/day for forage (beef), (EPA 1998a).
P_f	=	Concentration of COPC in forage ingested by the animal (mg/kg). Calculated using the same equation as for homegrown produce.
$Qs_{soil(beef)}$	=	Quantity of soil ingested by the beef cattle (kg/day). EPA (1998a) recommends a default $Qs_{soil(beef)}$ value of 0.5 kg/day.
Cs	=	Average soil concentration (mg/kg).
Bs	=	Soil bioavailability factor (unitless). EPA (1998a) recommends a default Bs value of 1.
Ba_{beef}	=	Biotransfer factor for beef (day/kg).
MF	=	Metabolism factor (unitless). EPA (1998a) recommends default MF values of 0.01 for bis(2-ethylhexyl)phthalate and 1 for all other constituents.

This calculation assumes that beef cattle only consume forage grown on contaminated soil (i.e., it is assumed that cattle do not also consume silage and grain produced on contaminated soil).

Uptake factors (Ba_{beef}) for inorganic chemicals from feed-to-beef are available from Baes et al. (1984). Uptake factors (Ba_{beef}) for organic chemicals (other than dioxins) from feed-to-beef are calculated using an equation developed by Travis and Arms (1998).

$$\log Ba_{beef} = -7.6 + \log K_{ow} \qquad (n=36,\ r=0.81)$$

Uptake factors calculated for feed-to-beef are also used to calculate concentrations in wild game (deer) using a venison to beef fat content ratio of 2.9/14.4.

Dairy Products

The following equation (EPA 1998a) calculates the concentration of a COPC in milk from dairy cattle that ingest contaminated plant and soil material.

$$A_{milk} = \left[\left(F_f \cdot Qp_f \cdot P_f\right) + Qs_{soil(milk)} \cdot Cs \cdot Bs\right] \cdot Ba_{milk} \cdot MF$$

where:

A_{milk} = Concentration of COPC in milk (mg/kg).

F_f = Fraction of forage grown on contaminated soil and ingested by the animal (unitless). EPA (1998a) recommends a default F_i value of 1 for all plant types when site-specific information is not available.

Qp_f = Quantity of forage ingested by the animal per day (kg/day). EPA (1998a) recommends that dairy cattle raised by subsistence dairy farmers be evaluated by using default value of Qp_1 = 13.2 kg/day for forage (milk).

P_f = Concentration of COPC in forage ingested by the animal (mg/kg). Calculated using the same equation as for homegrown produce.

$Qs_{soil(milk)}$ = Quantity of soil ingested by the dairy cattle (kg/day). EPA (1998a) recommends a default $Qs_{soil(milk)}$ value of 0.4 kg/day.

Cs = Average soil concentration (mg/kg).

Bs = Soil bioavailability factor (unitless). EPA (1998a) recommends a default Bs value of 1.

Ba_{milk} = Biotransfer factor for milk (day/kg).

MF = Metabolism factor (unitless). EPA (1998a) recommends default MF values of 0.01 for bis(2-ethylhexyl)phthalate and 1 for all other constituents.

This calculation assumes that dairy cattle only consume forage grown on contaminated soil (i.e., it is assumed that cattle do not also consume silage and grain produced on contaminated soil).

Uptake factors (Ba_{milk}) for inorganic chemicals from feed-to-milk are available from Baes et al. (1984). Uptake factors for organic chemicals from feed-to-milk (Ba_{milk}) are calculated using an equation developed by Travis and Arms (1988).

$$\log Ba_{milk} = -8.10 + \log K_{ow} \qquad (n = 28, r = 0.73)$$

Poultry

The following equation (EPA 1998a) calculates the concentration of a COPC in chicken meat from free-range chickens that ingest contaminated plant and soil material.

$$A_{chicken} = \left(F_{grain} \cdot Qp_{grain(chicken)} \cdot P_{grain} + Qs_{soil(chicken)} \cdot Cs \cdot Bs\right) \cdot Ba_{chicken}$$

where:

$A_{chicken}$ = Concentration of COPC in chicken meat (mg/kg).

F_{grain} = Fraction of grain grown on contaminated soil and ingested by the animal (unitless). EPA (1998a) recommends a default F_i value of 1 for all plant types when site-specific information is not available.

$Qp_{grain(chicken)}$ = Quantity of grain ingested by the animal per day (kg/day). The EPA (1998a) recommends that chickens raised by subsistence farmers be evaluated by using a default $Qp_{grain(chicken)}$ value of 0.2 kg/day for grain (chicken).

P_{grain} = Concentration of COPC in grain ingested by the animal (mg/kg). Calculated using the same equation as for homegrown produce.

$Qs_{soil(chicken)}$	=	Quantity of soil ingested by the chicken (kg/day). The EPA (1998a) recommends a default $Qs_{soil(chicken)}$ value of 0.022 kg/day.
Cs	=	Average soil concentration (mg/kg).
Bs	=	Soil bioavailability factor (unitless). The EPA (1998a) recommends a default Bs value of 1.
$Ba_{chicken}$	=	Biotransfer factor for chicken (day/kg).

This calculation assumes that chickens only consume grain grown on contaminated soil.

Uptake factors for poultry ($Ba_{chicken}$) are extrapolated from the beef uptake factors using the ratio of fat in chicken vs. beef. The feed-to-poultry uptake factor can be calculated using a chicken-to-beef fat content ratio of 8/17.

Game

The following equation calculates the concentration of a COPC in deer meat from deer that ingest contaminated plant and soil material (EPA 1998a).

$$A_{game} = \left(F_{forage} \cdot Qp_{forage(deer)} \cdot P_{forage} + Qs_{soil(deer)} \cdot Cs \cdot Bs\right) \cdot Ba_{deer} \cdot MF$$

where:

A_{game}	=	Concentration of COPC in deer meat (mg/kg).
F_{forage}	=	Fraction of forage grown on contaminated soil and ingested by the animal (unitless).
$Qp_{forage(deer)}$	=	Quantity of forage ingested by the animal per day (kg/day). A $Qp_{forage(deer)}$ value of 1.463 kg/day for forage (deer) is used based on a deer body weight of 66.5 kg and a forage ingestion rate of 0.022 kg/kg-body weight/day (Higley and Kuperman 1996).
P_{forage}	=	Concentration of COPC in forage ingested by the animal (mg/kg). Calculated using the same equation as for homegrown produce.
$Qs_{soil(deer)}$	=	Quantity of soil ingested by the deer (kg/day).
Cs	=	Average soil concentration over exposure duration at 1 cm soil depth (mg/kg).
Bs	=	Soil bioavailability factor (unitless). The EPA OSW recommends a default Bs value of 1.
Ba_{deer}	=	Biotransfer factor for venison (day/kg).
MF	=	Metabolism factor (unitless). The EPA (1998a) recommends default MF values of 0.01 for bis(2-ethylhexyl)phthalate and 1 for all other constituents.

This calculation assumes that deer only consume forage grown on contaminated soil.

2.2.3.2 Use of SESOIL and Groundwater Flow Models

Seasonal Soil Compartment (SESOIL) modeling was performed at NFSS to predict the rate of contaminant migration through the unsaturated zone to the water table based on leaching from contaminated soils to groundwater. The results of the SESOIL modeling were used in the groundwater transport model to simulate lateral transport of contaminants from principal source areas to receptor locations. The soil leachability analysis is a screening analysis performed to

define migration constituents of potential concern (mCOPCs). In general terms, the mCOPCs are those constituents with the potential to leach to the water table at unacceptable concentrations. These concentrations are used to estimate future risk from exposure to groundwater COPCs.

For SESOIL modeling, the seventeen EUs used for the BRA were redefined into 14 physical EUs (i.e., the EU where the samples were collected). Therefore, separate sets of migration site-related constituents (mSRCs) were developed for these 14 EUs and evaluated for potential leachability threat to groundwater by performing leachability analysis. The soil leachability analysis is a screening analysis performed to define the mCOPCs. In general terms, the mCOPCs are those constituents with the potential to leach to the water table at unacceptable concentrations. A detailed discussion of the development of the mCOPCs is presented in Appendix E.

At the NFSS, the depth to water table (also known as unsaturated zone or the vadose zone) ranges from 1.9 ft to 11.5 ft bgs (Appendix E, Section 3, Table 2). SESOIL is applicable only to the vadose zone of thickness of 1.9 to 11.5 ft. For SESOIL modeling purposes, EU 15 (interconnected waterways), EU 16 (pipelines) and EU 17D (deep soils) samples were removed from their risk EU and categorized within the EU in which they are physically located. The reason for this is that EU 15, EU 16 and EU 17D span multiple EUs and the SESOIL modeling focused on physical EU boundaries and associated soil data in the unsaturated soil zone. The redistribution of these samples resulted in different minimum and maximum detected concentrations than those generated in the BRA SRC tables. SESOIL modeling was performed for mCOPCs that were expected to reach the water table within 10,000 years for metals and radionuclides and 1,000 years for organic compounds. The maximum soil concentration data collected at different depth intervals above the water table for each EU were used as the source term concentrations as input to SESOIL. The model was calibrated against the percolation rate developed by Hydrologic Evaluation of Landfill Performance (HELP) model simulations (Schroeder et al. 1994). The source term concentrations for all the mCOPCs from each EU, and the final site-specific hydrogeologic parameter values including the calibrated parameters are presented in Appendix E.

The SESOIL predicted maximum leachate concentrations do not represent groundwater concentrations. Once the leachate reaches the water table, contaminant concentration will be diluted by groundwater flow in the aquifer. Therefore, the predicted maximum leachate concentrations were divided by the site-specific dilution attenuation factor (DAF; i.e., 20) to estimate the maximum groundwater concentrations. If the estimated maximum groundwater concentration of a mCOPC from an EU was predicted to be greater than its MCL/Risk Based Concentration (RBC) then that mCOPC was identified as a final mCOPC to be modeled using MODFLOW-SURFACT (HGL 1996).

The results of SESOIL modeling are shown in Appendix E. Presented in this table are the SESOIL predicted peak leachate concentrations at the water table / vadose zone interface beneath the source area and the corresponding time for peak leachate concentrations. The predicted peak contaminant fluxes are also presented in this table. Appendix E contains the predicted contaminate flux for all mCOPCs. Appendix E, Table 5 shows that, among the VOCs, only methylene chloride is expected to exceed its MCL in groundwater based on leaching from contaminated soils from EUs 4, 8 and 13. Carbazole, an SVOC in EU 8, was also predicted to produce groundwater concentrations above its MCL/RBC based on leaching from contaminated soils from EU 8. Therefore, methylene chloride and carbazole were identified as final mCOPCs. Metals that were identified as final mCOPCs are antimony (EU 13), arsenic (EUs 12, 13 and 14), boron (EU 13), and cadmium (EU 13). Total uranium was identified as a final mCOPC from all the EUs. Among the radionuclides, Ra-226, U-234, U-235 and U-238 were predicted to reach the

water table exceeding their respective MCLs/RBCs within 10,000 years and were identified as final mCOPCs. Ra-226 is expected to exceed its MCL in groundwater based on leaching from EUs 5, 6, 7, 8, 11, 13, and 14. U-234, U-235 and U-238 are expected to exceed their MCLs in groundwater based on leaching from all 14 EUs except U-235 is not predicted to exceed its MCL in groundwater based on leaching from EUs 2, 3, 9, and 12.

It should be noted here that the SESOIL predicted maximum leachate concentrations do not represent groundwater concentrations. Once the leachate reaches the water table, contaminant concentration will be diluted by aquifer flow and the resulting groundwater concentrations may be significantly lower than the leachate concentrations generated by SESOIL. Therefore, SESOIL results should be understood and used in this context, and the predicted concentrations at downgradient receptors/exposure points based on MODFLOW-SURFACT (HGL 1996) simulations using the SESOIL results performed by HydroGeoLogic, Inc. (HGL) should be used for comparison against the groundwater criteria.

The three-dimensional (3-D) groundwater flow and contaminant transport numerical model, referenced earlier as MODFLOW-SURFACT, was developed by HydroGeoLogic, Inc. The computer model and results are described in detail in the *Draft Groundwater Flow and Contaminant Transport Modeling Report* (HGL 2007). The model addresses the long-term fate and transport of constituents in groundwater.

Inputs to the model included information from the SESOIL modeling described above and the following additional "source terms".

1. The results of Hydrologic Evaluation of Landfill Performance (HELP; Schroeder et al. 1994) and one-dimensional (1-D) MODFLOW-SURFACT modeling. The HELP model and 1-D model were applied to the IWCS and vertical transport of contaminants was estimated assuming IWCS contents (residues, contaminated soils, and other materials) were unsaturated.

2. The existing plume maps. The plume maps identify limited areas on-site where current concentrations of constituents exist in groundwater above the background UTLs or MCLs, as appropriate.

The model results were used to evaluate future risks to off-site receptors. Results of the modeling are described in Section 5.5.

2.2.3.3 Pathway-Specific Intakes

The following subsections present the equations used to quantify exposure for receptors identified at NFSS and the intake resulting from exposure. The equations presented below are taken from RAGS (EPA 1989) except where noted otherwise. Exposure parameters for the RME and CTE scenarios are presented in Tables 2.3 and 2.4, respectively. The subsistence farmer and residential scenarios include both adult and child receptors. When calculating cancer risks, EPA (1991b) recommends using age-adjusted intakes. Therefore, age-adjusted intakes are calculated assuming 6 years exposure as a child and 24 years exposure as an adult for a combined 30-year exposure. Age-adjusted intake parameters for RME and CTE scenarios for the subsistence farmer are presented in Tables 2.3a and 2.4a, respectively. Age-adjusted intake parameters for RME and CTE scenarios for the resident receptor are presented in Tables 2.3b and 2.4b, respectively. In these tables the age-adjusted factor replaces the exposure parameters listed below them in order to calculate the age-adjusted intake. Cancer risk is then calculated using this age-adjusted intake.

Because the risk characterization equation for carcinogens is developed assuming a lifetime of exposure, the exposure averaging time is the average lifetime or 70 years. For non-cancer toxic effects, the reference dose (RfD) does not assume a lifetime exposure so age-adjustment is not calculated for non-cancer risks. The averaging time equals the years of exposure duration. This means that the age-adjusted receptor yields a more conservative cancer risk characterization while the child-only receptor yields a more conservative risk characterization for non-cancer risks.

Soil and Sediment Exposure Pathways

Incidental ingestion of soils and sediments is estimated using the following equation:

$$\textit{Chemical Daily Intake (mg / kg - d)} = \frac{C_s \times IR_s \times CF \times EF \times ED}{BW \times AT}$$

where:

C_s	=	chemical concentration in soils or sediments (mg/kg)
IR_s	=	ingestion rate (mg soil or sediment/day)
CF	=	conversion factor (10^{-6} kg/mg)
EF	=	exposure frequency (days/year)
ED	=	exposure duration (years)
BW	=	body weight (kg)
AT	=	averaging time (days)

The evaluation of the dermal exposure pathway follows guidance presented in EPA's RAGS *Volume I, Human Health Evaluation Manual* (Part E, Supplemental Guidance for Dermal Risk Assessment) (EPA 2004a). Specifically, the following information and procedures from RAGS Part E were used in the calculation of dermal uptake for chemical constituents. Gastrointestinal absorption (GI) and dermal absorption (ABS) factors were taken from RAGS Part E. For exposure to soil and sediment, when no chemical-specific ABS value was available, no quantitative assessment of the dermal pathway is included in the intake calculation. The dermal absorbed dose (DAD) from chemicals in soils and sediments is calculated as follows (EPA 2004a):

$$\textit{Chemical DAD (mg / kg – d)} = \frac{C_s \; x \; CF \; x \; AF \; x \; ABS \; x \; EF \; x \; ED \; x \; EV \; x \; SA}{BW \; x \; AT}$$

where:

DAD	=	dermal absorbed dose (mg/kg-d)
C_s	=	chemical concentration in soils or sediments (mg/kg)
CF	=	conversion factor (10^{-6} kg/mg)
AF	=	soil or sediment to skin adherence factor (mg/cm^2)
ABS	=	chemical-specific absorption factor (ABS) (unitless)
EF	=	exposure frequency (days/yr)
ED	=	exposure duration (years)
EV	=	event frequency (1 event/day)
SA	=	skin surface area exposed to soil or sediment (cm^2/event)
BW	=	body weight (kg), and
AT	=	averaging time (days)

Inhalation of chemicals in soils or dry sediments is calculated as follows:

$$\textit{Chemical Daily Intake (mg / kg – d)} = \frac{C_s \times IR_a \times ET \times EF \times ED \times (VF^{-1} + PEF^{-1})}{BW \times AT}$$

where:

C_s	=	chemical concentration in soils or sediments (mg/kg)
IR_a	=	inhalation rate (m^3/hour)
ET	=	exposure time (hours/day)
EF	=	exposure frequency (days/year)
ED	=	exposure duration (years)
VF	=	volatilization factor (chemical-specific m^3/kg)
PEF	=	particulate emission factor (1.32×10^9 m^3/kg)
BW	=	body weight (kg)
AT	=	averaging time (days)

There is no EPA-accepted model for evaluating inhalation of volatiles in wet sediments; therefore, this pathway is evaluated qualitatively.

Groundwater and Surface Water Exposure Pathways

Water ingestion (both drinking and incidental) is estimated for chemicals by the following equation:

$$\textit{Chemical Daily Intake (mg / kg – d)} = \frac{C_w \times IR_w \times EF \times ED}{BW \times AT}$$

where:

C_w	=	chemical concentration in water (mg/L)
IR_w	=	ingestion rate (L/day)
EF	=	exposure frequency (days/year)
ED	=	exposure duration (years)
BW	=	body weight (kg)
AT	=	averaging time (days)

The dermal absorbed dose from dermal contact with chemicals in surface water or groundwater is calculated as follows (EPA 2004a):

$$\textit{Chemical DAD (mg / kg – d)} = \frac{DA_{event} \times EV \times EF \times ED \times SA}{BW \times AT}$$

where:

DAD	=	dermal absorbed dose (mg/kg-day)
DA_{event}	=	absorbed dose per event in water (mg/cm^2-event)
EV	=	event frequency (1 event/day)
EF	=	exposure frequency (days/year)
ED	=	exposure duration (years)

SA	=	surface area of skin exposed (cm^2)
BW	=	body weight (kg)
AT	=	averaging time (days)

For inorganics, DA_{event} (mg/cm^2-event) is calculated as follows:

$$DA_{event} = K_p \times C_w \times t_{event}$$

where:

DA_{event}	=	absorbed dose per event in water (mg/cm^2-event)
K_p	=	permeability coefficient from water (chemical-specific, cm/hr)
C_w	=	concentration of chemical in water ($mg/cm^3 = 10^{-3}$ x mg/L)
t_{event}	=	duration of event (hr/event)

For organics, DA_{event} (mg/cm2-event) is calculated as follows:

$$If\ t_{event} < t^*\ then:\ DA_{event} = 2\ FA \times K_p \times C_w \times (6 \times t_{event}/B)^{1/2}$$

$$If\ t_{event} > t^*\ then:\ DA_{event} = FA \times K_p \times C_w\ [\{(t_{event}/(1+B)\} + 2\ t_{event}\ \{(1+3B+3B^2)/(1+B)^2\}]$$

where:

DA_{event}	=	absorbed dose per event in water (mg/cm^2-event)
FA	=	fraction absorbed water (chemical-specific, dimensionless)
K_p	=	permeability coefficient from water (chemical-specific, cm/hr)
C_w	=	concentration of chemical in water ($mg/cm^3 = 10^{-3}$ x mg/L)
t_{event}	=	duration of event (hr/event)
B	=	Chemical-specific constant reflecting the partitioning properties
t*	=	Chemical-specific time to reach steady-state (hour)

Values and equations for FA, K_p, t*, and B can be found in RAGS, Part E (EPA 2004a). If a K_p is not found, it is calculated using the following empirical predictive formula:

$$\log (K_p) = -2.80 + 0.66 \log (K_{ow}) - 0.0056\ MW$$

where:

K_{ow}	=	octanol/water coefficient (chemical-specific)
MW	=	molecular weight (g/mole)

The daily intake from the inhalation of VOCs while showering is evaluated using the following equation:

$$Chemical\ Daily\ Intake\ (mg/kg-d) = \frac{C_w \times K \times IR_a \times EF \times ED}{BW \times AT}$$

where:

C_w	=	chemical concentration in water (mg/L)
K	=	volatilization factor (unitless, 0.0005 x 1,000 L/m3 from Andelman 1990)
IR_a	=	indoor inhalation rate (L/day)
EF	=	exposure frequency (days/year)
ED	=	exposure duration (years)
BW	=	body weight (kg)
AT	=	averaging time (days)

There is no EPA-accepted model for evaluating inhalation of volatiles in surface water and groundwater in outdoor situations; therefore, these pathways are evaluated qualitatively.

Food Pathways

The daily intake rates from consumption of food produced on-site (homegrown produce, beef, poultry, deer, and dairy) are estimated using the following equation:

$$\textit{Chemical Intake (mg / kg - d)} = \frac{C_f \times IR_f \times FI \times EF \times ED}{BW \times AT}$$

where:

C_f	=	chemical concentration in food item (produce, meat, or milk) (mg/kg)
IR_f	=	ingestion rate of produce (kg/meal)
FI	=	contamination fraction (unitless)
EF	=	exposure frequency (meals/year)
ED	=	exposure duration (years)
BW	=	body weight (kg)
AT	=	averaging time (days)

When calculating chemical concentrations in milk, it was assumed that 1 L of milk weighs 1 kg.

2.3 TOXICITY ASSESSMENT

The acquisition of quantitative indicators of toxicity (e.g. cancer slope factors [CSFs], RfDs, and reference concentrations [RfCs]) follows the EPA (2003a) hierarchal approach, which supersedes the original hierarchy presented in RAGS (EPA 1989). The revised recommended toxicity value hierarchy is as follows:

- **Tier 1- EPA's IRIS -** Toxicity criteria used from the most current update of the EPA Integrated Risk Information System (IRIS) (EPA 2004b).

- **Tier 2- EPA's Provisional Peer Reviewed Toxicity Values (PPRTVs)** – The Office of Research and Development/National Center for Environmental Assessment/Superfund Health Risk Technical Support Center (STSC) develops PPRTVs on a chemical specific basis when requested by EPA's Superfund program.

- **Tier 3- Other Toxicity Values** – Tier 3 includes additional EPA and non-EPA sources of toxicity information. Priority should be given to those sources of information that are the most current, the basis for which is transparent and publicly available, and which have been peer reviewed.

IRIS remains in the Tier 1 source in the recommended hierarchy as the generally preferred source of human health toxicity values. IRIS is an electronic database containing the most current descriptive and quantitative EPA regulatory toxicity information for non-radiological and radiological constituents. Files maintained in IRIS contain information related to non-carcinogenic and carcinogenic health effects of constituents. IRIS normally represents the official Agency scientific position regarding the toxicity of the chemicals based on the data available at the time of the review.

Tier 2 is EPA's PPRTVs. Generally, PPRTVs are derived for one of two reasons. First, the STSC is conducting a batch-wise review of the toxicity values in Health Effects Assessment Summary Tables (HEAST) (now a Tier 3 source)(EPA 1995a). As such reviews are completed, those toxicity values will be removed from HEAST, and any new toxicity value developed in such a review will be a PPRTV and placed in the PPRTV database. Second, Regional Superfund Offices may request a PPRTV for contaminants lacking a relevant IRIS value. The STSC uses the same methodologies to derive PPRTVs for either case.

The third tier includes other sources of information. Priority is given to sources that provide toxicity information based on similar methods and procedures as those used for Tier 1 and Tier 2, contain values which are peer reviewed, are available to the public, and are transparent about the methods and processes used to develop the values. Toxicity values developed by the U.S. Army and the Department of Defense for military unique compounds are considered Tier 3.

Additional sources may be identified for Tier 3. Toxicity values that fall within the third tier in the hierarchy include, but need not be limited to, the following sources.

- The California Environmental Protection Agency (Cal EPA 2006) toxicity values are peer reviewed and address both cancer and non-cancer effects. Cal EPA toxicity values are available on the Cal EPA internet website at http://www.oehha.ca.gov/risk/chemicalDB//index.asp.

- The Agency for Toxic Substances and Disease Registry (ATSDR) Minimal Risk Levels (MRLs) are estimates of the daily human exposure to a hazardous substance that is likely to be without appreciable risk of adverse non-cancer health effects over a specified duration of exposure. The ATSDR MRLs are peer reviewed and are available at http://www.atsdr.cdc.gov/mrls.html on the ATSDR website (ATSDR 2006).

- HEAST toxicity values are Tier 3 values. As noted above, the STSC is conducting a batch wise review of HEAST toxicity values (EPA 1995a). The toxicity values remaining in are considered Tier 3 values. The radionuclides HEAST toxicity values are available at http://www.epa.gov/radiation/heast/.

- New York Codes, Rules and Regulations (6 NYCRR Part 375) official compilation of the New York State codes, rules and regulations regarding environmental remediation and technical support documents for the State's brownfield program http://www.dec.state.ny.us/website/der/superfund/ (NYCRR 2005).

Toxicity criteria are presented in Table 2.2. For some chemicals there are no EPA-approved toxicity criteria. In some cases, toxicity criteria from similar chemicals are used as surrogates for these compounds. In other cases, there is no appropriate surrogate and so no risk calculation can be completed for those chemicals. Chemicals with no toxicity criteria are listed in Table 2.5. Where available, surrogates are also identified in Table 2.5.

Route-to-route extrapolation can be used where no toxicity values are available for a given route of exposure. For example, CSFs and RfDs derived for oral exposures may be adjusted or used as is, to assess exposure via inhalation or dermal contact. EPA guidance, RAGS Part E, *Supplemental Guidance for Dermal Risk Assessment* was followed for assessment of the dermal route of exposure (EPA 2004a). For many chemicals, a scientifically defensible database does not exist for adjusting oral slope factors and RfDs to estimate a dermal toxicity value. Information on the fraction of a compound that is actually absorbed through the skin is also lacking. For the HHRA quantitative assessment of risk due to dermal exposure to contaminated soil was completed only for chemicals with EPA recommended gastrointestinal absorption efficiencies and dermal ABSs. EPA recommended gastrointestinal absorption efficiencies and dermal ABSs are presented in Table 2.2. When the EPA-recommended gastrointestinal absorption efficiency was greater than 50 percent, oral CSFs and RfDs were used without adjustment to assess potential dermal risks. If the chemical-specific GI factor is less than 50 percent, the oral toxicity criteria are adjusted by the GI to generate dermal toxicity criteria.

Table 2.2 presents a summary of chemical-specific characteristics used to estimate dermal absorbed dose, the concentrations present in vapors or dust, and COPC-uptake in food items.

Lead Toxicity

Lead was identified as a COPC but does not have toxicological reference values because risks from exposure to lead are better evaluated by predicting the associated blood lead level. Blood lead levels have been accepted as the best measure of external dose of lead. Sensitive populations include preschool-age children and fetuses. In fetuses and children, a blood lead level of between 10 and 15 micrograms per deciliter (µg/dL) has been associated with a level at which no adverse effects would be expected. The approach used here relates intake of lead from soil to blood lead concentrations in residential children and to women of childbearing age who may be exposed to lead in soil while working at the site. Protection of a hypothetical fetus of an occupationally exposed mother ensures that other workers at the site will be adequately protected.

A risk-based screening level of 400 mg/kg lead in soil was established for NFSS based on EPA's: *Lead; Identification of Dangerous Levels of Lead*, 66 Fed. Reg. 1206, January 5, 2001. This rule establishes the following standards for bare residential soil: a hazard standard of 400 mg/kg by weight in play areas based on the play area bare soil sample and an average of 1200 mg/kg in bare soil in the remainder of the yard based on an average of all other samples collected. (40 CFR § 745.65(c)). EPA's older "Interim Guidance on Establishing Soil Lead Cleanup Levels at Resource Conservation and Recovery Act (RCRA) Facilities" (EPA 1994a) also recommended 400 mg/kg. The allowable concentration of 400 mg/kg lead in soil is supported by EPA's IEUBK for Lead in Children (IEUBK) (EPA 1994b). The IEUBK predicts that 400 mg/kg of lead in soil could cause a 6-year-old resident child (averaged across the preceding 84 months) to have a probability of no greater than 5% of having a blood lead level of 10 micrograms/deciliter (µg/dL). For residents and farmers receptors, the concentration of lead in soil in each EU is compared to the screening level of 400 mg/kg lead.

Recommendations of EPA's Technical Review Workgroup (TRW) for lead are used to assess risks associated with adult worker exposures to lead in soil (EPA 1996a). The TRW approach for assessing non-residential adult risks utilizes some basic algorithms to relate soil lead intake to blood lead concentrations in women of childbearing age. The basis for the calculation is the relationship between the concentration of lead in soil and the blood lead concentration in a developing fetus of adult women that have occupational site exposures. The TRW model uses the same threshold for elevated blood lead concentrations as the IEUBK. The highest acceptable fetal blood lead level was set at the 95^{th} percentile of 10 µg/dL, which is the concentration recommended by EPA (1996a).

The TRW model assumes that the increase in blood lead from exposure to lead in soil is linear. A linear biokinetic slope factor was developed for the model based on available data relating fetal blood lead levels to maternal blood lead levels and soil exposure. Using the TRW risk estimation algorithm which assumes a typical adult blood lead level of 2.0 µg/dL and an inter-individual variability in blood lead of 1.9 (recommended for non-Hispanic white populations such as the one found near the site), the acceptable concentration of lead in soil is calculated for each receptor group (maintenance, construction, and industrial workers). The algorithm and assumptions used to calculate these values are presented in Figure 2.7. PRGs for industrial workers, maintenance workers, and construction workers are 840 mg/kg, 420 mg/kg, and 88 mg/kg, respectively.

There is no equivalent lead exposure model for water. However, the National Pollution Drinking Water Regulations health standard for lead, found at 40 CFR § 141.80(c) is promulgated as a treatment technique, with a trigger action level of 0.015 mg/L. This trigger action level for lead is used as the PRG for groundwater and surface water.

2.4 RISK CHARACTERIZATION

Risk characterization integrates the findings of the exposure assessment and toxicity assessment to estimate the likelihood that a receptor may experience an adverse effect as the result of exposure to COPCs (EPA 1989). Risks were calculated using toxicity information and intakes calculated as part of the exposure assessment. Total risk refers to the risk associated with all COPCs in the EU. Constituents not identified as COPCs are not included in the quantitative calculations.

2.4.1 Carcinogenic Risk Characterization Methodology

CSFs are used to estimate potential cancer risks from modeled exposures to COPCs in the on-site EUs. For carcinogenic COPCs, incremental lifetime cancer risk (ILCRs), or the increased lifetime probability of cancer, is calculated for each EU using RME assumptions. The resulting ILCRs are compared to the range specified in the NCP (EPA 1990). The NCP specifies a target risk range of 10^{-6} to 10^{-4}, or the probability that one additional person in a population of 1 million to one additional person in a population of 10,000 persons may develop cancer as the result of exposure to contaminants at NFSS. ILCRs below 10^{-6} are considered acceptable risks. ILCRs above 10^{-4} are considered unacceptable risks. Risks between 10^{-6} and 10^{-4} fall into the NCP "area of concern." EUs resulting in an ILCR greater than 10^{-6} are evaluated using CTE exposure assumptions. All EUs required CTE scenarios because RME risks exceed 10^{-6}. However, these exceedances are sometimes based on exposure to site-wide (EU 17) groundwater rather than from exposure to COPCs directly within the EU boundary. Both the RME and CTE risk results should be considered in making any decisions to address risks between 10^{-6} and 10^{-4}. The incremental lifetime risk of developing cancer was determined as follows (EPA 1989):

$$ILCR = I \times CSF$$

where:

ILCR	=	incremental lifetime cancer risk (unitless probability)
I	=	chronic daily intake or DAD from exposure assessment (mg/kg-day)
CSF	=	cancer slope factor $(mg/kg\text{-}day)^{-1}$

Use of the ILCR assumes that the constituent carcinogenesis does not exhibit a threshold and that the dose-response relationship is linear in the low dose range. ILCRs calculated using this equation are considered to be inaccurate at cancer risks that fall in the nonlinear, high dose response range (i.e., greater than $1x10^{-2}$). When the predicted theoretic cancer risk calculated using the previous equation is greater than $1x10^{-2}$, cancer risk is estimated by the one-hit model (EPA, 1998a) as follows:

$$ILCR = 1 - exp^{(-I)(CSF)}$$

where:

ILCR	=	incremental lifetime cancer risk (unitless), adjusted for background
$exp^{[(-I)(CSF)]}$	=	the exponential of the negative of the risk calculated by ILCR =(I)(CSF)
I	=	chronic daily intake (mg/kg-day)
CSF	=	cancer slope factor $(mg/kg\text{-}day)^{-1}$

Use of the one-hit model was model was necessary for some VOCs in groundwater. It was not required in any other environmental media. The one-hit model is not a component of RESRAD; therefore, it was not used to evaluate risks from ROPCs.

For a given pathway, with simultaneous exposure of a receptor to several carcinogens, the total risk to a receptor is the sum of the ILCRs for each carcinogenic COPC in a given medium. The equation used to calculate the total ILCR is:

$$ILCR_{total} = \sum ILCR_i$$

where:

$ILCR_{total}$	=	total incremental lifetime cancer risk (unitless probability)
$ILCR_i$	=	ILCR for the i^{th} constituent

2.4.2 Non-carcinogenic Risk Characterization

In addition to calculating the probability of developing cancer due to exposure to COPCs, the BRA evaluated the likelihood that an individual may experience non-carcinogenic toxic effects due to exposures to COPCs. The term "toxic effects" describes a wide variety of systemic effects, ranging from minor ailments, such as skin irritation and headaches, to more substantial effects, such as kidney or liver disease and neurological damage. The risks associated with exposure to toxic constituents were evaluated by comparing intake calculated using RME intake assumptions to a RfD. The RfD is the threshold, below which no toxic effects are expected to occur in a normal population, including sensitive subpopulations. The ratio of intake over a specified period

to the RfD for that constituent derived from a similar exposure period is termed the HQ (EPA 1989) and is defined as:

$$HQ = \frac{I}{RfD}$$

where:

HQ	=	hazard quotient (unitless ratio)
I	=	chronic daily intake (mg/kg-day)
RfD	=	reference dose (mg/kg-day)

The HQs for each COPC were summed to obtain an HI for each EU. This approach is different from the probabilistic approach used to evaluate carcinogens. An HI greater than 1 was defined as the level of concern for potential adverse non-carcinogenic health effects (EPA 1989). EUs with RME HIs greater than 0.1 (one-tenth the level of concern) were further evaluated using CTE assumptions. All EUs require CTE scenarios because RME HIs exceed 0.1. However, please note that these exceedances are sometimes based on exposure to site-wide (EU 17) groundwater rather than from exposure to COPCs directly within the EU boundary. Both the RME and CTE HIs should be considered in decisions to address risks further, either through continued study or engineered control measures. An HQ of 0.01 does not imply a one in 100 chance of an adverse effect; it indicates only that the estimated intake is 100 times less than the threshold level at which adverse health effects may occur. For simultaneous exposure of a receptor to several constituents, HIs were calculated as the sum of the individual HQs for all non-carcinogenic COPCs encountered for each pathway as follows:

$$HI = S\ HQ_i$$

where:

HI	=	hazard index
HQ_i	=	hazard quotient for the i^{th} constituent

2.4.3 Risk Characterization Results

The following subsections present the risk characterization results in a narrative form for each of the NFSS site EUs by receptor. Tables 2.6 through 2.22 present this information as summaries of the quantitative results of the risk assessment for all scenarios and pathways for RME and CTE evaluations. Risk estimates of zero indicate that either there are no COPCs in this medium or that toxicity criteria are not available. Risk estimates for individual COPCs for all scenarios and exposure pathways are presented in Appendix A. In Appendix A, risk estimates are presented by EU. Within an EU, RME risk estimates are presented first followed by CTE risk estimates when COPCs were identified for the RME case. For this presentation of results, COCs are defined based on total risk by medium and then by COPC-specific risk. Cancer risk must exceed 1×10^{-4} in a specific medium for any carcinogenic COCs to be identified. When medium-specific risk exceeds 1×10^{-4}, any COPC posing a 1×10^{-5} risk or greater is identified as a COC. The total non-cancer HI must be greater than 1 by medium for any non-cancer COCs to be identified in this results discussion. When a medium-specific HI exceeds 1, any COPC with an HQ greater than 1 is identified as a COC. When medium-specific risk exceeds 1×10^{-4} and/or HI exceeds 1, but no COPC-specific risks exceed 1×10^{-5} or HQs exceed 1, then the COPC contributing the greatest cancer risk or HQ is cited. Potential risks are quantified for all identified receptors using

conservative (90-95th percentile) or RME scenario exposure assumptions. Receptors whose potential risks exceeded a HI of 0.1 or a cancer risk of 1 x 10^{-6} are also evaluated using median or CTE assumptions. If these thresholds are not exceeded CTE risks are not discussed, however they are presented in the total ILCR and HI summary tables.

EU-specific risk results are presented below. As discussed in Section 2.2.2.2, when calculating cancer risks, EPA (1991b) recommends using age-adjusted intakes. Therefore age-adjusted intakes are calculated assuming 6 years exposure as a child and 24 years exposure as an adult for a combined 30-year exposure. Cancer risk is then calculated using this age-adjusted intake. A similar age-adjustment is not calculated for non-cancer risks because for non-cancer risks the child-only receptor yields a more conservative estimate of risk. Therefore, separate HQs are calculated for adults and children.

2.4.3.1 Exposure Unit 1

Table 2.6 presents a summary of the total ILCR and HI results for both RME and CTE scenarios for each of the receptors at EU 1.

EU 1 Future Subsistence Farmer Scenario

The future subsistence farmer scenario was assessed for exposure to soil zero to 10 ft bgs in EU 1. Farmer receptors in EU 1 are also assumed to be exposed to site-wide (EU 17) groundwater. See the EU 17 summary for the discussion of risks from exposure to site-wide groundwater. Risks from soil exposure, including food pathways, are summarized below.

RME Summary. RME ILCR from direct contact with soil is estimated to be 7.0 x 10^{-8}. RME ILCR from ingestion of food items is estimated to be 9.6 x 10^{-7}. No carcinogenic COCs are identified in EU 1 soil.

Adult and child RME HIs from direct contact with soil are estimated to be 0.08 and 0.5, respectively. Adult and child RME HIs from ingestion of food items are estimated to be 1.7 and 2.5, respectively. No COPC-specific HQs exceed 1 for either receptor.

CTE Summary. CTE ILCR from direct contact with soil is estimated to be 8.8 x 10^{-9}. CTE ILCR from ingestion of food items is estimated to be 3.9 x 10^{-7}. No carcinogenic COCs are identified in EU 1 soil.

Adult and child CTE HIs from direct contact with soil are estimated to be 0.02 and 0.2, respectively. Adult and child CTE HIs from ingestion of food items are estimated to be 0.6 and 1.1, respectively. No COPC-specific HQs exceed 1 for either receptor.

EU 1 Future Resident Scenario

The future resident scenario was assessed for exposure to soil zero to 10 ft bgs in EU 1. Residential receptors in EU 1 are also assumed to be exposed to site-wide (EU 17) groundwater. See the EU 17 summary for the discussion of risks from exposure to site-wide groundwater. Risks from soil exposure, including food pathways, are summarized below.

RME Summary. RME ILCR from direct contact with soil is estimated to be 6.3 x 10^{-8}. RME ILCR from ingestion of food items is estimated to be 2.5 x 10^{-8}. No carcinogenic COCs are identified in EU 1 soil.

Adult and child RME HIs from direct contact with soil are estimated to be 0.06 and 0.5, respectively. Adult and child RME HIs from ingestion of food items are estimated to be 0.2 for both receptor populations. No COPC-specific HQs exceed 1 for either receptor.

CTE Summary. CTE ILCR from direct contact with soil is estimated to be 8.8×10^{-9}. CTE ILCR from ingestion of food items is estimated to be 4.4×10^{-9}. No carcinogenic COCs are identified in EU 1 soil.

Adult and child CTE HIs from direct contact with soil are estimated to be 0.02 and 0.2, respectively. Adult and child CTE HIs from ingestion of food items are estimated to be 0.07 and 0.8, respectively. No COPC-specific HQs exceed 1 for either receptor.

EU 1 Future Industrial Worker Scenario

The future industrial worker scenario was assessed for exposure to soil zero to 0.5 ft bgs in EU 1.

RME Summary. RME ILCR from direct contact with soil is estimated to be 6.0×10^{-9}. The RME HI from direct contact with soil is estimated to be 0.03. No carcinogenic or non-carcinogenic COCs are identified in EU 1 soil.

CTE Summary. CTE ILCR from direct contact with soil is estimated to be 8.6×10^{-10}. The CTE HI from direct contact with soil is estimated to be 0.03. No carcinogenic or non-carcinogenic COC are identified in EU 1 soil.

EU 1 Future Construction Worker Scenario

The future construction worker scenario was assessed for exposure to soil zero to 10 ft bgs in EU 1. Construction worker receptors in EU 1 are also assumed to be exposed to site-wide (EU 17) groundwater. See the EU 17 summary for the discussion of risks from exposure to site-wide groundwater. Risks from soil exposure are summarized below.

RME Summary. RME ILCR from direct contact with soil is estimated to be 1.8×10^{-9}. The RME HI from direct contact with soil is estimated to be 0.2. No carcinogenic or non-carcinogenic COCs are identified in EU 1 soil.

CTE Summary. CTE ILCR from direct contact with soil is estimated to be 1.1×10^{-10}. The CTE HI from direct contact with soil is estimated to be 0.01. No carcinogenic or non-carcinogenic COCs are identified in EU 1 soil.

EU 1 Current and Future Maintenance Worker Scenario

The current and future maintenance worker scenario was assessed for exposure to soil zero to 0.5 ft bgs in EU 1.

RME Summary. RME ILCR from direct contact with soil is estimated to be 1.1×10^{-8}. The RME HI from direct contact with soil is estimated to be 0.07. No carcinogenic or non-carcinogenic COCs are identified in EU 1 soil.

CTE Summary. CTE ILCR from direct contact with soil is estimated to be 9.6×10^{-10}. The CTE HI from direct contact with soil is estimated to be 0.03. No carcinogenic or non-carcinogenic COC are identified in EU 1 soil.

EU 1 Current Trespasser/Future Recreational Visitor Scenario

The trespasser/recreational visitor scenario was assessed for exposure to soil zero to 0.5 ft bgs in EU 1. In addition, they are assumed to consume game that reside in EU 1.

RME Summary. Adult and adolescent RME ILCRs from direct contact with soil are estimated to be 2.5×10^{-9} and 2.8×10^{-9}, respectively. Adult and adolescent RME ILCRs from ingestion of food items are estimated to be 1.4×10^{-11} and 9.1×10^{-12}, respectively. No carcinogenic COCs are identified in EU 1 soil.

Adult and adolescent RME HIs from direct contact with soil are estimated to be 0.01 and 0.04, respectively. Adult and child RME HIs from ingestion of food items are estimated to be 0.00002 and 0.00004, respectively. No non-carcinogenic COCs are identified in EU 1 soil.

CTE Summary. Adult and adolescent CTE ILCRs from direct contact with soil are estimated to be 6.8×10^{-11} and 1.9×10^{-10}, respectively. Adult and adolescent CTE HIs from ingestion of food items are estimated to be 2.1×10^{-12} and 4.1×10^{-12}, respectively. No carcinogenic COC are identified in EU 1 soil.

Adult and adolescent CTE HIs from direct contact with soil are estimated to be 0.002 and 0.004, respectively. Adult and adolescent CTE HIs from ingestion of food items are estimated to be 0.00001 and 0.00002, respectively. No non-carcinogenic COC are identified in EU 1 soil.

2.4.3.2 Exposure Unit 2

Table 2.7 presents a summary of the total ILCR and HI results for both RME and CTE scenarios for each of the receptors at EU 2.

EU 2 Future Subsistence Farmer Scenario

The future subsistence farmer scenario was assessed for exposure to soil zero to 10 ft bgs in EU 2. Farmer receptors in EU 2 are also assumed to be exposed to site-wide (EU 17) groundwater. See the EU 17 summary for the discussion of risks from exposure to site-wide groundwater. Risks from soil exposure, including food pathways, are summarized below.

RME Summary. RME ILCR from direct contact with soil is estimated to be 9.4×10^{-4}. RME ILCR from ingestion of food items is estimated to be 3.8×10^{-3}. Benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(k)fluoranthene, dibenz(a,h)anthracene, and indeno(1,2,3-cd)pyrene are COCs for direct contact with soil and/or the food pathway.

Adult and child RME HIs from direct contact with soil are estimated to be 0.1 and 0.7, respectively. Adult and child RME HIs from ingestion of food items are estimated to be 2.3 and 3.5, respectively. Boron is a COC for the food pathway.

CTE Summary. CTE ILCR from direct contact with soil is estimated to be 1.1×10^{-4}. CTE ILCR from ingestion of food items is estimated to be 1.4×10^{-3}. Benzo(a)anthracene, benzo(a)pyrene,

benzo(b)fluoranthene, dibenz(a,h)anthracene, and indeno(1,2,3-cd)pyrene are COCs for direct contact with soil and/or the food pathway.

Adult and child CTE HIs from direct contact with soil are estimated to be 0.02 and 0.2, respectively. Adult and child CTE HIs from ingestion of food items are estimated to be 0.8 and 1.8, respectively. No COPC-specific HQs exceed 1 for either receptor.

EU 2 Future Resident Scenario

The future resident scenario was assessed for exposure to soil zero to 10 ft bgs in EU 2. Residential receptors in EU 2 are also assumed to be exposed to site-wide (EU 17) groundwater. See the EU 17 summary for the discussion of risks from exposure to site-wide groundwater. Risks from soil exposure, including food pathways, are summarized below.

RME Summary. RME ILCR from direct contact with soil is estimated to be 8.4×10^{-4}. RME ILCR from ingestion of food items is estimated to be 6.7×10^{-4}. Benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, dibenz(a,h)anthracene, and indeno(1,2,3-cd)pyrene are COCs for direct contact with soil and/or the food pathway.

Adult and child RME HIs from direct contact with soil are estimated to be 0.09 and 0.7, respectively. Adult and child RME HIs from ingestion of food items are estimated to be 0.4 and 0.3, respectively. No non-carcinogenic COCs are identified in EU 2 soil.

CTE Summary. CTE ILCR from direct contact with soil is estimated to be 1.1×10^{-4}. CTE ILCR from ingestion of food items is estimated to be 1.2×10^{-4}. Benzo(a)anthracene, benzo(a)pyrene, and dibenz(a,h)anthracene are COCs for direct contact with soil and/or the food pathway.

Adult and child CTE HIs from direct contact with soil are estimated to be 0.03 and 0.2, respectively. Adult and child CTE HIs from ingestion of food items are estimated to be 0.1 for both receptors. No non-carcinogenic COCs are identified in EU 2 soil.

EU 2 Future Industrial Worker Scenario

The future industrial worker scenario was assessed for exposure to soil zero to 0.5 ft bgs in EU 2.

RME Summary. RME ILCR from direct contact with soil is estimated to be 1×10^{-4}. The RME HI from direct contact with soil is estimated to be 0.04. No carcinogenic or non-carcinogenic COCs are identified in EU 2 soil.

CTE Summary. CTE ILCR from direct contact with soil is estimated to be 1.3×10^{-5}. The CTE HI from direct contact with soil is estimated to be 0.03. No carcinogenic or non-carcinogenic COCs are identified in EU 2 soil.

EU 2 Future Construction Worker Scenario

The future construction worker scenario was assessed for exposure to soil zero to 10 ft bgs in EU 2. Construction worker receptors in EU 2 are also assumed to be exposed to site-wide (EU 17) groundwater. See the EU 17 summary for the discussion of risks from exposure to site-wide groundwater. Risks from soil exposure, including food pathways, are summarized below.

RME Summary. RME ILCR from direct contact with soil is estimated to be 2.2×10^{-5}. The RME HI from direct contact with soil is estimated to be 0.2. No carcinogenic or non-carcinogenic COCs are identified in EU 2 soil. The lead EPC in EU 2 soil exceeds the construction worker PRG; therefore, lead is retained as a COC.

CTE Summary. CTE ILCR from direct contact with soil is estimated to be 1.4×10^{-6}. The CTE HI from direct contact with soil is estimated to be 0.013. No carcinogenic or non-carcinogenic COCs are identified in EU 2 soil. The lead EPC in EU 2 soil exceeds the construction worker PRG; therefore, lead is retained as a COC. Note that the same EPC is used for both RME and CTE scenarios.

EU 2 Current and Future Maintenance Worker Scenario

The current and future maintenance worker scenario was assessed for exposure to soil zero to 0.5 ft bgs in EU 2.

RME Summary. RME ILCR from direct contact with soil is estimated to be 1.8×10^{-4}. The RME HI from direct contact with soil is estimated to be 0.1. Benzo(a)pyrene, benzo(b)fluoranthene, and dibenz(a,h)anthracene are COCs for direct contact with soil. No non-carcinogenic COCs are identified in EU 2 soil.

CTE Summary. CTE ILCR from direct contact with soil is estimated to be 1.5×10^{-5}. The CTE HI from direct contact with soil is estimated to be 0.04. No carcinogenic or non-carcinogenic COCs are identified in EU 2 soil.

EU 2 Current Trespasser/Future Recreational Visitor Scenario

The trespasser/recreational visitor scenario was assessed for exposure to soil zero to 0.5 ft bgs in EU 2. In addition, they are assumed to consume game that resides in EU 2.

RME Summary. Adult and adolescent RME ILCRs from direct contact with soil are estimated to be 4.2×10^{-5} and 4.7×10^{-5}, respectively. Adult and adolescent RME ILCRs from ingestion of food items are estimated to be 6.1×10^{-8} and 4.0×10^{-8}, respectively. No carcinogenic COCs are identified in EU 2 soil.

Adult and adolescent RME HIs from direct contact with soil are estimated to be 0.02 and 0.04, respectively. Adult and child RME HIs from ingestion of food items are estimated to be 0.00002 and 0.00004, respectively. No non-carcinogenic COCs are identified in EU 2 soil.

CTE Summary. Adult and adolescent CTE ILCRs from direct contact with soil are estimated to be 1×10^{-6} and 3.0×10^{-6}, respectively. Adult and adolescent CTE ILCRs from ingestion of food items are estimated to be 9.1×10^{-9} and 1.8×10^{-8}, respectively. No carcinogenic COCs are identified in EU 2 soil.

Adult and adolescent CTE HIs from direct contact with surface soil are estimated to be 0.002 and 0.005, respectively. Adult and child CTE HIs from ingestion of food items are estimated to be 0.00001 and 0.00002, respectively. No non-carcinogenic COCs are identified in EU 2 soil.

2.4.3.3 Exposure Unit 3

Table 2.8 presents a summary of the total ILCR and HI results for both RME and CTE scenarios for each of the receptors at EU 3.

EU 3 Future Subsistence Farmer Scenario

The future subsistence farmer scenario was assessed for exposure to soil zero to 10 ft bgs in EU 3. Farmer receptors in EU 3 are also assumed to be exposed to site-wide (EU 17) groundwater. See the EU 17 summary for the discussion of risks from exposure to site-wide groundwater. Risks from soil exposure, including food pathways, are summarized below.

RME Summary. RME ILCR from direct contact with soil is estimated to be 1.6×10^{-5}. RME ILCR from ingestion of food items is estimated to be 2.6×10^{-5}. No carcinogenic COCs are identified in EU 3 soil.

Adult and child RME HIs from direct contact with soil are estimated to be 0.07 and 0.6, respectively. Adult and child RME HIs from ingestion of food items are estimated to be 0.3 and 0.5, respectively. No non-carcinogenic COCs are identified in EU 3 soil.

CTE Summary. CTE ILCR from direct contact with soil is estimated to be 3.1×10^{-6}. CTE ILCR from ingestion of food items is estimated to be 6.9×10^{-6}. No carcinogenic COCs are identified in EU 3 soil.

Adult and child CTE HIs from direct contact with soil are estimated to be 0.02 and 0.15, respectively. Adult and child CTE HIs from ingestion of food items are estimated to be 0.01 and 0.03, respectively. No non-carcinogenic COCs are identified in EU 3 soil.

EU 3 Future Resident Scenario

The future resident scenario was assessed for exposure to soil zero to 10 ft bgs in EU 3. Residential receptors in EU 3 are also assumed to be exposed to site-wide (EU 17) groundwater. See the EU 17 summary for the discussion of risks from exposure to site-wide groundwater. Risks from soil exposure, including food pathways, are summarized below.

RME Summary. RME ILCR from direct contact with soil is estimated to be 1.6×10^{-5}. RME ILCR from ingestion of food items is estimated to be 1.4×10^{-5}. No carcinogenic COCs are identified in EU 3 soil.

Adult and child RME HIs from direct contact with soil are estimated to be 0.07 and 0.5, respectively. Adult and child RME HIs from ingestion of food items are estimated to be 0.03 for both receptors. No non-carcinogenic COCs are identified in EU 3 soil.

CTE Summary. CTE ILCR from direct contact with soil is estimated to be 3.1×10^{-6}. CTE ILCR from ingestion of food items is estimated to be 2.5×10^{-6}. No carcinogenic COCs are identified in EU 3 soil.

Adult and child CTE HIs from direct contact with soil are estimated to be 0.02 and 0.15, respectively. Adult and child CTE HIs from ingestion of food items are estimated to be 0.01 for both receptors. No non-carcinogenic COCs are identified in EU 3 soil.

EU 3 Future Industrial Worker Scenario

The future industrial worker scenario was assessed for exposure to soil zero to 0.5 ft bgs in EU 3.

RME Summary. RME ILCR from direct contact with soil is estimated to be 5.6×10^{-8}. The RME HI from direct contact with soil is estimated to be 0.003. No carcinogenic or non-carcinogenic COCs are identified in EU 3 soil.

CTE Summary. CTE ILCR from direct contact with soil is estimated to be 7.3×10^{-9}. The CTE HI from direct contact with soil is estimated to be 0.002. No carcinogenic or non-carcinogenic COCs are identified in EU 3 soil.

EU 3 Future Construction Worker Scenario

The future construction worker scenario was assessed for exposure to soil zero to 10 ft bgs in EU 3. Construction worker receptors in EU 3 are also assumed to be exposed to site-wide (EU 17) groundwater. See the EU 17 summary for the discussion of risks from exposure to site-wide groundwater. Risks from soil exposure, including food pathways, are summarized below.

RME Summary. RME ILCR from direct contact with soil is estimated to be 5.8×10^{-7}. The RME HI from direct contact with soil is estimated to be 0.2. No carcinogenic or non-carcinogenic COCs are identified in EU 3 soil.

CTE Summary. CTE ILCR from direct contact with soil is estimated to be 3.1×10^{-8}. The CTE HI from direct contact with soil is estimated to be 0.01. No carcinogenic or non-carcinogenic COCs are identified in EU 3 soil.

EU 3 Current and Future Maintenance Worker Scenario

The current and future maintenance worker scenario was assessed for exposure to soil zero to 0.5 ft bgs in EU 3.

RME Summary. RME ILCR from direct contact with soil is estimated to be 1×10^{-7}. The RME HI from direct contact with soil is estimated to be 0.006. No carcinogenic or non-carcinogenic COCs are identified in EU 3 soil.

CTE Summary. CTE ILCR from direct contact with soil is estimated to be 8.2×10^{-9}. The CTE HI from direct contact with soil is estimated to be 0.002. No carcinogenic or non-carcinogenic COCs are identified in EU 3 soil.

EU 3 Current Trespasser/Future Recreational Visitor Scenario

The trespasser/recreational visitor scenario was assessed for exposure to soil zero to 0.5 ft bgs in EU 3. In addition, they are assumed to consume game that resides in EU 3.

RME Summary. Adult and adolescent RME ILCRs from direct contact with soil are estimated to be 2.3×10^{-8} and 2.6×10^{-8}, respectively. Adult and adolescent RME ILCRs from ingestion of food items are estimated to be 1.4×10^{-10} and 9.1×10^{-11}, respectively. No carcinogenic COCs are identified in EU 3 soil.

Adult and adolescent RME HIs from direct contact with soil are estimated to be 0.001 and 0.003, respectively. Adult and child RME HIs from ingestion of food items are estimated to be 0.000002 and 0.000003, respectively. No non-carcinogenic COCs are identified in EU 3 soil.

CTE Summary. Adult and adolescent CTE ILCRs from direct contact with soil are estimated to be 5.7×10^{-10} and 1.7×10^{-9}, respectively. Adult and adolescent RME ILCRs from ingestion of food items are estimated to be 2.1×10^{-11} and 4.1×10^{-11}, respectively. No carcinogenic COCs are identified in EU 3 soil.

Adult and adolescent RME HIs from direct contact with soil are estimated to be 0.0001 and 0.0003, respectively. Adult and child RME HIs from ingestion of food items are estimated to be 0.0000008 and 0.000002.

2.4.3.4 Exposure Unit 4

Table 2.9 presents a summary of the total ILCR and HI results for both RME and CTE scenarios for each of the receptors at EU 4.

EU 4 Future Subsistence Farmer Scenario

The future subsistence farmer scenario was assessed for exposure to soil zero to 10 ft bgs in EU 4. Farmer receptors in EU 4 are also assumed to be exposed to EU 4 groundwater.

RME Summary. RME ILCR from direct contact with soil is estimated to be 6.2×10^{-4}. RME ILCR from ingestion of food items is estimated to be 7.5×10^{-3}. Aroclor-1254, aroclor-1260, benzo(a)pyrene, benzo(b)fluoranthene, indeno(1,2,3-cd)pyrene, tetrachloroethene, and arsenic are COCs for direct contact with soil and/or the food pathway.

Adult and child RME HIs from direct contact with soil are estimated to be 19 and 76, respectively. Adult and child RME HIs from ingestion of food items are estimated to be 300 and 892, respectively. Aroclor-1254, aroclor-1260, and boron are COCs for direct contact with soil and/or food pathways.

RME ILCR from exposure to EU 4 groundwater is estimated to be 9.5×10^{-1}. Bis(2-ethylhexyl)phthalate, methylene chloride, tetrachloroethene, trichloroethene, vinyl chloride, and arsenic are COCs for exposure to groundwater.

Adult and child RME HIs from exposure to EU 4 groundwater are estimated to be 2480 and 3362, respectively. Cis-1,2-dichloroethene, methylene chloride, tetrachloroethene, trichloroethene, vinyl chloride, arsenic, barium, boron, copper, manganese, nickel, and vanadium are COCs for exposure to groundwater. Lead EPC exceeds the drinking water action level and also is a COC.

CTE Summary. CTE ILCR from direct contact with soil is estimated to be 8.0×10^{-5}. CTE ILCR from ingestion of food items is estimated to be 3.0×10^{-3}. Aroclor-1254, aroclor-1260, benzo(a)pyrene, benzo(b)fluoranthene, and indeno(1,2,3-cd)pyrene are COCs for direct contact with soil and/or the food pathway.

Adult and child CTE HIs from direct contact with soil are estimated to be 3.5 and 24.7, respectively. Adult and child CTE HIs from ingestion of food items are estimated to be 110 and 686, respectively. Aroclor-1254, aroclor-1260, and boron are COCs for direct contact with soil and/or food pathways.

CTE ILCR from exposure to EU 4 groundwater is estimated to be 2.8×10^{-1}. Methylene chloride, tetrachloroethene, trichloroethene, vinyl chloride, and arsenic are COCs for exposure to groundwater.

Adult and child CTE HIs from exposure to groundwater are estimated to be 1394 and 1915, respectively. Cis-1,2-dichloroethene, tetrachloroethene, trichloroethene, vinyl chloride, aluminum, arsenic, boron, manganese, and vanadium are COCs for exposure to groundwater. Lead EPC exceeds the drinking water action level and also is a COC. Note that the same lead EPC is used for both RME and CTE scenarios.

EU 4 Future Resident Scenario

The future resident scenario was assessed for exposure to soil zero to 10 ft bgs in EU 4. Residential receptors in EU 4 are also assumed to be exposed to EU 4 groundwater.

RME Summary. RME ILCR from direct contact with soil is estimated to be 5.6×10^{-4}. RME ILCR from ingestion of food items is estimated to be 3.3×10^{-4}. Aroclor-1260, benzo(a)pyrene, benzo(b)fluoranthene, and arsenic are COCs for direct contact with soil, and/or food pathway.

Adult and child RME HIs from direct contact with soil are estimated to be 15.4 and 75.7, respectively. Adult and child RME HIs from ingestion of food items are estimated to be 2.5 and 2.9, respectively. Aroclor-1260, benzo(a)pyrene, arsenic and tetrachloroethene are COCs for direct contact with soil and/or food.

RME ILCR from exposure to EU 4 groundwater is estimated to be 9.5×10^{-1}. Bis(2-ethylhexyl)phthalate, methylene chloride, tetrachloroethene, trichloroethene, vinyl chloride, and arsenic are COCs for exposure to groundwater.

Adult and child RME HIs from exposure to groundwater are estimated to be 1709 and 3361, respectively. Cis-1,2-dichloroethene, methylene chloride, tetrachloroethene, trichloroethene, vinyl chloride, arsenic, barium, boron, copper, manganese, nickel, and vanadium are COCs for exposure to groundwater. Lead EPC exceeds the drinking water action level and also is a COC.

CTE Summary. CTE ILCR from direct contact with soil is estimated to be 8.0×10^{-5}. CTE ILCR from ingestion of food items is estimated to be 5.9×10^{-5}. Aroclor-1260 is a COC for direct contact with soil and/or food.

Adult and child CTE HIs from direct contact with soil are estimated to be 7.9 and 14.8, respectively. Adult and child CTE HIs from ingestion of food items are estimated to be 0.7 and 0.9, respectively. Aroclor-1260 is a COC for direct contact with soil.

CTE ILCR from exposure to groundwater is estimated to be 2.8×10^{-1}. Methylene chloride, tetrachloroethene, trichloroethene, vinyl chloride, and arsenic are COCs for exposure to groundwater.

Adult and child CTE HIs from exposure to groundwater are estimated to be 1397 and 1915, respectively. Cis-1,2-dichloroethene, tetrachloroethene, trichloroethene, vinyl chloride, aluminum, arsenic, boron, manganese, and vanadium are COCs for exposure to groundwater. Lead EPC exceeds the drinking water action level and also is a COC.

EU 4 Future Industrial Worker Scenario

The future industrial worker scenario was assessed for exposure to soil zero to 0.5 ft bgs in EU 4.

RME Summary. RME ILCR from direct contact with soil is estimated to be 4.2×10^{-5}. The RME HI from direct contact with soil is estimated to be 2.5. Aroclor-1260 is a COC based on both carcinogenic and non-carcinogenic risk.

CTE Summary. CTE ILCR from direct contact with soil is estimated to be 6.2×10^{-6}. The CTE HI from direct contact with soil is estimated to be 1.4. No carcinogenic or non-carcinogenic COCs are identified in EU 4 soil.

EU 4 Future Construction Worker Scenario

The future construction worker scenario was assessed for exposure to soil zero to 10 ft bgs in EU 4. Construction worker receptors in EU 4 are also assumed to be exposed to EU 4 groundwater.

RME Summary. RME ILCR from direct contact with soil is estimated to be 1.6×10^{-5}. The RME HI from direct contact with soil is estimated to be 23. Aroclor-1260 is a COC based on non-carcinogenic risk. The lead EPC in soil exceeds the construction worker PRG; therefore, lead is retained as a COC.

RME ILCR from exposure to groundwater is estimated to be 9.9×10^{-3}. Tetrachloroethene, trichloroethene, vinyl chloride, and arsenic are COCs for exposure to groundwater. RME HI from exposure to groundwater is estimated to be 1508. Cis-1,2-dichloroethene, tetrachloroethene, trichloroethene, and vinyl chloride are COCs for exposure to groundwater.

CTE Summary. CTE ILCR from direct contact with soil is estimated to be 9.6×10^{-7}. The CTE HI from direct contact with soil is estimated to be 1.4. No carcinogenic COCs are identified in EU 4 soil. Aroclor-1260 is a COC based on the non-carcinogenic risk. The lead EPC in soil exceeds the construction worker PRG; therefore, lead is retained as a COC.

CTE ILCR from exposure to groundwater is estimated to be 1.5×10^{-3}. Tetrachloroethene, trichloroethene, and vinyl chloride are COCs for exposure to groundwater. CTE HI from exposure to groundwater is estimated to be 256. Tetrachloroethene trichloroethylene, and vinyl chloride are COCs for exposure to groundwater.

EU 4 Current and Future Maintenance Worker Scenario

The current and future maintenance worker scenario was assessed for exposure to soil zero to 0.5 ft bgs in EU 4.

RME Summary. RME ILCR from direct contact with soil is estimated to be 7.8×10^{-5}. The RME HI from direct contact with soil is estimated to be 4.6. No carcinogenic COCs are identified in EU 4 soil. Aroclor-1260 is a COC based on the non-carcinogenic risk. The lead EPC in soil exceeds the construction worker PRG; therefore, lead is retained as a COC.

CTE Summary. CTE ILCR from direct contact with soil is estimated to be 6.9×10^{-6}. The CTE HI from direct contact with soil is estimated to be 1.5. Aroclor-1260 is a COC identified in EU 4 soil based on non-carcinogenic risk.

EU 4 Current Trespasser/Future Recreational Visitor Scenario

The trespasser/recreational visitor scenario was assessed for exposure to soil zero to 0.5 ft bgs in EU 4. In addition, they are assumed to consume game that resides in EU 4.

RME Summary. Adult and adolescent RME ILCRs from direct contact with soil are estimated to be 1.8×10^{-5} and 1.9×10^{-5}, respectively. Adult and adolescent RME ILCRs from ingestion of food items are estimated to be 8.5×10^{-8} and 5.6×10^{-8}, respectively. No carcinogenic COCs are identified in EU 4 soil.

Adult and adolescent RME HIs from direct contact with soil are estimated to be 0.9 and 2.9, respectively. Adult and child RME HIs from ingestion of food items are estimated to be 0.005 and 0.009, respectively. Aroclor-1260 is a COC for the adolescent trespasser/recreational visitor based on the non-carcinogenic risk from direct contact with soil.

CTE Summary. Adult and adolescent CTE ILCRs from direct contact with soil are estimated to be 5.0×10^{-7} and 1.4×10^{-6}, respectively. Adult and adolescent CTE ILCRs from ingestion of food items are estimated to be 1.3×10^{-8} and 2.5×10^{-8}, respectively. No carcinogenic COCs are identified in EU 4 soil.

Adult and adolescent CTE HIs from direct contact with soil are estimated to be 0.08 and 0.2, respectively. Adult and child CTE HIs from ingestion of food items are estimated to be 0.002 and 0.005, respectively. No non-carcinogenic COCs are identified in EU 4 soil.

2.4.3.5 Exposure Unit 5

Table 2.10 presents a summary of the total ILCR and HI results for both RME and CTE scenarios for each of the receptors at EU 5.

EU 5 Future Subsistence Farmer Scenario

The future subsistence farmer scenario was assessed for exposure to soil zero to 10 ft bgs in EU 5 and sediment/surface water in wetland and ditch areas within EU 5. Farmer receptors in EU 5 are also assumed to be exposed to site-wide (EU 17) groundwater. See the EU 17 summary for the discussion of risks from exposure to site-wide groundwater. Risks from soil exposure, including food pathways, and surface water are summarized below. No COPCs were identified in sediment; therefore, no sediment results are presented.

RME Summary. RME ILCR from direct contact with soil is estimated to be 1×10^{-6}. RME ILCR from ingestion of food items is estimated to be 9.4×10^{-6}. No carcinogenic COCs are identified in EU 5 soil. Adult and child RME HIs from direct contact with soil are estimated to be 0.04 and 0.3, respectively. Adult and child RME HIs from ingestion of food items are estimated to be 0.7 and 1.1, respectively. No COPC-specific HQs exceed 1 for either receptor.

RME ILCR from exposure to surface water is estimated to be 2.6×10^{-6}. No carcinogenic COCs are identified in EU 5 surface water. Adult and child RME HIs from exposure to surface water are estimated to be 0.00002 and 0.00004, respectively. No non-carcinogenic RME COCs are identified for EU 5 surface water.

CTE Summary. CTE ILCR from direct contact with soil is estimated to be 2.5×10^{-7}. CTE ILCR from ingestion of food items is estimated to be 3.6×10^{-6}. No carcinogenic COCs are identified in EU 5 soil. Adult and child CTE HIs from direct contact with soil are estimated to be 0.01 and 0.1, respectively. Adult and child CTE HIs from ingestion of food items are estimated to be 0.2 and 0.6, respectively. No COPC-specific HQs exceed 1 for either receptor.

CTE ILCR from exposure to surface water is estimated to be 7.5×10^{-7}. No carcinogenic COCs are identified in EU 5 surface water. Adult and child CTE HIs from exposure to surface water are estimated to be 0.000007 and 0.00001, respectively. No non-carcinogenic CTE COCs are identified for EU 5 surface water.

EU 5 Future Resident Scenario

The future resident scenario was assessed for exposure to soil zero to 10 ft bgs in EU 5 and sediment/surface water in wetland and ditch areas within EU 5. Residential receptors in EU 5 are also assumed to be exposed to site-wide (EU 17) groundwater. See the EU 17 summary for the discussion of risks from exposure to site-wide groundwater. Risks from soil exposure, including food pathways, are summarized below. No COPCs were identified in sediment; therefore, only surface water is discussed.

RME Summary. RME ILCR from direct contact with soil is estimated to be 1×10^{-6}. RME ILCR from ingestion of food items is estimated to be 1.6×10^{-6}. No carcinogenic COCs are identified in EU 5 soil. Adult and child RME HIs from direct contact with soil are estimated to be 0.03 and 0.3, respectively. Adult and child RME HIs from ingestion of food items are both estimated to be 0.1. No COPC-specific HQs exceed 1 for either receptor.

RME ILCR from exposure to surface water is estimated to be 2.6×10^{-6}. No carcinogenic COCs are identified in EU 5 surface water. Adult and child RME HIs from exposure to surface water are estimated to be 0.00002 and 0.00004, respectively. No non-carcinogenic RME COCs are identified for EU 5 surface water.

CTE Summary. CTE ILCR from direct contact with soil is estimated to be 2.5×10^{-7}. RME ILCR from ingestion of food items is estimated to be 2.8×10^{-7}. No carcinogenic COCs are identified in EU 5 soil. Adult and child CTE HIs from direct contact with soil are estimated to be 0.01 and 0.1, respectively. Adult and child CTE HIs from ingestion of food items are estimated to be 0.03 and 0.04, respectively. No COPC-specific HQs exceed 1 for either receptor.

CTE ILCR from exposure to surface water is estimated to be 7.5×10^{-7}. No carcinogenic COCs are identified in EU 5 surface water. Adult and child CTE HIs from exposure to surface water are estimated to be 0.000007 and 0.00001, respectively. No non-carcinogenic CTE COCs are identified for EU 5 surface water.

EU 5 Future Industrial Worker Scenario

The future industrial worker scenario was assessed for exposure to soil zero to 0.5 ft bgs in EU 5 and sediment/surface water in wetland and ditch areas within EU 5. No COPCs were identified in sediment; therefore, only soil and surface water are discussed.

RME Summary. RME ILCR from direct contact with soil is estimated to be 2.6×10^{-7}. The RME HI from direct contact with soil is estimated to be 1.0. No carcinogenic or non-carcinogenic COCs are identified in EU 5 soil.

RME ILCR from exposure to surface water is estimated to be 1.4×10^{-6}. No carcinogenic COCs are identified in EU 5 surface water. The RME HI for future industrial worker direct exposure to surface water is estimated to 0.00002. No noncarcinogenic COCs are identified in EU 5 surface water.

CTE Summary. The CTE ILCR HI from direct contact with soil is estimated to be 3.3×10^{-8}. The CTE HI from direct contact with soil is estimated to be 0.017. No carcinogenic or non-carcinogenic COCs are identified in EU 5 soil.

CTE ILCR from exposure to surface water is estimated to be 1.6×10^{-7}. No carcinogenic COCs are identified in EU 5 surface water. The CTE HI for future industrial worker direct exposure to surface water is estimated to 0.000007. No noncarcinogenic COCs are identified in EU 5 surface water.

EU 5 Future Construction Worker Scenario

The future construction worker scenario was assessed for exposure to soil zero to 10 ft bgs in EU 5 and sediment/surface water in wetland and ditch areas within EU 5. Construction receptors in EU 5 are also assumed to be exposed to site-wide (EU 17) groundwater. See the EU 17 summary for the discussion of risks from exposure to site-wide groundwater. Risks from soil and surface water exposure are summarized below. No COPCs were identified in sediment.

RME Summary. RME ILCR from direct contact with soil is estimated to be 4.5×10^{-8}. The RME HI from direct contact with soil is estimated to be 0.12. No carcinogenic or non-carcinogenic COCs are identified in EU 5 soil.
RME ILCR from exposure to surface water is estimated to be 1.2×10^{-7}. No carcinogenic COCs are identified in EU 5 surface water. The RME HI for future construction worker direct exposure to surface water is estimated to 0.00004. No noncarcinogenic COCs are identified in EU 5 surface water

CTE Summary. CTE ILCR from direct contact with soil is estimated to be 2.2×10^{-9}. The CTE HI from direct contact with soil is estimated to be 0.006. No carcinogenic or non-carcinogenic COCs are identified in EU 5 soil.

CTE ILCR from exposure to surface water is estimated to be 4.8×10^{-8}. No carcinogenic COCs are identified in EU 5 surface water. The CTE HI for future construction worker direct exposure to surface water is estimated to 0.00001. No noncarcinogenic COCs are identified in EU 5 surface water

EU 5 Current and Future Maintenance Worker Scenario

The current and future maintenance worker scenario was assessed for exposure to soil zero to 0.5 ft bgs in EU 5 and sediment/surface water in wetland and ditch areas within EU 5. No COPCs were identified in sediment; therefore, only soil and surface water are discussed.

RME Summary. RME ILCR from direct contact with soil is estimated to be 4.7×10^{-7}. The RME HI from direct contact with soil is estimated to be 0.04. No carcinogenic or non-carcinogenic COCs are identified in EU 5 soil.

RME ILCR from exposure to surface water is estimated to be 2.9×10^{-6}. No carcinogenic COCs are identified in EU 5 surface water. The RME HI for current and future maintenance worker direct exposure to surface water is estimated to 0.00004. No noncarcinogenic COCs are identified in EU 5 surface water.

CTE Summary. CTE ILCR from direct contact with soil is estimated to be 3.8×10^{-8}. The CTE HI from direct contact with soil is estimated to be 0.018. No carcinogenic or non-carcinogenic COCs are identified in EU 5 soil.

CTE ILCR from exposure to surface water is estimated to be 3.2×10^{-7}. The CTE HI for current and future maintenance worker direct exposure to surface water is estimated to be 0.00001. No carcinogenic COCs are identified in EU 5 surface water.

EU 5 Current Trespasser/Future Recreational Visitor Scenario

The trespasser/recreational visitor scenario was assessed for exposure to soil zero to 0.5 ft bgs in EU 5 and sediment/surface water in wetland and ditch areas within EU 5. In addition, they are assumed to consume game that resides in EU 5. No COPCs were identified in sediment; therefore, only soil (including food pathways) and surface water are discussed.

RME Summary. Adult and adolescent RME ILCRs from direct contact with soil are estimated to be 1.1×10^{-7} and 1.2×10^{-7}, respectively. Adult and adolescent RME ILCRs from ingestion of food items are estimated to be 3.3×10^{-10} and 2.2×10^{-10}, respectively. No carcinogenic COCs are identified in EU 5 soil.

Adult and adolescent RME HIs from direct contact with soil are estimated to be 0.008 and 0.021, respectively. Adult and child RME HIs from ingestion of food items are estimated to be 0.000004 and 0.000008, respectively. No non-carcinogenic COCs are identified in EU 5 soil.

Adult and adolescent RME ILCRs from exposure to surface water are estimated to be 3.5×10^{-6} and 1.4×10^{-6}, respectively. No carcinogenic COCs are identified in EU 5 surface water. RME HIs from exposure to surface water are estimated to be 0.00005 and 0.00008, respectively. No noncarcinogenic COCs are identified in EU 5 surface water.

CTE Summary. Adult and adolescent CTE ILCRs from direct contact with soil are estimated to be 2.6×10^{-9} and 7.6×10^{-9}, respectively. Adult and adolescent RME ILCRs from ingestion of food items are estimated to be 5.0×10^{-11} and 9.8×10^{-11}, respectively. No carcinogenic COCs are identified in EU 5 soil.

Adult and adolescent CTE ILCRs from exposure to surface water are both estimated to be 2.6×10^{-7}. No carcinogenic COCs are identified in EU 5 surface water. CTE HIs from exposure to surface water are estimated to be 0.000007 and 0.00001, respectively. No noncarcinogenic COCs are identified in EU 5 surface water

2.4.3.6 Exposure Unit 6

Table 2.11 presents a summary of the total ILCR and HI results for both RME and CTE scenarios for each of the receptors at EU 6.

EU 6 Future Subsistence Farmer Scenario

The future subsistence farmer scenario was assessed for exposure to soil zero to 10 ft bgs in EU 6. Farmer receptors in EU 6 are also assumed to be exposed to site-wide (EU 17) groundwater. See the EU 17 summary for the discussion of risks from exposure to site-wide groundwater. Risks from soil exposure, including food pathways, are summarized below.

RME Summary. RME ILCR from direct contact with soil is estimated to be 1.9×10^{-5}. RME ILCR from ingestion of food items is estimated to be 2.2×10^{-5}. No carcinogenic COCs are identified in EU 6 soil. Adult and child RME HIs from direct contact with soil are estimated to be 0.1 and 0.8, respectively. Adult and child RME HIs from ingestion of food items are estimated to be 0.6 and 0.9, respectively. No COPC-specific HQs exceed 1 for either receptor; therefore, no non-carcinogenic COCs are identified in EU 6 soil.

CTE Summary. CTE ILCR from direct contact with soil is estimated to be 3.8×10^{-6}. CTE ILCR from ingestion of food items is estimated to be 4.3×10^{-6}. No carcinogenic COCs are identified in EU 6 soil. Adult and child CTE HIs from direct contact with soil are estimated to be 0.03 and 0.2, respectively. Adult and child CTE HIs from ingestion of food items are estimated to be 0.2 and 0.5, respectively. No non-carcinogenic COCs are identified in EU 6 soil.

EU 6 Future Resident Scenario

The future resident scenario was assessed for exposure to soil zero to 10 ft bgs in EU 6. Residential receptors in EU 6 are also assumed to be exposed to site-wide (EU 17) groundwater. See the EU 17 summary for the discussion of risks from exposure to site-wide groundwater. Risks from soil exposure, including food pathways, are summarized below.

RME Summary. RME ILCR from direct contact with soil is estimated to be 1.9×10^{-5}. RME ILCR from ingestion of food items is estimated to be 1.7×10^{-5}. No carcinogenic COCs are identified in EU 6 soil. Adult and child RME HIs from direct contact with soil are estimated to be 0.09 and 0.8, respectively. Adult and child RME HIs from ingestion of food items are estimated to be 0.07 for both receptors. No non-carcinogenic COCs are identified in EU 6 soil.

CTE Summary. CTE ILCR from direct contact with soil is estimated to be 3.8×10^{-6}. CTE ILCR from ingestion of food items is estimated to be 3.1×10^{-6}. No carcinogenic COCs are identified in EU 6 soil. Adult and child CTE HIs from direct contact with soil are estimated to be 0.03 and 0.2, respectively. Adult and child CTE HIs from ingestion of food items are estimated to be 0.02 and 0.03, respectively. No non-carcinogenic COCs are identified in EU 6 soil.

EU 6 Future Industrial Worker Scenario

The future industrial worker scenario was assessed for exposure to soil zero to 0.5 ft bgs in EU 6.

RME Summary. RME ILCR from direct contact with soil is estimated to be 9.9×10^{-9}. The RME HI from direct contact with soil is estimated to be 0.01. No carcinogenic or non-carcinogenic COCs are identified in EU 6 soil.

CTE Summary. CTE ILCR from direct contact with soil is estimated to be 1.4×10^{-9}. The CTE HI from direct contact with soil is estimated to be 0.01. No carcinogenic or non-carcinogenic COCs are identified in EU 6 soil.

EU 6 Future Construction Worker Scenario

The future construction worker scenario was assessed for exposure to soil zero to 10 ft bgs in EU 6. Construction worker receptors in EU 6 are also assumed to be exposed to site-wide (EU 17) groundwater. See the EU 17 summary for the discussion of risks from exposure to site-wide groundwater. Risks from soil exposure are summarized below.

RME Summary. RME ILCR from direct contact with soil is estimated to be 6.9×10^{-7}. The RME HI from direct contact with soil is estimated to be 0.3. No carcinogenic or non-carcinogenic COCs are identified in EU 6 soil.

CTE Summary. CTE ILCR from direct contact with soil is estimated to be 3.6×10^{-8}. The CTE HI from direct contact with soil is estimated to be 0.01. No carcinogenic or non-carcinogenic COCs are identified in EU 6 soil.

EU 6 Current and Future Maintenance Worker Scenario

The current and future maintenance worker scenario was assessed for exposure to soil zero to 0.5 ft bgs in EU 6.

RME Summary. RME ILCR from direct contact with soil is estimated to be 1.8×10^{-8}. The RME HI from direct contact with soil is estimated to be 0.01. No carcinogenic or non-carcinogenic COCs are identified in EU 6 soil.

CTE Summary. CTE ILCR from direct contact with soil is estimated to be 1.6×10^{-9}. The RME HI from direct contact with soil is estimated to be 0.003. No carcinogenic or non-carcinogenic COCs are identified in EU 6 soil.

EU 6 Current Trespasser/Future Recreational Visitor Scenario

The trespasser/recreational visitor scenario was assessed for exposure to soil zero to 0.5 ft bgs in EU 6. In addition, they are assumed to consume game that resides in EU 6.

RME Summary. Adult and adolescent RME ILCRs from direct contact with soil are estimated to be 4.2×10^{-9} and 4.6×10^{-9}, respectively. Adult and adolescent RME ILCRs from ingestion of food items are estimated to be 2.3×10^{-11} and 1.5×10^{-11}, respectively. No carcinogenic COCs are identified in EU 6 soil.

Adult and adolescent RME HIs from direct contact with soil are estimated to be 0.001 and 0.004, respectively. Adult and child RME HIs from ingestion of food items are estimated to be 0.000008 and 0.00002, respectively. No non-carcinogenic COCs are identified in EU 6 soil.

CTE Summary. Adult and adolescent CTE ILCRs from direct contact with soil are estimated to be 1.1×10^{-10} and 3.1×10^{-10}, respectively. Adult and adolescent RME ILCRs from ingestion of food items are estimated to be 3.5×10^{-12} and 6.8×10^{-12}, respectively. No carcinogenic COCs are identified in EU 6 soil.

Adult and adolescent CTE HIs from direct contact with soil are estimated to be 0.0002 and 0.0004, respectively. Adult and child RME HIs from ingestion of food items are estimated to be 0.000004 and 0.000008, respectively. No non-carcinogenic COCs are identified in EU 6 soil.

2.4.3.7 Exposure Unit 7

Table 2.12 presents a summary of the total ILCR and HI results for both RME and CTE scenarios for each of the receptors at EU 7.

EU 7 Future Subsistence Farmer Scenario

The future subsistence farmer scenario was assessed for exposure to soil zero to 10 ft bgs in EU 7. Farmer receptors in EU 7 are also assumed to be exposed to site-wide (EU 17) groundwater. See the EU 17 summary for the discussion of risks from exposure to site-wide groundwater. Risks from soil exposure, including food pathways, are summarized below.

RME Summary. RME ILCR from direct contact with soil is estimated to be 3.3×10^{-6}. RME ILCR from ingestion of food items is estimated to be 1.5×10^{-5}. No carcinogenic COCs are identified in EU 7 soil. Adult and child RME HIs from direct contact with soil are estimated to be 0.04 and 0.3, respectively. Adult and child RME HIs from ingestion of food items are estimated to be 0.3 and 0.4, respectively. No non-carcinogenic COCs are identified in EU 7 soil.

CTE Summary. CTE ILCR from direct contact with soil is estimated to be 3.8×10^{-7}. CTE ILCR from ingestion of food items is estimated to be 5.7×10^{-6}. No carcinogenic COCs are identified in EU 7 soil. Adult and child CTE HIs from direct contact with soil are estimated to be 0.01 and 0.09, respectively. Adult and child CTE HIs from ingestion of food items are estimated to be 0.1 and 0.2, respectively. No non-carcinogenic COCs are identified in EU 7 soil.

EU 7 Future Resident Scenario

The future resident scenario was assessed for exposure to soil zero to 10 ft bgs in EU 7. Residential receptors in EU 7 are also assumed to be exposed to site-wide (EU 17) groundwater. See the EU 17 summary for the discussion of risks from exposure to site-wide groundwater. Risks from soil exposure, including food pathways, are summarized below.

RME Summary. RME ILCR from direct contact with soil is estimated to be 1.1×10^{-6}. RME ILCR from ingestion of food items is estimated to be 2.9×10^{-6}. No carcinogenic COCs are identified in EU 7 soil. Adult and child RME HIs from direct contact with soil are estimated to be 0.03 and 0.3, respectively. Adult and child RME HIs from ingestion of food items are estimated to be 0.03 and 0.04, respectively. No non-carcinogenic COCs are identified in EU 7 soil.

CTE Summary. CTE ILCR from direct contact with soil is estimated to be 2.8×10^{-7}. CTE ILCR from ingestion of food items is estimated to be 5.2×10^{-7}. No carcinogenic COCs are identified in EU 7 soil. Adult and child CTE HIs from direct contact with soil are estimated to be 0.01 and 0.09, respectively. Adult and child CTE HIs from ingestion of food items are estimated to be 0.01 for both receptors. No non-carcinogenic COCs are identified in EU 7 soil.

EU 7 Future Industrial Worker Scenario

The future industrial worker scenario was assessed for exposure to soil zero to 0.5 ft bgs in EU 7.

RME Summary. Seven COPCs were identified in soil 0 to 0.5 bgs; however, none of these COPCs have cancer toxicity criteria. As a result, no RME ILCR can be calculated. The RME HI

from direct contact with soil is estimated to be 0.003. No carcinogenic or non-carcinogenic COCs are identified in EU 7 soil.

CTE Summary. Seven COPCs were identified in soil 0 to 0.5 bgs; however, none of these COPCs have cancer toxicity criteria. As a result, no CTE ILCR can be calculated. The CTE HI from direct contact with soil is estimated to be 0.003. No carcinogenic or non-carcinogenic COCs are identified in EU 7 soil.

Future Construction Worker Scenario

The future construction worker scenario was assessed for exposure to soil zero to 10 ft bgs in EU 7. Construction worker receptors in EU 7 are also assumed to be exposed to site-wide (EU 17) groundwater. See the EU 17 summary for the discussion of risks from exposure to site-wide groundwater. Risks from soil exposure, including food pathways, are summarized below.

RME Summary. RME ILCR from direct contact with soil is estimated to be 7.8×10^{-8}. The RME HI from direct contact with soil is estimated to be 0.11. No carcinogenic or non-carcinogenic COCs are identified in EU 7 soil.

CTE Summary. CTE ILCR from direct contact with soil is estimated to be 4.8×10^{-9}. The CTE HI from direct contact with soil is estimated to be 0.006. No carcinogenic or non-carcinogenic COCs are identified in EU 7 soil.

EU 7 Current and Future Maintenance Worker Scenario

The current and future maintenance worker scenario was assessed for exposure to soil zero to 0.5 ft bgs in EU 7.

RME Summary. Seven COPCs were identified in soil 0 to 0.5 bgs; however, none of these COPCs have cancer toxicity criteria. As a result, no RME ILCR can be calculated. The RME HI from direct contact with soil is estimated to be 0.006. No carcinogenic or non-carcinogenic COCs are identified in EU 7 soil.

CTE Summary. Seven COPCs were identified in soil 0 to 0.5 bgs; however, none of these COPCs have cancer toxicity criteria. As a result, no CTE ILCR can be calculated. The CTE HI from direct contact with soil is estimated to be 0.003. No carcinogenic or non-carcinogenic COCs are identified in EU 7 soil.

EU 7 Current Trespasser/Future Recreational Visitor Scenario

The trespasser/recreational visitor scenario was assessed for exposure to soil zero to 0.5 ft bgs in EU 7. In addition, they are assumed to consume game that resides in EU 7.

RME Summary. Seven COPCs were identified in soil 0 to 0.5 bgs; however, none of these COPCs have cancer toxicity criteria. As a result, no RME ILCR can be calculated. Adult and adolescent RME HIs from direct contact with soil are estimated to be 0.001 and 0.003, respectively. Adult and child RME HIs from ingestion of food items are estimated to be 0.000001 and 0.000002, respectively. No non-carcinogenic COCs are identified in EU 7 soil.

CTE Summary. Seven COPCs were identified in soil 0 to 0.5 bgs; however, none of these COPCs have cancer toxicity criteria. As a result, no CTE ILCR can be calculated. Adult and

adolescent CTE HIs from direct contact with soil are estimated to be 0.00021 and 0.0004, respectively. Adult and child RME HIs from ingestion of food items are estimated to be 0.0000005 and 0.000001, respectively. No non-carcinogenic COCs are identified in EU 7 soil.

2.4.3.8 Exposure Unit 8

Table 2.13 presents a summary of the total ILCR and HI results for both RME and CTE scenarios for each of the receptors at EU 8.

EU 8 Future Subsistence Farmer Scenario

The future subsistence farmer scenario was assessed for exposure to soil zero to 10 ft bgs in EU 8. Future subsistence farmer receptors in EU 8 are also assumed to be exposed to site-wide (EU 17) groundwater. See the EU 17 summary for the discussion of risks from exposure to site-wide groundwater. Risks from soil exposure, including food pathways, are summarized below.

RME Summary. RME ILCR from direct contact with soil is estimated to be 1.1×10^{-3}. RME ILCR from ingestion of food items is estimated to be 4.7×10^{-3}. Heptachlor expoxide, benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, carbazole, dibenz(a,h)anthracene, and indeno(1,2,3-cd)pyrene are COCs for direct contact with soil and/or the food pathway.

Adult and child RME HIs from direct contact with soil are estimated to be 0.3 and 2.2, respectively. Adult and child RME HIs from ingestion of food items are estimated to be 2.5 and 4.5, respectively. Aroclor-1260 and uranium are COCs via the direct contact with soil and/or the food pathway.

CTE Summary. CTE ILCR from direct contact with soil is estimated to be 1.2×10^{-4}. CTE ILCR from ingestion of food items is estimated to be 1.7×10^{-3}. Benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, dibenz(a,h)anthracene, and indeno(1,2,3-cd)pyrene are COCs for direct contact with soil and/or the food pathway.

Adult and child CTE HIs from direct contact with soil are estimated to be 0.07 and 0.6, respectively. Adult and child CTE HIs from ingestion of food items are estimated to be 0.9 and 2.7, respectively. Aroclor-1260 is a COC for the food pathway.

EU 8 Future Resident Scenario

The future resident scenario was assessed for exposure to soil zero to 10 ft bgs in EU 8. Residential receptors in EU 8 are also assumed to be exposed to site-wide (EU 17) groundwater. See the EU 17 summary for the discussion of risks from exposure to site-wide groundwater. Risks from soil exposure, including food pathways, are summarized below.

RME Summary. RME ILCR from direct contact with soil is estimated to be 9.5×10^{-4}. RME ILCR from ingestion of food items is estimated to be 7.5×10^{-4}. Heptachlor expoxide, benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, carbazole, dibenz(a,h)anthracene, and indeno(1,2,3-cd)pyrene are COCs for direct contact with soil and/or the food pathway.

Adult and child RME HIs from direct contact with soil are estimated to be 0.3 and 2.2, respectively. Adult and child RME HIs from ingestion of food items are estimated to be 0.3 for both receptors. Uranium is a COC via the direct contact with soil pathway.

CTE Summary. CTE ILCR from direct contact with soil is estimated to be 1.2×10^{-4}. CTE ILCR from ingestion of food items is estimated to be 1.3×10^{-4}. Benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, and dibenz(a,h)anthracene are COCs for direct contact with soil and/or the food pathway.

Adult and child CTE HIs from direct contact with soil are estimated to be 0.09 and 0.6, respectively. Adult and child CTE HIs from ingestion of food items are estimated to be 0.1 for both receptors. No non-carcinogenic COCs are identified in EU 8 soil.

EU 8 Future Industrial Worker Scenario

The future industrial worker scenario was assessed for exposure to soil zero to 0.5 ft bgs in EU 8.

RME Summary. RME ILCR from direct contact with soil is estimated to be 1.4×10^{-4}. Benzo(a)pyrene and dibenz(a,h)anthracene are COCs for direct contact with soil. The RME HI from direct contact with soil is estimated to be 0.1. No non-carcinogenic COCs are identified in EU 8 soil.

CTE Summary. CTE ILCR from direct contact with soil is estimated to be 1.8×10^{-5}. The CTE HI from direct contact with soil is estimated to be 0.09. No carcinogenic or non-carcinogenic COCs are identified in EU 8 soil.

EU 8 Future Construction Worker Scenario

The future construction worker scenario was assessed for exposure to soil zero to 10 ft bgs in EU 8. Construction worker receptors in EU 8 are also assumed to be exposed to site-wide (EU 17) groundwater. See the EU 17 summary for the discussion of risks from exposure to site-wide groundwater. Risks from soil exposure, including food pathways, are summarized below.

RME Summary. RME ILCR from direct contact with soil is estimated to be 2.5×10^{-5}. The RME HI from direct contact with soil is estimated to be 0.8. No carcinogenic or non-carcinogenic COCs are identified in EU 8 soil.

CTE Summary. CTE ILCR from direct contact with soil is estimated to be 1.5×10^{-6}. The CTE HI from direct contact with soil is estimated to be 0.04. No carcinogenic or non-carcinogenic COCs are identified in EU 8 soil.

EU 8 Current and Future Maintenance Worker Scenario

The current and future maintenance worker scenario was assessed for exposure to soil zero to 0.5 ft bgs in EU 8.

RME Summary. RME ILCR from direct contact with soil is estimated to be 2.5×10^{-4}. Benzo(a)anthracene, benzo(a)pyrene, and dibenz(a,h)anthracene are COCs for direct contact with soil. The RME HI from direct contact with soil is estimated to be 0.2. No non-carcinogenic COCs are identified in EU 8 soil.

CTE Summary. CTE ILCR from direct contact with soil is estimated to be 2.0×10^{-5}. The CTE HI from direct contact with soil is estimated to be 0.09. No carcinogenic or non-carcinogenic COCs are identified in EU 8 soil.

EU 8 Current Trespasser/Future Recreational Visitor Scenario

The trespasser/recreational visitor scenario was assessed for exposure to soil zero to 0.5 ft bgs in EU 8. In addition, they are assumed to consume game that resides in EU 8.

RME Summary. Adult and adolescent RME ILCRs from direct contact with soil are estimated to be 5.7×10^{-5} and 6.4×10^{-5}, respectively. Adult and adolescent RME ILCRs from ingestion of food items are estimated to be 9.1×10^{-8} and 5.9×10^{-8}, respectively. No carcinogenic COCs are identified in EU 8 soil.

Adult and adolescent RME HIs from direct contact with soil are estimated to be 0.04 and 0.1, respectively. Adult and child RME HIs from ingestion of food items are estimated to be 0.000009 and 0.00002, respectively. No non-carcinogenic COCs are identified in EU 8 soil.

CTE Summary. Adult and adolescent CTE ILCRs from direct contact with soil are estimated to be 1.4×10^{-6} and 4.0×10^{-6}, respectively. Adult and adolescent CTE ILCRs from ingestion of food items are estimated to be 1.4×10^{-8} and 2.7×10^{-8}, respectively. No carcinogenic COCs are identified in EU 8 soil.

Adult and adolescent CTE HIs from direct contact with soil are estimated to be 0.005 and 0.01, respectively. Adult and child CTE HIs from ingestion of food items are estimated to be 0.000004 and 0.000008, respectively. No non-carcinogenic COCs are identified in EU 8 soil.

2.4.3.9 Exposure Unit 9

Table 2.14 presents a summary of the total ILCR and HI results for both RME and CTE scenarios for each of the receptors at EU 9. No COPCs were identified in sediment and surface water in the west drainage ditch. Therefore, the discussion below is limited to soil and groundwater exposures.

EU 9 Future Subsistence Farmer Scenario

The future subsistence farmer scenario was assessed for exposure to soil zero to 10 ft bgs in EU 9. Farmer receptors in EU 9 are also assumed to be exposed to site-wide (EU 17) groundwater. See the EU 17 summary for the discussion of risks from exposure to site-wide groundwater. Risks from soil exposure, including food pathways, are summarized below.

RME Summary. Only four COPCs were identified in EU 9 soil (0 – 10 ft) and none have cancer toxicity criteria; therefore no RME ILCR can be calculated. Adult and child RME HIs from direct contact with soil are estimated to be 0.05 and 0.4, respectively. Adult and child RME HIs from ingestion of food items are estimated to be 0.3 and 0.4, respectively. No non-carcinogenic COCs are identified in EU 9 soil.

CTE Summary. No CTE ILCR can be calculated. Adult and child CTE HIs from direct contact with soil are estimated to be 0.012 and 0.11, respectively. Adult and child CTE HIs from ingestion of food items are estimated to be 0.1 and 0.2, respectively. No non-carcinogenic COCs are identified in EU 9 soil.

EU 9 Future Resident Scenario

The future resident scenario was assessed for exposure to soil zero to 10 ft bgs in EU 9. Residential receptors in EU 9 are also assumed to be exposed to site-wide (EU 17) groundwater. See the EU 17 summary for the discussion of risks from exposure to site-wide groundwater. Risks from soil exposure, including food pathways, are summarized below.

RME Summary. Only four COPCs were identified in EU 9 soil (0 – 10 ft) and none have cancer toxicity criteria; therefore no RME ILCR can be calculated. Adult and child RME HIs from direct contact with soil are estimated to be 0.04 and 0.4, respectively. Adult and child RME HIs from ingestion of food items are estimated to be 0.05 and 0.4, respectively. No non-carcinogenic COCs are identified in EU 9 soil.

CTE Summary. No CTE ILCR can be calculated. Adult and child CTE HIs from direct contact with soil are estimated to be 0.012 and 0.11, respectively. Adult and child CTE HIs from ingestion of food items are estimated to be 0.02 for both receptors. No non-carcinogenic COCs are identified in EU 9 soil.

EU 9 Future Industrial Worker Scenario

The future industrial worker scenario was assessed for exposure to soil zero to 0.5 ft bgs in EU 9.

RME Summary. RME ILCR from direct contact with soil is estimated to be 7.4×10^{-9}. The RME HI from direct contact with soil is estimated to be 0.012. No carcinogenic or non-carcinogenic COCs are identified in EU 9 soil.

CTE Summary. CTE ILCR from direct contact with soil is estimated to be 1.1×10^{-9}. The CTE HI from direct contact with soil is estimated to be 0.011. No carcinogenic or non-carcinogenic COCs are identified in EU 9 soil.

EU 9 Future Construction Worker Scenario

The future construction worker scenario was assessed for exposure to soil zero to 10 ft bgs in EU 9. Construction worker receptors in EU 9 are also assumed to be exposed to site-wide (EU 17) groundwater. See the EU 17 summary for the discussion of risks from exposure to site-wide groundwater. Risks from soil exposure, including food pathways, are summarized below.

RME Summary. Only four COPCs were identified in EU 9 soil (0 – 10 ft) and none have cancer toxicity criteria; therefore no RME ILCR can be calculated. The RME HI from direct contact with soil is estimated to be 0.13. No non-carcinogenic COCs are identified in EU 9 soil.

CTE Summary. No CTE ILCR can be calculated. The CTE HI from direct contact with soil is estimated to be 0.007. No non-carcinogenic COCs are identified in EU 9 soil.

EU 9 Current and Future Maintenance Worker Scenario

The current and future maintenance worker scenario was assessed for exposure to soil zero to 0.5 ft bgs in EU 9.

RME Summary. RME ILCR from direct contact with soil is estimated to be 1.4×10^{-8}. The RME HI from direct contact with soil is estimated to be 0.025. No carcinogenic or non-carcinogenic COCs are identified in EU 9 soil.

CTE Summary. CTE ILCR from direct contact with soil is estimated to be 1.2×10^{-9}. The CTE HI from direct contact with soil is estimated to be 0.011. No carcinogenic or non-carcinogenic COCs are identified in EU 9 soil.

EU 9 Current Trespasser/Future Recreational Visitor Scenario

The trespasser/recreational visitor scenario was assessed for exposure to soil zero to 0.5 ft bgs in EU 9. In addition, they are assumed to consume game that resides in EU 9.

RME Summary. Adult and adolescent RME ILCRs from direct contact with soil are estimated to be 1.9×10^{-9} and 1.6×10^{-9}, respectively. Adult and adolescent RME ILCRs from ingestion of food items are estimated to be 1.7×10^{-11} and 1.1×10^{-11}, respectively. No carcinogenic COCs are identified in EU 9 soil.

Adult and adolescent RME HIs from direct contact with soil are estimated to be 0.005 and 0.012, respectively. Adult and child RME HIs from ingestion of food items are estimated to be 0.000002 and 0.000003, respectively. No non-carcinogenic COCs are identified in EU 9 soil.

CTE Summary. Adult and adolescent CTE ILCRs from direct contact with soil are estimated to be 7.2×10^{-11} and 1.8×10^{-10}, respectively. Adult and adolescent CTE ILCRs from ingestion of food items are estimated to be 2.6×10^{-12} and 5.1×10^{-12}, respectively. No carcinogenic COCs are identified in EU 9 soil.

Adult and adolescent RME HIs from direct contact with soil are estimated to be 0.0006 and 0.0016, respectively. Adult and child RME HIs from ingestion of food items are estimated to be 0.0000008 and 0.000002, respectively. No non-carcinogenic COCs are identified in EU 9 soil.

2.4.3.10 Exposure Unit 10

Only the current and future maintenance worker scenario was evaluated for EU 10. Table 2.15 presents the summary of risk to both RME and CTE scenarios. This scenario does not include exposure to the contents of the IWCS. It is assumed that exposure to the contents of the IWCS would pose an unacceptable risk.

EU 10 Current and Future Maintenance Worker Scenario

The current and future maintenance worker scenario was assessed for exposure to soil zero to 0.5 ft bgs in EU 10.

RME Summary. RME ILCR from direct contact with soil is estimated to be 2.4×10^{-6}. The RME HI from direct contact with soil is estimated to be 0.04. No carcinogenic or non-carcinogenic COCs are identified in EU 10 soil.

CTE Summary. CTE ILCR from direct contact with soil is estimated to be 1.8×10^{-7}. The CTE HI from direct contact with soil is estimated to be 0.02. No carcinogenic or non-carcinogenic COCs are identified in EU 10 soil.

2.4.3.11 Exposure Unit 11

Table 2.16 presents a summary of the total ILCR and HI results for both RME and CTE scenarios for each of the receptors at EU 11.

EU 11 Future Subsistence Farmer Scenario

The future subsistence farmer scenario was assessed for exposure to soil zero to 10 ft bgs in EU 11. Farmer receptors in EU 11 are also assumed to be exposed to site-wide (EU 17) groundwater. See the EU 17 summary for the discussion of risks from exposure to site-wide groundwater. Risks from soil exposure, including food pathways, are summarized below.

RME Summary. RME ILCR from direct contact with soil is estimated to be 4.0×10^{-5}. RME ILCR from ingestion of food items is estimated to be 1.5×10^{-4}. Benzo(a)pyrene, benzo(b)fluoranthene, and indeno (1,2,3-cd)pyrene are COCs via the food pathway.

Adult and child RME HIs from direct contact with soil are estimated to be 0.2 and 1.7, respectively. Adult and child RME HIs from ingestion of food items are estimated to be 1.2 and 1.6, respectively. Uranium is a COC via the direct contact with soil pathway.

CTE Summary. CTE ILCR from direct contact with soil is estimated to be 4.6×10^{-6}. CTE ILCR from ingestion of food items is estimated to be 5.4×10^{-5}. No carcinogenic COCs are identified in EU 11 soil.

Adult and child CTE HIs from direct contact with soil are estimated to be 0.06 and 0.5, respectively. Adult and child CTE HIs from ingestion of food items are estimated to be 0.4 and 0.7, respectively. No non-carcinogenic COCs are identified in EU 11 soil.

EU 11 Future Resident Scenario

The future resident scenario was assessed for exposure to soil zero to 10 ft bgs in EU 11. Residential receptors in EU 11 are also assumed to be exposed to site-wide (EU 17) groundwater. See the EU 17 summary for the discussion of risks from exposure to site-wide groundwater. Risks from soil exposure, including food pathways, are summarized below.

RME Summary. RME ILCR from direct contact with soil is estimated to be 3.6×10^{-5}. RME ILCR from ingestion of food items is estimated to be 3.0×10^{-5}. No carcinogenic COCs are identified in EU 11 soil.

Adult and child RME HIs from direct contact with soil are estimated to be 0.2 and 1.7, respectively. Adult and child RME HIs from ingestion of food items are estimated to be 0.1 and 0.2, respectively. Uranium is a COC via direct contact with soil.

CTE Summary. CTE ILCR from direct contact with soil is estimated to be 4.6×10^{-6}. CTE ILCR from ingestion of food items is estimated to be 5.4×10^{-6}. No carcinogenic COCs are identified in EU 11 soil.

Adult and child CTE HIs from direct contact with soil are estimated to be 0.06 and 0.5, respectively. Adult and child CTE HIs from ingestion of food items are estimated to be 0.05 and 0.06, respectively. No non-carcinogenic COCs are identified in EU 11 soil.

EU 11 Future Industrial Worker Scenario

The future industrial worker scenario was assessed for exposure to soil zero to 0.5 ft bgs in EU 11.

RME Summary. RME ILCR from direct contact with soil is estimated to be 7.0×10^{-6}. The RME HI from direct contact with soil is estimated to be 0.1. No carcinogenic or non-carcinogenic COCs are identified in EU 11 soil.

CTE Summary. CTE ILCR from direct contact with soil is estimated to be 9.1×10^{-7}. The CTE HI from direct contact with soil is estimated to be 0.1. No carcinogenic or non-carcinogenic COCs are identified in EU 11 soil.

EU 11 Future Construction Worker Scenario

The future construction worker scenario was assessed for exposure to soil zero to 10 ft bgs in EU 11. Construction worker receptors in EU 11 are also assumed to be exposed to site-wide (EU 17) groundwater. See the EU 17 summary for the discussion of risks from exposure to site-wide groundwater. Risks from soil exposure, including food pathways, are summarized below.

RME Summary. RME ILCR from direct contact with soil is estimated to be 9.4×10^{-7}. The RME HI from direct contact with soil is estimated to be 0.6. No carcinogenic or non-carcinogenic COCs are identified in EU 11 soil.

CTE Summary. CTE ILCR from direct contact with soil is estimated to be 5.8×10^{-8}. The CTE HI from direct contact with soil is estimated to be 0.03. No carcinogenic or non-carcinogenic COCs are identified in EU 11 soil.

EU 11 Current and Future Maintenance Worker Scenario

The current and future maintenance worker scenario was assessed for exposure to soil zero to 0.5 ft bgs in EU 11.

RME Summary. RME ILCR from direct contact with soil is estimated to be 1.3×10^{-5}. The RME HI from direct contact with soil is estimated to be 0.3. No carcinogenic or non-carcinogenic COCs are identified in EU 11 soil.

CTE Summary. CTE ILCR from direct contact with soil is estimated to be 1×10^{-6}. The CTE HI from direct contact with soil is estimated to be 0.1. No carcinogenic or non-carcinogenic COCs are identified in EU 11 soil.

EU 11 Current Trespasser/Future Recreational Visitor Scenario

The trespasser/recreational visitor scenario was assessed for exposure to soil zero to 0.5 ft bgs in EU 11. In addition, they are assumed to consume game that resides in EU 11.

RME Summary. Adult and adolescent RME ILCRs from direct contact with soil are estimated to be 2.9×10^{-6} and 3.3×10^{-6}, respectively. Adult and adolescent RME ILCRs from ingestion of food items are estimated to be 4.1×10^{-9} and 2.6×10^{-9}, respectively. No carcinogenic COCs are identified in EU 11 soil.

Adult and adolescent RME HIs from direct contact with soil are estimated to be 0.06 and 0.1, respectively. Adult and child RME HIs from ingestion of food items are estimated to be 0.00001 and 0.00002, respectively. No non-carcinogenic COCs are identified in EU 11 soil.

CTE Summary. Adult and adolescent CTE ILCRs from direct contact with soil are estimated to be 7.2×10^{-8} and 2.1×10^{-7}, respectively. Adult and adolescent CTE ILCRs from ingestion of food items are estimated to be 6.1×10^{-10} and 1.2×10^{-9}, respectively. No carcinogenic COCs are identified in EU 11 soil.

Adult and adolescent CTE HIs from direct contact with soil are estimated to be 0.007 and 0.02, respectively. Adult and child RME HIs from ingestion of food items are estimated to be 0.000006 and 0.00001, respectively. No non-carcinogenic COCs are identified in EU 11 soil.

2.4.3.12 Exposure Unit 12

Table 2.17 presents a summary of the total ILCR and HI results for both RME and CTE scenarios for each of the receptors at EU 12.

EU 12 Future Subsistence Farmer Scenario

The future subsistence farmer scenario was assessed for exposure to soil zero to 10 ft bgs in EU 12. Farmer receptors in EU 12 are also assumed to be exposed to site-wide (EU 17) groundwater. See the EU 17 summary for the discussion of risks from exposure to site-wide groundwater. Risks from soil exposure, including food pathways, are summarized below.

RME Summary. RME ILCR from direct contact with soil is estimated to be 1.3×10^{-4}. RME ILCR from ingestion of food items is estimated to be 3.1×10^{-4}. Benzo(a)pyrene, benzo(b)fluoranthene, indeno(1,2,3-cd)pyrene, and arsenic are COCs for direct contact with soil and/or the food pathway.

Adult and child RME HIs from direct contact with soil are estimated to be 0.2 and 1.7, respectively. Adult and child RME HIs from ingestion of food items are estimated to be 1.3 and 1.6, respectively. Arsenic is a COC via the direct contact with soil pathway.

CTE Summary. CTE ILCR from direct contact with soil is estimated to be 2.1×10^{-5}. CTE ILCR from ingestion of food items is estimated to be 1×10^{-4}. Benzo(a)pyrene, benzo(b)fluoranthene, indeno(1,2,3-cd)pyrene, and arsenic are COCs for direct contact with soil and/or the food pathway.

Adult and child CTE HIs from direct contact with soil are estimated to be 0.06 and 0.5, respectively. Adult and child CTE HIs from ingestion of food items are estimated to be 0.4 and 0.7, respectively. No non-carcinogenic COCs are identified in EU 12 soil.

EU 12 Future Resident Scenario

The future resident scenario was assessed for exposure to soil zero to 10 ft bgs in EU 12. Residential receptors in EU 12 are also assumed to be exposed to site-wide (EU 17) groundwater. See the EU 17 summary for the discussion of risks from exposure to site-wide groundwater. Risks from soil exposure, including food pathways, are summarized below.

RME Summary. RME ILCR from direct contact with soil is estimated to be 1.2×10^{-4}. RME ILCR from ingestion of food items is estimated to be 1.1×10^{-4}. Benzo(a)pyrene and arsenic are COCs for direct contact with soil and/or the food pathway.

Adult and child RME HIs from direct contact with soil are estimated to be 0.2 and 1.7, respectively. Adult and child RME HIs from ingestion of food items are estimated to be 0.2 for both receptors. Arsenic is a COC via the direct contact with soil pathway.

CTE Summary. CTE ILCR from direct contact with soil is estimated to be 2.1×10^{-5}. CTE ILCR from ingestion of food items is estimated to be 1.9×10^{-5}. No carcinogenic COCs are identified in EU 12 soil.

Adult and child CTE HIs from direct contact with soil are estimated to be 0.06 and 0.5, respectively. Adult and child CTE HIs from ingestion of food items are estimated to be 0.06 and 0.07, respectively. No non-carcinogenic COCs are identified in EU 12 soil.

EU 12 Future Industrial Worker Scenario

The future industrial worker scenario was assessed for exposure to soil zero to 0.5 ft bgs in EU 12.

RME Summary. RME ILCR from direct contact with soil is estimated to be 1.6×10^{-5}. The RME HI from direct contact with soil is estimated to be 0.08. No carcinogenic or non-carcinogenic COCs are identified in EU 12 soil.

CTE Summary. CTE ILCR from direct contact with soil is estimated to be 2.8×10^{-6}. The CTE HI from direct contact with soil is estimated to be 0.07. No carcinogenic or non-carcinogenic COCs are identified in EU 12 soil.

EU 12 Future Construction Worker Scenario

The future construction worker scenario was assessed for exposure to soil zero to 10 ft bgs in EU 12. Construction worker receptors in EU 12 are also assumed to be exposed to site-wide (EU 17) groundwater. See the EU 17 summary for the discussion of risks from exposure to site-wide groundwater. Risks from soil exposure, including food pathways, are summarized below.

RME Summary. RME ILCR from direct contact with soil is estimated to be 4.0×10^{-6}. The RME HI from direct contact with soil is estimated to be 0.6. No carcinogenic or non-carcinogenic COCs are identified in EU 12 soil.

CTE Summary. CTE ILCR from direct contact with soil is estimated to be 2.2×10^{-7}. The CTE HI from direct contact with soil is estimated to be 0.03. No carcinogenic or non-carcinogenic COCs are identified in EU 12 soil.

EU 12 Current and Future Maintenance Worker Scenario

The current and future maintenance worker scenario was assessed for exposure to soil zero to 0.5 ft bgs in EU 12.

RME Summary. RME ILCR from direct contact with soil is estimated to be 3.0×10^{-5}. The RME HI from direct contact with soil is estimated to be 0.2. No carcinogenic or non-carcinogenic COCs are identified in EU 12 soil.

CTE Summary. CTE ILCR from direct contact with soil is estimated to be 2.9×10^{-6}. The CTE HI from direct contact with soil is estimated to be 0.07. No carcinogenic or non-carcinogenic COCs are identified in EU 12 soil.

EU 12 Current Trespasser/Future Recreational Visitor Scenario

The trespasser/recreational visitor scenario was assessed for exposure to soil zero to 0.5 ft bgs in EU 12. In addition, they are assumed to consume game that resides in EU 12.

RME Summary. Adult and adolescent RME ILCRs from direct contact with soil are estimated to be 7.1×10^{-6} and 4.6×10^{-6}, respectively. Adult and adolescent RME ILCRs from ingestion of food items are estimated to be 3.9×10^{-9} and 2.6×10^{-9}, respectively. No carcinogenic COCs are identified in EU 12 soil.

Adult and adolescent RME HIs from direct contact with soil are estimated to be 0.03 and 0.08, respectively. Adult and child RME HIs from ingestion of food items are estimated to be 0.000006 and 0.00001, respectively. No non-carcinogenic COCs are identified in EU 12 soil.

CTE Summary. Adult and adolescent CTE ILCRs from direct contact with soil are estimated to be 2.2×10^{-7} and 5.1×10^{-7}, respectively. Adult and adolescent CTE ILCRs from ingestion of food items are estimated to be 5.9×10^{-10} and 1.2×10^{-9}, respectively. No carcinogenic COCs are identified in EU 12 soil.

Adult and adolescent RME HIs from direct contact with soil are estimated to be 0.004 and 0.01, respectively. Adult and child RME HIs from ingestion of food items are estimated to be 0.000003 and 0.000006, respectively. No non-carcinogenic COCs are identified in EU 12 soil.

2.4.3.13 Exposure Unit 13

Table 2.18 presents a summary of the total ILCR and HI results for both RME and CTE scenarios for each of the receptors at EU 13.

EU 13 Future Subsistence Farmer Scenario

The future subsistence farmer scenario was assessed for exposure to soil zero to 10 ft bgs in EU 13. Farmer receptors in EU 13 are also assumed to be exposed to EU 13 groundwater (see Section 2.1.2.6).

RME Summary. RME ILCR from direct contact with soil is estimated to be 3.5×10^{-5}. RME ILCR from ingestion of food items is estimated to be 9.7×10^{-5}. No carcinogenic COCs are identified in EU 13 soil.

Adult and child RME HIs from direct contact with soil are estimated to be 0.2 and 1.1, respectively. Adult and child RME HIs from ingestion of food items are estimated to be 4.4 and 6.9, respectively. Aroclor-1254, copper, and zinc are COCs for food pathways.

RME ILCR from exposure to EU 13 groundwater is estimated to be 3.2×10^{-3}. Bis(2-ethylhexyl)phthalate, trichloroethene, and arsenic are COCs for exposure to groundwater.

Adult and child RME HIs from exposure to groundwater are estimated to be 38 and 40, respectively. Cis-1,2-dichloroethene, trichloroethene, aluminum, arsenic, boron, manganese, and vanadium are COCs for exposure to groundwater. Lead EPC exceeds the drinking water action level and also is a COC.

CTE Summary. CTE ILCR from direct contact with soil is estimated to be 5.3×10^{-6}. CTE ILCR from ingestion of food items is estimated to be 3.3×10^{-5}. No carcinogenic COCs are identified in EU 13 soil.

Adult and child CTE HIs from direct contact with soil are estimated to be 0.04 and 0.3, respectively. Adult and child CTE HIs from ingestion of food items are estimated to be 1.5 and 3.6, respectively. Aroclor-1254 is a COC via the direct contact with soil and food pathways.

CTE ILCR from exposure to groundwater is estimated to be 6.1×10^{-4}. Trichloroethene and arsenic are COCs for exposure to groundwater. Adult and child CTE HIs from exposure to groundwater are estimated to be 23 and 28, respectively. Cis-1,2-dichloroethene, trichloroethene, aluminum, arsenic, boron, manganese, and vanadium are COCs for exposure to groundwater. Lead EPC exceeds the drinking water action level and also is a COC.

EU 13 Future Resident Scenario

The future resident scenario was assessed for exposure to soil zero to 10 ft bgs in EU 13. Residential receptors in EU 13 are also assumed to be exposed to EU 13 groundwater.

RME Summary. RME ILCR from direct contact with soil is estimated to be 3.2×10^{-5}. RME ILCR from ingestion of food items is estimated to be 2.8×10^{-5}. No carcinogenic COCs are identified in EU 13 soil.

Adult and child RME HIs from direct contact with soil are estimated to be 0.2 and 1.1, respectively. Adult and child RME HIs from ingestion of food items are estimated to be 0.5 and 0.6, respectively. No COPC-specific HQs exceed 1 for either receptor.

RME ILCR from exposure to groundwater is estimated to be 3.2×10^{-3}. Bis(2-ethylhexyl)phthalate, trichloroethene, and arsenic are COCs for exposure to groundwater. Adult and child RME HIs from exposure to groundwater are estimated to be 36 and 40, respectively. Cis-1,2-dichloroethene, trichloroethene, aluminum, arsenic, boron, manganese and vanadium are COCs for exposure to groundwater. Lead EPC exceeds the drinking water action level and also is a COC.

CTE Summary. CTE ILCR from direct contact with soil is estimated to be 5.3×10^{-6}. CTE ILCR from ingestion of food items is estimated to be 5.1×10^{-6}. No carcinogenic COCs are identified in EU 13 soil.

Adult and child CTE HIs from direct contact with soil are estimated to be 0.06 and 0.3, respectively. Adult and child CTE HIs from ingestion of food items are estimated to be 0.2 for both receptors. No non-carcinogenic COCs are identified in EU 13 soil.

CTE ILCR from exposure to groundwater is estimated to be 6.1×10^{-4}. Trichloroethene and arsenic are COCs for exposure to groundwater. Adult and child CTE HIs from exposure to groundwater are estimated to be 23 and 28, respectively. Trichloroethene, aluminum, arsenic, boron, manganese, and vanadium are COCs for exposure to groundwater. Lead EPC exceeds the drinking water action level and also is a COC.

EU 13 Future Industrial Worker Scenario

The future industrial worker scenario was assessed for exposure to soil zero to 0.5 ft bgs in EU 13.

RME Summary. RME ILCR from direct contact with soil is estimated to be 1.5×10^{-6}. The RME HI from direct contact with soil is estimated to be 0.04. No carcinogenic COCs are identified in EU 13 soil.

CTE Summary. CTE ILCR from direct contact with soil is estimated to be 2.0×10^{-7}. The CTE HI from direct contact with soil is estimated to be 0.03. No carcinogenic or non-carcinogenic COCs are identified in EU 13 soil.

EU 13 Future Construction Worker Scenario

The future construction worker scenario was assessed for exposure to soil zero to 10 ft bgs in EU 13. Construction worker receptors in EU 13 are also assumed to be exposed to EU 13 groundwater.

RME Summary. RME ILCR from direct contact with soil is estimated to be 1×10^{-6}. The RME HI from direct contact with soil is estimated to be 0.4. No carcinogenic or non-carcinogenic COCs are identified in EU 13 soil.

RME ILCR from exposure to groundwater is estimated to be 7.1×10^{-5}. RME HI from exposure to groundwater is estimated to be 4.2. Arsenic is a groundwater COC based on both carcinogenic and non-carcinogenic risk.

CTE Summary. CTE ILCR from direct contact with soil is estimated to be 5.9×10^{-8}. The CTE HI from direct contact with soil is estimated to be 0.02. No carcinogenic or non-carcinogenic COCs are identified in EU 13 soil.

CTE ILCR from exposure to groundwater is estimated to be 1.2×10^{-5}. CTE HI from exposure to groundwater is estimated to be 0.7. Arsenic is a carcinogenic and noncarcinogenic COC identified in EU 13 groundwater.

EU 13 Current and Future Maintenance Worker Scenario

The current and future maintenance worker scenario was assessed for exposure to soil zero to 0.5 ft bgs in EU 13.

RME Summary. RME ILCR from direct contact with soil is estimated to be 2.8×10^{-6}. The RME HI from direct contact with soil is estimated to be 0.08. No carcinogenic or non-carcinogenic COCs are identified in EU 13 soil.

CTE Summary. CTE ILCR from direct contact with soil is estimated to be 2.3×10^{-7}. The CTE HI from direct contact with soil is estimated to be 0.03. No carcinogenic or non-carcinogenic COCs are identified in EU 13 soil.

EU 13 Current Trespasser/Future Recreational Visitor Scenario

The trespasser/recreational visitor scenario was assessed for exposure to soil zero to 0.5 ft bgs in EU 13. In addition, they are assumed to consume game that resides in EU 13.

RME Summary. Adult and adolescent RME ILCRs from direct contact with soil are estimated to be 6.4×10^{-7} and 7.2×10^{-7}, respectively. Adult and adolescent RME ILCRs from ingestion of food items are estimated to be 1×10^{-9} and 6.5×10^{-10}, respectively. No carcinogenic COCs are identified in EU 13 soil.

Adult and adolescent RME HIs from direct contact with soil are estimated to be 0.02 and 0.04, respectively. Adult and child RME HIs from ingestion of food items are estimated to be 0.00004 and 0.00007, respectively. No carcinogenic or non-carcinogenic COCs are identified in EU 13 soil.

CTE Summary. Adult and adolescent CTE ILCRs from direct contact with soil are estimated to be 1.6×10^{-8} and 4.6×10^{-8}, respectively. Adult and adolescent RME ILCRs from ingestion of food items are estimated to be 1.5×10^{-10} and 2.9×10^{-10}, respectively. No carcinogenic COCs are identified in EU 13 soil.

Adult and adolescent RME HIs from direct contact with soil are estimated to be 0.002 and 0.005, respectively. Adult and child RME HIs from ingestion of food items are estimated to be 0.00002 and 0.00004, respectively. No carcinogenic or non-carcinogenic COCs are identified in EU 13 soil.

2.4.3.14 Exposure Unit 14

Table 2.19 presents a summary of the total ILCR and HI results for both RME and CTE scenarios for each of the receptors at EU 14.

EU 14 Future Subsistence Farmer Scenario

The future subsistence farmer scenario was assessed for exposure to soil zero to 10 ft bgs in EU 14. Farmer receptors in EU 14 are also assumed to be exposed to site-wide (EU 17) groundwater. See the EU 17 summary for the discussion of risks from exposure to site-wide groundwater. Risks from soil exposure, including food pathways, are summarized below.

RME Summary. RME ILCR from direct contact with soil is estimated to be 3.1×10^{-10}. RME ILCR from ingestion of food items could not be estimated because there are no oral toxicity criteria for any of the COPCs. No carcinogenic COCs are identified in EU 14 soil.

Adult and child RME HIs from direct contact with soil are estimated to be 0.14 and 1.2, respectively. Adult and child RME HIs from ingestion of food items are estimated to be 12 and 15, respectively. Di-n-octylphthalate and boron are COCs via the food pathway.

CTE Summary. CTE ILCR from direct contact with soil is estimated to be 1.9×10^{-11}. CTE ILCR from ingestion of food items could not be estimated because there are no oral toxicity

criteria for any of the COPCs. Adult and child CTE HIs from direct contact with soil are estimated to be 0.04 and 0.4, respectively. Adult and child CTE HIs from ingestion of food items are estimated to be 4.2 and 6.4, respectively. Di-n-octylphthalate and boron are COCs via the food pathway.

EU 14 Future Resident Scenario

The future resident scenario was assessed for exposure to soil zero to 10 ft bgs in EU 14. Residential receptors in EU 14 are also assumed to be exposed to site-wide (EU 17) groundwater. See the EU 17 summary for the discussion of risks from exposure to site-wide groundwater. Risks from soil exposure, including food pathways, are summarized below.

RME Summary. RME ILCR from direct contact with soil is estimated to be 4.5×10^{-11}. RME ILCR from ingestion of food items could not be estimated because there are no oral toxicity criteria for any of the COPCs. No carcinogenic COCs are identified in EU 14 soil.

Adult and child RME HIs from direct contact with soil are estimated to be 0.13 and 1.2, respectively. Adult and child RME HIs from ingestion of food items are estimated to be 2.0 and 2.2, respectively. Boron is a COC via the food pathway.

CTE Summary. CTE ILCR from direct contact with soil is estimated to be 1.9×10^{-11}. RME ILCR from ingestion of food items could not be estimated because there are no oral toxicity criteria for any of the COPCs. Adult and child CTE HIs from direct contact with soil are estimated to be 0.04 and 0.4, respectively. Adult and child CTE HIs from ingestion of food items are estimated to be 0.7 and 0.8, respectively. Boron is a COC via the food pathway.

EU 14 Future Industrial Worker Scenario

The future industrial worker scenario was assessed for exposure to soil zero to 0.5 ft bgs in EU 14.

RME Summary. RME ILCR from direct contact with soil is estimated to be 5.2×10^{-10}. The RME HI from direct contact with soil is estimated to be 0.07. No carcinogenic or non-carcinogenic COCs are identified in EU 14 soil.

CTE Summary. CTE ILCR from direct contact with soil is estimated to be 1.2×10^{-10}. The CTE HI from direct contact with soil is estimated to be 0.06. No carcinogenic or non-carcinogenic COCs are identified in EU 14 soil.

EU 14 Future Construction Worker Scenario

The future construction worker scenario was assessed for exposure to soil zero to 10 ft bgs in EU 14. Construction worker receptors in EU 14 are also assumed to be exposed to site-wide (EU 17) groundwater. See the EU 17 summary for the discussion of risks from exposure to site-wide groundwater. Risks from soil exposure, including food pathways, are summarized below.

RME Summary. RME ILCR from direct contact with soil is estimated to be 6.5×10^{-11}. The RME HI from direct contact with soil is estimated to be 0.5. No carcinogenic or non-carcinogenic COCs are identified in EU 14 soil.

CTE Summary. CTE ILCR from direct contact with soil is estimated to be 1.6×10^{-11}. The CTE HI from direct contact with soil is estimated to be 0.02. No carcinogenic or non-carcinogenic COCs are identified in EU 14 soil.

EU 14 Current and Future Maintenance Worker Scenario

The current and future maintenance worker scenario was assessed for exposure to soil zero to 0.5 ft bgs in EU 14.

RME Summary. RME ILCR from direct contact with soil is estimated to be 2.9×10^{-9}. The RME HI from direct contact with soil is estimated to be 0.14. No carcinogenic or non-carcinogenic COCs are identified in EU 14 soil.

CTE Summary. CTE ILCR from direct contact with soil is estimated to be 6.7×10^{-10}. The CTE HI from direct contact with soil is estimated to be 0.06. No carcinogenic or non-carcinogenic COCs are identified in EU 14 soil.

EU 14 Current Trespasser/Future Recreational Visitor Scenario

The trespasser/recreational visitor scenario was assessed for exposure to soil zero to 0.5 ft bgs in EU 14. In addition, they are assumed to consume game that resides in EU 14.

RME Summary. Adult and adolescent RME ILCRs from direct contact with soil are estimated to be 2.0×10^{-10} and 1×10^{-10}, respectively. RME ILCR from ingestion of food items could not be estimated because there are no oral toxicity criteria for any of the COPCs. No carcinogenic COCs are identified in EU 14 soil.

Adult and adolescent RME HIs from direct contact with soil are estimated to be 0.03 and 0.07, respectively. Adult and child RME HIs from ingestion of food items are estimated to be 0.00001 and 0.00003, respectively. No carcinogenic or non-carcinogenic COCs are identified in EU 14 soil.

CTE Summary. Adult and adolescent CTE ILCRs from direct contact with soil are estimated to be 1.3×10^{-11} and 2.2×10^{-11}, respectively. RME ILCR from ingestion of food items could not be estimated because there are no oral toxicity criteria for any of the COPCs. No carcinogenic COCs are identified in EU 14 soil.

Adult and adolescent RME HIs from direct contact with soil are estimated to be 0.004 and 0.009, respectively. Adult and child RME HIs from ingestion of food items are estimated to be 0.00001 for both receptors. No carcinogenic or non-carcinogenic COCs are identified in EU 14 soil.

2.4.3.15 Exposure Unit 15

Table 2.20 presents a summary of the total ILCR and HI results for both RME and CTE scenarios for each of the receptors at EU 15. EU 15 exposures are limited to surface water and sediment in the central ditch and tributary ditches. Five COPCs were identified in surface water; however, none have toxicity criteria. As a result, ILCRs and HIs could not be calculated for exposures to surface water. The summaries below discuss risks from exposure to COPCs in sediment.

EU 15 Future Subsistence Farmer Scenario

RME Summary. RME ILCR from direct contact with sediment is estimated to be 6.1×10^{-7}. Adult and child RME HIs from direct contact with sediment are estimated to be 0.002 and 0.01, respectively. No carcinogenic or non-carcinogenic COCs are identified in EU 15 sediment.

RME ILCR from direct contact with surface water cannot be calculated. Adult and child RME HIs from direct contact with surface water are estimated to be 0.00003 and 0.00006, respectively. No carcinogenic or non-carcinogenic COCs are identified in EU 15 surface water.

CTE Summary. CTE ILCR from direct contact with sediment is estimated to be 6.2×10^{-8}. Adult and child CTE HIs from direct contact with sediment are estimated to be 0.0003 and 0.002, respectively. No carcinogenic or non-carcinogenic COCs are identified in EU 15 sediment.

CTE ILCR from direct contact with surface water cannot be calculated. Adult and child CTE HIs from direct contact with surface water are estimated to be 0.000009 and 0.00002, respectively. No carcinogenic or non-carcinogenic COCs are identified in EU 15 surface water.

EU 15 Future Resident Scenario

RME Summary. RME ILCR from direct contact with sediment is estimated to be 5.6×10^{-7}. Adult and child RME HIs from direct contact with sediment are estimated to be 0.001 and 0.01, respectively. No carcinogenic or non-carcinogenic COCs are identified in EU 15 sediment.

RME ILCR from direct contact with surface water cannot be calculated. Adult and child RME HIs from direct contact with surface water are estimated to be 0.00003 and 0.00006, respectively. No carcinogenic or non-carcinogenic COCs are identified in EU 15 surface water.

CTE Summary. CTE ILCR from direct contact with sediment is estimated to be 5.7×10^{-8}. Adult and child CTE HIs from direct contact with sediment are estimated to be 0.0002 and 0.002, respectively. No carcinogenic or non-carcinogenic COCs are identified in EU 15 sediment.

CTE ILCR from direct contact with surface water cannot be calculated. Adult and child CTE HIs from direct contact with surface water are estimated to be 0.000009 and 0.00002, respectively. No carcinogenic or non-carcinogenic COCs are identified in EU 15 surface water.

EU 15 Future Industrial Worker Scenario

RME Summary. RME ILCR from direct contact with sediment is estimated to be 4.7×10^{-8}. The RME HI from direct contact with sediment is estimated to be 0.0004. No carcinogenic or non-carcinogenic COCs are identified in EU 15 sediment.

RME ILCR from direct contact with surface water cannot be calculated. The RME HI from direct contact with surface water is estimated to be 0.00003. No carcinogenic or non-carcinogenic COCs are identified in EU 15 surface water.

CTE Summary. CTE ILCR from direct contact with sediment is estimated to be 2.9×10^{-9}. The CTE HI from direct contact with sediment is estimated to be 0.0001. No carcinogenic or non-carcinogenic COCs are identified in EU 15 sediment.

CTE ILCR from direct contact with surface water cannot be calculated. The CTE HI from direct contact with surface water is estimated to be 0.000009. No carcinogenic or non-carcinogenic COCs are identified in EU 15 surface water.

EU 15 Future Construction Worker Scenario

RME Summary. RME ILCR from direct contact with sediment is estimated to be 2.4×10^{-8}. The RME HI from direct contact with sediment is estimated to be 0.005. No carcinogenic or non-carcinogenic COCs are identified in EU 15 sediment.

RME ILCR from direct contact with surface water cannot be calculated. The RME HI from direct contact with surface water is estimated to be 0.00006. No carcinogenic or non-carcinogenic COCs are identified in EU 15 surface water.

CTE Summary. CTE ILCR from direct contact with sediment is estimated to be 3.0×10^{-8}. The CTE HI from direct contact with sediment is estimated to be 0.0006. No carcinogenic or non-carcinogenic COCs are identified in EU 15 sediment.

CTE ILCR from direct contact with surface water cannot be calculated. The CTE HI from direct contact with surface water is estimated to be 0.00002. No carcinogenic or non-carcinogenic COCs are identified in EU 15 surface water.

EU 15 Current and Future Maintenance Worker Scenario

RME Summary. RME ILCR from direct contact with sediment is estimated to be 1.7×10^{-7}. The RME HI from direct contact with sediment is estimated to be 0.001. No carcinogenic or non-carcinogenic COCs are identified in EU 15 sediment.

RME ILCR from direct contact with surface water cannot be calculated. The RME HI from direct contact with surface water is estimated to be 0.00006. No carcinogenic or non-carcinogenic COCs are identified in EU 15 surface water.

CTE Summary. CTE ILCR from direct contact with sediment is estimated to be 6.9×10^{-9}. The CTE HI from direct contact with sediment is estimated to be 0.0002. No carcinogenic or non-carcinogenic COCs are identified in EU 15 sediment.

CTE ILCR from direct contact with surface water cannot be calculated. The CTE HI from direct contact with surface water is estimated to be 0.00002. No carcinogenic or non-carcinogenic COCs are identified in EU 15 surface water.

EU 15 Current Trespasser/Future Recreational Visitor Scenario

RME Summary. Adult and adolescent RME ILCRs from direct contact with sediment are estimated to be 1.8×10^{-7} and 2.2×10^{-7}, respectively. Adult and adolescent RME HIs from direct contact with sediment are estimated to be 0.001 and 0.004, respectively. No carcinogenic or non-carcinogenic COCs are identified in EU 15 sediment.

RME ILCR from direct contact with surface water cannot be calculated. The adult and adolescent RME HI from direct contact with surface water is estimated to be 0.00006 and 0.0001, respectively. No carcinogenic or non-carcinogenic COCs are identified in EU 15 surface water.

CTE Summary. Adult and adolescent CTE ILCR from direct contact with sediment is estimated to be 3.8×10^{-9} and 1.2×10^{-8}, respectively. Adult and adolescent CTE HI from direct contact with sediment is estimated to be 0.0001 and 0.0003, respectively. No carcinogenic or non-carcinogenic COCs are identified in EU 15 sediment.

Adult and adolescent CTE ILCR from direct contact with surface water cannot be calculated. Adult and adolescent CTE HI from direct contact with surface water is estimated to be 0.000009 and 0.00002, respectively. No carcinogenic or non-carcinogenic COCs are identified in EU 15 surface water.

2.4.3.16 Exposure Unit 16

EU 16 consists of sediment and surface water in on-site pipelines. In addition, it contains soil immediately adjacent to pipelines that may be contaminated from pipeline leaks. The future construction worker is the only receptor exposed to COPCs in EU 16. Table 2.21 presents the summary of risk to both RME and CTE scenarios.

EU 16 Future Construction Worker Scenario

The future construction worker scenario was assessed for exposure to sediment and surface water in pipelines and soil zero to 10 ft bgs in EU 16.

RME Summary. RME ILCR from direct contact with soil is estimated to be 9.2×10^{-7}. The RME HI from direct contact with soil is estimated to be 0.2. No carcinogenic or non-carcinogenic COCs are identified in EU 16 soil.

RME ILCR from direct contact with sediment is estimated to be 1.3×10^{-6}. The RME HI from direct contact with sediment is estimated to be 1.6. Aroclor-1254 is a COC in sediment based on non-carcinogenic risk. The lead EPC in sediment exceeds the construction worker PRG for soil; therefore, lead is retained as a COC.

RME ILCR from exposure to surface water is estimated to be 5.9×10^{-4}. RME HI from exposure to surface water is estimated to be 996. Aroclor-1254 is a COC in surface water based on both carcinogenic and non-carcinogenic risk.

CTE Summary. CTE ILCR from direct contact with soil is estimated to be 4.6×10^{-8}. The CTE HI from direct contact with sediment is estimated to be 0.01. No carcinogenic or non-carcinogenic COCs are identified in EU 16 soil.

CTE ILCR from direct contact with sediment is estimated to be 1.7×10^{-7}. The CTE HI from direct contact with soil is estimated to be 0.2. No carcinogenic or non-carcinogenic COCs are identified in EU 16 sediment. The lead EPC in sediment exceeds the construction worker PRG for soil; therefore, lead is retained as a COC.

CTE ILCR from exposure to surface water is estimated to be 2.4×10^{-4}. CTE HI from exposure to surface water is estimated to be 414. Aroclor-1254 is a COC in surface water based on both carcinogenic and non-carcinogenic risk.

2.4.3.17 Exposure Unit 17

Table 2.22 presents a summary of the total ILCR and HI results for both RME and CTE scenarios for each of the receptors at EU 17. EU 17 is a "site-wide" EU and consists of data collected in all other EUs. EU 17 contains soil, sediment, surface water, and groundwater. Seven COPCs were identified in EU 17 surface water; however, none have toxicity criteria. As a result, risks from surface water exposures could not be calculated. The summaries below discuss risks from exposures to soil, groundwater, and sediment.

EU 17 Future Subsistence Farmer Scenario

The future subsistence farmer scenario was assessed for exposure to soil zero to 10 ft bgs in EU 17. Farmer receptors in EU 17 are also assumed to be exposed to EU 17 groundwater, surface water, and sediment.

RME Summary. RME ILCR from direct contact with soil is estimated to be 1.7×10^{-4}. RME ILCR from ingestion of food items is estimated to be 8.9×10^{-4}. Aroclor-1260, benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, indeno(1,2,3-cd)pyrene, tetrachloroethene, and arsenic are COCs for direct contact with soil and/or the food pathway.

Adult and child RME HIs from direct contact with soil are estimated to be 0.9 and 4.1, respectively. Adult and child RME HIs from ingestion of food items are estimated to be 14 and 39, respectively. Aroclor-1260 is a COC for direct contact with soil and/or food pathways.

RME ILCR from exposure to groundwater is estimated to be 1.2×10^{-1}. Bis(2-ethylhexyl)phthalate, methylene chloride, tetrachloroethene, and arsenic are COCs for exposure to groundwater.

Adult and child RME HIs from exposure to groundwater are estimated to be 245 and 328, respectively. Tetrachloroethene, arsenic, boron, manganese, and vanadium are COCs for exposure to groundwater. Lead EPC exceeds the drinking water action level and also is a COC.

RME ILCR from direct contact with sediment is estimated to be 1.8×10^{-5}. No carcinogenic COCs are identified in EU 17 sediment. Adult and child RME HIs from direct contact with sediment are estimated to be 0.6 and 2.9, respectively. Aroclor-1254 is a COC in sediment based on non-carcinogenic risk.

RME ILCR from direct contact with surface water could not be calculated. Adult and child RME HIs from direct contact with surface water are 0.00003 and 0.00007, respectively. No carcinogenic or non-carcinogenic COCs are identified in EU 17 surface water.

CTE Summary. CTE ILCR from direct contact with soil is estimated to be 2.1×10^{-5}. CTE ILCR from ingestion of food items is estimated to be 3.2×10^{-4}. Aroclor-1260, benzo(a)pyrene, benzo(b)fluoranthene, indeno(1,2,3-cd)pyrene and tetrachloroethene are COCs for direct contact with soil and/or the food pathway.

Adult and child CTE HIs from direct contact with soil are estimated to be 0.2 and 0.9, respectively. Adult and child CTE HIs from ingestion of food items are estimated to be 5.1 and 30, respectively. Aroclor-1260 is a COC for direct contact with soil and/or food pathways.

CTE ILCR from exposure to groundwater is estimated to be 2.9×10^{-2}. Tetrachloroethene and arsenic are COCs for exposure to groundwater. Adult and child CTE HIs from exposure to groundwater are estimated to be 139 and 309, respectively. Tetrachloroethene, aluminum, arsenic, manganese and vanadium are COCs for exposure to groundwater. Lead EPC exceeds the drinking water action level and also is a COC.

CTE ILCR from direct contact with sediment is estimated to be 1.2×10^{-6}. Adult and child CTE HIs from direct contact with soil are estimated to be 0.07 and 0.2, respectively. No carcinogenic or non-carcinogenic COCs are identified in EU 17 sediment.

CTE ILCR from direct contact with surface water could not be calculated. Adult and child CTE HIs from direct contact with surface water are 0.00001 and 0.00002, respectively. No carcinogenic or non-carcinogenic COCs are identified in EU 17 surface water.

EU 17 Future Resident Scenario

The future resident scenario was assessed for exposure to soil zero to 10 ft bgs in EU 17. Residential receptors in EU 17 are also assumed to be exposed to EU 17 groundwater, surface water, and sediment.

RME Summary. RME ILCR from direct contact with soil is estimated to be 1.5×10^{-4}. RME ILCR from ingestion of food items is estimated to be 2.1×10^{-4}. Aroclor-1260, benzo(a)anthracene, benzo(a)pyrene, tetrachloroethene, and arsenic are COCs for direct contact with soil and/or the food pathway.

Adult and child RME HIs from direct contact with soil are estimated to be 0.8 and 4.1, respectively. Adult and child RME HIs from ingestion of food items are estimated to be 0.3 for both receptors. Aroclor-1260 is a COC for direct contact with soil pathway.

RME ILCR from exposure to groundwater is estimated to be 1.2×10^{-1}. Tetrachloroethene, aluminum, arsenic, manganese and vanadium are COCs for exposure to groundwater.

Adult and child RME HIs from exposure to groundwater are estimated to be 171 and 328, respectively. Tetrachloroethene, arsenic, boron, manganese, and vanadium are COCs for exposure to groundwater. Lead EPC exceeds the drinking water action level and also is a COC.

RME ILCR from direct contact with sediment is estimated to be 1.6×10^{-5}. No carcinogenic COCs are identified in EU 17 sediment. Adult and child RME HIs from direct contact with sediment are estimated to be 0.4 and 2.9, respectively. Aroclor-1254 is a COC in sediment based on non-carcinogenic risk.

RME ILCR from direct contact with surface water could not be calculated. Adult and child RME HIs from direct contact with surface water are 0.00003 and 0.00007, respectively. No carcinogenic or non-carcinogenic COCs are identified in EU 17 surface water.

CTE Summary. CTE ILCR from direct contact with soil is estimated to be 2.1×10^{-5}. CTE ILCR from ingestion of food items is estimated to be 3.7×10^{-5}. No carcinogenic or COCs are identified in EU 17 soil.

Adult and child CTE HIs from direct contact with soil are estimated to be 0.2 and 0.9, respectively. Adult and child CTE HIs from ingestion of food items are estimated to be 0.1 for both receptors. No non-carcinogenic COCs are identified in EU 17 sediment.

CTE ILCR from exposure to groundwater is estimated to be 2.9×10^{-2}. Tetrachloroethene and arsenic are COCs for exposure to groundwater.

Adult and child CTE HIs from exposure to groundwater are estimated to be 139 and 309, respectively. Tetrachloroethene, aluminum, arsenic, manganese and vanadium are COCs for exposure to groundwater. Lead EPC exceeds the drinking water action level and also is a COC.

CTE ILCR from direct contact with sediment is estimated to be 1×10^{-6}. Adult and child CTE HIs from direct contact with sediment are estimated to be 0.05 and 0.2, respectively. No carcinogenic or non-carcinogenic COCs are identified in EU 17 sediment.

CTE ILCR from direct contact with surface water could not be calculated. Adult and child CTE HIs from direct contact with surface water are 0.00001 and 0.00002, respectively. No carcinogenic or non-carcinogenic COCs are identified in EU 17 surface water.

EU 17 Future Industrial Worker Scenario

The future industrial worker scenario was assessed for exposure to soil zero to 0.5 ft bgs, surface water, and sediment in EU 17.

RME Summary. The RME ILCR from direct contact with soil is estimated to be 3.7×10^{-5}. The RME HI from direct contact with soil is estimated to be 0.3. No carcinogenic or non-carcinogenic COCs are identified in EU 17 sediment.

The RME ILCR from direct contact with sediment is estimated to be 1.3×10^{-6}. The RME HI from direct contact with sediment is estimated to be 0.09. No carcinogenic or non-carcinogenic COCs are identified in EU 17 sediment.

The RME ILCR from direct contact with surface water could not be calculated. The RME HI from direct contact with surface water are 0.00003. No carcinogenic or non-carcinogenic COCs are identified in EU 17 surface water.

CTE Summary. CTE ILCR from direct contact with soil is estimated to be 5.0×10^{-6}. The CTE HI from direct contact with soil is estimated to be 0.2. No carcinogenic or non-carcinogenic COCs are identified in EU 17 soil.

The CTE ILCR from direct contact with sediment is estimated to be 5.0×10^{-8}. The CTE HI from direct contact with sediment is estimated to be 0.01. No carcinogenic or non-carcinogenic COCs are identified in EU 17 sediment.

The CTE ILCR from direct contact with surface water could not be calculated. The CTE HI from direct contact with surface water is estimated to be 0.00001. No carcinogenic or non-carcinogenic COCs are identified in EU 17 surface water.

EU 17 Future Construction Worker Scenario

The future construction worker scenario was assessed for exposure to soil zero to 10 ft bgs in EU 17. Construction worker receptors in EU 17 are also assumed to be exposed to EU 17 groundwater, surface water, and sediment.

RME Summary. RME ILCR from direct contact with soil is estimated to be 4.2×10^{-6}. The RME HI from direct contact with soil is estimated to be 1.3. No COPC-specific HQs exceed 1 for either receptor.

RME ILCR from exposure to groundwater is estimated to be 9.2×10^{-4}. RME HI from exposure to groundwater is estimated to be 144. Tetrachloroethene is a COC for exposure to groundwater. Although the lead EPC exceeds the drinking water action level, it is not a COC for construction workers because groundwater ingestion is incidental.

RME ILCR from direct contact with sediment is estimated to be 5.8×10^{-7}. The RME HI from direct contact with sediment is estimated to be 1.0. No carcinogenic or non-carcinogenic COCs are identified in EU 17 sediment.

The RME ILCR from direct contact with surface water could not be calculated. The RME HI from direct contact with surface water was estimated to be 0.00007. No carcinogenic or non-carcinogenic COCs are identified in EU 17 surface water.

CTE Summary. CTE ILCR from direct contact with soil is estimated to be 2.6×10^{-7}. The CTE HI from direct contact with soil is estimated to be 0.08. No carcinogenic or non-carcinogenic COCs are identified in EU 17 soil.

CTE ILCR from exposure to groundwater is estimated to be 1.4×10^{-4}. CTE HI from exposure to groundwater is estimated to be 24. Tetrachloroethene was identified as a COC in EU 17 groundwater for its non-carcinogenic risks.

CTE ILCR from direct contact with sediment is estimated to be 7.6×10^{-8}. The CTE HI from direct contact with sediment is estimated to be 0.1. No carcinogenic or non-carcinogenic COCs are identified in EU 17 sediment.

CTE ILCR from direct contact with surface water could not be calculated. The RME HI from direct contact with surface water was estimated to be 0.00002. No carcinogenic or non-carcinogenic COCs are identified in EU 17 surface water.

EU 17 Current and Future Maintenance Worker Scenario

The current and future maintenance worker scenario was assessed for exposure to soil zero to 0.5 ft bgs, sediment, and surface water in EU 17.

RME Summary. The RME ILCR from direct contact with soil is estimated to be 6.7×10^{-5}. The RME HI from direct contact with soil is estimated to be 0.6. No carcinogenic or non-carcinogenic COCs are identified in EU 17 soil.

The RME ILCR from direct contact with sediment is estimated to be 4.4×10^{-6}. The RME HI from direct contact with sediment is estimated to be 0.3. No carcinogenic or non-carcinogenic COCs are identified in EU 17 sediment.

The RME LCR from direct contact with surface water could not be calculated. The RME HI from direct contact with surface water was estimated to be 0.00007. No carcinogenic or non-carcinogenic COCs are identified in EU 17 surface water.

CTE Summary. The CTE ILCR from direct contact with soil is estimated to be 5.6×10^{-6}. The CTE HI from direct contact with soil is estimated to be 0.2. No carcinogenic or non-carcinogenic COCs are identified in EU 17 soil.

The CTE ILCR from direct contact with sediment is estimated to be 1.4×10^{-7}. The CTE HI from direct contact with sediment is estimated to be 0.04. No carcinogenic or non-carcinogenic COCs are identified in EU 17 sediment.

The CTE ILCR from direct contact with surface water could not be calculated. The CTE HIs from direct contact with surface water was estimated to be 0.00002. No carcinogenic or non-carcinogenic COCs are identified in EU 17 surface water.

EU 17 Current Trespasser/Future Recreational Visitor Scenario

The trespasser/recreational visitor scenario was assessed for exposure to soil zero to 0.5 ft bgs in EU 17. In addition, they are assumed to consume game that resides in EU 17.

RME Summary. Adult and adolescent RME ILCRs from direct contact with soil are estimated to be 1.5×10^{-5} and 1.7×10^{-5}, respectively. Adult and adolescent RME ILCRs from ingestion of food items are estimated to be 3.1×10^{-8} and 2.0×10^{-8}, respectively. No carcinogenic COCs are identified in EU 17 soil.

Adult and adolescent RME HIs from direct contact with soil are estimated to be 0.1 and 0.4, respectively. Adult and child RME HIs from ingestion of food items are estimated to be 0.0006 and 0.001, respectively. No non-carcinogenic COCs are identified in EU 17 soil.

Adult and adolescent RME ILCRs from direct contact with sediment are estimated to be 4.6×10^{-6} and 6.0×10^{-6}, respectively. Adult and adolescent RME HIs from direct contact with sediment are estimated to be 0.3 and 1.1, respectively. The highest COPC-specific HQ is 1.0 for adolescent exposures to aroclor-1254 via the direct contact with sediment pathway.

Adult and adolescent CTE ILCR from direct contact with surface water could not be calculated. Adult and child CTE HIs from direct contact with surface water are 0.00007 and 0.0001, respectively. No carcinogenic or non-carcinogenic COCs are identified in EU 17 surface water.

CTE Summary. Adult and adolescent CTE ILCRs from direct contact with soil are estimated to be 4.0×10^{-7} and 1.1×10^{-6}, respectively. Adult and adolescent CTE ILCRs from ingestion of food items are estimated to be 4.6×10^{-9} and 9.1×10^{-9}, respectively. No carcinogenic COCs are identified in EU 17 soil.

Adult and adolescent CTE HIs from direct contact with soil are estimated to be 0.01 and 0.03, respectively. Adult and child CTE HIs from ingestion of food items are estimated to be 0.0003 and 0.0006, respectively. No non-carcinogenic COCs are identified in EU 17 soil.

Adult and adolescent CTE ILCRs from direct contact with sediment are estimated to be 6.3×10^{-8} and 2.2×10^{-7}, respectively. Adult and adolescent RME HIs from direct contact with sediment

are estimated to be 0.01 and 0.05, respectively. No carcinogenic or non-carcinogenic COCs are identified in EU 17 sediment.

Adult and adolescent CTE ILCR from direct contact with surface water could not be calculated. Adult and adolescent CTE HIs from direct contact with surface water are 0.00001 and 0.00002, respectively. No carcinogenic or non-carcinogenic COCs are identified in EU 17 surface water.

Risks from High Concentrations of Essential Nutrients

As discussed in Section 2.1.2.4, if the EPC for an essential nutrient exceeds twice the background concentration for that nutrient, then the nutrient is identified as a COPC. Any nutrient identified a COPC is evaluated in this risk characterization. A daily intake calculation is performed for the most sensitive receptor (i.e., subsistence farmer) to determine if the intake exceeds the recommended daily values (DV) based on a 2000-calorie per day diet. Exhibit 2.2 presents DVs and the corresponding intake in a 70 kg adult. If intake exceeds the DV, then the nutrient is identified below. However, note that this designation does not necessarily mean that the nutrient is present at toxic levels. It only implies that the DV would be exceeded in a subsistence farmer receptor residing in the EU. Magnesium (EU 10 soil and EU 14 soil), calcium (EU 4 groundwater), and iron (EU 4 groundwater and EU 17 groundwater) are present at concentrations that could result in a daily intake that exceeds the DV.

Exhibit 2.2. Recommended Daily Values for Essential Nutrients

Nutrient	DV (mg/day)	Adult Intake (mg-kg/day)
Iron	18	0.26
Magnesium	400	5.7
Calcium	1,000	14.3
Potassium	3,500	50
Sodium	2,400	34.3

2.5 UNCERTAINTY ANALYSIS

Risk values calculated in a HHRA are not fully probabilistic estimates of risk, but conditional estimates given a considerable number of conservative assumptions about exposure and toxicity. Therefore, there are many uncertainties inherent in the risk assessment evaluations. For example, uncertainty will always surround estimates of environmental concentrations at waste sites. The objective is to understand, minimize, and quantify this uncertainty in the risk assessment. There are uncertainties with the exposure assessment, the toxicity information used in the risk assessment and the risk characterization.

2.5.1 Uncertainty Related to Environmental Data

Uncertainty is associated with the process of data collection, analysis, and evaluation. The characterization of data from waste sites presents considerable uncertainty due to variation in wastes, environmental media, and time. Characterization of surface water and sediment is especially difficult due to impacts from other discharges in the area and the variability of flow in the drainage ditches. The site is adjacent to two landfills, one of which is a hazardous waste landfill. Some drainage ditches from the adjacent landfills convey surface water onto NFSS property. In addition, windborne contaminants could be transported from the landfills to NFSS.

EPCs for metals in groundwater are based on total values rather than dissolved. Turbid samples could result in elevated concentrations of metals that may not, in fact, be dissolved contaminants. The use of total metals concentrations likely overestimates risks from exposure to groundwater.

The sampling program at NFSS was designed to minimize the potential to underestimate EPCs. This included the collection of biased samples in latter stages of the RI to target area of suspected or known contamination. Use of the EPC also tends to overestimate risk, as for many of the data sets, the EPC is actually the maximum detected concentration of the constituent in the EU

Background levels were established using data collected from locations near the site. Background was established to distinguish between naturally occurring or ubiquitous anthropogenic chemicals found near the site from chemicals associated with past waste activities at the areas under investigation. Up-gradient and down-gradient surface water and sediment samples were collected in order to characterize chemicals associated with the site.

The NFSS dataset does include TICs; however, they do not dominate the data set in any location or media. TICs were excluded from the BRA dataset during the data verification process. These compounds could not be definitively identified and few have EPA-approved toxicity criteria. This step of eliminating TICs could potentially underestimate risks.

Uncertainty is minimized in the analysis of the data by adhering to strict QA/QC standards both in the field and in the laboratory. All data used in the BRA were subject to validation and verification procedures. The uncertainty associated with the statistical analyses of environmental data is low, with little introduction of bias.

The State of New York defines surface soil as 0 – 2 inches below the vegetation root system to assess chemical risk and 0 - 6 inches below ground surface to assess radiological risk. In this BRA, surface soil is defined as 0 – 6 inches below ground surface and includes the root zone excluded in the State of New York definition. Therefore, there is the possibility of including slightly more soil in the BRA definition. Contamination at NFSS was deposited over 10 years ago and therefore, there is likely to be a layer of soil and organic matter over any contamination that was released directly to the surface. Therefore, the use of the 0–6 inch definition may capture more of this contamination that was originally deposited on the soil surface. The 0-2 inch definition may miss surface-deposited contamination that has subsequently been covered over. However, in general, the slight difference between the BRA definition and the State of New York definition is not expected to have any significant impact on the identification of COPCs and the calculation of EPCs.

2.5.2 Uncertainty in Exposure Assessment

Exposure assessment may introduce considerable uncertainty in the risk assessment process. Uncertainty in all elements of the exposure assessment are brought together and compounded in the estimate of intake or dose. The professional judgment of the risk assessor becomes particularly important for exposure assessment when the risk assessor must examine and interpret diverse information, including the nature, extent, and magnitude of contamination; transport of chemicals in the environment; identification of exposure routes; identification of receptor groups currently exposed and potentially exposed in the future; and activity patterns of receptors and receptor groups.

The following types of uncertainty have been identified in the exposure assessment:

- Scenario Uncertainty - missing or incomplete information needed to define the exposure scenario or pathway. For example, there may be additional exposure pathways that were not quantified;

- Model Uncertainty - inability to quantify all assumptions in model variables. For example, exposure parameters are often based on 50^{th} and 95^{th} percentile values and do not account for the full range of possible values; and

- Parameter Uncertainty - inadequate information to quantify an exposure variable or parameter. For example, detailed studies have not been performed on all of the exposure parameters need to calculate intakes.

Receptors for the EUs at NFSS are defined based on information provided by the facility and potential future land use at and near the site. Site-specific information for the EUs was used to develop exposure assumptions and intake parameters, if available. However, many assumptions were based on EPA standard default parameters. Many of the RME exposure parameters represent 90th to 95th percentile values. When several upper bound values are combined in estimating exposure for any one pathway, resulting risk estimates may well be in excess of the 99th percentile exposure and thereby be outside the range of exposures that might reasonably be expected to occur at a site. Therefore, resulting RME risks calculations are conservative and most likely overestimate the actual exposures that may be associated with the site. The CTE scenario was provided to account for this overestimation. CTE parameters represent 50^{th} percentile values and more closely represents typical or average exposures.

The risk assessment treats each exposure parameter as a single point estimate. None of these parameters, however, is truly a single value. Instead, a range of values or distribution would more accurately represent these parameters. Defining a range of values for any given parameter is actually a measure of variability in the risk assessment.

For quantification of potential risk from dermal exposure to soil, two exposure factors contribute significantly to uncertainty; the soil-to-skin adherence factor and the dermal ABS. Soil-to-skin adherence factors impact the estimated intake from dermal exposure to contaminated soil; however, there are limited studies that address this issue. Soil-to-skin adherence factors are influenced by soil properties (e.g. particle size, moisture content), the part of the body exposed and activities the person is engaged in. The adherence factors used in the HHRA are based on EPA guidance (EPA 2004a).

Another area of uncertainty concerning quantification of potential risk presented through dermal exposure to soil is the fraction of a constituent in soil that is actually absorbed through the skin or the dermal ABS. Here again limited compound specific information is available. Compound specific dermal ABSs were taken from EPA 2004a. For dermal exposure to soil and sediment, when no chemical-specific ABS value is available from EPA 2004a, no quantitative assessment of the dermal pathway is included in the risk calculation. Therefore, any potential risk from compounds lacking ABS is not included in the risk summaries.
Risk from ingestion of food items is based on both modeled uptake concentrations and modeled human intake. It is not based on any direct measurement of COPC concentrations in food items. Therefore, there is uncertainty in both the estimated chemical concentrations in food and the estimated intake by human receptors.

2.5.3 Uncertainty Related to Toxicity Information

Although EPA provides point estimate toxicity values, a significant amount of uncertainty surrounds these values. Identification of the sources of this uncertainty enables the risk assessor to establish the degree of confidence associated with the toxicity measures.

Uncertainty is inherent within the toxicity assessment and is primarily due to differences in study design, test species and gender, routes of exposure, or dose-response relationships. A major source of uncertainty involves using toxicity values based on experimental studies that substantially differ from typical human exposure scenarios. The derivation of the toxicity values must consider differences such as (1) using dose-response information from animal studies to predict effects in humans, (2) using dose-response information from high-dose studies to predict adverse health effects at low doses, (3) using data from short-term studies to predict chronic effects, and (4) extrapolating from specific homogeneous populations to general heterogeneous populations.

The CSFs in particular are based on studies that may differ greatly from realistic situations. Experimental cancer bioassays typically expose animals to very high levels of chemicals (i.e., the maximum tolerated dose) for their entire lifetime. After the appropriate studies have been identified, the slope factor is calculated as the upper 95th percent confidence limit of the slope of the dose-response curve. This introduces conservatism into the risk assessment. The derivation of RfDs also generally involves the use of animal studies. Uncertainty factors ranging from 1 to 10,000 are incorporated into the RfD to provide an extra level of public health protection. The uncertainty factors used depend on the type of study from which the value was derived (e.g., animal or human, chronic or acute). The scientific basis for this practice is somewhat uncertain. In general, high uncertainty factors are meant to bias the results conservatively so that exposures at the RfD level will not result in adverse health effects.

Route-to-route extrapolation can be used to estimate toxicity values for pathways that lack toxicity values. For example, a chemical-specific gastrointestinal ABS may be used to convert an oral administered dose to a dermal adsorbed dose. However, for many chemicals scientifically defensible data does not exist for making adjustment of an CSF_o/RfD_o to estimate a dermal toxicity value. For quantification of potential risk due to dermal exposure to contaminants in soil, CSF_os and RfD_os were adjusted using gastrointestinal absorption efficiencies drawn from *Risk Assessment Guidance for Superfund: Volume I Human Health Evaluation Manual (Part E, Supplemental Guidance for Dermal Risk)* (EPA 2004a) and supplemental dermal absorption fractions values from soil (ABS_d) posted on the RAGS E website in September 2004. When compound-specific gastrointestinal ABSs were greater than 50 percent, CSF_os and RfD_os were not adjusted. Quantification of the dermal pathway was only performed for constituents with EPA recommended gastrointestinal absorption efficiencies and dermal ABSs. The uncertainty associated with using the absorbed dose toxicity values for the dermal pathway is moderate and the bias unknown.

There are many chemicals for which no toxicity values exist and for which little information is available. A quantitative risk estimate cannot be calculated for these chemicals. For example, many chemicals are not evaluated for the inhalation pathway because of limited inhalation-based toxicological information. The lack of toxicity information for some chemicals may contribute to the underestimation of risks.

As indicated in Table 2.5, thirty-three COPCs have no approved toxicity criteria for any pathway. Where reasonable surrogates are available, they were used. The use of surrogates reduces the number of COPCs without toxicity criteria down to thirteen. Of these thirteen constituents, five are essential human nutrients. For these constituents, comparisons to DVs were made in lieu of risk calculations. Lead was evaluated based on acceptable blood lead levels, rather than toxicity criteria. For the remaining seven COPCs, no quantitative risk estimates could be calculated.

The cancer potency of PCB mixtures was evaluated using a tiered approached. Three tiers of human slope factors have been established for environmental exposure to PCB mixtures depending on the risk and persistence of the congeners present. Three aroclor mixtures (1242, 1254 and 1260) have been designated as SRCs at NFSS. Since these mixtures are highly chlorinated, and therefore persistent, and because exposures at NFSS could potentially include food pathways, the high risk and persistence upper bound CSF_o and RfD_o for aroclor-1254 was used to characterize risk due to these PCB mixtures.

EPA's quantitative estimate for the cancer risk associated with inhalation exposures to benzene is reported to range from $2.2x10^{-6}$ to $7.8x10^{-6}$ per $\mu g/m^3$ inhalation unit risk. This range accounts for population variability in intakes rates of drinking water, air, and food. To extrapolate to oral risk, the inhalation unit risk range is first converted to units of dose (mg/kg/day). The risk estimate range is then divided by this dose to generate an CSF_o in units of inverse dose. Since the inhalation unit risk range is converted to units of dose using standard air intake factors (i.e. $20m^3$/day, 70 kg bodyweight, 50% ABS) it should be recognized that this conversion does not account for population variability and is likely to overestimate mean intake rates.

2.5.4 Uncertainty in Risk Characterization

Uncertainties in any phase of the risk analysis (i.e., data evaluation, exposure assessment, and toxicity assessment) are reflected in the risk estimates. Additional uncertainty is associated with the summation of risks and HQs for multiple chemical contaminants. As stated in RAGS (U.S. EPA 1989), "The assumption of dose additivity ignores possible synergisms or antagonisms among chemicals, and assumes similarity in mechanisms of action and metabolism." However, summing cancer risks and HQs for multiple substances in the risk assessment generally provides a more conservative estimate of risk.

Cancer and non-cancer risks are summed in the risk characterization process (separately for carcinogens and non-carcinogens) to estimate potential risks associated with the simultaneous exposure to multiple chemicals. For carcinogens, this results in giving class B or class C carcinogens the same weight as class A carcinogens. It also equally weights slope factors derived from animal data with those derived from human data. Uncertainties in the combined risks also are compounded because RfDs and CSFs do not have equal accuracy or levels of confidence and are not based on the same severity of effect.

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3.0 BASELINE HUMAN HEALTH RADIOLOGICAL RISK ASSESSMENT

The HHRA was conducted by utilizing the RESRAD computer code Version 6.22 to evaluate radiological contaminants in soil and sediment and by using RAGS methods to evaluate radiological contaminants in surface water and groundwater. Estimating radiological risks with RESRAD uses methods consistent with those presented in RAGS; however RESRAD presents several advantages over standard RAGS methods, including the following:

- RESRAD models future conditions, taking into account source removal by radiological decay, leaching, erosion, etc., and radiological ingrowth;
- RESRAD considers site-specific variables, such as rainfall, soil density, etc., that may impact results;
- RESRAD considers source geometry, taking into account the thickness and surface area of soil contamination;
- RESRAD is an integrated code that accounts for all potential exposure pathways with a single calculation or "run"; and
- RESRAD provides both carcinogenic risk and radiological dose estimates for comparison to appropriate regulatory limits.

Except for these differences, evaluation of radiological contaminants using RESRAD calculations for soil and sediment and RAGS methods for surface water and groundwater parallel the HHRA for chemical constituents. The same exposure parameters are utilized (although units may vary), similar exposure pathways are considered (external gamma exposure replaces dermal contact), and the same exposure scenarios are evaluated.

Presentation of the methodology and results of the HHRA for radiological constituents in all media are organized as follows:

- Section 3.1 (Data Evaluation) provides the criteria that are used to evaluate and screen the NFSS site data and determine the ROPCs that are evaluated in the HHRA;
- Section 3.2 (Exposure Assessment) defines the exposure setting, the CSM, exposure concentrations, and pathway-specific intakes;
- Section 3.3 (Radionuclide Toxicity Assessment) presents the methodology and guidance that are used to perform the radiological toxicity assessment;
- Section 3.4 (Risk Characterization) presents the methodology that is used to conduct the risk characterization for ROPCs and presents a summary of the risk assessment results; and
- Section 3.5 (Uncertainty Analysis) presents uncertainties associated with the radiological HHRA.

Detailed results of the ROPC screens and risk calculations for each pathway, medium, and EU are presented in Appendix B.

Note that while the HHRA focuses on risk-based criteria, it is conceivable that radiological dose-based limits may be selected for the site. The two primary differences in carcinogenic risk and radiological dose estimates include the following:

1. Carcinogenic risks are presented as lifetime estimates while radiological doses are yearly estimates; and

2. CSFs convert an exposure to risk (e.g., risk per pCi uptake), while dose factors convert an exposure to radiological dose (e.g., mrem/yr per pCi uptake).

Besides these two differences, carcinogenic risk and radiological dose calculations are identical. The RESRAD code simultaneously calculates risk and dose for comparison against appropriate limits. RAGS-based calculations for surface water and groundwater have also been modified to estimate radiological dose. Therefore, both risk-based and radiological dose-base endpoints are presented in this HHRA.

EPA identifies all radionuclides as carcinogens. Uranium, however, is also known to have non-carcinogenic hazardous properties when ingested or inhaled (i.e., uranium is a kidney toxicant independent of radiological characteristics). Assessment of the non-carcinogenic properties of uranium is found in Section 2 of the HHRA and is not repeated here. Section 3 assesses only the baseline carcinogenic risk and radiological dose from exposure to radionuclides, assuming 25 mrem/yr as the dose-based guideline for comparison, since this level is a common benchmark for regulating radiologically impacted sites.

3.1 DATA EVALUATION

3.1.1 Initial Data Reduction

The site database contains results for 15 radiological SRCs (plus measurements of alpha and beta activity), all of which are considered in the ROPC determination process. However, the radiological constituents most likely to become ROPCs at NFSS are members of the naturally occurring uranium, thorium, and actinium decay series, as shown in Figures 3.1, 3.2, and 3.3. These radionuclides are found in natural ores from which NFSS radiological constituents were derived. Because CSFs are limited to radionuclides with half-lives of six months or longer, the primary list of potential radiological constituents includes only the long-lived radionuclides in these series. Short-lived decay products are included in slope factors for long-lived radionuclides so they need not be evaluated separately. It is assumed that short-lived radionuclides exist in equilibrium with their nearest long-lived parent. For example, Ac-228 is assumed to be in equilibrium with Ra-228. This approach is consistent with RAGS methodology and allows for the use of "+D" (plus daughter) slope factors from HEAST. For example, the Ra-228+D CSF from HEAST is used to calculate risk from Ra-228 in equilibrium with its short-lived decay product Ac-228.

The list of long-lived radionuclides includes U-238, U-234, Th-230, Ra-226 and Pb-210 from the uranium series; Th-232, Ra-228 and Th-228 from the thorium series; and U-235, Pa-231 and Ac-227 from the actinium series. (Pb-210 is not on the analyte list for NFSS samples; therefore, Pb-210 is assumed to be in equilibrium with Ra-226, its closest long-lived parent.) A few man-made

radionuclides that may be attributable to site-related activities are also identified as ROPCs and are evaluated in risk calculations. These include strontium-90+D (Sr-90+D) in sediment and cesium-137+D (Cs-137+D) in soil, sediment and groundwater.

The site database includes results obtained through different analytical methods, sometimes producing multiple entries for a single sample and radionuclide (e.g., some radionuclides are analyzed with both gamma spectroscopy and alpha spectroscopy). Because of the multiple analytical methods and the established relationships between radionuclides in decay series, not all data should be used at face value in risk calculations. Instead, a series of tests is performed to refine the data set used in the risk calculations so that each sample contained a single result for each radionuclide. Site data are refined as described below:

- Many samples were analyzed by both alpha spectrometry and gamma spectrometry. Because the detection limits and analytical errors are lower for alpha spectrometry, this method is used preferentially to estimate the source term.

- Results for parent radionuclides are sometimes reported in addition to results for short-lived decay products. To eliminate this duplication and/or mislabeling, the parent radionuclide result is always used and equilibrium conditions are assumed.

- Thorium series radionuclides are assumed to be present in equilibrium when radionuclide-specific data are not available.

- Uranium isotopes U-234, U-235, and U-238 are assumed to be present at a concentration ratio of 1.0: 0.05: 1.0, respectively.

- Actinium-227 is assumed to be in equilibrium with Pa-231.

This approach simplified the source term calculation process by eliminating extraneous information and improved the overall quality of the data set used in risk calculations.

Finally, a "hot rock" was identified in EU 6. This rock was about the size of a dime and contained over 800,000 pCi/g of Ra-226 and similar elevated concentrations of other radionuclides. Sampling effectively removed this rock, which is not representative of adjacent soils. The associated results are not subject to risk/dose calculations.

3.1.2 Radionuclide Data Screening

Risk calculation methods for both radiological and non-radiological constituents follow guidance provided by RAGS, but some adjustments are required for radionuclides. Radionuclides underwent a background screen, a weight-of-evidence screen, and a risk screen to identify ROPCs for the NFSS BRA.

The background screen for radionuclides is identical to the screen presented for chemicals in Section 2.1.2.2. If the smaller of the 95% UCL and maximum detected value (i.e., the EPC) of a radionuclide is below the background UTL, the radionuclide is not considered a ROPC. However, if a radionuclide is present at concentrations above the background UTL, that radionuclide is retained as a ROPC, depending on the results of the weight-of-evidence screen. Figure 3.4 is a graphical depiction of the ROPC selection process.

The weight-of-evidence screening for radionuclides is identical to that described for chemicals in Section 2.1.2.3.

Site-specific risk-based screening levels for radiological constituents were calculated for use in ROPC screens. These site-specific values are based on the identical models used to estimate risk, thus potential inconsistencies with the sometimes relatively non-conservative standard PRG methods (e.g., as published by EPA Region 9) are avoided.

Other potential radiological screening values include MCLs from the National Primary Drinking Water Regulations - Radionuclides (40 CFR Part 141) as reported in Federal Register Volume 65, Number 236 (76708-76753). The limits in the final rule became effective December 8, 2003, and include a combination of radionuclide-specific and radiation-specific limits. Specifically, limits are presented for radium, uranium, alpha activity, and radiological dose from beta/gamma activity. Of these, the beta/gamma dose-based limit of 4 mrem/yr applies only to man-made radionuclides and, therefore, is not a suitable screening level for the naturally occurring site-related radionuclides at NFSS. Concentration-based MCLs may be used to identify ROPCs during the weight-of-evidence screen. However, radionuclides identified above the corresponding background UTL value are conservatively retained as ROPCs even when those detected in water are below the MCLs. ROPC screens are presented for each medium in Appendix B.

Table 3.1 presents a list of EUs with ROPCs by medium. Note that for surface water, only "total activity" in EU 16 is present above the background UTL and total activity cannot be broken into radioisotopic constituents. Risk and dose calculations are not possible since there are no quantitative ROPCs for surface water. Table 3.2 lists the specific identified ROPCs by medium.

3.2 EXPOSURE ASSESSMENT

With the exception of the calculation of pathway-specific intakes, the exposure assessment for radionuclides is identical to that described for chemicals in Section 2.2. Section 2.2 discussions of the characterization of the exposure setting and the CSMs are not repeated here.

RESRAD (ANL 2001b) automatically calculates pathway-specific intake as part of each "run." Detailed equations for pathway-specific intakes are presented in ANL 2001b and are not repeated here. In general, the RESRAD code uses the same equations listed in Section 2.2.3. Exceptions include units for constituent concentration (e.g., pCi/g instead of mg/kg), the addition of the external radiation pathway, and the exclusion of the dermal contact pathway. The radon pathway may also be modeled by the RESRAD code. However, indoor radon modeling is highly uncertain due to the localized environmental variability and problems with predicting future construction design. Modeling uncertainties are, therefore, considered too great to accurately predict results distinguishable from natural background in future hypothetical structures, and remediation to radium standards is assumed sufficient to address indoor radon standards and guidelines [Federal Register Volume 62, No. 139 (pg 39082)]. Consequently, remediation to radium standards at the NFSS is assumed sufficient to satisfy radon standards and guidelines in indoor air.

While RESRAD equations are not presented in this HHRA, the receptor-specific and medium-specific input parameters are presented in Table 3.3 and 3.4 for RME and CTE receptors, respectively. These tables list receptor-specific inputs (e.g., soil ingestion rates) and inputs that describe the physical characteristics of the contaminated media (e.g., soil erosion rates). For

medium-specific inputs, site-specific values are used when available, or are estimated using available site information. The preference is first to use site-specific data first, second to use values recommended or otherwise employed by EPA, and last to use RESRAD defaults. Table 3.4 also presents a ratio of CTE to RME values to demonstrate how risk estimate reductions are produced when utilizing CTE versus RME parameters.

With RESRAD input parameters in place, unit concentrations (i.e., 1 pCi/g) were used to generate risk-to-source ratios (RSRs) and dose-to-source ratios (DSRs). An RSR represents the risk per unit concentration (risk-g/lifetime-pCi) and a DSR represents the dose per unit concentration (mrem-g/yr-pCi). EPCs in pCi/g from each EU were multiplied by the appropriate RSR and DSR values to estimate the risk and dose, respectively. RSRs and DSRs by radionuclide and exposure pathway are presented in Appendix B.

For groundwater, the relevant exposure parameters are incorporated into the following equations for use in calculating lifetime risk (Eq. 3.1) and yearly radiological dose-based (Eq. 3.2), respectively.

$$\text{Intake (pCi)} = EPC_N \times IR \times EF \times ED \qquad \text{Eq. 3.1}$$

EPC_N = net (above background) EPC (pCi/L)
IR = ingestion rate (L/day)
EF = exposure frequency (days/yr)
ED = exposure duration (yrs)

$$\text{Intake (pCi/yr)} = EPC_N \times IR \times EF \qquad \text{Eq. 3.2}$$

EPC_N = net (above background) EPC (pCi/L)
IR = ingestion rate (L/day)
EF = exposure frequency (days/yr)

Given the large uncertainty in the RESRAD groundwater model, groundwater ingestion is not included in the RESRAD "runs". Actual, not modeled concentrations are used to estimate risk due to groundwater. Exposure parameters for the groundwater ingestion pathway are listed in Tables 2.2 (for RME) and 2.3 (for CTE). Finally, net exposure concentrations are used for all media, as shown in equations. 3.1 and 3.2. Risk and dose estimates include contributions from background concentrations; therefore, subtraction of background concentrations is performed because radiological dose-based limits are net values, and risks associated with background concentrations are often in excess of the CERCLA target risk range.

3.3 RADIONUCLIDE TOXICITY ASSESSMENT

Table 3.5 presents CSFs for ROPCs and Table 3.6 presents dose conversion factors for ROPCs. CSF values in Table 3.5 are from HEAST and represent the risk per unit activity ingested in water, food and soil and risk per unit activity inhaled. The CSF values for external exposure represent the risk per year per unit concentration in soil.

Dose factors listed in Table 3.6 are from the Federal Guidance Report No. 11 (EPA 1988) for ingestion and inhalation and Federal Guidance Report 12 (EPA 1993a) for external exposures. RESRAD adjusts the external factors to account for environmental factors such as the thickness and surface area of contaminated soil as described in *Groundshine (External Dose) Methodologies* found on the RESRAD Internet site http://web.ead.anl.gov/resrad/documents/.

Specific numeric values for the external pathways are not listed in Table 3.6 because they are not presented in RESRAD output. Dose conversion factors in federal guidance reports are presented in Standard International units and have been converted to traditional units (e.g., pCi) for use in this assessment.

3.4 RISK CHARACTERIZATION

Tables 3.7 through 3.23 present risk and radiological dose estimates for EU 1 through EU 17, respectively, and include results by medium and receptor. Risk results for the subsistence farmer child and adult are combined for a lifetime adult/child exposure. The same is true for resident child and adult. Dose results are presented on a per year basis, thus separate estimates are presented for an adult and a child. Risk and dose results for other receptors are not subdivided. Results are presented where the CSM specifies a complete exposure pathway; otherwise no value ("--") is presented. The following text summaries focus on risk results, but parenthetical dose estimates are provided for adult and child receptors [e.g., 10^{-4} (10, 5 mrem/yr); risk value (adult dose, child dose)]. For brevity, these summaries focus on receptors and medium combinations that produce either a risk greater than or equal to the upper end of the CERCLA risk range (10^{-4}) or a radiological dose greater than or equal to 25 mrem/yr. Note that dose and risk estimates from exposure to soil and groundwater ingestion may be combined, although they are presented separately here. Also note that exposures are estimating by modeling over a 1,000-year period (i.e., from year 0 to year 1,000) and the maximum exposures over that period are used as the baseline for RME and CTE risk and dose estimates. In general, risks from exposure to most ROPCs peak at year 0. The exception is Th-230 that, due to the ingrowth of Ra-226, can drive risk at year 1,000. Note, however, that risks are not added across time; as stated above, the maximum exposure over the 1,000-year period is reported below, using both RME and CTE parameters. Detailed radionuclide-specific and pathway-specific risk and dose estimates by EU and medium are presented in Appendix B.

For purpose of quantifying risks, the NFSS was divided into 18 EUs. EUs 1 through 14 are terrestrial. Soil is evaluated in each of these 14 EUs. EU 15 is the main drainage ditch system and EU 16 consists of abandoned pipes and sewers below ground. For defining environmental media within EUs, sediments are operationally defined as being in ditches that are submerged (wet) for at least six months of the year (i.e., 50 percent of the year). Areas submerged for less than 50 percent of the year are defined as soil areas. Only EUs 5, 9, 15, 16, and 17 contain surface water and sediment. EU 17 is a site-wide unit and includes data for all media including groundwater. EU 18 contains off-site areas where background samples were collected. Background risks for EU 18 were not quantified, rather background levels were used to identify ROPCs. Groundwater contamination is evaluated in three EUs; however, VOC contaminants in groundwater are localized in two EUs, EU 4 and EU 13. Therefore, groundwater ROPCs are identified for EUs 4, 13, and 17.

Table 3.7 presents RME and CTE risk and dose calculations for EU 1 by medium and receptor. RME risks at or above 1×10^{-4} and RME doses at or above 25 mrem/yr are estimated for soil and surface soil. The maximum risks are estimated for subsistence farmer receptors with 2.5×10^{-2} (1924, 696 mrem/yr) for soil (including food pathways). Major exposure pathways include plant ingestion followed by external gamma for all receptors. Risk driving radionuclides are Ra-226, Pb-210 and Th-230 with the Pb-210 contribution to risk being primarily through the plant ingestion pathway. CTE risks at or above 1×10^{-4} and CTE doses at or above 25 mrem/yr are estimated for soil.

Table 3.8 presents RME and CTE risk and dose calculations for EU 2 by medium and receptor. RME risks at or above 1×10^{-4} and RME doses at or above 25 mrem/yr are estimated for soil and surface soil. The maximum risks are estimated for subsistence farmer receptors with 5.2×10^{-3} (396, 143 mrem/yr) for soil (including food pathways). Major exposure pathways include plant ingestion followed by external gamma for all receptors. Risk driving radionuclides are Ra-226 and Pb-210 with the Pb-210 contribution to risk being primarily through the plant ingestion pathway. CTE risks at or above 1×10^{-4} are estimated for soil and surface soil. CTE doses at or above 25 mrem/yr are estimated for soil, while CTE doses for surface soil are estimated to be below 25 mrem/yr.

Table 3.9 presents RME and CTE risk and dose calculations for EU 3 by medium and receptor. RME risks at or above 1×10^{-4} and RME doses at or above 25 mrem/yr are estimated for soil and surface soil. The maximum risks are estimated for subsistence farmer receptors with 2.9×10^{-3} (226, 81 mrem/yr) for soil (including food pathways). Major exposure pathways include plant ingestion followed by external gamma for all receptors. Risk driving radionuclides are Ra-226 and Pb-210 with the Pb-210 contribution to risk being primarily through the plant ingestion pathway. CTE risks at or above 1×10^{-4} and CTE doses at or above 25 mrem/yr are estimated for soil and surface soil.

Table 3.10 presents RME and CTE risk and dose calculations for EU 4 by medium and receptor. RME risks at or above 1×10^{-4} are estimated for soil and groundwater, while RME risks for surface soil are estimated to be below 1×10^{-4}. RME doses at or above 25 mrem/yr are estimated for soil and groundwater, while RME doses for surface soil are estimated to be below 25 mrem/yr. The maximum risks are estimated for subsistence farmer receptors with 3.9×10^{-4} (29, 10 mrem/yr) for soil (including food pathways) and 1.7×10^{-3} (140, 29 mrem/yr) for groundwater. Major exposure pathways include plant ingestion followed by external gamma for all receptors. Risk driving radionuclides are Ra-226 and Pb-210 with the Pb-210 contribution to risk being primarily through the plant ingestion pathway. CTE risks for all receptors are estimated to be less than 1×10^{-4} and CTE doses for all receptors are estimated to be below 25 mrem/yr except for groundwater ingestion. The subsistence farmer adult and resident adult CTE doses from groundwater ingestion are estimated at 86 mrem/yr.

Table 3.11 presents RME and CTE risk and dose calculations for EU 5 by medium and receptor. RME risks at or above 1×10^{-4} are estimated for soil and surface soil, while RME risks are estimated to be below 1×10^{-4} for sediment. RME doses at or above 25 mrem/yr are estimated for soil and surface soil, while RME doses are estimated to be below 25 mrem/yr for sediment. The maximum risks are estimated for subsistence farmer receptors with 4.1×10^{-2} (3127, 1128 mrem/yr) for soil (including food pathways). Major exposure pathways include plant ingestion followed by external gamma for all receptors. Risk driving radionuclides are Ra-226 and Pb-210 with the Pb-210 contribution to risk being primarily through the plant ingestion pathway. CTE risks at or above 1×10^{-4} are estimated for soil, while CTE risks are estimated to be below 1×10^{-4} for sediment. CTE doses at or above 25 mrem/yr are estimated for soil, but are estimated to be below 25 mrem/yr for sediment.

Table 3.12 presents RME and CTE risk and dose calculations for EU 6 by medium and receptor. RME risks at or above 1×10^{-4} and RME doses at or above 25 mrem/yr are estimated for soil and surface soil. The maximum risks are estimated for subsistence farmer receptors with 3.2×10^{-2} (2474, 890 mrem/yr) for soil (including food pathways). Major exposure pathways include plant ingestion followed by external gamma for all receptors. Risk driving radionuclides are Ra-226 and Pb-210 with the Pb-210 contribution to risk being primarily through the plant ingestion

pathway. CTE risks at or above 1 x 10^{-4} and CTE doses at or above 25 mrem/yr are estimated for soil.

Table 3.13 presents RME and CTE risk and dose calculations for EU 7 by medium and receptor. RME risks at or above 1 x 10^{-4} and RME doses at or above 25 mrem/yr are estimated for soil and surface soil. The maximum risks are estimated for subsistence farmer receptors with 2.8 x 10^{-2} (2178, 784 mrem/yr) for soil (including food pathways). Major exposure pathways include plant ingestion followed by external gamma for all receptors. Risk driving radionuclides are Ra-226 and Pb-210 with the Pb-210 contribution to risk being primarily through the plant ingestion pathway. CTE risks at or above 1 x 10^{-4} and CTE doses at or above 25 mrem/yr are estimated for soil.

Table 3.14 presents RME and CTE risk and dose calculations for EU 8 by medium and receptor. RME risks at or above 1 x 10^{-4} and RME doses at or above 25 mrem/yr are estimated for soil and surface soil. The maximum risks are estimated for subsistence farmer receptors with 4.8 x 10^{-3} (371, 139 mrem/yr) for soil (including food pathways). Major exposure pathways include plant ingestion followed by external gamma for all receptors. Risk driving radionuclides are Ra-226 and Pb-210 with the Pb-210 contribution to risk being primarily through the plant ingestion pathway. CTE risks at or above 1 x 10^{-4} are estimated for soil, while CTE risks are estimated to be below 1 x 10^{-4} for surface soil. CTE doses at or above 25 mrem/yr are estimated for soil, while CTE doses are estimated to be below 25 mrem/yr for surface soil.

Table 3.15 presents RME and CTE risk and dose calculations for EU 9 by medium and receptor. RME risks at or above 1 x 10^{-4} are estimated for soil and surface soil, while RME risks are estimated to be below 1 x 10^{-4} for sediment. RME doses at or above 25 mrem/yr are estimated for soil only, while RME doses for surface soil and sediment are estimated to be below 25 mrem/yr. The maximum risks are estimated for subsistence farmer receptors with 1.5 x 10^{-3} (105, 39 mrem/yr) for soil (including food pathways). Major exposure pathways include plant ingestion followed by external gamma for all receptors. Risk driving radionuclides are Ra-226 and Pb-210 with the Pb-210 contribution to risk being primarily through the plant ingestion pathway. CTE risks at or above 1 x 10^{-4} are estimated for soil only, while CTE risks are estimated to be below 1 x 10^{-4} for surface soil and sediment. CTE doses at or above 25 mrem/yr are estimated for soil only, while CTE doses are estimated to be below 25 mrem/yr for surface soil and sediment.

Table 3.16 presents RME and CTE risk and dose calculations for EU 10 by medium and receptor. No ROPCs are identified for soil. RME risks at or above 1 x 10^{-4} and RME doses at or above 25 mrem/yr are estimated for surface soil. The maximum risks are estimated for a maintenance worker with 3.6 x 10^{-4} (28 mrem/yr) for surface soil. The major exposure pathway is external gamma for this receptor. Risk driving radionuclides are Ac-227, Pa-231, and Ra-226. CTE risks are estimated to be below 1 x 10^{-4} for surface soil. Likewise, CTE doses are estimated to be below 25 mrem/yr for surface soil.

Table 3.17 presents RME and CTE risk and dose calculations for EU 11 by medium and receptor. RME risks at or above 1 x 10^{-4} and RME doses at or above 25 mrem/yr are estimated for soil and surface soil. The maximum risks are estimated for subsistence farmer receptors with 2.7 x 10^{-2} (2481, 921 mrem/yr) for soil (including food pathways). Major exposure pathways include plant ingestion followed by external gamma for all receptors. Risk driving radionuclides are Ra-226, Pb-210, and uranium with the Pb-210 contribution to risk being primarily through the plant ingestion pathway. CTE risks at or above 1 x 10^{-4} and CTE doses at or above 25 mrem/yr are estimated for soil.

Table 3.18 presents RME and CTE risk and dose calculations for EU 12 by medium and receptor. RME risks at or above 1×10^{-4} and RME doses at or above 25 mrem/yr are estimated for soil and surface soil. The maximum risks are estimated for subsistence farmer receptors with 8.8×10^{-3} (681, 245 mrem/yr) for soil (including food pathways). Major exposure pathways include plant ingestion followed by external gamma for all receptors. Risk driving radionuclides are Ra-226 and Pb-210 with the Pb-210 contribution to risk being primarily through the plant ingestion pathway. CTE risks at or above 1×10^{-4} and CTE doses at or above 25 mrem/yr are estimated for soil.

Table 3.19 presents RME and CTE risk and dose calculations for EU 13 by medium and receptor. RME risks at or above 1×10^{-4} are estimated for soil, surface soil, and groundwater. RME doses at or above 25 mrem/yr are estimated for soil and surface soil, while RME doses for groundwater are estimated to be below 25 mrem/yr. The maximum risks are estimated for subsistence farmer receptors with 1.1×10^{-1} (8213, 2980 mrem/yr) for soil (including food pathways) and 1.1×10^{-4} (19, 3.9 mrem/yr) for groundwater. Major exposure pathways include plant ingestion followed by external gamma for all receptors. Risk driving radionuclides are Ra-226 and Pb-210 with the Pb-210 contribution to risk being primarily through the plant ingestion pathway. CTE risks at or above 1×10^{-4} and CTE doses at or above 25 mrem/yr are estimated for soil, while CTE risks and doses for groundwater are estimated to be below 1×10^{-4} and 25 mrem/yr, respectively.

Table 3.20 presents RME and CTE risk and dose calculations for EU 14 by medium and receptor. RME risks at or above 1×10^{-4} and RME doses at or above 25 mrem/yr are estimated for soil and surface soil. The maximum risks are estimated for subsistence farmer receptors with 3.6×10^{-2} (2640, 956 mrem/yr) for soil (including food pathways). Major exposure pathways include plant ingestion followed by external gamma for all receptors. Risk driving radionuclides are Ra-226 and Pb-210 with the Pb-210 contribution to risk being primarily through the plant ingestion pathway. CTE risks at or above 1×10^{-4} and CTE doses at or above 25 mrem/yr are estimated for soil.

Table 3.21 presents RME and CTE risk and dose calculations for EU 15 by medium and receptor. No ROPCs are identified for soil and all risks for sediment are estimated to be below 1×10^{-4} with a maximum of 6.3×10^{-6} (0.04, 0.21 mrem/yr) for the subsistence farmer.

Table 3.22 presents RME and CTE risk and dose calculations for EU 16 by medium and receptor. No EU 16 ROPCs are identified for surface soil. RME risks are estimated to be below 1×10^{-4} for soil and sediment. Likewise, RME doses are estimated to be below 25 mrem/yr for soil and sediment. The maximum risks are estimated for a construction worker with 1.4×10^{-6} (2.0 mrem/yr) for soil. The major exposure pathway is external gamma for this receptor. The risk driving radionuclide is Th-232. CTE risks and doses for soil and sediment are estimated to be below 1×10^{-4} and 25 mrem/yr, respectively.

Table 3.23 presents RME and CTE risk and dose calculations for EU 17 by medium and receptor noting that EU 17 represents the entire site. RME risks at or above 1×10^{-4} and RME doses at or above 25 mrem/yr are estimated for soil, surface soil, and groundwater. RME risks and doses for sediment are estimated to be below 1×10^{-4} and 25 mrem/yr, respectively. The maximum risks are estimated for subsistence farmer receptors with 7.7×10^{-3} (620, 226 mrem/yr) for soil (including food pathways) and 5.6×10^{-4} (47, 10 mrem/yr) for groundwater. Major exposure pathways include plant ingestion followed by external gamma for all receptors. Risk driving radionuclides are Ra-226 and Pb-210 with the Pb-210 contribution to risk being primarily

through the plant ingestion pathway. CTE risks at or above 1×10^{-4} and CTE doses at or above 25 mrem/yr are estimated for soil and groundwater, while CTE risks and doses for sediment are estimated to be below 1×10^{-4} and 25 mrem/yr, respectively.

In summary, risk estimates exceed 1×10^{-4} and dose estimates exceeds 25 mrem/yr from exposure to soil, surface soil, and groundwater in various EUs across the site. Table 3.24 lists the specific EUs with results that exceed risk and dose criteria. Note that all risk and dose estimates for sediment are below criteria and no ROPCs are identified for surface water. Ra-226 and Pb-210 dominate risk and dose estimates primarily from plant ingestion and from the external gamma pathway for all other receptors. Table 3.25 lists the ROPCs that are ROCs by medium and receptor, where an ROC is any ROPC with a risk of at least 1×10^{-5} when the total risk from exposure to all ROPCs combined is equal to or greater than 1×10^{-4}. All ROPCs except Sr-90 are identified as ROCs for some receptor/medium combination. There are no ROCs for exposure to sediment or surface water.

3.5 UNCERTAINTY ANALYSIS

Uncertainties associated with the assessment of radiological risk calculations are similar to those associated with chemical risk and dose calculations. Therefore, the discussions presented in Section 2.5 generally apply and are not repeated here. The nature of radiological calculations using RESRAD does introduce some uncertainties for which there is no chemical assessment equivalent. For example, RESRAD includes environmental factors that are applied over 1,000 years, or as dictated by Applicable or Relevant and Appropriate Requirements (ARARs) or stakeholders. One thousand years is considered because radiological dose-based limits often apply over a thousand year evaluation period, a period over which the impacts of radiological ingrowth and decay are factored along with reasonably conceivable future exposure scenarios. These environmental factors include the geometry of the contaminated zone, meteorological information such as average rainfall, geotechnical parameters such as distribution coefficients, shielding factors, and other factors. Site-specific information for many of these environmental factors is often unavailable introducing uncertainty in the risk estimates. Similarly, applying these factors over a 1,000-year period introduces uncertainty by assuming that conditions today will still exist over the evaluation period. In general, these factors are selected to assure overestimates of risk without introducing arbitrary or prohibitive conservatism. The selection of exposure parameters are, to the extent possible, selected using available site information and reasonable anticipated future conditions to limit these uncertainties.

The risk coefficients and dose factors used in this assessment are based on the assumption that there is no threshold for health effects, i.e., that there is some risk of cancer at all exposure levels above zero, and that the dose-response relationship is linear in the low-dose portion of the curve. Using this assumption, the cancer risk coefficients and dose factors are constants, and risks and doses are directly related to intake. In fact, a number of studies have been conducted which indicate that a threshold exists for radiation exposures, i.e., exposures below a certain level do not appear to result in cancer induction. Nevertheless, the use of risk factors based on the protective assumption of a linear no-threshold dose-response relationship is the default approach for estimating radiological risks and should result in a conservative estimate of risk. The radiological risk coefficients and dose factors used in this assessment are generally accepted by the scientific community as representing reasonable, but conservative, projections of the hazards associated with radiation exposure.

Risk coefficients are used to assess population-averaged risk due to chronic lifetime exposure, of an average individual, to a constant environmental concentration. Risk coefficients are not intended for application to specific individuals (e.g., by age or gender) and use of HEAST slope factors for specific receptor groups, while necessary, is a source of uncertainty. The radiological cancer risks were estimated using risk coefficients developed by EPA and published in Federal Guidance Report No. 13 (EPA 1999b). These risk coefficients represent the estimated lifetime cancer risk per unit intake averaged over all ages and both genders and include the impact of competing risks. Extensive human radiation toxicity data were, used to establish risk coefficients, including data on individuals who survived the atomic bombs at Hiroshima and Nagasaki. Epidemiological data is also available from studies of medical exposures to humans including the use of colloidal thorium-232 (thorotrast) injected into patients as a radiographic contrast medium between 1928 and 1955; and studies of radium dial painters, radium chemists, and technicians exposed through medical procedures in the early 1900s. These studies are identified and discussed in Federal Guidance Report No. 13 and the references cited therein. These cancer risk coefficients have been used in numerous radiological risk assessments and provide a conservative, but reasonable, estimate of the risks associated with radiation exposure. The uncertainty associated with using these standard cancer risk coefficients to assess radiation toxicity is considered to be relatively low.

Estimates of the radiation dose were made using standard dose factors given in Federal Guidance Report Nos. 11 (EPA 1988) and 12 (EPA 1993a). These dose factors are based on the metabolic and anatomical model of an adult male, the ICRP reference man weighing 70 kg (about 150 pounds)(ICRP 1981). The ICRP selected such a standardized individual for its dosimetry models because the main concern was worker protection and the majority of radiation workers are adult males. Although children are more susceptible to radiation exposure since radiation doses are larger for children than adults for the same intake of radioactivity, such effects are significant only for very young children. The uncertainty associated with using dose factors originally developed for adults when evaluating the subsistence farmer child or resident child is relatively low, and does not significantly affect the radiation doses presented in this document. As described for the radiological cancer risk coefficients, these dose factors have been used in numerous assessments and evaluations for exposures to radiation and the uncertainty associated with their use is considered to be low.

Uncertainties also exist when compiling radiological data and calculating EPCs. Radiological datasets often do not include results for all long-lived radionuclides, thus certain assumptions are made for completeness. For example, the NFSS dataset does not contain Pb-210 data but it is very likely that Pb-210 and Ra-226 are in secular equilibrium. Therefore, the Ra-226 concentration was assigned to Pb-210. Similar assumptions are made in this assessment for radionuclides in the thorium series, Pa-231 and Ac-227, and uranium isotopes. Specifically, as described in Section 3.1.1:

- Th-232, Ra-228 and Th-228 are assumed to be in equilibrium so if results are not reported for any one radionuclide, a value may be assigned from other series constituents.

- If Pa-231 was reported but Ac-227 was not, the Pa-231 value was assigned to Ac-227; or if Ac-227 was reported but Pa-231 was not, the Ac-227 value was assigned to Pa-231.

- Uranium isotopes are assumed to be present at natural abundances. Therefore, concentrations are assigned assuming that U-234 and U-238 concentrations were equivalent and that U-235 was present at five percent of the U-234 or U-238 concentration.

These assumptions are made to assure a comprehensive risk evaluation for all potential radiological contaminants (measured or implied), but these assumptions are also a source of uncertainty.

Finally, it is noted that current maintenance workers may spend as much as 8 hours per day at the site, whereas the modeled scenario specifies only 5.5 hours per day of outdoor exposure. If future workers spend additional time on-site, whether indoors or outdoors, the risk/dose estimates would increase. These increases could cause the modeled maintenance worker to accrue higher risk/dose than the modeled industrial worker, who spends 7 hours indoors and 1 hour outdoors on-site.

4.0 SCREENING LEVEL ECOLOGICAL RISK ASSESSMENT

An ecological risk assessment defines the likelihood of harmful effects on plants and animals as a result of exposure to environmental stressors, usually chemical and radiological constituents that occur at a site. There are two types of ecological risk assessments: screening and baseline. A screening ecological risk assessment (SERA) relies on available site data (often limited to abiotic chemical data) and is intended to be conservative. A baseline ecological risk assessment (BERA) requires more complete site-specific exposure and effects information, including such measurements as body burden measurements, biosurveys, and bioassays, and it often uses less conservative, yet more realistic, assumptions. This section presents a SERA for various locations at the NFSS.

4.1 INTRODUCTION AND SCOPE

The scope of the SERA is to determine the potential for adverse ecological impacts resulting from exposure to chemicals and radionuclides released to the environment through past site operations related to the NFSS and the IWCS. The SERA will provide information to scientists and managers for the first scientific management/decision point (SMDP) that will enable them to conclude either that ecological risks at the site are negligible, that further information and evaluation are necessary to better define potential ecological risks at the site, or that mitigation should be done without further evaluation. Further evaluation required by the SMDP, if any, will be provided in another document.

The SERA uses available site analyte concentrations in soil, sediment, and surface water from the NFSS. Risks to ecological receptors are evaluated by performing a multi-step screen (also known as a graded approach for radionuclides) that identifies EUs and media where specific analyte concentrations are above values that are deemed safe for one or more receptors. The SERA also identifies receptors that are particularly at risk. The results also provide information about the relative magnitude of risk from different analytes. For this SERA, future risks are assumed to be the same as current risks presented here; however, for some chemicals, this may be overly conservative due to degradation. The approaches and methods that are used are described in the following sections of the SERA:

- screening level problem formulation (Section 4.2),
- screening level ecological exposure assessment (Section 4.3),
- screening level exposure estimates (Section 4.4),
- screening level risk characterization (Section 4.5),
- uncertainties (Section 4.6),
- refinement of the screening level ERA (Section 4.7),
- scientific/management decision point (Section 4.8), and
- summary of the SERA (Section 4.9).

4.2 SCREENING LEVEL PROBLEM FORMULATION

This section presents the problem formulation for the SERA. Problem formulation is the process for generating and evaluating preliminary hypotheses regarding why ecological effects occurred or may occur from chemicals and radionuclides released by man into the environment. During

this process, the manner in which ecosystem characteristics influence when, how, and why particular ecological entities may become exposed and exhibit adverse effects due to chemical and radiological stressors are evaluated (EPA 1998b). The process of problem formulation provides a systematic approach for organizing and evaluating available information, potential ecological receptors, stressors, exposure pathways, and effects.

For this SERA, the problem formulation includes two levels of screens: a site-wide screen followed by an EU-specific screen. Briefly, the site-wide screening compares the maximum detected concentration of COPCs against screening benchmarks and ROPCs against generic biota concentration guides (BCGs) identified using procedures developed by DOE (DOE 2002). The EU-specific screen uses site-specific exposure parameters, specific ecological exposure classes and receptors, as well as receptor-specific toxicity reference values (TRVs) to calculate HQs for chemical constituents, and site-specific BCGs for radionuclides. The two levels of screens are discussed in more detail in the sections that follow and summarized in Section 4.3.1. The screening-level problem formulation for this SERA consists of the following:

- A description of the environmental setting, with emphasis on habitats present at the NFSS (Section 4.2.1);
- A description of the ecological CSMs that identify contaminant sources, source media, transport mechanisms, exposure media and routes, and potential receptors at the NFSS (Section 4.2.2);
- Identification of assessment endpoints and measures of effect (Section 4.2.3);
- Selection of receptor groups and receptors (Section 4.2.4); and
- Selection of EUs (Section 4.2.5).

4.2.1 Environmental Setting

Much of the environmental setting information, including a general description of the site and its history, regional geology, meteorology, surrounding land use, and grounds maintenance was presented in Sections 1.2 and 2.2.1 through 2.2.1.4 so it is not repeated in detail in this section. The classes of substances that were associated with historical uses at the NFSS include metals, explosives (TNT), and radionuclides (especially uranium isotopes, radium, and Th-230). A commercial hazardous waste landfill borders the northern portion of the NFSS, while a commercial solid waste disposal facility borders the NFSS to the east. A commercial utility company power line transmission right-of-way borders the NFSS to the west.

The NFSS site exposure setting is described in Section 2.2. The description below summarizes the terrestrial and aquatic habitats pertaining to the SERA. Terrestrial habitats are discussed in Section 4.2.1.1 whereas aquatic habitats are discussed in Section 4.2.1.2. Rare ecological species are discussed in Section 4.2.1.3, and grounds maintenance activities are discussed in Section 2.2.1.4. Additional details for terrestrial resources are available in the *Ecological Reconnaissance Report* by Maxim Technologies (Maxim 2002) found in Appendix D.

4.2.1.1 Terrestrial Habitats

The NFSS is predominantly low-lying, with little topographic relief. Both terrestrial and wetland ecosystems are present at the NFSS. A soil survey performed for Niagara County stated that the "natural drainage is the major limitation to use" of the NFSS soils (USDA 1972). The regional direction of surface drainage is northward toward Lake Ontario.

Seven habitat types were identified as differing significantly from one another ecologically (Maxim 2002). These habitat types are the basic units to be evaluated in this SERA. These habitat types include: 36 ha (90 acres) of maintained turf/mowed grass; 10 ha (25 acres) of ash-elm-maple forest with a scrub-shrub understory; 6.5 ha (16 acres) of sedges, reeds, rushes, and cattails; 6 ha (15 acres) of upland northern hardwoods intermixed with old field; 4 ha (10 acres) of mixed hardwoods with a sparse understory intermixed with wetland areas; 10 ha (25 acres) of mixed upland hardwoods with a sparse scrub-shrub understory; and 4 ha (10 acres) of dense mixed northern hardwoods with a dense scrub understory. Most of these areas have been subjected to a great deal of recent and historic disturbance. Types of historic disturbance include clearing, digging of ditches for drainage and landform manipulation for the construction of roads, railroads, buildings and process structures, and installation of sewerage. In the 1980's, the IWCS and temporary lagoons were engineered for the storage of radioactive waste. Recent disturbance includes remediation of areas of the site by the DOE, mowing of grass, and clearing of wooded areas of the site for the study of site contamination.

The predominant vegetation on the site is elm *(Ulmus americana*) and ash *(Fraxinus pennsylvanica* and *F. americana*) forest with common reeds *(Phragmites communis*) and cattails *(Typha latifolia* and *T. angustifolia*) predominating in the low-lying areas. In areas of the site where clearing or landform manipulation has taken place, mowed bluegrass, fescue, and old field vegetation dominate. "Old field" is used to describe the vegetation associated in an area where the native vegetation was cleared and then the area was left fallow. Aggressive colonizers including goldenrod *(Solidago canadensis*), Queen Anne's Lace *(Daucus carota*), bull thistle *(Cirsium vulgare*), and poison ivy *(Rhus toxicodendron)* dominate this association. A more complete list of plant species on the NFSS can be found in the ecological reconnaissance report presented in Appendix D.

Wildlife species were identified during previous site work (Maxim 2002c) during various times of the year yielded information on species considered to be both year-round and migratory species. Some of these species are mammals such as white-tailed deer (*Odocoileus virginianus*), coyote (*Canis latrans*), red fox (*Vulpes vulpes*), rabbits (Leporidae), raccoons (*Procyon lotor*), groundhogs (*Marmota monax*), chipmunks (*Tamias striatus*), and mice (Cricetidae, Muridae); birds such as hawks (Accipitridae), herons (Ardeidae), pheasants, (*Phasianus colchicus*), geese (Anatidae), ducks (Anatidae), doves (Columbidae); and various amphibians and invertebrates.

Areas of the NFSS exhibit wetland characteristics (i.e. hydric soils, wetland vegetation, and wetland hydrology). The federal jurisdictional status of these areas has not been determined. Review of the Ransomville, New York Quadrangle National Wetland Inventory (NWI) map indicated that a portion of the northeastern corner of the NFSS has been identified as type PF01A wetland. This wetland is a palustrine, forested, broad-leaf deciduous, temporary wetland. The New York Freshwater Wetlands Act of 1975 regulates wetlands 12.4 acres or larger in size. Smaller wetlands may be subject to protection if they are considered to be of unusual local importance. No wetland areas that meet the Wetlands Act of 1975 criteria were identified during a review of a wetland map downloaded from NYSDEC Website:

http://www.dec.state.ny.us/website/dfwmr/habitat/wetmap/le5.html. Thus, no federally designated wetlands exist on NFSS.(NYSDEC 2004).

4.2.1.2 Aquatic Habitats

The NFSS drainage patterns are somewhat complex (Figures 2.4 and 2.5). The overall flow direction is generally from south-southeast to north-northwest. There are numerous outfalls from the property, some of which have multiple off-site contributing sources. Most of the site is very flat and, therefore, it is difficult to determine precisely the exact locations of the drainage divides that separate the various tributary areas. The off-site contributing tributary areas were determined from topographic maps because right of entry agreements do not currently exist.

No perennial streams, navigable waterways, or impoundments are present on the site; there is one perennially flowing ditch (Appendix D). The seasonal presence of water in each of the tributary areas is described in the following paragraphs. Surface water and moist sediments may only be present during part of the year for some areas, which limits the numbers and types of aquatic biota that survive in the ditches. For this SERA, sediments are operationally defined as being in ditches that are submerged (wet) for at least 50 percent of the year. Thus, whether a ditch is wet at least 50 percent of the year dictates the types of appropriate ecological receptors for that ditch. Areas wet at least 50 percent of the year are shown in Figure 2.5. There are eight (8) drainage outfalls, draining their respective tributary areas from the NFSS property. There are also small areas near the NFSS perimeter fence that contribute to minor off-site sheet flow. These small zones of direct off-site sheet flow will be addressed individually under the sections detailing the tributary areas to which they are adjacent.

The eight tributary areas in the following discussion, listed from west to east as they exit the NFSS property are:

- the West Ditch,
- the Central Ditch,
- the CWM West Ditch,
- the CWM Mid Ditch,
- the CWM East Ditch,
- the N Street South Ditch,
- the O Street North Ditch, and
- the O Street South Ditch.

Detailed descriptions of these eight drainages are presented in Appendix D. Thus, only brief summaries of the eight drainages are presented below. The following descriptions of observed water flow in each of the ditches are to detail the intermittent versus perennial stream flow. Note that observations made during August and September 2001 (see Appendix D) may not be entirely accurate since the summer of 2001 was atypically dry. It should also be noted that the survey was conducted by SAIC during the early spring (May 6, 2002) and descriptions of the types and density of flora in the ditches will change considerably as the late spring and summer proceeds.

West Ditch Tributary Area

The outfall to the West Ditch tributary is located on the north side of the property approximately 200 feet west of Lutts Road. The West Ditch tributary area receives drainage from both on-site and off-site sources. As shown on Figure 2.4, the West Ditch flow is from south to north with

several ditches contributing drainage from both the east and west. The West Ditch traverses a 20.4 m (67 ft) length of NFSS property. The West Ditch has intermittent flow throughout the year. The ditch, at the time of the May 2002 SAIC survey, contained a minor amount of flowing water approximately two inches deep and eight inches wide, some shallow ponded areas, and mostly grasses lining the sides and bottom of the ditch. There were intermittent small patches of reeds in the bottom and occasional piles of vegetative debris (remnants from the 2001 clearing activities).

Central Ditch Tributary Area

The outfall to the Central Ditch tributary is located on the north side of the property approximately 122 m (400 ft) west of Campbell Street. The Central Ditch tributary area has drainage from both on-site and off-site sources. This is the largest of the NFSS tributary areas as illustrated on Figure 2.4. Most of the drainage entering the Central Ditch flows from the east. Much of that drainage is from various Modern Landfill properties off-site sources. The Central Ditch traverses the entire north-south length of the NFSS property 832 m (2730 ft) and is the only ditch on-site that has flowing water year-round. Thus, this ditch is wet more than 50 percent of the year and could support a benthic macroinvertebrate community. The South 16, South 31, and Modern Ditches flow into the Central Ditch and also are wet more than 50 percent of the year (see Figure 2.5). The condition of the Central Ditch at the time of the May 2002 SAIC survey was a minor amount of water flow, especially north of the major east ditch confluences. Intermittent areas of ponded water were present along the length of the ditch. The vegetation growing in the bottom and sides of the ditch was mostly grasses and reeds with a few patches of vegetative debris from the 2001 clearing effort. South of the NFSS fence were the only cattails seen in the Central Ditch.

CWM West Ditch Tributary Area

The outfall to the CWM West Ditch tributary is located on the north side of the property immediately east of Campbell Street. The CWM West Ditch tributary area drains a small area of NFSS property east and south of the Campbell Street and N Street intersection. This ditch has intermittent flow and is wet less than 50 percent of the year so it could not support a benthic macroinvertebrate community based on the operational definition of sediment at the NFSS. The ditch had no apparent flow at the time of the May 2002 SAIC survey. The ditch's vegetation consisted of grass and a few small trees. The tributary area consists of a grass covered open area with a few trees, debris piles and water filled low spots. The topography is flat, and much of the precipitation is likely lost to infiltration, evaporation, and transpiration.

CWM Mid Ditch Tributary Area

The outfall to the CWM Mid Ditch tributary is located on the north side of the property approximately 457 m (1500 ft) east of Campbell Street. The CWM Mid Ditch tributary area drains a small area of NFSS property north of N Street and south of the north property fence. This ditch has intermittent flow throughout the year and is wet less than 50 percent of the year so it could not support a benthic macroinvertebrate community based on the operational definition of sediment at the NFSS. The ditch had no apparent flow at the time of the May 2002 SAIC survey. The ditch's vegetation consisted of grass and a few small trees. The tributary area consists of a wooded area. The topography is flat and much of the precipitation is likely lost to infiltration, evaporation and transpiration.

CWM East Ditch Tributary Area

The outfall to the CWM East Ditch tributary is located on the north side of the property approximately 244 m (800 ft) west of MacArthur Street. The CWM East Ditch tributary area drains an area of NFSS property north and south of N Street. This ditch has intermittent flow, but is wet at least 50 percent of the year so it could support a benthic macroinvertebrate community. The CWM East Ditch had a few feet of water in it at the time of the May 2002 SAIC survey. The ditch's vegetation consisted of grass and a few small trees. The tributary area consists of a grass covered open area, large wooded area and the N Street South Pond. The topography there is flat and much of the precipitation is likely lost to infiltration, evaporation and transpiration.

N Street South Ditch Tributary Area

The outfall to the N Street South Ditch tributary is located on the east side of the property approximately 24 m (80 ft) south of the N Street and MacArthur Street intersection. The N Street South Ditch tributary area is quite small, probably less than 0.8 ha (2 acres) near the southwest corner of the N Street and MacArthur Street intersection. This ditch has intermittent flow, but is wet at least 50 percent of the year so it could support a benthic macroinvertebrate community. The N Street South Ditch had small areas of ponded water and is lined with grasses and reeds.

O Street North Ditch Tributary Area

The outfall to the "O" St. North Ditch tributary is located on the east side of the property approximately 24 m (80 ft) north of the O Street and MacArthur Street intersection. The O Street North Ditch tributary area consists of an area on the north side of O Street that extends approximately 579 m (1900 ft) west of MacArthur Street. This ditch has intermittent flow, but is wet at least 50 percent of the year so it could support a benthic macroinvertebrate community. The O Street North Ditch had small areas of ponded water and is lined with grasses, reeds and small trees. This pond collects the drainage from the wooded area located to the north. It appears that this pond is stagnant for most of the year. Only during very wet times does it rise to a level where it will flow into the O Street North Ditch. Therefore, much of the precipitation in this tributary area is likely lost to infiltration, evaporation and transpiration.

O Street South Ditch Tributary Area

The outfall to the O Street South Ditch tributary is located on the east side of the property approximately 24 m (80 ft) south of the O Street and MacArthur Street intersection. The O Street South Ditch tributary area is small and extends between the O Street and the south property line fence for approximately 274 m (900 ft) west of MacArthur Street. This ditch is intermittent and is wet less than 50 percent of the year so it could not support a benthic macroinvertebrate community based on the operational definition of sediment at the NFSS. The O Street South Ditch had small areas of ponded water and is lined with grasses, reeds and small trees during a May 2002 survey by SAIC.

4.2.1.3 Rare Ecological Species

Data from the U.S. Fish and Wildlife Service indicated that no federally threatened or endangered species were identified for the NFSS (U.S. Fish and Wildlife Service 2000). The New York Natural Heritage Program of NYSDEC reported that one rare species, the Drummond's rock cress *(Arabis drummondi*i), has been found in Niagara County, New York (Young and Weldy 2004).

This vascular plant species, which is endangered in New York, was identified in 1893 in Lewiston, New York. Drummond's rock cress is commonly found on rocky or gravelly soils in ungrazed or lightly grazed areas. Appropriate habitat for this species does not occur naturally at NFSS. This species was not observed on the NFSS. The U.S. Fish and Wildlife Service data and the NYSDEC report can be found in Appendix D.

4.2.1.4 Sensitive Environments

A list of 31 sensitive environments recognized by the USEPA for their hazard ranking system (HRS) for the National Priority List (EPA 1990) is presented in Table 4.1, along with an indication whether those environments are present at the NFSS. Wetlands are the only sensitive environment on the list that are known to be present on the NFSS.

4.2.2 Ecological Conceptual Site Models

Ecological conceptual site models (ECSMs) depict and describe the known and expected relationships among the stressors, pathways, and assessment endpoints that are considered in the risk assessment, along with a rationale for their inclusion. Two ECSMs are presented for this SERA. One ECSM is associated with the general screen (Figure 4.1). The other ECSM represents the site-specific analysis screen (Figure 4.2). The ECSMs were developed using the available site-specific information and professional judgment. The contamination mechanism, source media, transport mechanism, exposure media, exposure routes, and ecological receptors for the ECSMs are described below.

Contamination Source

The contamination mechanism, which is the contamination source, includes historic site operations and transport of waste to IWCS for both the NFSS general screening and NFSS site-specific analysis screen ECSMs.

Source Media

The source medium is soil for both the NFSS general screen and NFSS site-specific analysis screen ECSMs. For the SERA, soil is defined as 0 – 2 feet below ground surface. Contaminants released from historic site operations or those transported to the IWCS went directly in the surrounding soil, which became the source medium.

Transport Mechanisms

The transport mechanisms for both the NFSS general screen and NFSS site-specific screen ECSMs include volatilization into the air, biota uptake, erosion to surface water and sediment, and leaching to groundwater. Volatilization is not a principal mechanism for either ECSM. Biota uptake is a transport mechanism because many contaminants are known to accumulate in biota, then those biota are free to move around. Deposition of eroded soils that contain contaminants into surface water and sediment is a valid transport mechanism for both ECSMs.

Exposure Media

Sufficient time (over 10 years) has elapsed for the soil contaminants in the original sources to have migrated to potential exposure media, resulting in possible exposure of plants and animals that come in contact with these media. The potential exposure media for both the NFSS general

screen and site-specific screen ECSMs include air, soil, food chain, surface water, sediment, and upper groundwater. Lower groundwater is not considered an exposure medium because ecological receptors are unlikely to contact groundwater at its depth of greater than 5 feet below ground surface. Upper groundwater could outcrop into surface water as a seep or spring, but is not considered an exposure medium until it does so. Soil, surface water, sediment, and food chain are the four principal exposure media for the NFSS site-specific screen ECSM.

Exposure Routes

Exposure routes are functions of the characteristics of the media in which the sources occur, and how both the released chemicals/radionuclides and receptors interact with those media (DOE 2002). For example, chemicals and radionuclides in surface water may be dissolved or suspended as particulates and be very mobile, whereas those constituents in soil may be much more stationary. For radionuclides, there are two, radiation-specific characteristics that need to be considered, including (1) variation in penetrating power and damage potential of the radiations of primary concern in radioactive decay (i.e., alpha particles, beta particles, and gamma rays); and (2) external exposure. The ecology of the receptors is important because it dictates their home range, whether the organism is mobile or immobile, local or migratory, burrowing or aboveground, plant-eating, animal-eating, or omnivorous, etc.

For the NFSS general screen ECSM, specific exposure routes are not identified or necessary because the general screen focuses on comparison of maximum detected concentrations of chemicals and radionuclides in the exposure media against published ecological toxicological benchmark concentrations derived for those media. However, the NFSS general screen ECSM does indicate whether the exposure routes from the exposure media to the ecological receptors are major or minor. Major exposure routes are evaluated quantitatively, whereas, minor routes are evaluated qualitatively. The NFSS general screen ECSM shows a major exposure route of soil to terrestrial animals. The NFSS general screen ECSM shows an incomplete exposure route of upper groundwater to terrestrial and aquatic plants and animals. Upper groundwater is discontinuous across the site and is below depths that would be directly contacted by ecological receptors. Specific exposure routes are not necessary for the general screen ECSM because the general screen only focuses on comparison of maximum detected concentrations of chemicals and radionuclides in the exposure media against published ecological toxicological benchmark concentrations derived for those media.

For the NFSS site-specific screen ECSM, the major exposure routes for soil include ingestion (for rabbits, deer, shrews, robins, and foxes), external radiation (for terrestrial plants, earthworms, rabbits, deer, shrews, robins, foxes, and hawks), and direct contact (for terrestrial plants). Radiation internal dose from ingestion or direct uptake is a major exposure pathway for terrestrial plants, earthworms, rabbits, deer, shrews, robins, foxes, and hawks. Minor exposure routes for soil include direct contact and inhalation of fugitive dust for rabbits, deer, shrews, robins, foxes, and hawks. The major exposure routes for surface water include ingestion, including radiation internal dose, and external radiation (for rabbits, deer, shrews, robins, foxes, hawks, aquatic biota, raccoons, ducks, and herons), and direct contact for aquatic biota. The major exposure routes for sediment include ingestion, including radiation internal dose, (for raccoons, ducks, and herons), direct contact (benthic invertebrates), and external radiation (benthic invertebrates, aquatic biota, raccoons, ducks, and herons). Minor exposure pathways for surface water and sediment include direct contact for raccoons and herons. The major exposure route for the food chain is ingestion, including radiation internal dose (for rabbits, deer, shrews, robins, foxes, hawks, raccoons, ducks, and herons).

The upper groundwater exposure routes of ingestion and direct contact are incomplete pathways for all terrestrial and aquatic ecological receptors because the upper groundwater is too deep beneath ground level for there to be direct exposure to any of the receptors. If the upper groundwater outcrops via seeps or springs into wetlands or the ditches, it becomes part of the surface water and is evaluated in the surface water pathway.

Ecological Receptors

For the NFSS general screen, specific ecological receptors are not identified but terrestrial and aquatic biota are each considered as a whole. Specific terrestrial and aquatic ecological receptors, as well as riparian receptors, are recognized in the NFSS site-specific screen ECSM (Figure 4.2). The specific terrestrial receptors include plants, soil invertebrates (earthworms), rabbits, deer, shrews, robins, foxes, and hawks. The specific aquatic receptors include benthic invertebrates and aquatic biota. Surface-feeding waterfowl receptors include the mallard duck. The riparian biota include raccoons and herons. These receptors are discussed in more detail in Section 4.2.4

4.2.3 Ecological Assessment Endpoints and Measures

The protection of ecological resources, such as habitats and species of plants and animals, is a principal motivation for conducting SERAs. Key aspects of ecological protection are presented as management goals, which are general goals established by legislation or agency policy and based on societal concern for the protection of certain environmental resources. For example, environmental protection is mandated by a variety of legislation and government agency policies (e.g., CERCLA and the National Environmental Policy Act). Other legislation includes the Endangered Species Act (16 U.S.C. 1531-1544, 1993, as amended) and the Migratory Bird Treaty Act (16 U.S.C. 703-711, 1993, as amended). To evaluate whether a management goal has been met, assessment endpoints, measures of effects, and decision rules were formulated. The management goals, assessment endpoints, measures of effects, and decision rules are discussed below.

For both the general screen and site-specific analysis screen, there are two management goals. However, the assessment endpoints differ between the general screen and site-specific analysis screen, as discussed below. The management goals for the SERA are:

- Management Goal 1: Protect terrestrial plant and animal populations from adverse effects due to the release or potential release of radionuclide and chemical substances associated with past federal government activities.

- Management Goal 2: Protect aquatic plant and animal populations and communities from adverse effects due to the release or potential release of radionuclide and chemical substances associated with past federal government activities.

Ecological assessment endpoints are selected to determine whether these management goals are met at the unit. An ecological assessment endpoint is a characteristic of an ecological component that may be affected by exposure to a stressor (e.g., constituent). Assessment endpoints are "explicit expressions of the actual environmental value that is to be protected" (EPA 1992c). Assessment endpoints often reflect environmental values that are protected by law, provide critical resources, or provide an ecological function that would be significantly impaired if the resources are altered (EPA 1998b). Unlike the HHRA process, which focuses on individual receptors, the SERA focuses on populations or groups of interbreeding nonhuman, non-domesticated receptors. Accordingly, assessment endpoints generally refer to characteristics of

populations and ecosystems. In the SERA process, risks to individuals are assessed only if they are protected under the Endangered Species Act or other species-specific legislation, if the species is a candidate for listing, or if it is considered rare.

Given the diversity of the biological world and the multiple values placed on it by society, there is no universally applicable list of assessment endpoints. Therefore, EPA's interim final *Ecological Risk Assessment Guidance for Superfund: Process for Designing and Conducting Ecological Risk Assessments* (EPA 1997b) was used to select assessment endpoints.

For the general screen, the assessment endpoints are any adverse effects on ecological receptors, where receptors are defined as any plant and animal populations, communities, habitats, and sensitive environments (EPA 1997b). Although the assessment endpoints for the general screen are associated with Management Goals 1 and 2, specific receptors are not identified with the assessment endpoints.

For the site-specific analysis screen, the assessment endpoints are more specific and are stated in terms of types of specific ecological receptors associated with each of the two management goals (Table 4.2). Assessment endpoints 1, 2, 3, and 4 entail the growth, survival, and reproduction of terrestrial receptors such as vegetation and soil invertebrates, herbivorous mammals, worm-eating/insectivorous mammals and birds, and carnivorous top predator mammals and birds, respectively for the NFSS. Assessment endpoints 1-4 are associated with Management Goal 1, protection of terrestrial vegetation and animal populations and communities. Assessment endpoint 5 deals with the growth, survival, and reproduction of sediment-dwelling biota, which links to Management Goal 2, protection of aquatic populations and communities. Assessment endpoints 6, 7, and 8 also link to Management Goal 2, and deal with the growth, survival, and reproduction of aquatic biota, surface-feeding waterfowl and aquatic biota-eating mammals and birds, respectively.

Assessment endpoints are evaluated through the use of measures (formerly named measurement endpoints). EPA defines measures as measurable ecological characteristics to quantify and predict change in the assessment endpoints, and they consist of measures of effect, measures of exposure, and measures of ecosystem and receptor characteristics (EPA 1998b). For example, measures of effects for this SERA are the attributes such as TRVs for chemicals, which are published for soil (plants and soil invertebrates), sediment (sediment-dwelling biota), surface water (aquatic biota), and wildlife [dietary No Adverse Effects Level (NOAELs)] as measures of effects. Additional measures of effects include generic BCGs for radionuclides for the general screen and early steps of the analysis, and site-specific BCGs for the later steps of the site-specific screen. Measures of exposure include attributes of the environment such as contaminant concentrations in soil, sediment, surface water, and biota. Measures of receptor characteristics include parameters such as home range, food intake rate, and dietary composition. Measures selection for ecological receptors considered the following criteria:

- The species should exhibit sensitivity to the constituent(s).

- The species should have a likely potential for exposure based upon its residency status, home range size, sedentary nature of the organism, habitat compatibility, exposure to contaminated media, exposure route and exposure mechanism compatibility.

- The species should exhibit life stage compatibility considering that short-lived organisms react more rapidly to contaminants, have higher turn-over rates and higher surface-to-

volume ratios than long-lived organisms that respond more slowly, have shorter turn-over rates and lower surface-to-volume ratios.

- The species should be easy to collect and monitor (population density and body burden should be large enough for adequate sample mass).

- The species should be suitable for laboratory or field experiments (behavioral, body burden assimilation, toxicity testing).

- The species should have available toxicological effects and exposure information.

- Ecosystem function considerations of the receptor (foodweb interactions, keystone species, performs vital ecosystem function, dominant species or tolerance/intolerance) should be accommodated.

- The species should be predictive of assessment endpoints (including protected species/species of special concern, recreational species, etc.).

Appropriate measures of exposure relating to the assessment endpoints for the general and site-specific screens include measured concentrations of chemicals and radionuclides in surface soil, sediment, and surface water. Additional measures of exposure for the site-specific screens include predicted concentrations of chemicals and radionuclides in vegetation and various receptor animals such as cottontail rabbits, shrews, American robins, and aquatic biota based on measured soil, sediment, and surface water concentrations. The measures for the site-specific analysis screen, and their relationship to their corresponding assessment endpoints, are summarized in Table 4.2.

For chemicals, the decision rules for the assessment endpoints come from the guidance literature of the federal and state Environmental Protection Agencies (EPA 1992c, 1996c, 1997b; NYSDEC 1994). Briefly, the first decision rule is based on the ratio or HQ of the (a) ambient exposure dose or EPC (numerator) of a given chemical and (b) ecological effects or toxicity reference value (denominator) of the same chemical. A ratio of 1 or smaller means that ecological risk is negligible while a ratio of greater than 1 means that ecological risk from that individual chemical is possible and that additional investigation should follow to confirm or refute this prediction. The second rule pertains to the sum of all the HQs or the HI for given groups of chemicals, e.g., all inorganics, all organics or all chemicals with a common mode of action. The calculation of HI's can be overly conservative for some groups of chemicals. A sum of 1 or smaller means there is not concern while a number greater than 1 means there may be a concern for that group of chemicals and that an SMDP is reached to evaluate whether further work is needed. The first decision rule is mentioned in the table about assessment endpoints on a receptor by receptor basis with their three outcomes: no further analysis, weight-of-evidence analysis, or more computations in the form of a BERA. An SMDP can also be reached to mitigate risks without further evaluation.

For radionuclides, the decision rules for the assessment endpoints are different and are stated quantitatively in terms of sums of fractions, which are the sums of ratios of radionuclide concentrations to BCGs (DOE 2002). A BCG is the measured or predicted concentration of a ROPC to which receptors can be exposed in the environmental medium without adverse effects to an organism (i.e., benchmark or toxicity reference value). The concentration of each ROPC is divided by its BCG, and the fractions are summed for all analytes and all media to which the

receptor is exposed. If the sum of fractions is less than or equals 1, the assessment endpoint is met and the risk is considered acceptable or protective of the ecological receptor. Sum of fractions greater than 1 result in a continuation of the analysis per the graded approach (i.e., general screen to site-specific screen, to site-specific analysis), ultimately to an SMDP. The decision rules associated with each assessment endpoint are presented in Table 4.2. The testable hypotheses for the decision rules are that the sum of fractions for the maximum or mean exposure concentrations of unit-related constituents present in soil, sediment, surface water, and biota do not exceed 1 for terrestrial and aquatic animal populations. For site-specific analysis, receptor species were selected to represent the assessment endpoints in order to verify or recant the testable hypothesis.

4.2.4 Selection of Ecological Receptor Species

The selection of ecological receptors for the site-specific analysis screen is based on plant and animal species that do or could occur in the terrestrial and aquatic habitats at the NFSS. Three criteria are used to select the specific receptors:

- Ecological relevance - indicates that the receptor has or represents a role in an important function such as energy fixation (e.g., plants), nutrient cycling (e.g., earthworms), and population regulation (e.g., hawks). The receptor species should include representatives of the applicable trophic levels that apply to the ECSM for the site.

- Susceptibility - indicates that the receptor is known to be sensitive to the chemicals and radionuclides at the site, and exposure is high due to food and habitat preferences.

- Management goals - refer to valuable roles in erosion control (e.g., plants), societal values (e.g., deer and waterfowl hunting), and regulatory protection (e.g., hawks, herons).

For the NFSS site-specific analysis screen, the recommended ecological receptors are terrestrial plants, soil invertebrates, cottontail rabbits (*Sylvilagus floridanus*), white-tailed deer (*Odocoileus virginianus*), short-tailed shrews (*Blarina brevicauda*), American robins (*Turdus migratoris*), red foxes (*Vulpes vulpes*), red-tailed hawks (*Buteo jamaicensis*), sediment-dwelling biota, aquatic biota, raccoons (*Procyon lotor*), mallard ducks (*Anas platyrhynchos*), and great blue herons (*Ardea herodias*).

Risks are quantitatively evaluated for each receptor.

4.2.4.1 Terrestrial Exposure Classes and Receptors

The terrestrial exposure classes and their receptors and justification for selection for the site-specific analysis screen are presented below.

Vegetation Terrestrial Exposure Class

The vegetation exposure class is applicable to the NFSS site-specific analysis. Plants represent the receptors for the vegetation exposure class. Plants have ecological relevance because they represent the base of the food web and are the primary producers that turn energy from the sun into organic material (plants) that provides food for many animals. In addition, plants are important in providing shelter and nesting materials to many animals, which is a major component of the animal's habitat. Plants provide natural cover and stability to soil and stream banks, thereby reducing soil erosion.

Plants have susceptibility to toxicity from chemicals and, to a lesser extent, radionuclides. Plants have roots that are in direct contact with surface soil, which provides them with direct exposure to contaminants in the soil. They also can have exposure to contaminants via direct contact on the leaves. There are published toxicity benchmarks for plants (Efroymson et. al. 1997a, 1997c).

There are management goals for plants because of their importance in erosion control. Thus, there is sufficient justification to warrant plants as a receptor for the SERA.

Soil-Dwelling Invertebrate Terrestrial Exposure Class

The soil-dwelling invertebrate terrestrial exposure class is applicable to the NFSS site-specific analysis. Earthworms represent the receptor for the soil-dwelling invertebrate class. Earthworms have ecological relevance because they are important for decomposition of detritus and for energy and nutrient cycling in soil (Efroymson 1997b, 1997c). Earthworms are probably the most important of the soil invertebrates in promoting soil fertility because they process much soil.

Earthworms have susceptibility to exposure to and toxicity from contaminants in soil. Although earthworms may have less sensitivity to radiation compared to vertebrate receptors, they are sensitive to various chemicals. Earthworms are nearly always in contact with soil and ingest soil, which results in constant exposure. Toxicity benchmarks are available for earthworms (Efroymson et. al. 1997b, 1997c).

Although management goals for earthworms are not immediately obvious, the important role of earthworms in soil fertility cannot be overlooked. Thus, there is sufficient justification to warrant earthworms as a receptor for the SERA.

Mammalian Herbivore Terrestrial Exposure Class

The mammalian herbivore terrestrial exposure class is applicable to the NFSS site-specific analysis. Cottontail rabbits and white-tailed deer represent the receptors for the mammalian herbivore exposure class. Both species have ecological relevance by consuming vegetation, which helps in the dispersion of some plant seeds. Small herbivorous mammals such as cottontail rabbits are components of the diet of terrestrial top predators.

Both species have susceptibility to exposure to, and toxicity from chemicals and radionuclides in soil and vegetation. Herbivorous mammals are exposed primarily through ingestion of plant material and incidental ingestion of contaminated surface soil containing chemicals and radionuclides, as well as by external radiation. Exposures by inhalation of COPCs in air or on suspended particulates, as well as exposures by direct contact with soil are assumed to be negligible. Dietary toxicity benchmarks are available for many contaminants for mammals (Sample et. al. 1996).
There are management goals for both species because of their societal values. Both species are game animals and regulated by New York hunting laws and they have aesthetic appeal to most people. State hunting seasons define bag limits (how many individual deer and rabbits can be harvested per day or season) and legal times when the species can be hunted, in order to protect the populations. Both species are susceptible to toxicity from contaminants, especially via the ingestion exposure pathway, and have ecological relevance. Thus, there is sufficient justification to warrant cottontail rabbits and white-tailed deer as receptors for the SERA.

Insectivorous Mammal and Bird Terrestrial Exposure Class

The insectivorous mammal and bird terrestrial exposure class is applicable to the NFSS site-specific analysis. Short-tailed shrews and American robins represent the receptors for the insectivorous mammal and bird terrestrial exposure class, respectively. Both species have ecological relevance because they help to control soil and aboveground invertebrate community size by consuming large numbers of invertebrates. Shrews are a prey item for terrestrial top predators.

Both species have susceptibility to exposure to, and toxicity from chemicals and radionuclides in soil, as well as contaminants in vegetation and soil invertebrates. Both species, but especially shrews because of their burrowing activity, are also susceptible to external radiation exposure. Insectivorous mammals such as short-tailed shrews and birds such as American robins are primarily exposed by ingestion of potentially contaminated prey (e.g., earthworms, insect larvae, slugs) as well as ingestion of soil. In addition, shrews ingest a small amount of leafy vegetation and the robin's diet consists of 50 percent of seeds and fruit. Dietary toxicity benchmarks are available for mammals and birds (Sample et. al. 1996). Both species are included as receptors for the SERA because there can be different toxicological sensitivity between mammals and birds exposed to the same contaminants.

There are management goals for robins because they are federally protected under the Migratory Bird Treaty Act of 1993, as amended. There are no specific management goals for shrews at the NFSS. Based on the management goals for robins, plus the susceptibility to contamination and ecological relevance for both species, there is sufficient justification to warrant shrews and robins as receptors for the SERA.

Terrestrial Top Predator Exposure Class

The terrestrial top predator exposure class is applicable to the NFSS site-specific analyses. Red foxes and red-tailed hawks represent the mammal and bird receptors for the terrestrial top predator exposure class, respectively. Both species have ecological relevance because as representatives of the top of the food chain for the NFSS terrestrial EUs, they control populations of prey animals such as small mammals and birds.

Both species have susceptibility to exposure to, and toxicity from chemicals and radionuclides in soil, as well as contaminants in vegetation and/or animal prey. Terrestrial top predators feed on small mammals and birds that may accumulate constituents in their tissues following exposure at the NFSS. There is a potential difference in toxicological sensitivity between mammals and birds exposed to the same contaminants, so it is prudent to examine a species from each taxon class (Mammalia and Aves, respectively). Red foxes are primarily carnivorous, but consume some plant material. The red-tailed hawk consumes only animal prey. Both species, but especially foxes, are exposed to external radiation. The foxes also may incidentally consume soil.

There are management goals for both species. Laws (New York trapping season regulations for foxes, and federal protection of raptor birds of prey for hawks under the Migratory Bird Treaty Act) protect these species. In addition, both species are susceptible to contamination, especially via the ingestion exposure pathway, and have ecological relevance as top predators in the terrestrial ecosystem. Thus, there is sufficient justification to warrant these two species as receptors for the SERA.

4.2.4.2 Aquatic Exposure Classes and Receptors

The aquatic exposure classes and their receptors and justification for selection in the site-specific analysis screen are presented below.

Aquatic Biota Exposure Class

The aquatic biota exposure class is applicable to the NFSS site-specific analysis. Aquatic biota (e.g., aquatic plants, invertebrates, and fish) represent the ecological receptors for the aquatic biota aquatic exposure class. Aquatic biota have ecological relevance because they represent the range of living organisms in the aquatic ecosystem. Aquatic biota provide food for various aquatic-eating predators.

Aquatic biota have susceptibility to exposure to, and toxicity from chemicals and radionuclides in surface water. The exposure concentration for aquatic biota is assumed to be equal to the measured environmental concentration because the biota have constant contact with the water, and the aquatic toxicity benchmarks that are used are expected to protect aquatic life from all exposure pathways, including ingestion of plants and animals contaminated by surface water. Aquatic biota are also susceptible to external exposure to radiation.

There are management goals for aquatic biota in laws that specify water quality standards to support designated uses (e.g., survival and propagation of aquatic life) for waters of the state. They are susceptible to contaminants because of constant exposure in water, and have ecological relevance to biota in the aquatic and terrestrial ecosystems. Thus, there is sufficient justification to warrant aquatic biota as a receptor class for the SERA.

Sediment-Dwelling Biota Exposure Class

The sediment-dwelling biota exposure class is applicable to the NFSS site-specific analysis. Sediment-dwelling biota (invertebrates) such as aquatic insect larvae like caddisflies (Trichoptera), mayflies (Ephemeroptera), and midges (Chironomidae), as well as non insects such as crayfish (Decapoda), snails (Gastropoda), and clams and bivalves (Pelycypoda) represent the receptors for the sediment-dwelling biota aquatic exposure class. These biota have ecological relevance to the aquatic food chain because they provide food for many aquatic biota species, and to some extent, some mammals and birds such as raccoons, mallards and herons. Although sediment-dwelling biota are not expected to be present at all the ditches at the NFSS, there is sufficient habitat at several ditches (Section 4.2.1.2).

Sediment-dwelling biota have susceptibility to exposure to, and toxicity from chemicals and radionuclides in sediment. These biota have direct contact with sediment and pore water. They have exposure to external radiation. Toxicity benchmarks are available for sediment-dwelling biota.

There are management goals for sediment-dwelling biota because the condition of these biota is linked to assessment of water quality use attainment. These biota are susceptible to contaminants because of constant exposure to sediment, and they have ecological relevance to aquatic biota as a major food source. Thus, there is sufficient justification to warrant sediment-dwelling biota as a receptor class for the SERA.

Waterfowl Exposure Class

The waterfowl exposure class is applicable to the NFSS site-specific analysis. Mallard ducks are surface-feeding ducks that obtain much of their food by dabbling in shallow water and filtering through soft mud with their beaks. Their food consists mostly of seeds of aquatic plants, as well as aquatic invertebrates (EPA 1993b). Animal matter can account for approximately 67 to 90% of the diet of breeding females during the spring and summer, but decrease to less than 10% of the diet during the winter. Mallards have ecological relevance as important components of the aquatic food web. As surface-feeding waterfowl, mallards help maintain the community sizes of aquatic vegetation, aquatic macroinvertebrates, and some sediment-dwelling biota.

Mallards have susceptibility to exposure to and toxicity from chemicals and radionuclides in surface water, aquatic biota vegetation, and sediment-dwelling biota. The potential for exposure to contaminants is high because they consume aquatic and sediment-dwelling biota that can accumulate high concentrations of some chemicals from water. In addition, this species can have further exposure via ingestion of contaminants in surface water that is used for a drinking water source. Mallards can receive external radiation exposure. Dietary toxicity published benchmarks for many inorganic and some organic substances are available for birds.

There are management goals for mallards. For example, mallards are protected under the Migratory Bird Treaty Act of 1993, as amended. They are also protected as a game species under the Migratory Bird Hunting and Conservation Stamp Act of 1934, as amended. Mallards are susceptible to contaminants, especially via ingestion exposure, and have ecological relevance. Thus, there is sufficient justification to warrant this receptor for the SERA.

Aquatic Biota-Eating Predator Exposure Class

The aquatic biota-eating predator aquatic exposure class is applicable to the NFSS site-specific analysis. Raccoons and great blue herons are riparian biota and represent the mammalian and bird receptors for the aquatic biota-eating predator exposure class, respectively. Riparian biota feed predominantly in and along the banks of streams. Both species have ecological relevance because as riparian biota that are aquatic biota-eating predators, they are important components of the aquatic food web by representing the top predators. As top predators, they help maintain the population sizes of the aquatic biota and some sediment-dwelling biota communities.

Both species have susceptibility to exposure to, and toxicity from chemicals and radionuclides in surface water, aquatic biota, and sediment-dwelling biota. The potential for exposure to contaminants is high for these two species because they consume aquatic biota, which can accumulate high concentrations of some chemicals from water. In addition, both species can have further exposure via ingestion of contaminants in surface water that is used for a drinking water source. In addition, both species can receive external radiation exposure. Dietary toxicity benchmarks are available for mammals and birds (Sample et. al. 1996), but there can be differences in toxicological sensitivity between mammals and birds exposed to the same contaminant so both species are appropriate.

There are management goals for both species because laws protect both species. For example, raccoons are regulated by New York trapping laws because they are fur-bearing mammals. Great blue herons are federally protected under the Migratory Bird Treaty Act of 1993, as amended. Both species are susceptible to contaminants, especially via ingestion exposure, and have

ecological relevance. Thus, there is sufficient justification to warrant these two receptors for the SERA.

4.2.5 Exposure Units

The SERA utilizes the same EUs as the HHRA, except for groundwater in EU 18 and pipeline material in EU 17, which are not evaluated quantitatively in the SERA. EUs are discussed in Section 2.2.2.2 and are portrayed on Figure 2.4. Available habitats in each of the EUs can be viewed on the habitat map in Appendix D and in Figure 2.4.

4.3 SCREENING LEVEL ECOLOGICAL EXPOSURE ASSESSMENT

Ecological risk screening for SRCs, COPCs, and ROPCs is performed by using methods based on EPA's *Ecological Risk Assessment Guidance for Superfund* (EPA 1997b) for chemicals and the DOE's *Graded Approach for Evaluating Radiation Doses to Aquatic and Terrestrial Biota* (DOE 2002) for radionuclides, respectively. SRCs are constituents measured at concentrations above background at the NFSS (Section 2.1.2). In these methods, concentrations of chemical SRCs in soil, sediment, and surface water are compared first to media- and chemical-specific ecological screening values (ESVs) to identify COPCs. Exposures to COPCs are calculated and compared to media-, receptor-, and chemical-specific TRVs. Published chemical-specific ESVs are used for the COPC screening, as are chemical- and receptor-specific TRVs. Concentrations of radionuclide SRCs in soil, sediment, and surface water at the NFSS are compared to benchmark values called BCGs (DOE 2002) to identify ROPCs. BCGs (DOE 2002) are used for the general screening step (A) and site-specific analysis steps B through D, but the benchmarks are revised for site-specific analysis step E by considering site-specific exposures of specific ecological receptors. Each of these toxicity benchmarks is defined later in the text.

The methods for performing ecological exposure assessment are presented in the following subsections, which describe:

- the approach to using screening and analysis methods (Section 4.3.1),
- the methods used to compute risks from exposure to COPCs (Section 4.3.2),
- the methods used to compute risks from exposure to ROPCs (Section 4.3.3),
- receptor-specific parameters to be used in the exposure equations (Section 4.3.4), and
- site-specific and chemical-specific exposure parameters (Section 4.3.5).

4.3.1 Methods

As described in the problem formulation section, NFSS risks are evaluated by a graded series of screening steps. The steps culminate in a scientific/management decision point. At this point, it is decided whether the NFSS or individual EUs of the NFSS are unlikely to cause harm to ecological receptors or whether more extensive sampling and data analysis for the NFSS is needed before site closure can be achieved. Screening of COPCs is based on methods presented in U.S. EPA's *Ecological Risk Assessment Guidance for Superfund* (EPA 1997c). The screening for COPCs begins by comparing site-wide maximum detected concentrations of chemicals in each media against media-specific ESVs. The ESVs are media-specific, conservative benchmarks that are intended to be protective of the majority of ecological receptors exposed to the media, and are essentially equivalent to BCGs. Any COPCs that exceed the ESVs are carried forward to additional screening that is performed by using methods described in steps 1 and 2 of Ecological

Risk Assessment Guidance for Superfund (ERAGS), whereby an exposure is calculated for each receptor and is divided by a TRV, resulting in an HQ for each COPC and each receptor. Screening of ROPCs is based on methods presented in U.S. DOE's technical standard, *Graded Approach for Evaluating Radiation Doses to Aquatic and Terrestrial Biota* (DOE 2002). In this method, concentrations of NFSS-related ROPCs are compared to BCGs, which are concentrations in soil, sediment, and surface water that are expected not to harm populations of ecological receptors. Exposure concentrations from the entire NFSS or from EUs defined in Section 2.2.2.2 are used for the screening evaluations.

Terrestrial plants are assumed to be exposed to COPCs and ROPCs by uptake from soil and to ROPCs by external radiation in soil. Terrestrial animals are assumed to be exposed by ingestion of COPCs and ROPCs in soil and food and to ROPCs by external radiation in soil. Sediment invertebrates are assumed to be exposed to COPCs by direct contact with sediment. However, they are not evaluated separately for radiation exposure because the graded approach (DOE 2002) considers sediment as only a source for external radiation to aquatic biota. Fish and other aquatic biota are more sensitive to radiation than sediment invertebrates (DOE 2002), so it is assumed that conditions that do not cause harm to aquatic biota also adequately protect sediment invertebrates. Aquatic biota are assumed to be exposed to COPCs and ROPCs by uptake from surface water and to ROPCs by external radiation. Surface-feeding waterfowl (mallards) are assumed to be exposed to COPCs and ROPCs by ingestion of surface water and sediment, by ingestion of food containing COPCs and ROPCs taken up from surface water and sediment, and to ROPCs by external radiation from sediment and surface water. Terrestrial animals that are exposed mainly through the aquatic food chain (raccoons and herons, termed riparian animals in DOE 2002) are assumed to be exposed to COPCs and ROPCs by ingestion of surface water and sediment, by ingestion of food containing COPCs and ROPCs taken up from surface water and sediment, and to ROPCs by external radiation from sediment and surface water.

Because the methods for screening COPCs and ROPCs are different, they are presented separately. Methods for COPCs are presented in Section 4.3.2 and methods for ROPCs are presented in Section 4.3.3.

4.3.2 Screening for COPCs

Screening for COPCs in soil, sediment, and surface water is evaluated by using a sequence of steps that lead to a decision whether to proceed to a more detailed BRA. This is shown diagrammatically on Figure 4.3. The screening for COPCs comprises two types. The first is a comparison of NFSS site-wide maximum concentrations of SRCs in abiotic media to ESVs for those media (Section 4.3.2.1, item 1). This approach conservatively rules out COPCs for which risks are negligible and determines whether the entire site can be dismissed for further evaluation. The second type of screen is based on EPA ERAGS (EPA 1997b). It consists of comparisons of calculated receptor-specific doses (average daily dose [ADD]) of COPCs at each EU to receptor-specific TRVs (Section 4.3.2.1, items 2 and 3). The dose calculations begin with maximum COPC concentrations and conservative assumptions about diet (Section 4.3.2.1, item 2) and progress to EPCs and more realistic assumptions about diet (Section 4.3.2.1, item 3), rather than being based exclusively on the most contaminated prey item. The components of this approach are described in the following subsections.

4.3.2.1 Screening Steps for COPCs

The screening steps progress from a general or site-wide screen through a more specific or EU-screen to a scientific/management decision point (see Figure 4-1). They are described as follows:

1. General screening step 1 – Use the maximum detected concentration of each SRC in soil, sediment, and surface water from the NFSS-wide data set and compare them to the media-specific ESVs. If the maximum detected site-wide concentration of the COPC for a given medium does not exceed the corresponding ESV, then that COPC does not require any further evaluation for that medium because its ecological risk is deemed negligible. However, if the maximum site-wide concentration of the COPC in an abiotic medium does exceed the corresponding ESV, if there is no ESV, or if the COPC is a PBT chemical, the COPC requires further evaluation and carries forward to the next step of the general screen.

2. General screening step 2 – Use the maximum detected concentration of each COPC in soil, sediment, and surface water from each EU along with receptor-specific exposures and benchmarks. For plants, soil invertebrates, aquatic biota, and sediment-dwelling biota, the exposure concentrations are the EU-specific maximum concentrations of COPCs in surface soil, surface water, and sediment, respectively. For wildlife receptors, the exposures are based on diets consisting entirely of the most highly contaminated food to calculate ADDs to the terrestrial and riparian mammals and birds. Calculate HQs for all receptors by dividing the soil concentrations by the TRVs for terrestrial plants and invertebrates, dividing the ADDs for terrestrial mammals and birds by the TRVs for those receptors, dividing the sediment concentrations by the TRVs for benthic invertebrates, dividing the surface water concentrations by the TRVs for aquatic biota, and dividing the ADDs for riparian mammals and birds by the TRVs for those receptors. Sum the HQs separately for organic and inorganic COPCs to obtain hazard indices (HIs) for soil, sediment, and surface water. If the sum of the HQs for each receptor is less than or equal to 1, risks from exposure to COPCs is judged to be negligible at all locations on the NFSS. If the sum of HQs is greater than 1 for any receptor, identify the COPCs that contribute most to the exceedance. Determine whether they are known to have toxic effects different from one another and consider grouping the HQs by mechanism of toxicity. If the sum of HQs for each group of COPCs with different toxic effects is less than or equal to 1, no further evaluation is required. For this step, the terrestrial mammals and birds are cottontail rabbit, white-tailed deer, short-tailed shrew, American robin, red fox, and red-tailed hawk. Surface-feeding waterfowl are mallards. Riparian animals are raccoon and great blue heron.

3. Site-specific analysis step – This step uses a conservative estimate of RME concentrations in EUs to identify EUs that require no further analysis. The RME is the lower of the 95% UCL of the mean and the maximum detected value. Use the RME concentration of each COPC in soil, sediment, and surface water from each EU along with dietary intakes presented in Tables 4.3 through 4.11 to calculate ADDs to the terrestrial and riparian mammals and birds. Calculate HQs for all receptors by dividing the soil concentrations by the TRVs for terrestrial plants and invertebrates, dividing the ADDs for terrestrial mammals and birds by the TRVs for those receptors, dividing the sediment concentrations by the TRVs for benthic invertebrates, dividing the surface water concentrations by the TRVs for aquatic biota, and dividing the ADDs for riparian mammals and birds by the TRVs for those receptors. Sum the HQs separately for organic and inorganic COPCs in soil, sediment, and surface water to obtain hazard indices (HIs). If the HIs for each receptor are less than or equal to 1, that EU does not need to be analyzed further. If the HIs are greater than 1 for any receptor, identify the COPCs that contribute most to the exceedance. Determine whether they are known to have toxic effects different from one another and consider grouping the HQs by mechanism of

toxicity. Proceed to a scientific/management decision point. If the HIs for each group of COPCs with different toxic effects are less than or equal to 1, no further evaluation is required. For this step, the terrestrial mammals and birds are cottontail rabbit, white-tailed deer, short-tailed shrew, American robin, red fox, and red-tailed hawk. Surface-feeding waterfowl are mallards. Riparian animals are raccoon and great blue heron.

4. Scientific/management decision point – Compare the risks calculated in step 2 to results using background concentrations of COPCs. Decide whether to carry out 1) NFA; 2) a weight-of-evidence evaluation; or 3) a comprehensive BERA, including collection of biota samples, evaluation of exposure frequencies, toxicity tests, etc.

4.3.2.2 Effects Evaluation for COPCs

Measures of toxicity such as effects on growth, reproduction, or survival are used as endpoints for the ESVs and TRVs that are used to compute HQs. The ESVs and TRVs are derived from published studies of exposure of various ecological receptors to contaminants under controlled conditions, and represent concentrations of a contaminant that are intended to be protective to receptors similar to those associated with the ESVs or TRVs.

The recommended ESVs (Appendix Table C-1 through C-3) for each abiotic medium were the lowest screening benchmarks from among the published benchmarks that were available in the open scientific literature. See table columns and footnotes for sources of toxicity data. Toxicity endpoints for TRVs for plants and soil invertebrates are shown in Appendix Tables C-4 and C-5. The preferred endpoint for mammals and birds is a chronic NOAEL for a measure of population maintenance, such as reproduction. If a chronic NOAEL is not available, a substitute is computed by one of the following procedures:

- divide a subchronic or acute NOAEL by 10,
- divide a chronic Lowest Observed Adverse Effects Level (LOAEL) by 10, or
- divide a subchronic or acute LOAEL by 100.

These values are used as TRVs for the computation of HQs for mammals and birds and are shown in Appendix Tables C-6 and C-7. Toxicity endpoints for TRVs for aquatic biota (Appendix Table C-9) and for sediment invertebrates (Appendix Table C-8) are also provided with sources listed on the tables.

4.3.2.3 Exposure Evaluation for COPCs

This subsection presents equations that are used to compute daily doses of non-radioactive chemicals. The dose that results from exposure of a receptor to chemicals in soil, sediment, or surface water is the product of the concentration of the chemical in the medium and exposure factors. Exposure factors describe how much of the available chemical is taken up by the receptor per unit of concentration in the medium. Exposures are calculated for the NFSS-wide and EU-specific analysis steps by assuming that the most likely contaminated food item makes up 100% of the diet, that the receptor is present at the NFSS 100% of the time, and all of the COPCs in the ingested food are absorbed.

Equations used to calculate exposure to COPCs are adapted from BCG equations for radionuclides (DOE 2002). Equations are given here for:

- terrestrial plants,
- soil invertebrates,
- terrestrial mammals and birds (rabbit, deer, shrew, robin, fox, and hawk),
- benthic invertebrates,
- aquatic biota,
- surface-feeding waterfowl (mallard), and
- riparian animals (raccoon, and heron).

Terrestrial plants

Exposure equations are not needed for terrestrial plants because the TRV for plants is the concentration in soil. Therefore, the measure of exposure of plants is the concentration of the COPC in soil at the NFSS or EU (Csoil, µg/kg dry weight for organics or mg/kg dry weight for inorganics).

Terrestrial soil invertebrates

Exposure equations are not needed for terrestrial invertebrates because the TRV for terrestrial invertebrates is the concentration in soil. Therefore, the measure of exposure of terrestrial invertebrates is the concentration of the COPC in soil at the NFSS or EU (Csoil, µg/kg dry weight for organics or mg/kg dry weight for inorganics).

Terrestrial animals (rabbit, deer, shrew, robin, fox, and hawk)

Terrestrial animals are exposed to COPCs by ingestion of food and soil. The equation for exposure of terrestrial animals (designated ta) to a single COPC in contaminated soil is:

$$ADD(soil, ta) = Csoil \times [CFta \times (SPv \times PI + BCFa \times AI + SI)]$$

where:

ADD(soil, ta)	=	ADD of COPC from soil (mg/kg fresh body weight/d);
Csoil	=	Concentration of COPC in soil (mg/kg dry weight);
CFta	=	Correction factor (CF) for area use or residence time of the receptor in the contaminated area (unitless, 1 unless specifically adjusted);
SPv	=	Soil-to-plant bioaccumulation factor [BAF mg/kg fresh tissue per mg/kg dry soil = (kg dry soil/kg fresh plant)];
PI	=	Plant intake (kg fresh plant/kg fresh body weight/d);
BAFa	=	Soil-to-animal BAF for terrestrial animals used as prey [mg/kg fresh tissue per mg/kg dry soil = (kg dry soil/kg fresh tissue)];
AI	=	Animal intake (kg fresh animal/kg fresh body weight/d); and
SI	=	Soil intake (kg dry soil/kg fresh body weight/d).

Receptor-specific intake parameters are discussed in Section 4.3.4, and chemical-specific BAFs are discussed in Section 4.3.5. Methods for the calculation of BAFa are presented in Section 4.3.6.

Benthic invertebrates

Exposure equations are not needed for benthic invertebrates because the TRV for benthic invertebrates is the concentration in sediment. Therefore, the measure of exposure of benthic

invertebrates is the concentration of the COPC in sediment at the NFSS or EU (Csed, µg/kg dry weight for organics or mg/kg dry weight for inorganics).

Aquatic biota

Exposure equations are not needed for aquatic biota because the TRV for aquatic biota is the concentration in surface water. Therefore, the measure of exposure of aquatic biota is the concentration of the COPC in surface water at the NFSS or EU (Csw, µg/L or mg/L).

Surface-feeding waterfowl (mallard), sediment

Surface-feeding waterfowl are exposed to COPCs in sediment by ingestion of food and sediment. The equation for exposure of surface-feeding waterfowl (designated wf) to a single COPC in sediment is:

$$ADD(sed, wf) = Csed \times [CFwf \times (SPv \times PI + BAFsed \times AI + SI)]$$

where:

ADD(sed, wf)	=	ADD of COPC from sediment (mg/kg fresh body weight/d);
Csed	=	Concentration of COPC in sediment (mg/kg dry weight);
CFwf	=	CF for area use or residence time of the receptor in the contaminated area (unitless, 1 unless specifically adjusted);
SPv	=	Sediment-to-plant BAF [mg/kg tissue per mg/kg dry sediment = (kg dry sediment/kg fresh plant)];
PI	=	Plant intake (kg fresh plant/kg body weight/d);
BAFsed	=	Sediment-to-biota BAF for prey [mg/kg tissue per mg/kg sediment = (kg dry sediment/kg fresh tissue)];
AI	=	Animal intake (kg fresh animal/kg body weight/d); and
SI	=	Sediment intake (kg dry sediment/kg body weight/d).

Receptor-specific intake parameters are discussed in Section 4.3.4, and chemical-specific BAFs are discussed in Section 4.3.5.

Surface-feeding waterfowl (mallard), water

Surface-feeding waterfowl are exposed to COPCs in surface water by ingestion of water. The equation for exposure of surface-feeding waterfowl (designated wf) to a single COPC in surface water is:

$$ADD(water, wf) = Csw \times CFwf \times WI$$

where:

ADD(water, wf)	= ADD of COPC from surface water (mg/kg fresh body wt-d);
Csw	= Concentration of COPC in surface water (mg/L);
CFwf	= CF for area use or residence time of the receptor in the contaminated area (unitless, 1 unless specifically adjusted);
WI	= Water intake (L/kg fresh body weight/d).

Receptor-specific intake parameters are discussed in Section 4.3.4.

Riparian animals (raccoon and heron), sediment

Riparian animals are exposed to COPCs in sediment by ingestion of food and sediment. The equation for exposure of riparian animals (designated ra) to a single COPC in sediment is:

$$ADD(sed, ra) = Csed \times [CFra \times (SPv \times PI + BAFsed \times AI + SI)]$$

where:

ADD(sed, ra)	=	ADD of COPC from sediment (mg/kg fresh body weight/d);
Csed	=	Concentration of COPC in sediment (mg/kg dry weight);
CFra	=	CF for area use or residence time of the receptor in the contaminated area (unitless, 1 unless specifically adjusted);
SPv	=	Sediment-to-plant BAF [mg/kg fresh tissue per mg/kg dry sediment = (kg dry sediment/kg fresh plant)];
PI	=	Plant intake (kg fresh plant/kg body weight/d);
BAFsed	=	Sediment-to-aquatic biota BAF for prey [mg/kg fresh tissue per mg/kg dry sediment = (kg dry sediment/kg fresh tissue)];
AI	=	Animal intake (kg/fresh animal/kg body weight/d); and
SI	=	Sediment intake (kg dry sediment/kg body weight/d).

Receptor-specific intake parameters are discussed in Section 4.3.4, and chemical-specific BAFs are discussed in Section 4.3.5.

Riparian animals (raccoon and heron), water

Riparian animals are exposed to COPCs in surface water by ingestion of food and water. The equation for exposure of riparian animals (designated ra) to a single COPC in contaminated surface water is:

$$ADD(water, ra) = Csw \times [CFra \times (BCFaq \times AI + WI)]$$

where:

ADD(water, ra)	=	ADD of COPC from surface water (mg/kg fresh body wt-d);
Csw	=	Concentration of COPC in surface water (mg/L);
CFra	=	Correction factor for area use or residence time of the receptor in the contaminated area (unitless, 1 unless specifically adjusted);
BCFaq	=	Water-to-aquatic biota bioconcentration factor (BCF) for prey [mg/kg fresh tissue per mg/L surface water = (L surface water/kg fresh tissue)];
AI	=	Animal intake (kg fresh animal/kg fresh body weight/d); and
WI	=	Water intake (L/kg fresh body weight/d).

Receptor-specific intake parameters are discussed in Section 4.3.4, and chemical-specific BCFs are discussed in Section 4.3.5.

4.3.2.4 Screening-level Risk Characterization for COPCs

Risks from exposure to COPCs are computed by dividing the total exposure to a COPC (sum of ADDs for all exposure media) by the corresponding TRV. This is the ratio of the daily exposure to the allowable daily dose that is attributable to the COPC. Because the mechanisms of toxicity

may differ among COPCs, toxic effects of exposure may not be additive. However, EPA guidance (EPA 1997a) states that the effects of many dissimilar COPCs appear to be additive. Therefore, the HQs are summed to obtain a HI, for a conservative estimate of total risk. As described in Section 4.3.2.1, if the HI is less than or equal to 1, the NFSS or EU does not need to be evaluated further. If the HI is greater than 1, the screening evaluation moves to the next step (Section 4.3.2.1).

4.3.3 Screening for ROPCs

Screening of ROPCs in soil, sediment, and surface water is evaluated by using U.S. DOE's graded approach (DOE 2002), which progresses from a general screen to a site- and receptor-specific screen. This is shown diagrammatically in Figure 4.4. The graded approach for evaluating radiation doses to aquatic and terrestrial biota is consistent with the standard ecological risk assessment paradigm in that it moves from a simple, relatively conservative screening evaluation to a more detailed and realistic assessment. Each step in the graded approach addresses the principal ERA components, and is a framework for organizing the successively rigorous steps, but with a particular emphasis on ionizing radiation. The graded approach does allow some flexibility in implementation of the steps, based on the characteristics of the site-data and professional judgment of the risk assessors. The components of this approach for screening ROPCs for the NFSS are described in the following subsections.

4.3.3.1 Screening Steps for ROPCs

The screening steps are defined in detail for radionuclide exposure by DOE (2002). The screens grow progressively more specific, as follows:

A. General screening step – Divide the maximum detected concentration of each ROPC in soil, sediment, and surface water from the NFSS-wide data set by the corresponding generic BCG. Sum the fractions separately for ROPCs in soil, sediment, and surface water. If the sum of fractions for radionuclides in soil or in sediment and surface water together is less than or equal to 1, risks from radionuclide exposure are judged to be negligible at all locations on the NFSS. If the sum of fractions is greater than 1, determine which ROPCs contribute the most to the exposure. This step is carried out by using DOE's RAD-BCG calculator, a spreadsheet program that contains the uptake factors, dose conversion factors, and other parameters necessary to do the exposure calculations for media-specific default receptors. For this step, the default terrestrial animal is the deer mouse, and the default riparian animal is the raccoon (DOE 2002). The default aquatic animal is a hypothetical small fish (DOE 2002). Further evaluation continues with a multistep site-specific analysis, beginning with the site-specific screening (Step B).

B. Site-specific analysis, step 1 – This step uses maximum concentrations in EUs to identify EUs that require no further analysis. Divide the maximum detected concentration of each ROPC in soil, sediment, and surface water from each EU by the corresponding generic BCG from step A. Sum the fractions separately for ROPCs in soil, sediment, and surface water. If the sum of fractions for radionuclides in soil or in sediment and surface water together is less than or equal to 1, that EU does not need to be analyzed further. If the sum of fractions is greater than 1, determine which ROPCs contribute the most to the exposure. Further evaluation continues with site-specific analysis (Step D).

C. Site-specific analysis, step 2 – This step uses average concentrations in EUs to identify EUs that require no further analysis. Divide the average concentration of each ROPC in soil, sediment, and surface water from each EU by the corresponding generic BCG from step A. Sum the fractions separately for ROPCs in soil, sediment, and surface water. If the sum of fractions for radionuclides in soil or in sediment and surface water together is less than or equal to 1, that group of analytes does not need to be analyzed further. If the sum of fractions is greater than 1, determine which ROPCs contribute the most to the exposure. Further evaluation continues with site-specific analysis (Step 3).

D. Site-specific analysis, step 3 – This step ensures that BCGs are appropriate for receptors at EUs that require further analysis. Identify the medium (soil, sediment, or surface water) and biota type (plant or animal) that causes failure of the screen. Modify BCGs with site-specific parameters (determine whether the limiting biota type is present at the NFSS) and whether the data can be re-aggregated. Site-specific BCGs for the receptors at risk are calculated by using published or calculated BAFs and the exposure equations given in the DOE graded approach (DOE 2002). These equations are presented in Section 4.3.3. BAFs are discussed further in Section 4.3.5**.** Divide the average concentration by the corresponding site-specific BCG. Sum the fractions separately for ROPCs in soil, sediment, and surface water. If the sum of fractions for radionuclides in soil or in sediment and surface water together is less than or equal to 1, that EU does not need to be analyzed further. If the sum of fractions is greater than 1, determine which ROPCs contribute the most to the exposure. The evaluation continues.

E. Site-specific analysis, step 4 – This step refines site-specific BCGs for receptors that appear to be adversely affected at the NFSS. Identify specific receptors that cause failure of the screen. Modify site-specific BCGs with receptor-specific parameters (allometric vs default BAFs, and the fraction of time the receptor is likely to be at the NFSS). In this step BAFs are calculated by using the allometric equations found in U.S. DOE's graded approach (DOE 2002), and realistic Area Use Factors (AUFs) are used for the receptors that are potentially at risk. Divide the average concentration of each ROPC for the limiting receptor in each EU by the corresponding revised BCG. Sum the fractions separately for ROPCs in soil, sediment, and surface water. If the sum of fractions for radionuclides in soil or in sediment and surface water together is less than or equal to 1, then further analyzation is not required. If the sum of fractions is greater than 1, a Scientific/management decision point is reached.

F. Scientific/management decision point – Compare risks calculated in step E to results using background levels of ROPCs. Decide whether to carry out 1) NFA; 2) a weight-of-evidence evaluation whether to perform a site-specific biota dose assessment; 3) a comprehensive BERA, including collection of biota samples, evaluation of exposure frequencies, etc.; or 4) actions to reduce radiological exposure to the ecological receptors.

As mentioned in the beginning of this section, the graded approach for screening ROPCs does permit flexibility in implementing specific steps of the process. The method states, "Any of the steps within the graded approach can be used at any time, but the general screening methodology will usually be the simplest, most cost-effective, and least time-consuming" (DOE 2002). Therefore, there is some latitude in applying the graded approach. For example, a preliminary review of the data may indicate that the NFSS is unlikely to pass the general screen (step A), and the evaluation might start with the EU-specific screen (step B). Alternatively, a review of the data might indicate that after completion of the general screen (step A), the process could move

directly to the site-specific screen using EU-averages (step C), thereby skipping the site-specific screen that uses EU-specific maximum concentrations.

4.3.3.2 Effects Evaluation for ROPCs

As previously stated, the BCG is the highest concentration of an ROPC in soil, sediment, or surface water that is expected to cause exposure of the receptors below a dose limit. DOE has determined (DOE 2002) that the daily dose limit for total radiation exposure is 1 rad/d for terrestrial plants and aquatic biota and 0.1 rad/d for mammals and birds. These values were stated by the National Council on Radiation Protection (NCRP 1987 and 1991) and the International Atomic Energy Agency (IAEA 1992) to be unlikely to cause harm to populations of those receptor types, and the limit of 1 rad/d for aquatic biota is included in DOE order 5400.5 (DOE 1990). Additional summaries and reviews of radiation effects data on biota confirmed the NCRP and IAEA findings (UNSCEAR 1996), United Kingdom Environmental Agency (Copplestone et al. 2001), and Canada's Atomic Energy Control Board (AECB 2002). These dose limits represent expected safe levels of exposure, and are consensus NOAELs for effects on population-relevant attributes in natural populations of biota (DOE 2002). These dose limits were used by DOE to compute BCGs for ROPCs (DOE 2002).

4.3.3.3 Exposure Evaluation for ROPCs

Exposure to ROPCs is a function of external and internal concentrations of ROPCs. Development of receptor-specific BCGs requires exposure equations that calculate external exposure to ROPCs and uptake and retention of ROPCs. The equations used to derive BCGs and the exposure equations are presented in the following subsection.

BCGs for ROPCs are calculated for:

- terrestrial plants,
- terrestrial animals,
- aquatic biota exposed to sediment,
- aquatic biota exposed to surface water,
- surface-feeding waterfowl,
- riparian animals exposed to sediment, and
- riparian animals exposed to surface water.

The estimated exposure of aquatic biota to ROPCs is calculated as the sum of internal exposure to ROPCs taken up from surface water and external exposure from sediment and surface water. The estimated exposure of riparian animals to ROPCs is calculated as the sum of internal exposure to ROPCs in food from sediment and surface water and external exposure from sediment and surface water. Equations for these exposures are presented below.

Terrestrial plants

Terrestrial plants are exposed to internal radiation by uptake from soil and by external radiation from soil. The equation for BCGs for terrestrial plants (designated tp) exposed to a single ROPC in soil is:

$$BCG(soil, tp) = DLtp / (SPv \times DCFint + DCFext,soil)$$

where:

BCG(soil, tp)	=	Concentration of ROPC in soil (pCi/g dry weight) that is expected to give a dose rate of DLtp to the terrestrial plant;
DLtp	=	Dose limit for terrestrial plants (1 rad/d);
SPv	=	Soil-to-plant BAF[pCi/g fresh tissue per pCi/g dry soil = (g dry soil/g fresh plant)];
DCFint	=	DCF to estimate the internal exposure to plant tissues from ROPC in the tissue (rad/d per pCi/g); and
DCFext,soil	=	DCF to estimate the external exposure to plant tissues from ROPC in soil (rad/d per pCi/g).

Radionuclide-specific BAFs and DCFs are discussed in Section 4.3.5.

Terrestrial animals (rabbit, deer, shrew, robin, fox, and hawk)

Terrestrial animals are exposed to internal radiation by uptake from food and ingested soil and by external radiation from soil. The equation for BCGs for terrestrial animals (designated ta) exposed to a single ROPC in soil is:

$$BCG(soil, ta) = DLta / [CFta \times (BAFta \times DCFint + DCFext,soil)]$$

where:

BCG(soil, ta)	=	Concentration of ROPC in soil (pCi/g dry weight) that is expected to give a dose rate of DLta to the terrestrial animal;
DLta	=	Dose limit for terrestrial plants (0.1 rad/d);
CFta	=	CF for area use or residence time of the receptor in the contaminated area (unitless, 1 unless specifically adjusted);
BAFta	=	Soil-to-animal BAF [pCi/g fresh tissue per pCi/g dry soil = (g dry soil/g fresh tissue)];
DCFint	=	DCF to estimate the internal exposure to animal tissues from ROPC in the tissue (rad/d per pCi/g); and
DCFext,soil	=	DCF to estimate the external exposure to animal tissues from ROPC in soil (rad/d per pCi/g).

Radionuclide-specific BAFs and DCFs are discussed in Section 4.3.5.

Aquatic biota, sediment

Aquatic biota are exposed to external radiation from sediment. The equation for BCGs for aquatic biota (designated aq) exposed to a single ROPC in sediment is:

$$BCG(sed, aq) = DLaq/ (CFaq \times DCFext, sed)$$

where:

BCG(sed, aq)	=	Concentration of ROPC in sediment (pCi/g dry weight) that is expected to give a dose rate of DLaq to the aquatic animal;
DLaq	=	Dose limit for aquatic animals (1 rad/d);
CFaq	=	CF for area use or residence time of the receptor in the contaminated area (unitless, 1 unless specifically adjusted);
DCFext,sed	=	DCF to estimate the external exposure to animal tissues from ROPC in sediment (rad/d per pCi/g).

Radionuclide-specific DCFs are discussed in Section 4.3.5.

Aquatic biota, water

Aquatic biota are exposed to internal radiation by uptake from water and to external radiation from water. The equation for BCGs for aquatic biota (designated aq) exposed to a single ROPC in surface water is:

$$BCG(water, aq) = DLaq / [CFaq \times (BCFaq \times DCFint + DCFext,water)]$$

where:

BCG(water, aq)	=	Concentration of ROPC in water (pCi/g) that is expected to give a dose rate of DLaq to the aquatic animal;
DLaq	=	Dose limit for aquatic animals (1 rad/d);
CFaq	=	CF for area use or residence time of the receptor in the contaminated area (unitless, 1 unless specifically adjusted);
BCFaq	=	Water-to-aquatic biota BCF [pCi/g fresh tissue per pCi/L water = (L water/g fresh tissue)];
DCFint	=	DCF to estimate the exposure to animal tissues from ROPC in the tissue (rad/d per pCi/L); and
DCFext,water	=	DCF to estimate the external exposure to animal tissues from ROPC in water (rad/d per pCi/L).

Radionuclide-specific BCFs and DCFs are discussed in Section 4.3.5.

Surface-feeding waterfowl (mallard), sediment

Surface-feeding waterfowl are exposed to internal radiation by uptake from food and sediment and by external radiation from sediment. The equation for BCGs for surface-feeding waterfowl (designated wf) exposed to a single ROPC in sediment is:

$$BCG(sed, wf) = DLra / [CFra \times (BAFra \times DCFint + DCFext, sed)]$$

where:

BCG(sed, wf)	=	Concentration of ROPC in sediment (pCi/g dry weight) that is expected to give a dose rate of DLra to the surface-feeding waterfowl;
DLra	=	Dose limit for waterfowl (0.1 rad/d);
CFra	=	CF for area use or residence time of the receptor in the contaminated area (unitless, 1 unless specifically adjusted);
BAFra	=	Sediment-to-animal BAF [pCi/g fresh tissue per pCi/g dry sediment = g dry sediment/g fresh tissue)];
DCFint	=	DCF to estimate the internal exposure to animal tissues from ROPC in the tissue (rad/d per pCi/g fresh tissue); and
DCFext,sed	=	DCF to estimate the external exposure to animal tissues from ROPC in sediment (rad/d per pCi/g dry sediment).

Radionuclide-specific BAFs and DCFs are discussed in Section 4.3.5.

Surface-feeding waterfowl (mallard), water

Surface-feeding waterfowl are exposed to external radiation from water. The equation for BCGs for surface-feeding waterfowl (designated wf) exposed to a single ROPC in surface water is:

$$BCG(sw, wf) = DLra / (CFra \times DCFext, sw)$$

where:

BCG(sw, wf)	=	Concentration of ROPC in surface water (pCi/L) that is expected to give a dose rate of DLra to the surface-feeding waterfowl;
DLra	=	Dose limit for waterfowl (0.1 rad/d);
CFra	=	CF for area use or residence time of the receptor in the contaminated area (unitless, 1 unless specifically adjusted); and
DCFext,sw	=	DCF to estimate the external exposure to animal tissues from ROPC in surface water (rad/d per pCi/L water).

Radionuclide-specific DCFs are discussed in Section 4.3.5.

Riparian animals (raccoon and heron), sediment

Riparian animals are exposed to internal radiation by uptake from food and sediment and to external radiation from sediment. The equation for BCGs for riparian animals (designated ra) exposed to a single ROPC in sediment is:

$$BCG(sed, ra) = DLra / [CFra \times (BAFra \times DCFint + DCFext, sed)]$$

where:

BCG(sed, ra)	=	Concentration of ROPC in sediment (pCi/g dry weight) that is expected to give a dose rate of DLra to the riparian animal;
DLra	=	Dose limit for riparian animals (0.1 rad/d);
CFra	=	CF for area use or residence time of the receptor in the contaminated area (unitless, 1 unless specifically adjusted);
BAFra	=	Sediment-to-animal BAF [pCi/g fresh tissue per pCi/g dry sediment = (g dry sediment/g fresh tissue)];
DCFint	=	DCF to estimate the internal exposure to animal tissues from ROPC in the tissue (rad/d per pCi/g fresh tissue); and
DCFext,sed	=	DCF to estimate the external exposure to animal tissues from ROPC in sediment (rad/d per pCi/g dry sediment).

Radionuclide-specific BAFs and DCFs are discussed in Section 4.3.5.

Riparian animals (raccoon and heron), water

Riparian animals are exposed to internal radiation by uptake from food and water and to external radiation from water. The equation for BCGs for riparian animals (designated ra) exposed to a single ROPC in surface water is:

$$BCG(sw, ra) = DLra / [CFra \times (BCFra \times DCFint + DCFext, sw)]$$

where:

BCG(sw, ra)	=	Concentration of ROPC in surface water (pCi/L) that is expected to give a dose rate of DLra to the riparian animal;
DLra	=	Dose limit for riparian animals (0.1 rad/d);
CFra	=	CF for area use or residence time of the receptor in the contaminated area (unitless, 1 unless specifically adjusted);
BAFra	=	Water-to-animal BAF [pCi/g fresh tissue per pCi/g surface water = (L water/kg fresh tissue)];
DCFint	=	DCF to estimate the exposure to animal tissues from ROPC in the tissue (rad/d per pCi/g fresh tissue); and
DCFext,sw	=	DCF to estimate the external exposure to animal tissues from ROPC in surface water (rad/d per pCi/L water).

Per DOE guidance (DOE 2002) BAFra may be calculated as the product of a water-to-fish BCF and a food-to-animal BAF. Radionuclide-specific BAFs and DCFs are discussed in Section 4.3.5.

4.3.3.4 Screening-level Risk Characterization for ROPCs

Risks from exposure to ROPCs are computed by dividing the concentration of each ROPC in the medium by the corresponding BCG. This results in the fraction of the allowable daily dose that is attributable to each ROPC. This fraction is equivalent to the HQ for COPCs. Because the mechanism of action of radiation is the same for all ROPCs, the fractions can be summed to compute the fraction of the allowable daily dose that is attributable to all ROPCs together. As described in Section 4.3.3.1, if the sum of fractions is less than or equal to 1, the NFSS or EU does not need to be evaluated further. If the sum of fractions is greater than 1, the screening evaluation moves to the next applicable step per the graded approach (Section 4.3.3.1).

4.3.4 Receptor Parameters

Calculation of receptor-specific BCGs requires parameters that describe the home range, body weight, food and water intake rates, and diet distribution. The indicator receptors for the screening ecological risk assessment (Section 4.2.4) are:

- terrestrial plants,
- earthworms,
- cottontail rabbit,
- white-tailed deer,
- short-tailed shrew,
- American robin,
- red fox,
- red-tailed hawk,
- benthic invertebrates,
- aquatic biota,
- mallard,
- raccoon, and
- great blue heron.

Receptor parameters are not needed for plants, earthworms, benthic invertebrates, or aquatic biota because BCGs for these receptors are empirically based rather than calculated. Receptor parameters for the other indicator receptors are shown in Tables 4.3 through 4.11.

4.3.5 BCFs, BAFs, and Other Exposure Parameters

Bioconcentration factors and BAFs are required in the exposure equations. Some of these values are available in guidance or other published literature, and some must be estimated. The order of preference for use of BCFs and BAFs is DOE guidance, other government agency guidance, open scientific literature, and calculations based on chemical properties. BCFs and BAFs can be calculated by using chemical properties of the COPCs and ROPCs such as the logarithm of the octanol-water partitioning coefficient [$\log(K_{ow})$], and the biological and radiological decay constants (λ_{bio} and λ_{rad}, respectively). Radionuclide-specific factors are presented in Appendix Table C-10; $\log(K_{ow})$ values can be found in Appendix Table C-11. However, predictions based on chemical properties rather than empirical observation can produce uptake factors that result in bioaccumulation of more contaminant than is present at the site. Therefore, a mass balance check is performed for each BAF to ensure that over-accumulation did not occur (Section 4.4). Receptor-specific parameters are also needed to calculate BAFs when empirically derived factors are not available. Receptor-specific parameters are presented in Section 4.3.4, in Tables 4.3 through 4.11.

4.3.5.1 BAFs for Terrestrial Plants (SPv)

Chemical concentrations in terrestrial plants are calculated by using factors for uptake from soil into the aboveground portion of plants. The concentration in aboveground portions of plants through root uptake from soil is a function of the chemical-specific soil concentration and chemical-specific plant BAFs (SPv).

SPvs for organic COPCs are taken from three sources and are presented in Appendix Table C-11. For most organic COPCs, SPvs are calculated using an equation developed by Travis and Arms (1988).

$$\log(SPv) = 1.588 - 0.578 \times \log(K_{ow})$$

where:

SPv = soil-to-plant BAF (kg dry soil/kg plant or g dry soil/g plant), and
K_{ow} = octanol-water partitioning coefficient (L/kg).

Values of $\log(K_{ow})$ are given in Tables C-10 and C-11. Additional information can be found in Appendix Table C-11.

SPVs for inorganic COPCs are taken from several sources, including EPA's *Soil Screening Guidance* (EPA 1996c), DOE uptake models (DOE 1998a), EPA guidance for hazardous waste combustion (EPA 1999a), WSDE Toxics Cleanup Program Table 749-5 (WSDE 2002), and Baes et al. (1984) and are provided in Table C-11. SPVs for ROPCs are taken from DOE's RAD-BCG calculator, WSDE (2002), or Baes et al. (1984) and are provided in Table C-11.

Empirically determined SPVs are used in preference to calculated or estimated values. Otherwise, the order of preference of the sources is the order in which they are given above. Default values (for example, from WSDE 2002) are not used if values based on chemical properties are available.

4.3.5.2 BAFs for Terrestrial Soil Invertebrates (BAFinv)

There are few published BAFs for uptake of COPCs and ROPCs from soil by terrestrial invertebrates. These are included in Table C-11. The WSDE has developed a soil screening method to evaluate contaminated sites (WSDE 2002). The method includes measured and default BAFs for soil invertebrates. For COPCs and ROPCs that have no published values, the following default values from that method are used (WSDE 2002):

- Nonchlorinated organic COPCs with log (K_{ow}) <5, 0.7;
- Nonchlorinated organic COPCs with log (K_{ow}) >5, 0.9;
- Chlorinated organic COPCs with log (K_{ow}) <5, 4.7;
- Chlorinated organic COPCs with log (K_{ow}) >5, 11.8; and
- Inorganic COPCs and ROPCs, 4.6.

These values are included in Table C-11.

4.3.5.3 BAFs for Terrestrial Animals (BAFta) and Riparian Animals (BAFra)

Published soil-to-animal BAFs are predominantly available only for soil invertebrates. For example, according to DOE guidance (DOE 2002), a soil-to-animal BAF for plant ingestion can be estimated as the product of SPv and a receptor-specific food-to-animal tissue BAF. Intake-to-tissue BAFs are available for beef cattle (Baes et al. 1984), but receptor-specific food-to-tissue data are not available for ecological receptors. Possible approaches for applying intake-to-beef BAFs to other animals include: 1) using the same intake-to-beef values along with calculations of receptor-specific daily COPC intake rate, 2) multiplying the intake-to-beef value by the ratio of receptor-specific food ingestion rate to the food ingestion rate for beef cattle, 3) scaling the intake-to-beef value to the metabolic rate of the receptor, or 4) using an equilibrium approach based on intake and depuration rates and not on the intake-to-beef values.

Some receptor-specific BAFs are found in WSDE Toxics Cleanup Program Table 749-5 (WSDE 2002). When receptor-specific published BAFs are not available, DOE (DOE 2002) recommends using an equilibrium calculation that depends on an allometric calculation of metabolic rate based on body weight. The food-to-tissue BAF is defined as the ratio of concentrations in tissue and food. The maximum concentration of a COPC or ROPC accumulated in tissues is determined by an equilibrium in which the uptake rate is equal to the depuration or elimination rate. The uptake rate is equal to the product of the average concentration in food, the rate of ingestion, and the fraction of ingested COPC or ROPC that is absorbed. The rate of ingestion is a function of body weight. The depuration rate is assumed to be related to metabolic rate, which is also a function of body weight.

When a previously unexposed animal becomes exposed to a constituent in its diet, the ratio of concentrations in tissue and food is low. The ratio increases as the constituent is accumulated until the maximum BAF is reached. A constituent that is accumulated slowly may not come to equilibrium during the lifetime of the animal, so a term for the time of exposure is included in the BAF equation. To ensure the maximum possible uptake, the value of the time term is the expected maximum lifespan of the receptor or twice the mean lifespan if a maximum value is not available. The following equations are derived from those presented by DOE (DOE 2002).

Terrestrial animals are assumed to be exposed to COPCs and ROPCs by ingestion of plants, terrestrial animals, and soil. The equation used to calculate the BAF for ingestion of COPCs and ROPCs in food and soil by terrestrial animals (designated ta) is:

$$BAFta = (PI \times SPv + AI \times BAFa + SI) \times f1 \times [1 - e^{(-(\lambda bio + \lambda rad) \times 365.25 \times T)}] / (\lambda_{bio} + \lambda_{rad})$$

where:

BAFta	=	Soil-to-tissue BAF for terrestrial animals [mg/kg fresh tissue per mg/kg dry soil or pCi/g fresh tissue per pCi/g dry soil = (kg dry soil/kg fresh tissue or g dry soil/g fresh tissue)];
PI	=	Plant ingestion rate (kg fresh plant/kg fresh body weight/d);
SPv	=	Soil-to-plant BAF [mg/kg fresh tissue per mg/kg dry soil or pCi/g fresh tissue per pCi/g dry soil = (kg dry soil/kg fresh plant or g dry soil/g fresh plant)];
AI	=	Animal prey ingestion rate (kg fresh animal/kg fresh body weight/d);
BAFa	=	BAF for animal prey [mg/kg tissue per mg/kg soil or pCi/g tissue per pCi/g soil = (kg dry soil/kg fresh tissue or g dry soil/g fresh tissue)];
SI	=	Soil ingestion rate (kg dry soil/kg body weight/d);
f1	=	Fraction of ingested COPC or ROPC that is retained (unitless, Table C-10);
e	=	Base of the natural logarithm;
λ_{bio}	=	Biological elimination constant for COPC or ROPC (d^{-1});
λ_{rad}	=	Radiological decay constant for ROPC (d^{-1}) = 0.693 / $T_{1/2}$, where $T_{1/2}$ = half-life of ROPC (d);
365.25	=	Correction factor (d/y); and
T	=	Lifespan of the receptor (y).

If both λ_{bio} and λ_{rad} are 0, i.e. in the case of a COPC for which λ_{bio} is not known, the expression $[1 - e^{(-(\lambda bio + \lambda rad) \times 365.25 \times T)}] / (\lambda_{bio} + \lambda_{rad})$ has a value of 1. Calculated values of BAFta are given in Table C-11.

Values of PI, AI, and SI are receptor-specific and are shown in Tables 4.3 through 4.11. Cottontail rabbits and white-tailed deer are assumed to be strict herbivores and, therefore, have an AI of 0. Values of SPv are given in Table C-11. If the receptor's animal diet is assumed to be earthworms (i.e., for shrew and robin), the value of BAFa is the BAFinv value from Table C-11. The animal prey of the red fox and red-tailed hawk is assumed to be shrews because shrews are highly exposed through their diet. Therefore, the BAFa value for exposure of fox and hawk are the BAFta values for shrews found in Table C-11.

Riparian animals are represented by raccoon and great blue heron. They are assumed to be exposed to sediment COPCs and ROPCs by ingestion of sediment. For ingestion of COPCs and ROPCs in sediment by a riparian animal,

$$BAFsed, ra = SI \times f1 \times [1 - e^{(-(\lambda bio + \lambda rad) \times 365.25 \times T)}] / (\lambda_{bio} + \lambda_{rad})$$

where:

BAFsed, ra	=	Sediment-to-tissue BAF [mg/kg fresh tissue per mg/kg dry sediment or pCi/g fresh tissue per pCi/g dry sediment = (kg dry sediment/kg fresh tissue or g dry sediment/g fresh tissue)];
SI	=	Sediment ingestion rate (kg dry sediment/kg fresh body weight/d);
f1	=	Fraction of ingested COPC or ROPC that is retained (unitless, Table C-11);
e	=	Base of the natural logarithm;
λ_{bio}	=	Biological decay constant for COPC or ROPC (d^{-1});
λ_{rad}	=	Radiological decay constant for ROPC (d^{-1}) = 0.693 / $T_{1/2}$, where $T_{1/2}$ = half-life of ROPC (d);
365.25	=	Correction factor (d/y); and
T	=	Lifespan of the receptor (y).

If both λ_{bio} and λ_{rad} are 0, i.e. in the case of a COPC for which λ_{bio} is not known, the expression $[1 - e^{(-(\lambda bio + \lambda rad)\times 365.25\times T)}] / (\lambda_{bio} + \lambda_{rad})$ has a value of 1. Values of BAFsed, ra are given in Table C-11.

Riparian animals are also assumed to be exposed to COPCs in surface water and aquatic biota. For ingestion of COPCs in food and surface water by a riparian receptor,

$$BAFsw, ra = (FI \times BCF + WI) \times f1 \times [1 - e^{(-(\lambda bio + \lambda rad)\times 365.25\times T)}] / (\lambda_{bio} + \lambda_{rad})$$

where:

BAFsw, ra	=	Water-to-tissue BAF [mg/kg fresh tissue per mg/L water = (L water/kg fresh tissue)];
FI	=	Aquatic food ingestion rate (kg fresh animal/kg fresh body weight/d);
BCF	=	BCF for aquatic biota (L water/kg fresh body wt);
WI	=	Water ingestion rate (L/kg fresh body weight/d);
f1	=	Fraction of ingested COPC or ROPC that is retained (unitless, Table C-10);
e	=	Base of the natural logarithm;
λ_{bio}	=	Biological elimination constant for COPC or ROPC (d^{-1});
λ_{rad}	=	Radiological decay constant for ROPC (d^{-1}) = 0.693 / $T_{1/2}$, where $T_{1/2}$ = half-life of ROPC (d);
365.25	=	Correction factor (d/y); and
T	=	Lifespan of the receptor (y).

If both λ_{bio} and λ_{rad} are 0, i.e. in the case of a COPC for which λ_{bio} is not known, the expression $[1 - e^{(-(\lambda bio + \lambda rad)\times 365.25\times T)}] / (\lambda_{bio} + \lambda_{rad})$ has a value of 1. Values of BCF are given in Table C-11.

Because the units of concentration are different for ROPCs from the units for COPCs, the equation for BAFsw, ra of ROPCs contains a unit correction factor. For ingestion of ROPCs in food and surface water by a riparian receptor,

$$BAFsw, ra = 0.001 \times (FI \times BCF + WI) \times f1 \times [1 - e^{(-(\lambda bio + \lambda rad)\times 365.25\times T)}] / (\lambda_{bio} + \lambda_{rad})$$

where:

BAFsw, ra = Water-to-tissue BAF [pCi/g fresh tissue per pCi/L water = (L water/g fresh tissue)];
0.001 = Correction factor, kg/g;
FI = Aquatic food ingestion rate (kg fresh food/kg fresh body weight/d);
BCF = BCF for aquatic biota (L water/kg fresh body wt);
WI = Water ingestion rate (L/kg fresh body weight/d);
f1 = Fraction of ingested COPC or ROPC that is retained (unitless, Table C-10);
e = Base of the natural logarithm;
λ_{bio} = Biological elimination constant for COPC or ROPC (d^{-1});
λ_{rad} = Radiological decay constant for ROPC (d^{-1}) = 0.693 / $T_{1/2}$, where $T_{1/2}$ = half-life of ROPC (d);
365.25 = Correction factor (d/y); and
T = Lifespan of the receptor (y).

Values of BAFsw, ra and BCF for ROPCs are given in Table C-11.

4.3.5.4 BCF for Aquatic Animals (BCFaq)

Published BCFaq values for aquatic animals are presented in Table C-11. For organic COPCs that have no published BCFaq, the following allometric equation (EPA 1999a) is used:

$$\log(BCFaq) = \log(0.91 \times \log(K_{ow}) - 1.975 \times [\log(6.8E\text{-}7 \times K_{ow} + 1) - 0.786]$$

where:

BCFaq = Water-to-aquatic biota bioconcentration factor (µg/kg fresh tissue per µg/L or mg/kg fresh tissue per mg/L; for units of pCi/g per pCi/L multiply by 0.001 g/kg), and
K_{ow} = Octanol-water partitioning coefficient.

Calculated BCFaq values are also given in Table C-11.

4.3.5.5 BAFs for Aquatic Plants

Aquatic plants are assumed to be rooted in sediment and have the same BAFs as terrestrial plants (SPv). SPvs for inorganic COPCs are taken from EPA (1999a) and Baes et al. (1984) and are provided in Table C-11. SPvs for ROPCs are taken from DOE's RAD-BCG calculator or Baes et al. (1984) and are provided in Table C-11.

4.3.5.6 Bioaccumulation Factors for Benthic Invertebrates (BAFsed)

There are few published BAFsed values for uptake of COPCs and ROPCs from sediment. The 90th percentile values from Table 2 of *Biota Sediment Accumulation Factors for Invertebrates: Review and Recommendations for the Oak Ridge Reservation* (DOE 1998b) are included in Table C-11. For other COPCs and ROPCs, default values for uptake from soil by terrestrial invertebrates (WSDE 2002) are used. They are:

- Nonchlorinated organic COPCs with log (K_{ow}) <5, 0.7;
- Nonchlorinated organic COPCs with log (K_{ow}) >5, 0.9;

- Chlorinated organic COPCs with log (K_{ow}) <5, 4.7;
- Chlorinated organic COPCs with log (K_{ow}) >5, 11.8; and
- Inorganic COPCs and ROPCs, 4.6.

These values are included in Table C-11.

4.3.5.7 Sediment-to-Water and Water-to-Sediment Concentration Conversions

Exposure of aquatic and riparian biota to radiation is evaluated for sediment and surface water simultaneously. Although surface water is intermittent at some locations at the NFSS, exposure to sediment and water together is evaluated to ensure a conservative screen. When only the sediment or surface water concentration is known at a particular location, DOE (2002) recommends estimating the missing value by using the soil-water partitioning coefficient K_d. Equations are slightly different for COPCs and ROPCs because of the units of concentration in water and sediment. The equation to estimate surface water concentration (designated Csw) from sediment concentration (designated Csed) for COPCs is:

$$Csw = Csed / K_d$$

where:

Csw = Concentration in surface water (mg/L);
Csed = Concentration in sediment (mg/kg dry sediment); and
K_d = Soil-water partitioning coefficient (L/kg dry sediment).

The equation to estimate surface water concentration (designated Csw) from sediment concentration (designated Csed) for ROPCs is:

$$Csw = Csed / 0.001 \times K_d$$

where:

Csw = Concentration in surface water (pCi/L);
Csed = Concentration in sediment (pCi/g dry sediment);
0.001 = Conversion factor, kg/g; and
K_d = Soil-water partitioning coefficient (L/kg dry sediment).

Conversely, the equation to estimate sediment concentration (designated Csed) of COPCs from surface water concentration (designated Csw) is:

$$Csed = Csw \times K_d$$

where:

Csed = Concentration in sediment (mg/kg dry sediment);
Csw = Concentration in surface water (mg/L); and
K_d = Soil-water partitioning coefficient (L/kg dry sediment).

The equation to estimate sediment concentration (designated Csed) of ROPCs from surface water concentration (designated Csw) is:

$$Csed = Csw \times 0.001 \times K_d$$

where:

Csed	=	Concentration in sediment (pCi/g dry sediment);
Csw	=	Concentration in surface water (pCi/L);
0.001	=	Conversion factor, kg/g; and
K_d	=	Soil-water partitioning coefficient (L/kg dry sediment).

Risks to the ecological receptors at NFSS are characterized in Section 4.5 by using the BCGs calculated with the equations presented in Section 4.3.2, exposures calculated with the equations presented in Section 4.3.3, the receptor parameters presented in Section 4.3.4, the bioconcentration factors presented in Section 4.3.5 and TRVs presented in Section 4.4. The results of this characterization will lead to a scientific/management decision point at which the course for further action will be decided.

4.4 SCREENING LEVEL EXPOSURE ESTIMATES AND RISK CHARACTERIZATION

Screening level exposure estimates were conducted in a series of steps of increasing specificity, as described for chemical SRCs in Section 4.3.2 and for radionuclide SRCs in Section 4.3.3. These steps allowed a screening level characterization of risks at the NFSS EUs.

For chemicals, a general screen (Step 1) of maximum SRC concentrations throughout NFSS was used to identify SRCs that required further site-by-site evaluation. The site-by-site evaluation was done by estimating the ADD exposure of each receptor from a) the maximum concentrations (Step 2), and b) where necessary, RME concentrations of SRCs in each EU (Step 3). Section 4.4.1 presents the screening level risk estimates for chemical SRCs.

For radionuclides, a general screen (step not numbered) of maximum SRC concentrations throughout NFSS was used to determine whether further site-by-site evaluation was necessary. In the first analysis step (Analysis Step 1), the maximum concentrations of SRCs in each EU were compared to BCGs) to identify EUs for which further evaluation was necessary. Successively more specific exposure estimates (Analysis Steps 2 and 3) were conducted at those EUs to characterize the radiation risks. Section 4.4.2 presents the screening level risk estimates for SRC radionuclides.

4.4.1 Chemicals

For chemicals, a general screen of maximum SRC concentrations was followed by site-by-site evaluation (Section 4.3.2.1). The ADD for each SRC and each receptor was divided by the corresponding toxicity reference value (TRV) to calculate HQs. Results of the screens are presented in the following subsections.

4.4.1.1 General Screen of SRCs (Step 1)

The maximum site-wide concentrations of SRCs were compared to the ESVs shown in Tables C-1, C-2, and C-3. In addition, organic chemicals for which the logarithm of the octanol-water partition coefficient (log K_{ow}) is above 3, along with cadmium, lead, mercury, and zinc, were declared to be persistent, bioaccumulative, or toxic (PBT) chemicals (Appendix Tables C-12 through C-14) and were retained (NYSDEC 2002), as was any COPC with no ESV. Appendix Table C-12 presents the site-wide screen of soil SRCs; Table C-13 presents the site-wide screen of sediment SRCs; and Table C-14 presents the site-wide screen of SRCs in surface water.

As a result of the general screening Step 1, 48 organic SRCs and 23 inorganic SRCs in soil (Table 4.12), 0 organic SRCs and 12 inorganic SRCs in sediment (Table 4.13), and 6 organic SRCs and 15 inorganic SRCs in surface water (Table 4.14) were retained for further site-by-site evaluation.

4.4.1.2 Site-by-site Screen of Maximum SRC Concentrations (Step 2)

In the next screening step (Step 2), the maximum concentration of each SRC remaining after the general (site-wide) screen was used to estimate exposures and HQs for each receptor at each EU. Effects evaluation was described in Section 4.3.2.2, and exposure equations were described in Section 4.3.2.3. Some of the COPCs could not be evaluated quantitatively for all receptors because some COPCs did not have TRVs. The COPCs and receptors for which there were no TRVs for exposure to soil are shown in Appendix Table C-287. These COPCs were not carried forward to Step 3 screening because no additional information could be gained from further analysis.

The Step 2 screens for SRCs in soil are presented in Tables C-15 through C-119 and summarized in Appendix Table C-288, and the Step 2 screens for SRCs in sediment and surface water are presented in Tables C-120 through C-135 and summarized in Appendix Table C-289.

Table 4.15 summarizes the Step 2 screening results for soil. Of the 48 organic COPCs that were screened, the number retained ranged from 0 for EUs 1, 3, 6, 7, 9 and 14 to 7 at EUs 2, 8, 11, and the site-wide EU 17. All EUs had multiple inorganic COPCs with HQs above 1 (Table 4.15). Of the 23 inorganic COPCs that were screened, the numbers retained ranged from 7 at EUs 3, 6 and 7 to 17 at EUs 2 and the site-wide EU 17.

The results of the Step 2 screen of COPCs in sediment and surface are shown in Table 4.16. These two media are shown together because both contribute to exposure of mammals and birds that eat a combination of surface water and sediment biota. Of the 6 organic COPCs in surface water that were screened, 2 PAHs had HQs above 1 at EU 5. These COPCs at EU 5 were carried forward for Step 3 screening. Otherwise, no organic COPC had an HQ above 1. Of the 12 inorganic COPCs in sediment and 15 inorganic COPCs in surface water that were screened, the numbers of inorganic COPCs with HQs above 1 were 1 at EU 9, 9 at EU 5, and 19 at EU 15 and the site-wide EU 17.

4.4.1.3 Site-by-site Screen of SRC EPC Concentrations (Step 3)

RME concentrations were used in the Step 3 screen to calculate HQs for the COPCs carried forward from the Step 2 screen. RME concentrations of SRCs were defined as the lower of the 95% UCL of the mean concentration and the maximum observed concentration.

Step 3 screens for COPCs in soil are shown in Appendix Tables C-136 through C-240 and summarized in Appendix Table C-290. Table 4.17 shows a summary of the results of the Step 3 screen of COPCs in soil. One COPEC each was eliminated from EUs 2, 5, 13, and 17, two were eliminated from EU 6, and three were eliminated from EUs 8 and 10. Otherwise, no additional COPCs were eliminated by the Step 3 screen, but HQs were reduced. In some cases, but not all, receptors that had HQs above 1 in the Step 2 screen had HQs below 1 in the Step 3 screen. COPCs with HQ greater than 1 were retained for the scientific/management decision point.

Step 3 screens for COPCs in sediment and surface water are shown in Appendix Tables C-241 through C-256 and summarized in Appendix Table C-291. Table 4.18 shows a summary of the results of the Step 3 screen of COPCs in sediment and surface water. Benzo(a)anthracene and chrysene at EU 5 were the only organic COPCs retained for the scientific/management decision point. One inorganic COPC was eliminated at EU 5, but none were eliminated at EUs 9 and 15 the site-wide EU 17. Total uranium remained as the sole inorganic with an HQ above 1 at EU 9.

4.4.1.4 Summary of COPC Screening

Chemicals in soil, surface water, and sediment were screened by a series of steps described in Section 4.3.3.1. In the first (Step 1), the maximum concentration of each chemical SRC in all of the EUs was screened against soil, sediment, and surface water screening levels, and it was concluded that further analysis was required for all three media (Tables 4.12, 4.13, and 4.14). In Step 2 screening, HQs were calculated for terrestrial, aquatic, benthic, and riparian receptors using EU-specific maximum COPC concentrations. All EUs had multiple COPCs with HQs above 1 in soil (Table 4.15), while 4 EUs (5, 9, 15, and the site-wide EU 17) had COPCs with HQs above 1 in sediment and surface water (Table 4.16). In Step 3, HQs were calculated for terrestrial, aquatic, benthic, and riparian receptors using EU-specific RME COPC concentrations. All EUs still had multiple COPCs (mostly inorganics) with HQs above 1 in soil (Table 4.17), and EUs 5, 9, 15, and the site-wide EU 17 also had COPCs (mostly inorganic) with HQs above 1 in sediment and surface water (Table 4.18). Therefore, all soil EUs and 4 surface water and sediment EUs were retained for the scientific/management decision point.

4.4.2 Radionuclides

For radionuclides, a general screen of site-wide maximum SRC concentrations was used to determine whether to proceed with screening of EUs (Section 4.3.3.1). Maximum concentrations of SRC radionuclides in each EU were then compared to BCGs to determine which EUs could be dropped from further evaluation (Site-specific Analysis Step 1, Section 4.4.4.2). The Step 1 screen was followed by a comparison of average concentrations of SRC radionuclides in each EU to BCGs (Site-specific Analysis Step 2, Section 4.4.2.3). Site-specific Analysis Step 3, in which average concentrations of ROPCs are compared to site-specific BCGs, is presented in 4.3.3.1.

4.4.2.1 General Site-wide Screen of SRCs (no step number assigned)

The general screens for SRC radionuclides in soil, sediment, and surface water are presented in Appendix Tables C-258 and C-259, respectively. The fraction of the BCG for each radionuclide was calculated by dividing the site-wide maximum concentration by the BCG. If the sum of fractions for soil or the sum of fractions for sediment and surface water together is greater than 1, EU-specific analysis is required. The sum of fractions for BCGs for SRC radionuclides in soil was 29.7 (Appendix Table C-258), indicating that EU-specific (Step 1) analysis of soil was required. The sum of fractions for BCGs for SRC radionuclides in sediment and surface water

together was 0.8 (Appendix Table C-259), indicating that EU-specific (Step 1) analysis of sediment and surface water was not required.

4.4.2.2 EU-specific Analysis of Maximum Concentrations (Step 1)

The EU-specific Analysis Step 1 screens for SRC radionuclides in soil are presented in Tables C-260 through C-274. Comparison of maximum concentrations in soil at each EU to BCGs showed sums of fractions above 1 for 10 of the EUs (Table 4.19). These EUs were carried forward for EU-specific Analysis Step 2 (Section 4.4.2.3).

4.4.2.3 EU-specific Analysis of Mean Concentrations (Step 2)

The EU-specific Analysis Step 2 screens for SRC radionuclides in soil are shown in Appendix Tables C-275 through C-284. Sums of fractions of BCGs remained above 1 for 1 of the EUs (Table 4.20). Thus 9 EUs (EUs 1, 2, 5, 6, 7, 8, 11, 14, and the site-wide EU 17) were dropped in Step 2 compared to Step 1. EU 13 was carried forward for Analysis Step 3 (Section 4.4.2.4). The radionuclide giving the highest fraction of BCG at EU 13 was radium-226, which had a fraction of BCG of 1.4. All other sums of fractions were below 0.1, and, therefore, contribute little to the total radiation dose.

The EU-specific Analysis Step 2 screens for SRC radionuclides in sediment and surface water were not required. The sum of fractions was below 1 in the general site-wide screen (Appendix Table C-259), indicating that radionuclides in sediment and surface water required no further analysis.

4.4.2.4 EU-specific Analysis with Site-specific BAFs (Step 3)

The SRC contributing most to radiation doses, as indicated by the sums of fractions, was shown in Analysis Step 2 to be radium-226 at EU 13.

The most sensitive receptor group was terrestrial animals. For EU-specific Analysis Step 3, BCGs for the terrestrial animal receptors were calculated as described in Section 4.3.3.1, item D, using equations found in US DOE (2002) guidance. The derivation of BCGs for Analysis Step 3 is shown in Appendix Table C-285. Whenever the derived BCG was higher than the generic BCG given in DOE 2002, the derived value was used.

According to US DOE (2002) guidance, the mean concentration of ROPCs at a site is an appropriate measure of radiation exposure to terrestrial animals, both because 1) individual animals move about the EU and may be exposed to the entire range of concentrations and 2) radiation dose limits are intended to protect populations, which are expected to be dispersed over the EU or the site and therefore are collectively exposed to the entire range of concentrations. Therefore, the mean concentration of each ROPC in soil at EU 13 was divided by the calculated site-specific BCG, and the fractions were summed (Appendix Table C-286). EU 13 was below BCGs at Analysis Step 3 and was dropped from further consideration.

4.4.2.5 Summary of ROPC Screening

Radionuclides in soil, surface water, and sediment were screened by a series of steps described by DOE (2002). In the first, the maximum concentration of each ROPC in all of the EUs was screened against generic BCGs, and it was concluded that further analysis was required for soil but not for surface water and sediment. Further EU-specific analysis was conducted as described

in Section 4.3.3.1 and US DOE (2002) guidance. Table 4.21 summarizes the results of ROPC screening by Analysis Steps 1, 2, and 3. In Analysis Step 1, EU-specific maximum ROPC concentrations were screened against the same generic BCGs, and 10 of the 16 EUs were retained for further analysis of soil (Table 4.19). In Analysis Step 2, EU-specific mean ROPC concentrations were screened against the generic BCGs; 1 soil EU was retained for further analysis (Table 4.20). In Analysis Step 3, site-specific BCGs were calculated for terrestrial animals as specified by US DOE (2002) guidance, and the mean ROPC concentrations were screened against the site-specific BCGs; concentrations at EU 13 were below the site-specific BCGs. Therefore, all soil EUs and all surface water and sediment EUs were eliminated because results of the series of screening steps implies that these EUs are unlikely to cause harm to ecological populations as a result of radiation damage.

4.4.3 Summary of Screening and Future Steps

COPC screens at three increasing levels of site-and receptor-specificity were performed and were retained at most of the soil EUs for soil, sediment, and surface water at NFSS. After the sequence of COPC screens, PAHs, DDT, and metals in soil were retained for further evaluation at all of the soil EUs (Table 4.22). From the sediment/surface water viewpoint, PAHs were retained for further analysis at EU 5, and metals were retained for further analysis at EUs 5, 9, 15, and 17 (Table 4.23). Further detailed analysis is planned to be completed in the FS or another document.

ROPC screens at four increasing levels of site- and receptor-specificity were performed for soil, sediment, and surface water at NFSS. After the sequence of ROPC screens, no EU remained.

4.5 UNCERTAINTIES

Uncertainties are present in each step of the SERA process. Uncertainties in each of the four inter-related steps of the EPA approach to the SERA are discussed as follows:

- Problem Formulation (Section 4.5.1),
- Exposure Assessment (Section 4.5.2),
- Effects Assessment (Section 4.5.3), and
- Risk Characterization (Section 4.5.4).

Evaluation of these uncertainties is part of the SERA process (EPA 1998b). Overall, attempts to minimize uncertainty in the SLERA included performing the SERA in adherence to published methods (EPA 1997b) for evaluating chemicals and DOE (2002) for evaluating radionuclides. The methods approach for chemicals as well as radionuclides consisted of a graded series of steps, starting with a very conservative screening, and proceeding to less conservative, or more realistic receptor-specific steps. The intent of the graded approach for the SERA is to identify chemicals and radionuclides that can be dropped from further evaluation at the completion of each step, thereby increasing efficiency by not having to conduct redundant or unnecessary calculations for analytes posing negligible risk.

Within the Exposure Assessment, Effects Assessment, and Risk Characterization sections, there are separate uncertainty discussions, as applicable, for the general screening and site-specific screening steps. In addition, brief separate discussions for chemical versus radionuclide uncertainties are provided as applicable.

4.5.1 Problem Formulation

Uncertainties associated with problem formulation are related to issues such as the (1) description of the environmental setting, (2) completeness of the ECSM, (3) identification of assessment endpoints and measures, (4) selection of receptors and (5) EUs. The uncertainty associated with each of these issues is briefly discussed below.

Environmental Setting

Uncertainty regarding the environmental setting is low because the areal size of the NFSS is relatively small so it has been adequately evaluated and characterized with respect to topography, geology, on-site and surrounding land use, grounds maintenance, and terrestrial and aquatic habitats (i.e., vegetation and biota).

ECSM

The ECSM contains a low degree of uncertainty. For example, the contamination mechanism (i.e., sources from historical operations) and source media (i.e., soil) are well defined. The transport mechanisms, which account for the movement of constituents from abiotic media to ecological receptors, were not specifically measured for the SERA so they have associated uncertainty. Exposure media were likely adequately identified (air, soil, food chain, surface water, and sediment), but the determination of the environmental concentration of contaminants in those media at exposure locations was based on many assumptions because some degree of uncertainty exists about the exact, predicted spatial distribution of contaminants. Exposure concentrations could have been over or underestimated, depending on how well the sampling plan predicts contaminant distribution. Additional discussion of the uncertainty associated with the exposure concentrations is presented below in Section 4.5.2, Exposure Assessment. Because COPC and ROPC concentrations were often measured at locations where contamination is expected to be high, the resulting RME concentrations are likely to be biased higher than the true site average, resulting in an overestimate of risk to populations. Uncertainty associated with the receptors is discussed below in conjunction with the assessment endpoints. Uncertainty associated with the identification of reasonable exposure routes is expected to be low because the exposure routes thought to provide the most exposure (major exposure routes) were included in the ECSM and subsequently evaluated quantitatively in the SERA. Minor exposure routes were ones whereby receptors could receive exposure to contaminants, but were not evaluated quantitatively due to limited toxicity information.

Assessment Endpoints and Measures

Uncertainty regarding the assessment endpoints and measures (i.e., measures of exposure, measures of effect, and measures of ecosystem or receptor characteristics) is expected to be low. The assessment endpoints were selected to evaluate whether the management goals (protection of terrestrial and aquatic plant and animal populations from adverse effects due to releases of chemicals and radionuclides associated with the NFSS) were met. Accordingly, it is assumed that an adequate number of assessment endpoints were selected, based on the available habitats and likely types of biota to occur at the NFSS. Likewise, the measures were specifically selected to evaluate each assessment endpoint. For example, measures of exposure such as maximum concentrations (for general screening) of soil, sediment, and surface water and RME concentrations for receptor-specific screening were conservatively selected and designed to overestimate rather than underestimate risk. Other measures of exposure such as dietary composition and ingestion rates, as well as uptake factors were also conservative to overestimate rather than underestimate

ecological risk. Measures of effect (ESVs, NOAEL TRVs, BCGs) were also conservative to overestimate rather than underestimate risk.

Ecological Receptors

There is some uncertainty associated with the selection of ecological receptors or indicator species. Indicator species for the assessment endpoints were selected based on several criteria: the organism must first occur in a habitat in which there is potential risk of exposure to adverse effects due to chemical contaminants, the receptors must have an ability to provide measurable responses or adequate analytical samples, and the receptor must have a high probability of occurrence at the NFSS given the seasonality and range, and making the selection biased towards species sufficiently studied to date. The species were selected to represent a feeding guild, or group of organisms with similar feedings modes and diets, including threatened & endangered (T&E) species, where relevant. These species may or may not accurately reflect risks to observed or unknown species at a given site. Exposures may be lower for species not evaluated compared to receptor species. Some species not evaluated may be more or less sensitive than those receptors for which toxicity data were available. In addition, the distribution and abundance of organisms comprising the ecological receptors at exposure locations have not been quantified by field studies. Therefore, risks may be either overestimated or underestimated.

Exposure Units

The 17 EUs on the NFSS varied in size and shape. The EU spatial boundaries were generally based on historical patterns of on-site processing activities or facilities, but there is some uncertainty regarding the appropriateness of boundaries. For example, EU 1 is referred to as the Baker-Smith Area, and historically consisted of a storehouse, pipe shop, welding shop, and machine shop where potentially hazardous materials may have been used and where radioactive residues had been stored. EU 1 is an irregularly shaped parcel of approximately 6.9 acres, with two squared sides connected by an arced third side. EU 1 is assumed to contain only contaminants associated with the above facilities, but there is a low uncertainty whether (1) its contaminants could have migrated off to surrounding EUs or (2) been transported in from surrounding buildings/facilities. There is an assumed, similar low uncertainty for each of the 17 EUs.

4.5.2 Exposure Assessment

This section begins with a discussion of the general uncertainties associated with exposure assessment as it relates to the exposure of chemicals and radionuclides to ecological receptors (Section 4.5.2.1). It then discusses specific uncertainties regarding the exposure assessment for chemicals (Section 4.5.2.2) as well as radionuclides (Section 4.5.2.3).

4.5.2.1 Exposure Assessment General Uncertainty

A key component of the exposure assessment for both COPCs and ROPCs is the EPC in each media. Because the exposure concentrations were based on a limited number of samples, there is uncertainty associated with the representativeness of the maximum as well as RME exposure concentrations. However, use of the EPC tends to overestimate risk, as for many of the data sets, the EPC is actually the maximum detected concentration of the constituent in the EU. The uncertainty is expected to be acceptable because the number of samples was defined in an approved sampling and analysis plan.

For some chemicals not detected in any sample, the detection limits were higher than the concentrations that cause adverse effects so the actual concentrations may or may not have exceeded the toxicological benchmark. Thus, there is uncertainty whether those non-detected analytes are at concentrations that pose unacceptable risk to ecological receptors. Exposure to chemicals never detected are not considered in this SLERA. Chemicals detected at least once were evaluated using one-half the detection limit as a surrogate concentration for non-detects.

BAFs are a relatively large source of uncertainty. The actual uptake and accumulation of contaminants from soil by plants and soil invertebrates, from sediment by sediment-dwelling invertebrates, from water by fish, and from ingested matter by wildlife receptors is dependent on site-specific factors such as but not limited to the pH, organic-carbon, and mineral content of the soil and sediment, the suspended sediment load of the water, and age and condition of the wildlife receptors. Published bioaccumulation and bioconcentration factors recommended by EPA for use in screening-level risk assessments are generally thought to be conservative. However, BAFs calculated by DOE (2002) methods result in higher exposures than BAFs calculated by EPA (1999b) methods. As a result, HQs for some metals, for example, would be one or two orders of magnitude lower if calculated by EPA (1999b) methods. It is likely that SPv, BAFa, BAFsed and BCFaq values used in this SERA overestimate the concentrations of COPCs in biota and, thus, overestimate the risk to predators. However, it is possible that in some cases, bioaccumulation and, thus, risk were underestimated.

The movement of COPCs and ROPCs from the exposure locations through direct and indirect pathways to ecological receptors was estimated from soil, surface water, and sediment samples taken at selected locations. This introduces uncertainties about the actual modes and pathways of exposure and the actual exposure concentrations of these contaminants to the ecological receptors. Exposure concentrations can differ from the predicted environmental concentrations as a result of physical and chemical processes during transport from source to receptor. These processes were not predicted quantitatively in this SLERA, and this contributes to uncertainty.

The modes and pathways used to characterize exposure of ecological receptors are the most important ones for the relatively large and active species in terrestrial habitats. Soil-dwelling terrestrial animals may be exposed to contaminants in soil by way of inhalation. However, it is expected that the concentration of VOCs in soil interstices, cavities, and burrows will be very small, therefore, inhalation exposure was not evaluated in the SERA. Overestimating exposure by using conservative exposure concentrations is thought to compensate for the underestimation of exposure that may result from neglecting exposure modes and pathways of lesser importance. Additional uncertainties are inherent in ingestion rates and dietary fractions of plants and animals. Likewise, the effects of dermal exposure may be underestimated. All in all, the general uncertainties associated with the exposure assessment for ecological receptors likely overestimate risk because of conservative exposure factors.

4.5.2.2 Exposure Evaluation for COPCs

This section discusses specific uncertainties associated with the exposure assessment for COPCs. For the general screening step 1, the exposure concentrations were simply the NFSS site-wide maximum concentrations for each media. Thus, the uncertainty associated with those concentrations were the uncertainties previously mentioned regarding the representativeness of the data.

For the general screening step 2 and site-specific analysis step 3, there is uncertainty associated with the receptor-specific exposures. General screening step 2 uses EU- and media-specific

maximum concentrations along with receptor-specific dietary exposure equations (as applicable), whereas site-specific analysis step 3 uses EU- and media-specific RME concentrations. Exposure concentrations for terrestrial plants and soil invertebrates, benthic invertebrates, and aquatic biota for general screening step 2 and site-specific analysis step 3 are simply media-specific EU maximums and EU RMEs, respectively, so their uncertainty is associated with the representativeness of the data and any analytical uncertainty. Uncertainty regarding the exposures for wildlife for general screening step 2 and site-specific analysis step 3 is associated with the ADD equations and their parameter values. The ADD equations and the proportions of dietary components and food intake rates for the wildlife receptors are based on published dietary exposures so their uncertainty is assumed to be minimized. Selection of conservative parameters for the ADD equations was intended to overestimate rather than underestimate ecological risk.

4.5.2.3 Exposure Evaluation for ROPCs

This section discusses specific uncertainties associated with the exposure assessment for ROPCs. Unlike COPCs, exposure of ecological receptors to ROPCs is a function of external and internal concentrations of ROPCs. Thus, uncertainty in the exposure evaluation and equations for ROPCs must take into account parameters associated with external as well as internal exposures. Note that there are three points that imply that radiation dose (and thus, risk) was overestimated:

1. Assumption that all of gamma radiation is absorbed by the receptor, although Blaylock, Frank, and O'Neal 1993 and Sample et al. 1997 state that absorption of moderate- to high-energy gamma by small animals is low;

2. Assumption of a quality factor of 20 for alpha radiation, although Kocher and Trabalka 2000 state that a factor of 5 to 10 is more appropriate for ecological receptors; and

3. Assumption that all daughter radionuclides are present at 100% abundance after the parent is taken up by the receptor, although some of the daughters would take several months to come to equilibrium.

Uncertainties are discussed below for the exposures of ROPCs to the three generic receptors: (1) terrestrial animals (deer mouse), (2) aquatic biota exposed to sediment and to water, and (3) riparian animals exposed to sediment and to water. Note that one parameter in the exposure dose calculation for all receptors, CFta (area use or residence time of the receptor at the contaminated site), was set at 1 for conservatism.

Terrestrial animals

There is uncertainty associated with three parameters in the exposure dose calculation equation: BAFta (soil-to-animal uptake BAF), DCFint, and DCFext,soil (dose correction factors to estimate internal and external doses to animal tissues from ROPCs in tissues and soil, respectively). The BAFta values were calculated using equations published by DOE (DOE 2002). Uncertainties about BAFta values are the same as for inorganic COPCs. DCFs were obtained either from published values in DOE (2002) or were calculated according to the methods in Eckerman and Ryman (1993). There is uncertainty associated with the DCFs because they are based on radiation exposure to humans, not wildlife. For example, EU 13, with a sum of fractions of 1.4, did not pass the screen. However, the radiation dose at EU 13 is likely overestimated because the assumed relative biological effectiveness factor (Q) for alpha radiation overestimates damage from alpha decay. Most of the dose at EU 13 comes from radium-226 plus daughters (Appendix Table C-291), primarily from internal alpha radiation. The Q factor for alpha radiation is

assumed to be 20 (that is, one alpha decay causes 20 times as much damage as a beta or gamma decay of the same energy). However, Kocher and Trabalka (2000) state that Q for ecological receptors should be between 5 and 10. Using a conservative value of 10 for Q, the sum of fractions at EU 13 would be 0.7 rather than 1.4. Therefore, it is unlikely that exposures to ROPCs at EU 13 cause unacceptable damage to ecological populations. The uncertainties in the BAFta and DCFs are assumed to be low.

Aquatic biota exposed to sediment

There is uncertainty associated with one of the parameters in the exposure dose calculation equation: DCFext,sed (dose correction factor to estimate internal and external doses to animal tissues from ROPCs in sediment). DCFs were obtained either from published values in DOE (2002) or were calculated according to the methods in Eckerman and Ryman (1993). There is uncertainty associated with the DCFs because they are based on radiation exposure to humans, not wildlife. The uncertainties in the DCFs are assumed to be low.

Aquatic biota exposed to water

There is uncertainty associated with three parameters in the exposure dose calculation equation: BCFaq (water-to-animal uptake BAF), DCFint, and DCFext,water (dose correction factors to estimate internal and external doses to animal tissues from ROPCs in tissues and water, respectively). The BCFaq values were calculated using equations published by EPA (EPA 1999a). DCFs were obtained either from published values in DOE (2002) or were calculated according to the methods in Eckerman and Ryman (1993). There is uncertainty associated with the DCFs because they are based on radiation exposure to humans, not wildlife. The uncertainties in the BCFaq and DCFs are assumed to be low.

Riparian animals exposed to sediment

There is uncertainty associated with three parameters in the exposure dose calculation equation: BAFra (sediment-to-animal uptake BAF), DCFint, and DCFext,sed (dose correction factors to estimate internal and external doses to animal tissues from ROPCs in tissues and sediment, respectively). The BAFra values were calculated using equations published by DOE (DOE 2002). DCFs were obtained either from published values in DOE (2002) or were calculated according to the methods in Eckerman and Ryman (1993). There is uncertainty associated with the DCFs because they are based on radiation exposure to humans, not wildlife. The uncertainties in the BAFra and DCFs are assumed to be low.

Riparian animals exposed to water

There is uncertainty associated with three parameters in the exposure dose calculation equation: BCFra (water-to-animal uptake BAF), DCFint, and DCFext,water (dose correction factors to estimate internal and external doses to animal tissues from ROPCs in tissues and water, respectively). The BCFra values were calculated using equations published by EPA (EPA 1999a). DCFs were obtained either from published values in DOE (2002) or were calculated according to the methods in Eckerman and Ryman (1993). There is uncertainty associated with the DCFs because they are based on radiation exposure to humans, not wildlife. The uncertainties in the BCFra and DCFs are assumed to be low.

4.5.3 Effects Assessment

This section begins with a discussion of the general uncertainties associated with effects assessment as it relates to chemicals and radionuclides for ecological receptors (Section 4.5.3.1). It then discusses specific uncertainties regarding the effects assessment for chemicals (Section 4.5.3.2) as well as radionuclides (Section 4.5.3.3).

4.5.3.1 Effects Assessment General Uncertainty

Effects benchmarks such as ESVs and TRVs for COPCs, and BCGs for ROPCs are derived from published studies of exposure of various ecological receptors to contaminants, mostly under controlled conditions, and are intended to be protective of receptors similar to those associated with the toxicity studies. However, because effects information is limited for any of the COPCs and ROPCs for all applicable receptors, the ESVs and TRVs and BCGs all have some degree of associated uncertainty. In addition, because the effects benchmarks are usually based on laboratory or highly controlled studies, there is some uncertainty whether they accurately relate to biota living under environmental conditions. Specific uncertainties associated with the ESVs, TRVs, and BCGs are discussed below in Sections 4.5.3.2 and 4.5.3.3.

Additional uncertainty exists as to the pertinence of individual organism toxicity for characterizing the risk to individuals, populations, and communities. Populations possibly may compensate for a loss of large numbers of juveniles or adults with increased survival or birth rates, and communities may possess functionally redundant species that are less sensitive to contaminants. Although the habitat at the exposure locations likely possesses some buffering mechanisms, a conservative approach to risk assessment is still justified based on organismal toxicity thresholds (i.e., NOAELs), which surely results in an overestimate of risk.

4.5.3.2 Effects Evaluation for COPCs

The measured endpoints representing toxicity that are associated with the ESVs and TRVs include growth, reproduction, or survival. These endpoints are considered to be the most ecological significant in terms of potential adverse impacts to populations and communities. Thus, toxicity benchmarks based on these endpoints are assumed to reduce the uncertainty regarding whether the COPC will likely cause a true adverse impact to ecological receptors.

To reduce uncertainty for the general screening step 1, the recommended ESVs for each abiotic medium were selected as the lowest (i.e., most conservative) from among the published screening benchmarks in the open scientific literature.

There is uncertainty associated with the TRVs used in the general screening Step 2 and site-specific analysis step 3. The TRVs for metals and organics for plants and soil invertebrates generally have high uncertainty as indicated by the authors who developed them because they are based on a limited number of toxicity studies. However, the TRVs for aquatic biota have low uncertainty because they are based on National Ambient Water Quality Criteria (NAWQC) or EPA Tier II values, which were developed from multiple studies utilizing multiple taxa of organisms. In addition, the TRVs for sediment dwelling biota generally have low uncertainty because they are based on NOAA and Ontario Ministry of the Environment (OME) values, which were calculated from multiple studies (NOAA 1997 and 1999).

There is uncertainty associated with the TRVs for wildlife receptors for several reasons. First, for birds and mammals, most toxicity values are extrapolated from laboratory studies and laboratory test species (e.g., rats, chickens). TRVs for wildlife receptors exposed to soils are derived from NOAELs or LOAELs reduced by safety factors of 10 for chronic LOAELs and subchronic NOAELs or 100 for subchronic LOAELs (Sample et al. 1996). It is uncertain whether the correction factors accurately adjusted the toxicity value to a realistic value, but they are assumed to err on being overly conservative. These thresholds would underestimate risk only to organisms that are considerably more sensitive than the receptor organisms for the specific toxicological endpoint. The TRV thresholds are more likely to overestimate risk to receptor organisms that are equally or less sensitive than the test organisms. In addition, no adjustment was made for the differences in metabolic rates among receptors of different sizes. Some authorities (Sample et al. 1996, DOE 2002) state that different metabolic rates result in different bioaccumulation rates and, therefore, toxicity because toxicity of most chemicals is related to bioaccumulation.

Second, for the metals that had an HQ > 1 for a mammal or bird receptor, there is uncertainty regarding which chemical form of the metals is actually present in the food of wildlife receptors. Chemical forms of the metals in the wildlife's food are important because they might be different from the ones upon which the TRVs were derived. For example, the TRV for vanadium (a possible COC at EU 2, EU 4, and others) for mammal receptors was derived from laboratory studies using sodium metavanadate ($NaVO_3$) (Sample et al. 1996). Metavanadate contains the vanadium in the form of a +5 valence state. However, vanadium can exist in other valence states ranging from +2 to +5 and form other compounds such as sulfides (combined with sulfur), chlorides (combined with chlorine), or oxygen to form oxides. It is uncertain whether those compounds would be equally toxic to mammals as the metavanadate. Likewise, the TRVs for aluminum for mammals and birds were derived using aluminum chloride and aluminum sulfate, respectively. The TRV for antimony for mammals was based on antimony potassium tartrate, whereas the TRV for arsenic was based on arsenite (valence state of +3). The TRV for lead for birds was based on lead acetate. It is unlikely that the form of aluminum, antimony, arsenic, lead, and vanadium in the food sources of wildlife at the NFSS is exactly the same as the chemical forms that were used to derive the TRVs. If these metals were in different chemical forms in the food of wildlife at the NFSS, it is reasonable to assume that their toxicity could be different from that indicated in the TRVs. The toxicities could vary because the different forms of the metals might have different bioavailability for absorption after being ingested by the wildlife receptors.

Third, the risks from exposure to multiple contaminants depend on contaminant interactions and the effects could be greater or less than those from a single chemical. The SERA provides findings for ecological COPC-specific risk estimates and assumed additivity when calculating HIs. Overall, the effects assessment probably overestimates toxicity because the TRVs are based on chemical-specific concentrations that cause no observed effect in test animals rather than an effect based on multiple chemicals or that may be observable but is not great enough to threaten populations.

TRVs were not available for some COPCs and some receptors. This situation likely results in underestimated risks.

4.5.3.3 Effects Evaluation for ROPCs

The dose limits for radiation exposure for terrestrial plants and aquatic biota (1 rad/d) and 0.1 rad/d for mammals and birds have been proposed as doses that are unlikely to harm populations (IAEA 1992, Barnthouse 1995), so there is low uncertainty in their protectiveness. Because these dose limits were used to calculate BCGs for ROPCs in soil, sediment, and surface water, they contribute low uncertainty to the BCGs. Individual plants or animals or tissues of plants and

animals may be more sensitive to radiation damage than the populations evaluated by IAEA (1992). For example, rapidly growing tissues such as root hairs may be particularly sensitive to external radiation if they are in close contact with contaminated media. Therefore, the SERA may underestimate risks from radiation by an unknown amount.

4.5.4 Risk Characterization

Because conservative exposure parameters (Section 4.3) were used to calculate HQs, the estimates of risk from ecological COPCs/ROPCs are conservative (that is, protective). Using conservative exposure concentrations and doses decreases the likelihood of underestimating the risk posed by each ecological COPC/ROPC and increases the likelihood of overestimating the risk. Note that for wildlife receptors not living in soil, sediment, or surface water, HQ is a function of COPC dose (ADD) or radiological dose, which, in turn, depends on a number of exposure factors (in addition to contaminant exposure concentration). Thus, several factors determine how conservative an HQ might be (in addition to contaminant exposure concentration).

The uncertainties described above ultimately produce uncertainty in the quantification of current risks to plants and animals at the EUs. Three additional areas of uncertainty exist in the risk characterization: off-site risk, background risk, and cumulative risk. Each is briefly described below.

4.5.4.1 Risk Outside the Modeled Study Area

It is unlikely that receptors outside the study area would have lower toxicity thresholds for COPCs and ROPCs than the thresholds used for receptors within the study area and there is little reason to expect that COPCs and ROPCs migrating outside the study area would be concentrated above predicted concentrations at the exposure locations unless a contaminant bioconcentrates in organisms that move extensively on and off the study area. In general, the risk to receptors outside the study area is likely to be overestimated rather than underestimated by the risk estimate for receptors within the NFSS.

4.5.4.2 Background Risk

Another source of uncertainty is ecological risk relative to background conditions. The background comparison consisted of comparing the chemical-specific 95% UTLs from the EUs against the background samples. Although EPA guidance recommends statistical comparisons of entire data distributions rather than comparisons to UTLs, those comparisons were not recommended or performed for the NFSS because mainly biased (not random) samples were collected, and the number of samples collected from the EUs were different than the number of samples from the background. Thus, uncertainty is expected to be reduced by using the UTLs for the background comparisons.

There is some uncertainty associated with the background values because they are based on a limited number of samples that are “non-contaminated with NFSS COPCs and ROPCs”. However, based on the rationale for sample locations for the background data set as documented in the RI report, the uncertainty that background data accurately represent background concentrations in the vicinity of NFSS is assumed to be low.

4.5.4.3 Cumulative Risk

Cumulative risk is possible when several living plants and animals are affected simultaneously. Harmful effects in communities (including effects on individual organisms) may cascade throughout the system and have indirect effects on the ability of a population to persist in the area even though individual organisms are not sensitive to the given COPCs or ROPCs in isolation.

In addition, cumulative risk more broadly includes risk from multiple sources at the site. Therefore, the ecological risk characterization for exposure locations may underestimate actual risks to plants and animals due to cumulative risks from multiple contaminant sources.

4.5.5 Summary of Uncertainties

The most important uncertainties in the ecological portion of the SERA for exposure locations are those surrounding the estimates of the contaminant concentrations or doses to which ecological receptors are actually exposed and the concentrations that present an acceptable level of risk or harmful effects (TRVs and BCGs). Additional uncertainties arise from other topics. For example, the lack of site-specific data on contaminant transport and transformation processes, animal behavior and diet, population dynamics, and the response of plant and animal populations to non-chemical and non-radiological stressors in their environments. Despite these uncertainties, the modeled exposure concentrations and published exposure and effects information allow risks to be characterized for various exposure locations according to exposure/effects scenarios. Furthermore, because of the emphasis on erring on the side of selecting conservative inputs for problem formulation and the exposure and effects assessments, the uncertainties associated with those steps mostly tend to overestimate rather than underestimate ecological risks. Therefore, risk predictions are unlikely to be higher than those reported in this SERA.

4.6 WEIGHT-OF-EVIDENCE ASSESSMENT

Weight-of-evidence (WOE) assessment means the technical process of gathering, organizing, and evaluating various types and qualities of environmental information about the plants and animals living in an area of potential contamination. Throughout the evaluation or weighing process, there is an attempt to see and understand the context of the risks, based on various pieces of evidence. The WOE assessment also aims to extend the separate findings from risk assessment towards the holistic view of risk management. Thus, there are elements from beyond the purely technical world of just risk assessment, e.g., chemical exposure and toxic effects. For example, in the WOE assessment topics such as land use and a comparison of chemical risk versus physical risk associated with remedial action or are evaluated.

By contrast, uncertainty analysis as developed in Section 4.5 focuses on the various technical aspects of risk assessment, e.g., problem formulation, exposure assessment, effects assessment, and risk characterization. There is emphasis and discussion on the degree of conservative exposure assumptions and conservative toxicological effects data that together assure one that the risk predictions would not become any worse.

EU 16 contains on-site pipelines used in former site operations. Exposure to material in the pipelines is limited to future construction workers who may be exposed to this material during pipeline removal. EU 17 is the sum of all EUs so EUs 16 and 17 are not evaluated in the WOE. The following EUs are part of this WOE assessment:

- Soil EUs – 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, and 14
- Sediment and surface water EUs – 5, 9, and 15

4.6.1 Eight Key Weight-of-Evidence Elements

Eight elements have been developed to weigh the NFSS SERA quantitative risk results and other evidence. They consist of two types: discriminatory, having the ability to rank the various EUs and common, supporting EUs more or less the same.

First, there are three elements that help to distinguish one EU from another:

1. Range of natural resources;
2. Range of HQs with emphasis on relatively high ones; and
3. Range of likely on-site and off-site migration of contaminants

Second, there are some common elements—that fit all EUs as follows:

4. Functioning on-site ecosystems;
5. No significant or unique ecological resources anywhere;
6. Future commercial/industrial land use likely;
7. Trade-off of physical habitat destruction to reduce risk from chemicals; and
8. Automatic protection of ecological resources from human health-driven remediation.

Together, these elements provide a holistic view and understanding of the ecological risk situation at NFSS.

4.6.2 Weight-of-Evidence Structure and Evaluations

This section reviews the name and definition, rationale, measurement, actual evaluation, and short summary for each of the eight WOE elements germane to the NFSS ecological risk assessment.

4.6.2.1 Element 1: Range of natural resources

Definition: Natural resources mean the vegetation and wildlife that together constitute a functioning habitat or ecosystem.

Rationale: The amount of standing vegetation or biomass per unit area offers one way to understand the range of natural resource conditions with the lower the biomass the lower the ability of the habitat to provide cover and food for wildlife. One reason for recognizing forests as being so important is that it requires decades for recovery of forests or re-growth once it is cut.

Measurement: The amount of biomass of vegetation provides a way of understanding the habitat. Each EU was measured for its total acreage and the dominant habitat type (defined as 50 or more percent). The EU was scored as if the entire EU contained the dominant habitat type. Some EUs have only one type of habitat and it is straightforward to score the habitat type. Others contain multiple types and the habitat that was 50 or more percent of the total became the representative habitat for that EU. All sediment/surface water habitats at NFSS are relatively degraded from physical activities, have similar low value and are similar in other ways too.

Evaluation: NFSS has three types of habitats: cleared or maintained turf (lowest biomass habitat), sedges, rushes and reeds (intermediate), and various types of forests, including ash, elm, and maple and also various upland hardwoods (highest biomass habitats). Here are the summaries of habitats.

- Lowest biomass habitats (maintained turf)
  EUs 6, 7, 10, 11, and 13

- Intermediate biomass (sedges rushes, and reeds)
  EU 9

- Highest biomass (various forests)
  EUs 1, 2, 3, 4, 5, 8, 12, and 14

EU 15 contains surface water and sediment in the main ditch system including Central Ditch, South 16 Ditch, South 31 Ditch, and Modern Ditch (see Figure 2.5). EU 15 is an aquatic habitat and not covered in the biomass metric.

Summary: Some EUs are more valuable than others with forests (most biomass) being the most valuable type of habitat (EUs 1, 2, 3, 4, 5, 8, 12, and 14). By contrast, the least valuable EUs are those with lower amounts of vegetation or biomass, such as the manicured grass areas (EUs 6, 7, 10, 11, and 13) with the sedges, reeds, and rushes being intermediate (EU 9).

4.6.2.2 Element 2: Range of HQs with emphasis on higher values

Definition: HQs are the ratios of chemical concentrations measured at the site to toxicological RfCs that, when they exceed one, can mean that a particular ecological receptor (plant or animal) may be in harm's way. All HQs are uncertain due to technical limitations of the methods used to derive exposure and effects numbers, which are used to compute HQs (see uncertainty section, Section 4.5).

Rationale: A lower HQ is better than a higher HQ because lower HQs suggest lower ecological risk. Note that this is a technical distinction and not a regulatory one where any risk greater than an HQ of 1 justifies further investigation. HQs of =1,000 were deemed to be reliable indicators of potential ecological risk because the exposure and effects numbers have less uncertainty than lower HQs.

Measurement: An HQ of 1,000 or higher in the SERA is assumed to be a more reliable technical indicator of ecological risk than an HQ of 100. Likewise, an HQ of 10 is more technically reliable than an HQ of 1. However, the relationships are not linear, i.e., an HQ of 100 is not 10 times the risk of an HQ of 10. The selection of HQ =1,000 as the measurement for evaluation and comparison of one EU to another EU is based on professional judgment. This measurement could be 100 or even 10; 1,000 was selected to better dramatize the size of the HQ and to reduce the number of COCs involved in the WOE assessment.

Evaluation: Only organic and inorganic chemicals showed HQs greater than 1. No radionuclides had HQs great than one. The summary of soil HQs of Step 3 screen of SRCs in soil (Table 4.17) lists the COCs and the relative sizes of the HQs (1 to 100, 100 to 1,000, and 1,000 and greater). HQs greater than 1,000 were selected for further study. There are no organic and five inorganic chemicals that are greater than 1,000. Aluminum can be removed because

according to EPA (2003b) when soil pH is great than 5.5, which is the case at NFSS, the bioavailability is too low to expose ecological receptors and any risk prediction would be based on very conservative and not-useful values. Thus, there are four inorganic COCs -- cadmium, chromium, lead, and zinc. For a better understanding of these COCs, we need to look at them from the viewpoint of their EU locations at NFSS. There are no sediment/surface water EUs (EUs 5, 9, and 15) with HQs greater than 1,000; and the sediment/surface water HQs are much lower than for soil. Here is how the EUs with soil HQs greater than 1,000 fall out:

- No soil HQs greater than 1,000
  EUs 6 and 7

- Soil HQ for cadmium greater than 1,000
  EU 1

- Soil HQ for chromium greater than 1,000
  EUs 9, 10, and 11

- Soil HQs for cadmium and chromium greater than 1,000
  EUs 5 and 12

- Soil HQs for cadmium and lead greater than 1,000
  EUs 2, 3, 4, 8, and 14

- Soil HQ for cadmium, chromium, lead, and zinc greater than 1,000
  EU 13

Summary: Most every EU showed HQs greater than 1 and most also have a few chemicals with HQs greater than 1,000. The latter were arrayed to obtain a better understanding of the gradient of conditions. For example, EUs 6 and 7 had no HQs higher than 1,000; others had only one metal (cadmium or chromium) -- EUs 1, 9, 10, and 11; others had two metals (cadmium, chromium, and/or lead) -- EUs 2, 3, 4, 5, 8, 12, and 14) and EU 13 with four metals each having soil HQs over 1,000.

4.6.2.3 Element 3: Range of likely on-site and off-site migration of contaminants

Definition: Contaminant migration is the movement of contaminants from the soil through ditches to other on-site or off-site environments.

Rationale: Off-site migration of chemicals is not desired because it can spread the contaminants and any associated risk to additional humans and ecological receptors living off-site.

Measurement: No quantitative surface water or sediment contaminant migration modeling has been conducted for NFSS. Therefore, another measurement was developed. Ditches containing sediment and surface water are viewed as conveyances for possible contaminant transfer on this relatively flat parcel of land. The relationship of conveyances (position, number, and amount of water) differs from EU to EU and these differences are documented and assessed. The fewer the ditches in or near a given EU the lower the likelihood of contaminant migration. Further, ditches were organized into those with water more than 50 percent of the time and those with water less than 50 percent of the time. It is assumed that the higher the percentage of water the greater the

likelihood for contaminant migration. Thus, the spatial relationship of each type of ditch to each EU was examined and classified.

Evaluation:. The topography of the entire site is relatively flat and the drainage ditches (EUs 5, 9, and 15) are necessary to move chemicals from one EU to another on-site location or to an off-site location. Here are the comparative findings:

- No drainage (land-locked)
  EU 13

- Lower drainage potential because ditches contain water less than 50 percent of the time
  EUs 1, 3, and 4 (ditch on one side of EU)
  EUs 5, 6, and 9 (two or more ditches or a middle one)

- Higher drainage potential because ditches contain water more than 50 percent of the time
  EUs 2, 8, and 10 (ditch on one side of EU)
  EUs 7, 11, 12, 14, and 15 (two or more ditches or a middle one)

Summary: The likelihood of drainage is comprised of sediment/surface water in EUs 5, 9, and 15. The gradient ranges from no possible drainage (EU 13), through lower drainage potential (EUs 1, 3, 4, 5, 6, and 9), to higher drainage potential (EUs 2, 7, 8, 10, 11, 12, 14, and 15).

4.6.2.4 Element 4: Functioning on-site ecosystems

Definition: A functioning ecosystem indicative of healthy-appearing terrestrial and aquatic ecosystems.

Rationale: The presence of a functioning ecosystem is desirable because this indicates that site contaminants have not diminished or removed such ecological functions as energy flow and nutrient cycling and that vegetation and wildlife are present at the site.

Measurement: The presence of habitats, all with varying amounts of above-ground biomass (an indication of primary productivity and the capacity to support wildlife) means that the various EUs at NFSS are functioning in terms of energy flow, nutrient cycling, and timber/wildlife recovery and production.

Evaluation: There are relatively extensive field write-ups about the site published in reports by Maxim Technologies. They are:

- Technical Memorandum # 1 NFSS Ecological Reconnaissance Report (Maxim 2002),
- Appendix A on ecological reconnaissance documentation,
- Appendix B on ecological checklists for NFSS,
- Appendix C on federal and state contact documentation for NFSS, and
- Appendix D on photos of ecological habitat on NFSS.

The information listed above from Maxim was summarized in the ecological risk chapter of the RI. In addition, SAIC visited the site and evaluated the ditches and this information is published in the ecological risk chapter in the RI. The COE (2006) visited the wetlands and ditches and scored them low, but noted that they are still functioning. The Maxim documents contain photographs of wooded areas with deer standing in them. It is important to note that the disturbed

habitats in some NFSS areas are the result of past physical disturbance rather than the consequences of chemical contaminants. Physical disturbance includes soil excavation/movement, past construction and equipment usage, ditch dredging with steep banks, and clear-cutting. NFSS is in various stages of ecological recovery or succession. Some areas are in a fixed state such as the maintained lawn. The fact that recovery is occurring across the site, even to the point of reforestation in some EUs, indicates that site contaminants are not inhibiting germination, colonization, distribution, and abundance of common species.

Summary: Each of the EUs at NFSS sustains plant growth and wildlife, such as deer, have been observed on-site. The eco-systems are recovering from previous physical disturbances and are functioning.

4.6.2.5 Element 5: No significant or unique ecological resources

Definition: Significant or unique resources are T&E species and important wetlands.

Rationale: The absence of significant unique resources is desirable because it means that special studies and coordination with trustees, such as the U.S. Fish & Wildlife Service, are not required, allowing expedited decision-making regarding the property by stakeholders and other regulatory groups.

Measurement: Lack of any T&E species or important wetland is the measurement. Scores based on completion of field inspections to existing wetlands and ditches are another measurement.

Evaluation: There are correspondences from various regulatory agencies regarding T&E species potentially at NFSS from about five years ago. This information is summarized in chapters 2 and 7 of the RI. Despite the cutover nature of the habitats at NFSS, there are some wetlands (see above ecological habitats for sedges, rushes, and reeds), but they are all scored at 1 (lowest score) according the recent COE field investigation (2006). The ditches also were scored as being 1 (COE 2006).

Summary: There is a lack of T & E species at NFSS. While wetlands are present, they exhibit low scores because of their physically degraded conditions. Thus, there are no significant or unique ecological resources at any of the EUs at NFSS.

4.6.2.6 Element 6: Future commercial/industrial land use likely

Definition: Future industrial/commercial land use at the site may alter some ecological habitats, and thus influence the importance of protecting ecological resources.

Rationale: Land use has a profound influence on what ecological resources would be valued and, therefore, protected. Commercial/industrial land use means that wildlife (their food and cover) will not need protection, and the standards of a wildlife refuge are not applicable.

Measurement: Current commercial/industrial EUs have more assurance of being/remaining that land use versus EUs that are yet to be designated (future) commercial/industrial EUs.

Evaluation: Future land use has not been decided, but any significant human use would result in lower protection of ecological resources. There are two assumed land uses: residential and industrial. Section 2 of the RI asserts and explains this, but there are no known consensus documents that declare any thing more definite than these two land uses. Both land uses are not

particularly attractive to wildlife and other ecological receptors. In addition, nearby habitats offer home ranges for wildlife to escape from any industrial/commercial land use activities. Thus, there will be no assumed wildlife refuge or any protection of special ecological resources. This applies to all EUs.

Summary: The assumed land uses (industrial/commercial) do not favor timber nor wildlife production. This applies to every EU across the entire NFSS.

4.6.2.7 Element 7: Tradeoff of physical habitat destruction to reduce risk from chemicals

Definition: The reduction or removal of chemicals to reduce or remove ecological risk likely destroys the physical and biological habitat of the very organisms being aided and this trade-off must be considered.

Rationale: Every EU has a trade-off between the benefits and disadvantages of remediation to remove chemical risk and the consequences of the remediation itself on habitats. Sometimes, it is better to manage the chemical risk than to remove it and, in the process, greatly change the very habitat you are seeking to protect. It is not desirable to destroy the physical habitat to protect it from chemical risk and once done it causes a loss of ecosystem functions and loss of wildlife habitat that can take many years (decades) to recover. Therefore, there is a tradeoff.

Measurement: Recovery time of the damaged ecosystem or EU can be 1 to 2 years to a maintained or mowed field, 3 to 10 years to return to an old field with shrubs, and 50 + years to return to a forest. This particular element uses technical common sense to conduct the evaluation.

Evaluation: As stated, there is a trade-off between two different kinds of ecological risk: physical alterations and residual contamination. That is, the localized ecosystem can either have clean soils/sediments because of removal and replacement but have a highly disturbed habitat as a result, or it can have exposure to contaminants in a habitat that is minimally disturbed. In some cases, it can be appropriate to allow plants and animals low in the food chain to be exposed to somewhat toxic concentrations, and spare important habitat. Especially when animals higher in the food chain (especially top carnivores) are not receiving toxic exposures. In the case of NFSS, there may be little benefit to removing contaminated media even when COPEC concentrations appear to be at harmful levels according to the field investigations.

Summary: Any remediation for ecological protection purposes can cause more habitat damage than chemical risk reduction is worth. This is true of every EU at NFSS.

4.6.2.8 Element 8: Automatic protection of ecological resources from health-driven remediation

Definition: Protection of ecological resources from site contamination would automatically be provided as a benefit from any human health-driven remediation.

Rationale: The lack of need for protection of human health and ecological resources, by definition, indicates NFA. Yet, protection of human health appears to be needed; for example, some of the EUs have greater than $1x10^{-4}$ risk for radionuclides. From the chemical risk viewpoint some EUs may need protection while others do not.

Measurement: An excess cancer risk threshold for the protection of human health of $1x10^{-4}$ or a Hazardous Index greater than one can lead to health-driven remediation. A lower cancer risk

value ($1x10^{-5}$ or $1x10^{-6}$) or a HI greater than one could show that no health-driven remediation is needed.

Evaluation: Based on an analysis of PRGs, there appears to be sufficient human health risk in some EUs, such as EU 8, that would likely require remediation. Any remediation that lowers chemical or radiological contamination will automatically protect ecological resources because of the biological similarities between humans and wildlife species. This protection could be total or partial and the exact relationships of human health-driven clean-up goals and remediation to ecological protection can best be defined in the FS. Potential remedial actions at NFSS to reduce soil concentrations of COCs below preliminary cleanup goals for human health would also result in a decrease of ecological risk. Any soil removal would decrease the concentrations of COCs and reduce the number of COCs in soil to which ecological receptors are exposed, thereby reducing ecological risk. When a human health cleanup goal is chosen it offers dual protectiveness to human health and ecological resources after any habitat disturbance has been reversed through ecological succession or environmental management.

Summary: Soil removals at NFSS are possible. The motive would be to achieve human health preliminary cleanup goals to protect human receptors associated with anticipated future land use. These removals would consequently reduce exposure and risk to any remaining ecological organisms at NFSS. All EUs in this condition would benefit.

4.6.3 Application of Weight-of-Evidence Elements

There are three logical outcomes, or next steps, based on the RI findings, including the WOE assessment. They are:

- BERA – SERA ecological risk findings not clear enough and need more work
- NFA – based on no to little risk or on WOE assessment when risk is predicted
- FS – yes, risk present and more work (not BERA) needed to show NFA

The following discussion explains why NFA is the correct recommendation for the NFSS. If NFA is not selected, then EUs would go to the FS where additional work on chemical form in soil (related to exposure and bioavailability) would be measured to explain the functioning ecosystems. By contrast, a BERA would not be needed because of the conservative nature of exposure and toxicological effects metrics that would continue to produce HQs greater than 1 despite the presence of vegetation and wildlife across NFSS.

Two WOE elements surely support NFA. They are no significant or unique ecological resources and likely land use is commercial/industrial or other intensive human use. Not one sensitive and/or significant habitat exists at NFSS; there is no critical habitat for T&E species and scattered wetlands and ditches are of low quality. It is important to note that low quality habitats in some NFSS areas are the result of past physical disturbance rather than consequences of chemical contaminants. Physical disturbance includes soil excavation/movement, past construction and equipment usage, ditch dredging with steep banks, and clear-cutting. As explained above the commercial/industrial land use is in harmony with this lack of ecologically significant resources. Both WOE elements make a low priority of timber production and wildlife propagation. Thus, from the viewpoint of ecological resources, it is recommended that all of NFSS be NFA.

Two additional WOE elements support NFA. The range of habitats measured as amount of biomass represents a typical habitat mix and the range of possible contaminant migration is mostly non-existent to slow. Any contaminants in the soil and sediment/surface water continue to

remain in place and would be expected to remain mostly in place among the erosion-inhibiting habitats of forest, maintained turf, and other vegetative cover. Again, from the ecological viewpoint, NFA is the logical choice to make for all EUs at NFSS.

However, there is also a range of HQs, especially from four metals (cadmium chromium, lead, and zinc), that are relatively high (=1,000) and would argue for some type of remediation to be determined in an FS. These high HQs are not purely technical metrics; rather they are more regulatory thresholds to prompt further work such as this WOE assessment. Based on the HQ element alone an FS would be the logical outcome. Considering this WOE element with other WOE elements shows otherwise. For example, the ecosystems at NFSS are functioning. Photographs from any angle show healthy-looking vegetation and wildlife, such as deer, have been photographed on-site. NFSS EUs, exhibit plant growth and animal life, interacting successfully with soil and other parts of the ecosystem to result in sustainable habitats year after year. Further, NFSS is in various stages of ecological recovery or succession. Some areas are in a fixed state such as the maintained lawn. The fact that recovery is occurring across the site, even to the point of reforestation in some EUs, indicates that site contaminants are not inhibiting germination, colonization, distribution, and abundance of commons species. Thus, the mathematical predictions of HQs with their regulatory dire interpretations are checked by the reality of functioning and recovering habitats at every EU. In short, one WOE element is balanced by another to result in the recommendation for NFA.

Finally, there are two WOE elements that provide some sobering considerations to any action other than NFA. One, there is a trade-off between physical and chemical risks where remediation for ecological protection can damage a physical habitat more than chemical risk reduction is worth. Also, if there were remediation for human health purposes, some protection would automatically apply to ecological resources.

If the WOE elements combined are not sufficient to moderate the WOE element about HQs and to show the correctness of an NFA decision, then the next step would be to go to the FS. In the FS, more technical work would be done on the interface of mathematically developed high HQs and the reality of functioning ecosystems with plant and animal life. More precisely, speciation measurements could be taken of the chemical forms of the metals in the soils. From that knowledge, arguments would be developed like the following one for chromium.

Chromium is a metal that occurs in different chemical forms with different bioavailabilities and toxicities. Chromium exists in different oxidation states, predominantly as trivalent chromium [Cr (III)] and hexavalent chromium [Cr (VI)]. Cr (III) is less bioavailable and less toxic than Cr (VI). Natural Cr (VI) is rare in nature (James 2002), and was not detected in the soil samples. Nearly all naturally occurring chromium is in the form of the Cr (III) (chromic) cation, which is in the trivalent oxidation state. Compounds of Cr (III) such as chromic acetate [Cr $(CH_3O_2)_3$] or chromic sulfate [Cr_2 $(SO_4)_3$] are soluble in water because they disassociate into Cr (III) ions and the corresponding anions (e.g., acetate and sulfate), which are soluble. However, Cr (III) ions react with negatively charged ions in soils and sediments and can form insoluble precipitates, which are not bioavailable. For example, Cr(III) reacts readily with hydroxide ions (OH^-) to form $Cr(OH)_3$, which has a solubility of about 5×10^{-8}µg Cr/L at pH 8 (James 2002) and is, therefore, not bioavailable. Some chromates, especially $BaCrO_4$, $HgCrO_4$, and $PbCrO_4$ are also very poorly soluble in water (Clifford 1988) and, therefore, are not readily bioavailable. Thus, Cr(III) forms insoluble compounds in soils that are not bioavailable.

In short, the preponderance of the eight WOE elements prompts the recommendation for NFA for all EUs at NFSS.

4.6.4 Weight-of-Evidence Summary

Section 4.6 advances and applies each of eight WOE elements to each of the EUs at NFSS. Three of the WOE elements can discriminate or rank the EUs while the other five WOE elements equally apply to all the EUs. There are three logical outcomes from this assessment: BERA, NFA, or FS. Seven of the eight WOE elements support NFA. The one contrary WOE element recognizes the mathematically predicted ecological risk for chemicals at NFSS as possibly leading to a different outcome. However, field observations (Maxim, SAIC, and COE) show relatively healthy and functioning terrestrial and aquatic ecosystems. Forest and other vegetation and wildlife, such as deer, are abundantly present at EUs. After weighing this seeming contradiction (mathematical risk predictions and actual field observations), it is shown that the reality of functioning vegetation and wildlife prevails. If there is any doubt, then more work on chemical form and bioavailability (actual chemical speciation measurements of soil) could be undertaken in an FS. It is predicted that the dilemma will be resolved in favor of NFA for ecological resources at NFSS. In conclusion, it is recommended that NFA is still the correct path forward.

4.7 SERA SUMMARY

The NFSS location consists of about 191 acres of predominately low-lying land or terrestrial habitats and water or aquatic habitats. Terrestrial habitats include maintained turf/mowed grass (about 90 acres); sedges, reeds, rushes, and cattails (about 16 acres); and mixtures of various forests, e.g., ash-elm-maple, mixed upland hardwoods, (about 85 acres). Wildlife species include white-tailed deer, rabbits, raccoons, groundhogs and other rodents as well as hawks, herons, pheasants, doves, and other birds. Other terrestrial organisms like reptiles and amphibians are also present. Aquatic habitats drain poorly among the various man-made ditches and there is only one perennially flowing ditch. This limits the types and numbers of aquatic organisms that can and do live at NFSS. In fact, there are only four EUs where sediment and surface water are assumed among the 16 EUs. Note that EU 17 represents the entire NFSS while EUs 1 through 15 are relatively small and are subsumed within EU 17. Note further that EU 15 consists of only sediment and surface water and that EU 16 consists of pipelines for which exposure is not calculated.

The methods emphasize a screening level approach to both exposure and risk characterization. Each is done in a series of steps of increasing specificity for both chemicals and radionuclides that are site-related compounds (SRCs). For chemicals, a general screen of maximum concentrations identifies the SRCs for further site-by-site or EU-specific evaluation. There are two additional steps where RME concentrations are compared to ESVs to develop HQs. For radionuclides, a general screen of maximum concentrations was used to determine whether further analysis was required. EU-specific steps followed in which concentrations were compared to BCGs to develop overall radiation doses. First, the results for the radionuclide screens are provided because of the straightforwardness of those findings. This is followed by the more complex findings for the chemicals.

For radionuclides, all of the 15 small EUs and the NFSS-wide EU 17 were eliminated by application of the various general and EU-specific screens.

For chemicals, no one of the 15 soil EUs nor the sixteenth NFSS-wide EU 17 could be dismissed because one or more chemicals were always present at sufficiently high concentrations to produce

an HQ greater than one (Table 4.22). For example, copper, selenium, and total uranium had HQs >1 at most every EU. However, at some EUs, fewer metals and no SVOCs had HQs >1, while at other EUs there were SVOCs with HQs >1. Thus, a simple pattern can emerge from the results present in Section 4.4.1. Briefly, there are six EUs where only metals define the sources of chemical risk to the various receptors and they are EUs 1, 3, 6, 7, 9, and 14. The following nine EUs have many metals and also SVOCs: EU 2, 4, 5, 8, 10, 11, 12, 13 and 17. There are four sediment and surface water EUs, one of them being the NFSS-wide EU 17. The results show them to be in two categories (Table 4.23): EU 5, 15, and 17 have many metals with HQs >1 (and EU 5 has a few SVOCs with HQs >1), and EU 9 has only one metal whose HQ exceeds one.

The exposure and risk characterization information has been conducted in order to facilitate the making of a decision relative to protection of the above mentioned habitats and ecological receptors. There are three types of possible decisions: (1) there is little to no ecological risk and nothing more needs to be done for protection, (2) a weight-of-evidence (WOE) evaluation of the screening results should be carried out, (3) there may be some ecological risk and more assessment, e.g., BERA, is necessary in order to better define the extent and magnitude of that ecological risk, or (4) there is ecological risk and its characterization is sufficient to identify what interim removal actions at which EU(s) would be prudent. To provide further aid to the decision makers, there is an ECSM that shows the sources of contamination, exposure pathways and the ecological receptors that could be exposed at NFSS. This information can be used by risk managers to make scientific management decisions.

Additionally, there is an uncertainty section that examines the various technical aspects of risk assessment, e.g., problem formulation, exposure assessment, effects assessment, and risk characterization. There is emphasis and discussion on the degree of conservative exposure assumptions and conservative toxicological effects data that together assure one that the risk predictions would not become any worse. A WOE assessment (Option 2 above) follows in which the technical information common to risk assessments is evaluated in the context of broader topics such as significance of ecological resources, human-dominated land use, and trade-offs for chemical risk and physical or remedial risk. A total of eight elements are developed to weigh the NFSS SERA quantitative results and other evidence. Each evaluation or weighing is presented in a logical order. Together, the WOE elements provide a holistic view and understanding of the ecological risk situation at NFSS. The outcome of this assessment is the recommendation for NFA for the relatively productive and recovering habitats, vegetation, and wildlife at NFSS.

5.0 BASELINE RISK ASSESSMENT SUMMARY

The NFSS BRA is composed of a HHRA and a SERA. The BRA evaluates current and future risks to human health and the environment from site contamination. The purpose of the BRA is to provide USACE and the regulatory agencies with a decision-making tool for use in determining the need for further investigation or site cleanup based upon present site conditions. The regulatory mandate from the NCP (EPA 1990) is to protect human health and the environment. The BRA evaluates potential risks at the site using a conservative methodology to ensure that this mandate is achieved.

The EPA and USACE guidance used to prepare the BRA rely on modeled risk estimates for representative receptors that may come into contact with chemical and radiological constituents at the site. The risk estimates are not based on observed impacts to actual people, plants, or animals at the site, nor are they based on measured levels of chemicals within the tissues of these potential receptors. The risk estimates are developed using mathematical models as opposed to actual observed or measured effects. Therefore, these risk estimates should be used only within the CERCLA framework for which they are intended and not for any other purpose such as wildlife management or the development of health advisories.

The HHRA and the SERA were conducted according to the methodology presented by the EPA in the Risk Assessment Guidance for Superfund (EPA 1989) and other guidance documents (see references in Section 6.0). The BRA evaluates both chemical and radiological constituents. The HHRA for radiological constituents is conducted using the residual radiation (RESRAD) computer code Version 6.2. The SERA for radiological constituents contained within Section 4 follows guidance in *A Graded Approach for Evaluating Radiation Doses to Aquatic and Terrestrial Biota* (DOE 2002), which is consistent with CERCLA guidance.

The need for remedial action at NFSS will be fully evaluated in the FS. The FS will draw upon the HHRA and the SERA and also will consider potential ARARs and other federal or state policies, guidelines, or rules developed to address potential risks at sites such as NFSS.

5.1 GENERAL SITE DESCRIPTION

The NFSS is located at 1397 Pletcher Road in Lewiston, NY. The 191-acre site is a remnant of a larger LOOW site used by the wartime MED. The NFSS and adjacent LOOW properties were developed for the production of TNT during World War II. However, TNT production never reached full capacity and the site became an interim storage facility, first receiving radioactive wastes and residues in 1944. Interim remedial actions addressed radioactive residues stored at various locations on the site and widespread contaminated soil on-site. In addition, these actions addressed on-site and off-site drainage areas that had been contaminated from migration of radioactive materials. During the interim action, conducted from 1982 to 1986, approximately 183,000 m^3 of residues and wastes were consolidated in a diked containment area known as the IWCS. The 10-acre engineered IWCS was covered with an interim facility cap and is located in the southwest corner of the site.

The HHRA and SERA both evaluate the entire NFSS property. Any residual radioactivity or chemical constituents presently existing in media outside of the IWCS is evaluated as part of this BRA. In addition, the IWCS is evaluated in its present state. The risk from potential opening (either intentional or accidental) of the IWCS is being evaluated separately as part of the FS.

Therefore, risk resulting from a breach is not quantified in this BRA. It is understood that the IWCS is only an interim remedial action, and therefore, an FS is already underway to determine a permanent solution for waste in the IWCS. In addition, the future existence and stability of the IWCS subjected to various IWCS failure events is being evaluated separately as part of the FS. It is assumed that a breach of the cap would result in unacceptable risk to human health and the environment.

5.2 HHRA OVERVIEW

The HHRA evaluates risk to a range of on-site human receptors that are either currently exposed, or are reasonably anticipated to be exposed, in the future to SRCs. Three buildings remain on-site, one of which is abandoned and is scheduled to be demolished. The remainder of the site is currently a combination of abandoned structures such as tank cradles and building foundations, open fields, and wooded areas all surrounded by a 7-ft security fence. It is bounded to the east and north by operating landfills. Under the current land use scenario, on-site receptors include adult and adolescent trespassers and maintenance workers. It is conceivable that future land use could include industrial use or, as a worst case, residential development or use for subsistence farming. The subsistence farmer land use scenario was evaluated in the HHRA as a conservative worst case. This scenario is highly unlikely due to proximity of the site to surrounding landfills and the poor yield and quality of on-site groundwater resources. Land use surrounding the NFSS is mixed. However, in the immediate vicinity of the NFSS, the predominant land use appears to be salvage, landfill, or waste management related purposes. The NFSS is surrounded by active or inactive waste handling operations on three sides and nearly two-thirds of the land within 0.8 km (0.5 mi) of NFSS is used for salvage, landfill or waste management related purposes. The close proximity of landfills and hazardous waste disposal operations make the NFSS an undesirable setting for subsistence farm land use. Therefore, the future on-site receptors evaluated include construction workers, maintenance workers, industrial workers, adult and adolescent recreational visitors, adult and child residents, and adult and child subsistence farmers. Only the current and future maintenance workers are assumed to be exposed at the surface of the IWCS. All other receptors are assumed to be exposed to non-IWCS areas.

NFSS is divided into 17 EUs for purposes of quantifying risks. EUs 1 through 14 are terrestrial (also called physical) EUs. Soil is evaluated in each of these 14 EUs. EU 15 is the main drainage ditch system and EU 16 consists of abandoned pipes and sewers below ground. For the purpose of defining environmental media within EUs, sediments are operationally defined as being in ditches that are submerged (wet) for at least six months of the year (i.e., 50 percent of the year). Areas submerged for less than 50 percent of the year are defined as soil areas. Only EUs 5, 9, 15, 16, and 17 contain surface water and sediment. EU 17 is a sitewide unit for all media and data. EU 18 contains off-site areas where background samples were collected. Background risks for EU 18 were not quantified, rather background levels were used to identify COPCs/ROPCs.

Groundwater contamination is evaluated in three EUs. EU 17 is a sitewide unit and includes all groundwater data. However, VOC contamination in groundwater is localized in two EUs, EU 4 and EU 13. Therefore, groundwater COPCs/ROPCs are identified for EUs 4, 13, and 17. EU 17 sitewide groundwater risks were used to characterize risks due to groundwater exposures in areas without EU-specific groundwater evaluations.

Human health risk estimates for all scenarios and pathways are presented in Appendices A and B for COPCs and ROPCs, respectively. These risk estimates are summarized in Section 5.4 by EU. RME risk estimates are presented first followed by CTE risk estimates. For purposes of this

results presentation, COCs/ROCs are defined based on total risk by medium and then by COPC/ROPC-specific risk. Cancer risk must exceed 1×10^{-4} in a specific medium for a given receptor for COCs/ROCs to be identified. When medium-specific risk exceeds 1×10^{-4}, any COPC/ROPC posing 1×10^{-5} risk or greater is identified as a COC/ROC. ROCs also are identified based on exceedance of a 25 mrem/yr dose. If total dose exceeds 25 mrem/yr in a specific medium for a given receptor, constituents exceeding 2.5 mrem/yr dose are identified as ROCs. The non-cancer HI must be greater than 1 in a specific medium for a given receptor for non-cancer COCs to be identified in this results discussion. When medium-specific HIs exceed 1, any COPC with an HI greater than 1 is identified as a COC. When medium-specific risks exceed 1×10^{-4} and/or HI greater than 1, but no COPC/ROPC-specific risks exceed 1×10^{-5} or HQ greater than 1, then the COPC/ROPC contributing the greatest risk/HQ is cited.

5.3 SERA OVERVIEW

The scope of the SERA is to determine the potential for adverse ecological impacts resulting from exposure to chemicals and radionuclides present from past AEC/MED activities at the site. The SERA provides information to scientists and managers for the first SMDP to enable them to decide whether ecological risks at the site are negligible, further information and evaluation are necessary to better define potential ecological risks at the site, or mitigation should be done without further evaluation. Further evaluation required by the SMDP, if any, will be provided in another document.

The SERA uses available site analyte concentrations in soil, sediment, and surface water from the NFSS and the IWCS. Risks to ecological receptors are evaluated by performing a multi-step screen (also known as a graded approach for radionuclides) that identifies EUs and media where specific analyte concentrations are above values that are deemed safe for one or more receptors. The SERA also identifies receptors that are particularly at risk. The results also provide information about the relative magnitude of risk from different analytes. For this SERA, future risks are assumed to be the same as current risks presented here; however, for some chemicals, this may be overly conservative due to degradation. The approaches and methods that are used are summarized below:

The SERA problem formulation includes two levels of screening: a general screening followed by a site-specific analysis. These screens are applied to COPCs and ROPCs identified as described in Section 2.1.2. Briefly, the general screening compares the maximum detected concentration of COPCs against screening benchmarks and ROPCs against generic BCGs developed by DOE (DOE 2002). The site-specific analysis uses site-specific information to calculate HQs for chemical constituents, and site-specific BCGs for radionuclides to evaluate whether EUs or receptors can be eliminated from further analysis due to negligible risk.

The NFSS landscape consists of predominately low-lying land or terrestrial habitats and water or aquatic habitats. Terrestrial habitats include maintained turf/mowed grass (about 90 acres); sedges, reeds, rushes, and cattails (about 16 acres); and mixtures of various forests, e.g., ash-elm-maple, mixed upland hardwoods, (about 85 acres). Wildlife species include white-tailed deer, rabbits, raccoons, groundhogs and other rodents as well as hawks, herons, pheasants, doves, and other birds. Other terrestrial organisms like reptiles and amphibians are also present. Aquatic habitats drain poorly among the various man-made ditches and there is only one perennially flowing ditch. This limits the types and numbers of aquatic organisms that can, and do, live at NFSS. In fact, there are only four EUs included in the SERA where sediment and surface water

are present. The SERA evaluates the same EUs as the HHRA except EU 16 (pipelines), which is not evaluated. Results of the SERA are summarized by EU below.

In addition to the technical findings of the ecological risk assessment, there is an uncertainty section which examines technical and conservative aspects of exposure, effects, and HQs, and a WOE assessment which examines technical assumptions and findings in light of other and less technical matters such as significance of resources, human-dominated land use, and trade-offs between chemical and physical risks. There are eight WOE elements and each is weighed relative to the other WOE elements to result in the recommendation for NFA.

5.4 EXPOSURE UNIT RISK SUMMARIES

The following section summarizes chemical and radiological risk results for human receptors as well as ecological risk by EU. The same receptors were evaluated for chemical and radiological risk. To characterize risk associated with exposure to groundwater, the sitewide groundwater characterization completed for EU 17 was added to risks associated with other EU media. Table ES.1 summarizes the COCs and ROCs by EU identified by the HHRA using RME exposure assumptions. When total cancer risk exceeds $1x10^{-4}$ chemical and radiological constituents exceeding $1x10^{-5}$ risk are listed as COCs/ROCs. Non-carcinogenic constituents with hazard indices greater than 1 are identified as COCs, and when total dose exceeds 25 mrem/year, radionuclides exceeding 2.5 mrem/yr are identified as ROCs. Note that, for radionuclides in soil, surface soil, and sediment, risk and dose estimates are presented for the year of maximum exposure (i.e., either year 0 or year 1,000), where an indication of year-1,000 peak exposure means Th-230, through ingrowth of Ra-226, is the driving radionuclide.

The methods used to derive CSFs for radiological and non-radiological constituents differ. EPA outlines the differences in chemical and radiological risk assessment in *Radiation Exposure and Risk Assessment Manual* (EPA 1996d) and in RAGS, EPA cautions against combining radiological and non-radiological risk (EPA 1989). Major differences between chemical and radiological risk assessment include:

- the radiological endpoint is fatal cancer – the chemical endpoint is tumorigenic cancer;
- radiological risk estimates are based primarily on human data – chemical risk estimates are based primarily on animal studies;
- radiological risk estimates are based on the central estimate of the mean – chemical risk estimates are based on the 95% UCL of the mean.

Additional considerations include the fact that the EPCs for radionuclides and non-radionuclides are specific to distinct models incorporating different assumptions. For the NFSS HHRA risks from non-radionuclides and radionuclides were assessed and presented separately in Sections 2.0 and 3.0, respectively. However, despite the differences noted above, excess cancer risk from both radionuclides and chemical carcinogens are summed in Table 5.1 to provide an estimate of the combined risk presented by all carcinogenic contaminants. For Table 5.1 sitewide groundwater risks (EU 17) were incorporated into the risk estimates for receptors in areas without EU-specific groundwater characterizations. Table 5.1 is included for information only. Cleanup goals for chemical and radiological constituents will be developed separately.

5.4.1 Exposure Unit 1 – Risk Summary

EU 1 Chemical HHRA Summary

RME ILCRs do not exceed 1 x 10^{-4} for any receptor; therefore, no carcinogenic COCs are identified. RME HIs exceed 1.0 for subsistence farmer (adult and child); however, no COPC-specific HQs exceed 1 for either receptor. The highest COPC-specific HQ is 0.9 for child exposures to mercury via the food pathway.

CTE ILCRs do not exceed 1 x 10^{-4} for any receptor; therefore, no carcinogenic COCs are identified. CTE HI exceeds 1.0 for subsistence farmer (child); however, no COPC-specific HQs exceed 1.0. The highest COPC-specific HQ is 0.7 for subsistence farmer adult exposures to mercury via the food pathway.

EU 1 Radiological HHRA Summary

RME risks at or above 1 x 10^{-4} and RME doses at or above 25 mrem/yr are estimated for soil and surface soil. Risk driving radionuclides are Ra-226, Pb-210 and Th-230 with the Pb-210 contribution to risk being primarily through the plant ingestion pathway. CTE risks at or above 1 x 10^{-4} and CTE doses at or above 25 mrem/yr are estimated for soil. Risk and dose estimates for all receptors and medium combinations reach maximums at year 1,000.

EU 1 Chemical SERA Summary

Ecological risks from soil exceed an HQ of 1 for 9 inorganics (boron, cadmium, copper, lithium, manganese, mercury, nickel, selenium, and uranium). Six of the ecological receptors (plants, invertebrates, rabbits, deer, shrews, and robins) had at least one HQ greater than 1 for one or more chemicals. The HQs ranged in magnitude from 1.0 (boron HQ for robins) to 1,400 (cadmium HQ for shrews).

EU 1 Radiological SERA Summary

The ecological risks from radionuclides in soil were negligible because the sum of fractions was less than 1.

5.4.2 Exposure Unit 2 – Risk Summary

EU 2 Chemical HHRA Summary

RME ILCRs exceed 1 x 10^{-4} for subsistence farmers, residents exposed to soil and industrial workers and maintenance workers exposed to surface soil. Carcinogenic COCs in soil include benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(k)fluoranthene, dibenz(a,h)anthracene, and indeno(1,2,3-cd)pyrene. RME HIs exceed 1.0 for subsistence farmer (adult and child) however, no COPC-specific HQs exceed 1.0. The highest COPC-specific HQ is 0.6 for boron. The lead EPC concentration in soil exceeds the construction worker PRG; therefore, lead is retained as a COC.

CTE ILCRs exceed 1 x 10^{-4} for subsistence farmers and residents. Carcinogenic COCs in soil include benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, dibenz(a,h)anthracene, and indeno(1,2,3-cd)pyrene. CTE HIs exceeded 1.0 for subsistence farmer (child); however, no

COPC-specific HQs exceed 1.0. The highest COPC-specific HQ is 0.7 for child exposures to aroclor-1260 via the food pathway. The lead EPC concentration in soil exceeds the construction worker PRG; therefore, lead is retained as a COC.

EU 2 Radiological HHRA Summary

RME risks at or above 1 x 10^{-4} are estimated for soil and surface soil. RME doses at or above 25 mrem/yr are also estimated for soil and surface soil. Risk driving radionuclides are Ra-226 and Pb-210 with the Pb-210 contribution to risk being primarily through the plant ingestion pathway. CTE risks at or above 1 x 10^{-4} are also estimated for soil and surface soil. CTE doses at or above 25 mrem/yr are estimated for soil, while CTE doses are estimated to be below 25 mrem/yr for surface soil. Risk and dose estimates for all receptors and medium combinations reach maximums at year 0.

EU 2 Chemical SERA Summary

Ecological risks from soil exceed an HQ of 1 for six SVOCs [benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(k)fluoranthene, chrysene, and indeno(1,2,3-cd)pyrene] and 17 inorganics (aluminum, antimony, barium, beryllium, boron, cadmium, chromium, copper, lead, lithium, manganese, mercury, nickel, selenium, vanadium, uranium, and zinc). Seven of the ecological receptors (all except hawks) had at least one HQ greater than 1 for one or more chemicals. The HQs ranged in magnitude from 1.0 [benzo(a)pyrene HQ for invertebrates] to 30,000 [aluminum HQ for shrews]. These HQs are conservative because of assumed high bioavailability and other high exposure and effects values used in the mathematical risk computations; this is explained in the uncertainty (Section 4.5) and weight-of-evidence (Section 4.6).

EU 2 Radiological SERA Summary

Ecological risks from radionuclides in soil are negligible because all radionuclides were screened out in the early, conservative, screening steps.

5.4.3 Exposure Unit 3 – Risk Summary

EU 3 Chemical HHRA Summary

RME ILCRs do not exceed 1 x 10^{-4} for any receptor; therefore, no carcinogenic COCs are identified. RME HIs do not exceed 1.0 for any receptor; therefore, no non-carcinogenic COCs are identified.

CTE ILCRs do not exceed 1 x 10^{-4} for any receptor; therefore, no carcinogenic COCs are identified. CTE HIs do not exceed 1.0 for any receptor; therefore, no non-carcinogenic COCs are identified.

EU 3 Radiological HHRA Summary

RME risks at or above 1 x 10^{-4} and RME doses at or above 25 mrem/yr are estimated for soil and surface soil. Risk driving radionuclides are Ra-226 and Pb-210 with the Pb-210 contribution to risk being primarily through the plant ingestion pathway. CTE risks at or above 1 x 10^{-4} and CTE doses at or above 25 mrem/yr are estimated for soil. Risk and dose estimates for all receptors reach maximums at year 0.

EU 3 Chemical SERA Summary

Ecological risks from soil exceed an HQ of 1 for 7 inorganics (boron, chromium, copper, lead, lithium, selenium, and uranium). Seven of the ecological receptors (all except hawks) had at least one HQ greater than 1 for one or more chemicals. The HQs ranged in magnitude from 1.1 (copper HQ for invertebrates) to 6,600 (lead HQ for robins). These HQs are conservative because of assumed high bioavailability and other high exposure and effects values used in the mathematical risk computations; this is explained in the uncertainty (Section 4.5) and weight-of-evidence (Section 4.6).

EU 3 Radiological SERA Summary

The ecological risks from radionuclides in soil were negligible because the radionuclides did not carry forward from the earlier screening steps.

5.4.4 Exposure Unit 4 – Risk Summary

EU 4 Chemical HHRA Summary

RME ILCRs for soil exceed 1×10^{-4} for subsistence farmers and residents. Carcinogenic COCs in soil include aroclor-1260, benzo(a)pyrene, and arsenic. RME HIs exceeded 1.0 for subsistence farmer (adult and child), resident (adult and child), industrial worker, construction worker, and maintenance worker. Aroclor-1254, aroclor-1260, and boron are COCs for direct contact with soil and/or food pathways. The lead EPC concentration in soil exceeds the construction worker PRGs; therefore, lead is retained as a COC.

RME ILCRs for EU 4 groundwater exceed 1×10^{-4} for subsistence farmers, residents, and construction workers. Bis(2-ethylhexyl)phthalate, methylene chloride, tetrachloroethene, trichloroethene, vinyl chloride, and arsenic are COCs for exposure to groundwater. RME HIs for EU 4 groundwater exceeded 1.0 for subsistence farmer (adult and child), resident (adult and child), and construction worker. Cis-1,2-dichloroethene, methylene chloride, tetrachloroethene, trichloroethene, vinyl chloride, arsenic, barium, boron, copper, manganese, nickel, and vanadium are COCs for exposure to groundwater. Lead EPC exceeds the drinking water action level and also is a COC.

CTE ILCRs for soil exceed 1×10^{-4} for subsistence farmers via the food pathway. Carcinogenic COCs in soil include aroclor-1254, aroclor-1260, benzo(a)pyrene, benzo(b)fluoranthene, indeno(1,2,3-cd)pyrene and tetrachlorethene. CTE HIs exceeded 1.0 for subsistence farmer (adult and child), resident (adult and child), and construction workers. Aroclor-1254 and aroclor-1260 are COCs for direct contact with soil and/or food pathways. The lead EPC concentration in soil exceeds the construction worker and maintenance worker PRGs; therefore, lead is retained as a COC.

CTE ILCRs for EU 4 groundwater exceed 1×10^{-4} for subsistence farmers, residents, and construction workers. Methylene chloride, tetrachloroethene, trichloroethene, vinyl chloride, and arsenic are COCs for exposure to groundwater. CTE HIs for EU 4 groundwater exceeded 1.0 for subsistence farmer (adult and child), resident (adult and child), and construction worker. Cis-1,2-dichloroethene, tetrachloroethene, trichloroethene, vinyl chloride, aluminum, arsenic, boron, manganese, and vanadium are COCs for exposure to groundwater. Lead EPC exceeds the drinking water action level and also is an EU 4 COC.

EU 4 Radiological HHRA Summary

RME risks at or above 1 x 10^{-4} are estimated for soil and groundwater, while RME risks are estimated to be below the 1 x 10^{-4} threshold for surface soil. RME doses at or above 25 mrem/yr are estimated for soil and groundwater, while RME doses are below the 25 mrem/yr threshold for surface soil. Risk driving radionuclides are Ra-226 and Pb-210 with the Pb-210 contribution to risk being primarily through the plant ingestion pathway. CTE risks are estimated to be at or above 1 x 10^{-4} for groundwater, while CTE risks for all receptors are estimated to be less than 1 x 10^{-4} for soil. CTE doses for all receptors are estimated to be below 25 mrem/yr, except for groundwater ingestion. The subsistence farmer adult and resident adult CTE doses from groundwater ingestion are estimated at 86 mrem/yr. Risk and dose estimates for all receptors reach maximums at year 1,000 for soil, except for the construction worker, whose dose reaches a maximum at year 0.

EU 4 Chemical SERA Summary

Ecological risks from soil exceed an HQ of 1 for six SVOCs [benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(k)fluoranthene, chrysene, and indeno(1,2,3-cd)pyrene] and 15 inorganics (aluminum, antimony, arsenic, barium, boron, cadmium, chromium, copper, lead, lithium, nickel, selenium, uranium, vanadium, and zinc). Seven of the ecological receptors (all except hawks) had at least one HQ greater than 1 for one or more chemicals. The HQs ranged in magnitude from 1.1 [benzo(a)pyrene HQ for plants] to 22,000 (lead HQ for robins). These HQs are conservative because of assumed high bioavailability and other high exposure and effects values used in the mathematical risk computations; this is explained in the uncertainty (Section 4.5) and weight-of-evidence (Section 4.6).

EU 4 Radiological SERA Summary

Ecological risks from radionuclides in soil are negligible because the radionuclides were screened out in the early, conservative, screening steps.

5.4.5 Exposure Unit 5 – Risk Summary

EU 5 Chemical HHRA Summary

RME ILCRs for soil, surface soil, and surface water do not exceed 1 x 10^{-4} for any receptor; therefore, no carcinogenic COCs are identified. No COPCs are identified in sediment. RME HIs for soil exceed 1.0 for subsistence farmer (adult and child) via the food pathway; however, no COPC-specific HQs exceed 1 for either receptor. The highest COPC-specific HQ is 0.7 for child exposures to boron via the food pathway. RME HIs from exposure to surface water could not be calculated because the five surface water COPCs do not have approved non-cancer toxicity criteria.

CTE ILCRs for soil and surface water do not exceed 1 x 10^{-4} for any receptor; therefore, no carcinogenic COCs are identified. No COPCs are identified in sediment. CTE HIs for soil do not exceed 1.0 for any receptor. RME HIs from exposure to surface water could not be calculated because the five surface water COPCs do not have approved non-cancer toxicity criteria.

EU 5 Radiological HHRA Summary

RME risks at or above 1 x 10^{-4} and RME doses at or above 25 mrem/yr are estimated for soil and surface soil, while RME risks and doses for sediment are estimated to be below 1 x 10^{-4} and 25 mrem/yr, respectively. Risk driving radionuclides are Ra-226 and Pb-210 with the Pb-210 contribution to risk being primarily through the plant ingestion pathway. CTE risks at or above 1 x 10^{-4} and CTE doses at or above 25 mrem/yr are estimated for soil. No ROCs are identified for sediment or surface water at EU 5. Risk and dose estimates for all receptors reach maximums at year 0.

EU 5 Chemical SERA Summary

Ecological risks from soil exceed an HQ of 1 for one SVOC [benzo(b)fluoranthene] and 10 inorganics (aluminum, barium, beryllium, boron, cadmium, chromium, copper, selenium, uranium, and zinc). Five of the ecological receptors (plants, soil invertebrates, deer, shrew, and robins) had at least one HQ greater than 1 for one or more chemicals. The HQs ranged in magnitude from 1.1 (beryllium HQs for shrews) to 6,500 (aluminum HQ for plants). These HQs are conservative because of assumed high bioavailability and other high exposure and effects values used in the mathematical risk computations; this is explained in the uncertainty (Section 4.5) and weight-of-evidence (Section 4.6).

Ecological risks from chemicals in sediment and surface water exceeded the HQ of 1 for two SVOCs [benzo(a)anthracene and chrysene] and eight inorganics (aluminum, cadmium, cobalt, copper, iron, lithium, silver, and vanadium). Of the five aquatic receptors (benthic invertebrates, aquatic biota, raccoons, mallards, and herons), aquatic biota and raccoons were the only three receptors that had at least one HQ greater than 1 for one or more chemicals. The HQs ranged in magnitude from 1.1 (lithium HQ for aquatic biota) to 110 (aluminum HQ for aquatic biota).

EU 5 Radiological SERA Summary

Ecological risks from radionuclides in soil are negligible because the radionuclides were screened out in the early, conservative, screening steps.

5.4.6 Exposure Unit 6 – Risk Summary

EU 6 Chemical HHRA Summary

RME ILCRs do not exceed 1 x 10^{-4} for any receptor; therefore, no carcinogenic COCs are identified. RME HIs do not exceed 1.0 for any receptor; therefore, no non-carcinogenic COCs are identified.

CTE ILCRs do not exceed 1 x 10^{-4} for any receptor; therefore, no carcinogenic COCs are identified. CTE HIs do not exceed 1.0 for any receptor; therefore, no non-carcinogenic COCs are identified.

EU 6 Radiological HHRA Summary

RME risks at or above 1 x 10^{-4} and RME doses at or above 25 mrem/yr are estimated for soil and surface soil. Risk driving radionuclides are Ra-226 and Pb-210 with the Pb-210 contribution to risk being primarily through the plant ingestion pathway. CTE risks at or above 1 x 10^{-4} and CTE

doses at or above 25 mrem/yr are estimated for soil. Risk and dose estimates for all receptors reach maximums at year 1,000.

EU 6 Chemical SERA Summary

Ecological risks from soil exceed an HQ of 1 for 7 inorganics (cadmium, copper, lithium, mercury, selenium, uranium, and zinc). Six of the ecological receptors (all except foxes and hawks) had at least one HQ greater than 1 for one or more chemicals. The HQs ranged in magnitude from 1.6 (copper HQ for robins) to 690 (cadmium HQ for shrews).

EU 6 Radiological SERA Summary

The ecological risks from radionuclides in soil were negligible because the radionuclides did not carry forward from the earlier screening steps.

5.4.7 Exposure Unit 7 – Risk Summary

EU 7 Chemical HHRA Summary

RME ILCRs do not exceed 1×10^{-4} for any receptor; therefore, no carcinogenic COCs are identified. RME HIs do not exceed 1.0 for any receptor; therefore, no non-carcinogenic COCs are identified.

CTE ILCRs do not exceed 1×10^{-4} for any receptor; therefore, no carcinogenic COCs are identified. CTE HIs do not exceed 1.0 for any receptor; therefore, no non-carcinogenic COCs are identified.

EU 7 Radiological HHRA Summary

RME risks at or above 1×10^{-4} and RME doses at or above 25 mrem/yr are estimated for soil and surface soil. Risk driving radionuclides are Ra-226 and Pb-210 with the Pb-210 contribution to risk being primarily through the plant ingestion pathway. CTE risks at or above 1×10^{-4} and CTE doses at or above 25 mrem/yr are also estimated for soil.. Risk and dose estimates for all receptors reach maximums at year 1,000.

EU 7 Chemical SERA Summary

Ecological risks from soil exceed an HQ of 1 for 7 inorganics (antimony, boron, copper, lithium, selenium, uranium, and zinc). Five of the eight ecological receptors (all except invertebrates, foxes, and hawks) had at least one HQ greater than 1 for one or more chemicals. The HQs ranged in magnitude from 1.1 (uranium HQ for robins] to 82 (zinc HQ for shrews).

EU 7 Radiological SERA Summary

The ecological risks from radionuclides in soil were negligible because the radionuclides did not carry forward from the earlier screening steps.

5.4.8 Exposure Unit 8 – Risk Summary

EU 8 Chemical HHRA Summary

RME ILCRs for soil exceed 1 x 10^{-4} for subsistence farmers, residents, industrial workers, and maintenance workers. Carcinogenic COCs in soil or food include aroclor-1260, heptachlor epoxide, benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(k)fluoranthene, carbazole, dibenz(a,h)anthracene, and indeno(1,2,3-cd)pyrene. RME HIs exceeded 1.0 for the subsistence farm child and adult and resident child. Aroclor-1260 and uranium (total) are COCs for direct contact with soil and/or food pathways.

CTE ILCRs for soil exceed 1 x 10^{-4} for subsistence farmers and residents. Carcinogenic COCs in soil include benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, dibenz(a,h)anthracene, and indeno(1,2,3-cd)pyrene. CTE HIs exceeded 1.0 for the subsistence farm child. Aroclor-1260 is a COC for the subsistence farm child exposure through the food pathway.

EU 8 Radiological HHRA Summary

RME risks at or above 1 x 10^{-4} and RME doses at or above 25 mrem/yr are estimated for soil and surface soil. Risk driving radionuclides are Ra-226 and Pb-210 with the Pb-210 contribution to risk being primarily through the plant ingestion pathway. CTE risks at or above 1 x 10^{-4} and CTE doses at or above 25 mrem/yr are estimated for soil, while CTE risks and doses for surface soil are estimated to be below 1 x 10^{-4} and 25 mrem/yr, respectively. Risk and dose estimates for all receptors reach maximums at year 0.

EU 8 Chemical SERA Summary

Ecological risks from soil exceed an HQ of 1 for four SVOCs [benzo(b)fluoranthene, benzo(k)fluoranthene, chrysene, and indeno(1,2,3-cd)pyrene] and 13 inorganics (aluminum, beryllium, boron, cadmium, chromium, copper, lead, lithium, nickel, selenium, uranium, vanadium, and zinc). Seven of the ecological receptors (all except hawks) had at least one HQ greater than 1 for one or more chemicals. The HQs ranged in magnitude from 1.1 [nickel HQ for plants] to 16,000 [aluminum HQ for shrews]. These HQs are conservative because of assumed high bioavailability and other high exposure and effects values used in the mathematical risk computations; this is explained in the uncertainty (Section 4.5) and weight-of-evidence (Section 4.6).

EU 8 Radiological SERA Summary

The ecological risks from radionuclides in soil were negligible because the sum of fractions was less than 1.

5.4.9 Exposure Unit 9 – Risk Summary

EU 9 Chemical HHRA Summary

Only four COPCs were identified in EU 9 soil and none have cancer toxicity criteria; therefore no RME ILCR can be calculated. No carcinogenic COCs are identified. No COPCs are identified in sediment or surface water. RME and CTE HIs do not exceed 1.0 for any receptor; therefore, no non-carcinogenic COCs are identified.

EU 9 Radiological HHRA Summary

RME risks at or above 1×10^{-4} are estimated for soil and surface soil, while RME risks are estimated to be below the 1×10^{-4} threshold for sediment. RME doses at or above 25 mrem/yr are estimated for soil only, while RME doses are estimated to be below the 25 mrem/yr threshold for surface soil and sediment. Risk driving radionuclides are Ra-226 and Pb-210 with the Pb-210 contribution to risk is primarily through the plant ingestion pathway. CTE risks at or above 1×10^{-4} and CTE doses at or above 25 mrem/yr are estimated for soil, while CTE risks and doses for surface soil and sediment are estimated to be below 1×10^{-4} and 25 mrem/yr, respectively. Risk and dose estimates for all receptors reach maximums at year 1,000.

EU 9 Chemical SERA Summary

Ecological risks from soil exceed an HQ of 1 for 10 inorganics (aluminum, beryllium, boron, cadmium, chromium, copper, lithium, selenium, uranium, and vanadium). Seven of the ecological receptors (all except hawks) had at least one HQ greater than 1 for one or more chemicals. The HQs ranged in magnitude from 1.1 (cadmium HQs for deer) to 20,000 (aluminum HQ for shrews). These HQs are conservative because of assumed high bioavailability and other high exposure and effects values used in the mathematical risk computations; this is explained in the uncertainty (Section 4.5) and weight-of-evidence (Section 4.6).

Ecological risks from chemicals in sediment and surface water exceeded the HQ of 1 for one inorganic (uranium) for two (aquatic biota and raccoons) of the five aquatic receptors. The highest HQ was for aquatic biota (HQ = 12), whereas the HQ for raccoons was 1.8.

EU 9 Radiological SERA Summary

The ecological risks from radionuclides in soil as well as sediment and surface water were negligible because the radionuclides did not carry forward from the earlier screening steps.

5.4.10 Exposure Unit 10 – Risk Summary

Note that this risk summary does not include exposure to material within the IWCS. It is assumed that exposure to the contents of the IWCS would pose an unacceptable risk.

EU 10 Chemical HHRA Summary

RME ILCRs do not exceed 1×10^{-4} for the current and future maintenance worker; therefore, no carcinogenic COCs are identified. RME HIs do not exceed 1.0 for the current and future maintenance worker; therefore, no non-carcinogenic COCs are identified.

CTE ILCRs do not exceed 1×10^{-4} for the current and future maintenance worker; therefore, no carcinogenic COCs are identified. CTE HIs do not exceed 1.0 for the current and future maintenance worker; therefore, no non-carcinogenic COCs are identified.

EU 10 Radiological HHRA Summary

RME risks at or above 1×10^{-4} and RME doses at or above 25 mrem/yr are estimated for surface soil only. Risk driving radionuclides are Ac-227, Pa-231, and Ra-226 primarily through the external gamma pathway. CTE risks at or above 1×10^{-4} and CTE doses at or above 25 mrem/yr are estimated for surface soil. Risk and dose estimates for all receptors reach maximums at year 0.

EU 10 Chemical SERA Summary

Ecological risks from soil exceed an HQ of 1 for one SVOC [benzo(b)fluoranthene] and 15 inorganics (aluminum, antimony, barium, beryllium, boron, cadmium, chromium, copper, lithium, manganese, nickel, selenium, uranium, vanadium, and zinc). Seven of the ecological receptors (all except hawks) had at least one HQ greater than 1 for one or more chemicals. The HQs ranged in magnitude from 1.0 (cadmium and nickel HQs for plants) to 21,000 (aluminum HQ for shrews). These HQs are conservative because of assumed high bioavailability and other high exposure and effects values used in the mathematical risk computations; this is explained in the uncertainty (Section 4.5) and weight-of-evidence (Section 4.6).

EU 10 Radiological SERA Summary

The ecological risks from radionuclides in soil were negligible because the sum of fractions did not exceed 1.

5.4.11 Exposure Unit 11 – Risk Summary

EU 11 Chemical HHRA Summary

RME ILCRs for soil exceed 1×10^{-4} for subsistence farmers. Carcinogenic COCs in soil include benzo(a)pyrene, benzo(b)fluoranthene, and indeno (1,2,3-cd)pyrene. RME HIs exceeded 1.0 for subsistence farmer (adult and child) and resident (child). Uranium (total) is a COC for direct contact with soil pathway.

CTE ILCRs do not exceed 1×10^{-4} for any receptor; therefore, no carcinogenic COCs are identified. CTE HIs do not exceed 1.0 for any receptor; therefore, no non-carcinogenic COCs are identified.

EU 11 Radiological HHRA Summary

RME risks at or above 1×10^{-4} and RME doses at or above 25 mrem/yr are estimated for soil and surface soil. Risk driving radionuclides are Ra-226, Pb-210, and uranium with the Pb-210 contribution to risk being primarily through the plant ingestion pathway. CTE risks at or above 1×10^{-4} and CTE doses at or above 25 mrem/yr are estimated for soil. Risk and dose estimates for all receptors reach maximums at year 0.

EU 11 Chemical SERA Summary

Ecological risks from soil exceed an HQ of 1 for four SVOCs [benzo(a)anthracene, benzo(a)pyrene, benzo(k)fluoranthene and indeno(1,2,3-cd)pyrene] and 14 inorganics (aluminum, antimony, barium, beryllium, boron, cadmium, chromium, copper, lithium, mercury, nickel, selenium, uranium, and vanadium). All eight of the ecological receptors had at least one HQ greater than 1 for one or more chemicals. The HQs ranged in magnitude from 1.1 (copper HQ for soil invertebrates) to 23,000 (aluminum HQ for shrews). These HQs are conservative because of assumed high bioavailability and other high exposure and effects values used in the mathematical risk computations; this is explained in the uncertainty (Section 4.5) and weight-of-evidence (Section 4.6).

EU 11 Radiological SERA Summary

The ecological risks from radionuclides in soil were negligible because the sum of fractions did not exceed 1.

5.4.12 Exposure Unit 12 – Risk Summary

EU 12 Chemical HHRA Summary

RME ILCRs for soil exceed 1 x 10^{-4} for subsistence farmers and residents. Carcinogenic COCs in soil (including food) benzo(a)pyrene, benzo(b)fluoranthene, indeno(1,2,3-cd)pyrene, and arsenic. RME HIs exceeded 1.0 for subsistence farmer (adult and child) and resident (child). Arsenic is a COC via the direct contact with soil pathway.

CTE ILCRs do not exceed 1 x 10^{-4} for any receptor; therefore, no carcinogenic COCs are identified. CTE HIs do not exceed 1.0 for any receptor; therefore, no non-carcinogenic COCs are identified.

EU 12 Radiological HHRA Summary

RME risks at or above 1 x 10^{-4} and RME doses at or above 25 mrem/yr are estimated for soil and surface soil. Risk driving radionuclides are Ra-226 and Pb-210 with the Pb-210 contribution to risk being primarily through the plant ingestion pathway. CTE risks at or above 1 x 10^{-4} and CTE doses at or above 25 mrem/yr are estimated for soil. Risk and dose estimates for all receptors reach maximums at year 1,000.

EU 12 Chemical SERA Summary

Ecological risks from soil exceed an HQ of 1 for six SVOCs [benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(k)fluoranthene, chrysene, and indeno(1,2,3-cd)pyrene] and 12 inorganics (aluminum, arsenic, beryllium, boron, cadmium, chromium, copper, lithium, selenium, uranium, vanadium, and zinc). Seven of the ecological receptors (all except hawks) had at least one HQ greater than 1 for one or more chemicals. The HQs ranged in magnitude from 1.0 [benzo(k)fluoranthene HQ for plants] to 21,000 [aluminum HQ for shrews]. These HQs are conservative because of assumed high bioavailability and other high exposure and effects values used in the mathematical risk computations; this is explained in the uncertainty (Section 4.5) and weight-of-evidence (Section 4.6).

EU 12 Radiological SERA Summary

The ecological risks from radionuclides in soil were negligible because the sum of fractions did not exceed 1.

5.4.13 Exposure Unit 13 – Risk Summary

EU 13 Chemical HHRA Summary

RME ILCRs for soil (including food) exceed 1 x 10^{-4} for subsistence farmers. Carcinogenic COCs in soil include aroclor-1254, benzo(a)pyrene, and arsenic. RME HIs exceed 1.0 for subsistence farmer (adult and child). Aroclor-1254, boron, copper and zinc are COCs for direct contact with soil and/or food pathways.

RME ILCRs for groundwater exceed 1 x 10^{-4} for subsistence farmers and residents. Bis(2-ethylhexyl)phthalate, trichloroethene, and arsenic are carcinogenic COCs for exposure to groundwater. RME HIs for soil (including food) exceeded 1.0 for subsistence farmer (adult and child) and resident (adult and child). Aroclor-1254, copper and zinc are non-carcinogenic COCs for exposure to food. Aluminum, arsenic, boron, manganese, vanadium, cis-1,2-dichloroethene, and trichloroethene are non-carcinogenic COCs for exposure to groundwater. Lead EPC exceeds the drinking water action level and also is a COC.

CTE ILCRs do not exceed 1 x 10^{-4} for any receptor; therefore, no carcinogenic COCs are identified. CTE HIs exceeded 1.0 for subsistence farmer (child). Aroclor-1254 is a COC for the direct contact with soil and/or food pathways.

CTE ILCRs for groundwater exceed 1 x 10^{-4} for subsistence farmers and residents. Trichloroethene and arsenic are carcinogenic COCs for exposure to groundwater. CTE HIs exceeded 1.0 for subsistence farmer (adult and child), resident (adult and child), and construction worker. Cis-1,2-dichloroethene, trichloroethene, arsenic, boron, manganese, and vanadium are non-carcinogenic COCs for exposure to groundwater. Lead EPC exceeds the drinking water action level and also is a COC.

EU 13 Radiological HHRA Summary

RME risks at or above 1 x 10^{-4} are estimated for soil, surface soil, and groundwater. RME doses at or above 25 mrem/yr are estimated for soil and surface soil, while groundwater RME doses are estimated to be below the 25 mrem/yr threshold. Risk driving radionuclides are Ra-226 and Pb-210 with the Pb-210 contribution to risk being primarily through the plant ingestion pathway. CTE risks at or above 1 x 10^{-4} and CTE doses at or above 25 mrem/yr are estimated for soil, but CTE risks and doses for groundwater are estimated to be below 1 x 10^{-4} and 25 mrem/yr, respectively. Risk and dose estimates for all receptors reach maximums at year 0.

EU 13 Chemical SERA Summary

Ecological risks from soil exceed an HQ of 1 for one SVOC [benzo(b)fluoranthene] and 12 inorganics (antimony, boron, cadmium, chromium, copper, lead, mercury, nickel, selenium, uranium, vanadium, and zinc). Seven of the ecological receptors (all except hawks) had at least one HQ greater than 1 for one or more chemicals. The HQs ranged in magnitude from 1.2 [selenium HQ for deer] to 14,000 (lead HQ for robins). These HQs are conservative because of assumed high bioavailability and other high exposure and effects values used in the mathematical risk computations; this is explained in the uncertainty (Section 4.5) and weight-of-evidence (Section 4.6).

EU 13 Radiological SERA Summary

The ecological risks from radionuclides in soil were negligible because the sum of fractions did not exceed 1.

5.4.14 Exposure Unit 14 – Risk Summary

EU 14 Chemical HHRA Summary

RME ILCRs do not exceed 1 x 10^{-4} for any receptor; therefore, no carcinogenic COCs are identified. RME HIs exceed 1.0 for subsistence farmer (adult and child) and resident (adult and child). Di-n-octylphthalate and boron are COCs via the food pathway.

CTE ILCRs do not exceed 1 x 10^{-4} for any receptor; therefore, no carcinogenic COCs are identified. CTE HI exceed 1.0 for subsistence farmer (adult and child) and resident (adult and child). Di-n-octylphthalate and boron are COCs via the food pathway.

EU 14 Radiological HHRA Summary

RME risks at or above 1 x 10^{-4} and RME doses at or above 25 mrem/yr are estimated for soil and surface soil. Risk driving radionuclides are Ra-226 and Pb-210 with the Pb-210 contribution to risk being primarily through the plant ingestion pathway. CTE risks at or above 1 x 10^{-4} and CTE doses at or above 25 mrem/yr are estimated for soil. Risk and dose estimates for all receptors reach maximums at year 0.

EU 14 Chemical SERA Summary

Ecological risks from soil exceed an HQ of 1 for 13 inorganics (aluminum, antimony, barium, beryllium, boron, cadmium, chromium, copper, lead, lithium, selenium, uranium, and zinc). Seven of the ecological receptors (all except hawks) had at least one HQ greater than 1 for one or more chemicals. The HQs ranged in magnitude from 1.1 (uranium HQ for plants) to 120,000 (aluminum HQ for shrews). These HQs are conservative because of assumed high bioavailability and other high exposure and effects values used in the mathematical risk computations; this is explained in the uncertainty (Section 4.5) and weight-of-evidence (Section 4.6).

EU 14 Radiological SERA Summary

The ecological risks from radionuclides in soil were negligible because the sum of fractions did not exceed 1.

5.4.15 Exposure Unit 15 – Risk Summary

EU 15 Chemical HHRA Summary

EU 15 exposures are limited to surface water and sediment in the central ditch and tributary ditches. Five COPCs were identified in surface water; however, none have toxicity criteria. As a result, ILCRs and HIs could not be calculated for exposures to surface water. The summaries below discuss risks from exposure to COPCs in sediment.

RME ILCRs for sediment do not exceed 1 x 10^{-4} for any receptor; therefore, no carcinogenic COCs are identified. RME HIs do not exceed 1.0 for any receptor; therefore, no non-carcinogenic COCs are identified.

CTE ILCRs for sediment do not exceed 1 x 10^{-4} for any receptor; therefore, no carcinogenic COCs are identified. CTE HIs do not exceed 1.0 for any receptor; therefore, no non-carcinogenic COCs are identified.

EU 15 Radiological HHRA Summary

No ROPCs are identified for soil. RME risks for sediment are estimated to be below 1 x 10^{-4} with a maximum of 6.3 x 10^{-6} for the subsistence farmer. RME doses are expected to be below 25 mrem/yr for sediment. CTE risks and doses for sediment are estimated to be below 1 x 10^{-4} and 25 mrem/yr, respectively. Risk and dose estimates for all receptors exposed to sediment reach maximums at year 1,000.

EU 15 Chemical SERA Summary

Ecological risks from sediment and surface water exceed an HQ of 1 for 19 inorganics (aluminum, arsenic, barium, boron, cadmium, cobalt, copper, iron, lead, lithium, manganese, mercury, nickel, selenium, silver, thallium, uranium, vanadium, and zinc). All of the five aquatic receptors had at least one HQ greater than 1 for one or more chemicals. The HQs ranged in magnitude from 1.0 (boron HQ for raccoons) to 330 (lead HQ for raccoon).

EU 15 Radiological SERA Summary

The ecological risks from radionuclides in sediment and surface water were negligible because none of the radionuclides were carried forward from the earlier screening steps.

5.4.16 Exposure Unit 16 – Risk Summary

EU 16 consists of sediment and surface water in on-site pipelines. In addition, it contains subsurface soil immediately adjacent to pipelines that may be contaminated from pipeline leaks. The future construction worker is the only receptor exposed to COPCs in EU 16. EU 16 was not evaluated in the SERA because there is not complete exposure pathway for ecological receptors.

EU 16 Chemical HHRA Summary

RME ILCR for soil does not exceed 1 x 10^{-4} for the construction worker; therefore, no carcinogenic COCs are identified. RME HI does not exceed 1.0 for the construction worker; therefore, no non-carcinogenic COCs are identified.

RME ILCR for sediment does not exceed 1 x 10^{-4} for the construction worker; therefore, no carcinogenic COCs are identified. The EU 16 construction worker is assumed to be exposed to contaminated sediment one workday per week for one year resulting in carcinogenic risk of 1.3 x 10^{-6}. Revising exposure times within EU 16 to be consistent with that of the LOOW BRA, would increase the exposure duration for chemical exposures, by a factor of five. That is, exposure duration would change from one 8-hour workday per week to five 8-hour workdays per week. Risk scales linearly with exposure duration so the revised risk would be 6.5 x 10^{-6}. No new COCs would be identified based on this revision and no new conclusions would be drawn by the BRA. RME HI exceeds 1.0 for the construction worker exposed to sediment. Aroclor-1254 is a COC in sediment based on non-carcinogenic risk. Increasing the construction worker exposure duration for EU 16 sediment increases the non-cancer estimate of risk, however, 83% of the non-cancer HI is due to Aroclor-1254 and, once again, no new COCs would be added. The lead EPC concentration in sediment exceeds the construction worker PRG for soil; therefore, lead is retained as a COC.

RME ILCR for the construction worker exposed to surface water is 5.9×10^{-4}, which exceeds the target risk threshold of 1×10^{-4}. Aroclor-1254 accounts for 97% of this risk. Increasing the construction worker exposure duration for surface water from one 8-hour workday per week to five 8-hour workdays per week raises the estimate of cancer risk from 5.9×10^{-4} to 2.8×10^{-3}. Although Aroclor-1254 would still account for 97% of ILCR, benzo(a)anthracene, benzo(b)fluoranthene, and benzo(k)fluoranthene would contribute risk just over the screening threshold of 1×10^{-5} and would have to be added as COCs. The surface water RME HI exceeds the target risk threshold of 1.0 for the construction worker. For non-cancer effects, Aroclor-1254 is the only COC. Increasing the construction worker exposure duration for surface water from one 8-hour workday per week to five 8-hour workdays per week raises the estimate of non-cancer risk and results in the addition of Aroclor-1260 as a COC. Since Aroclors are addressed collectively as PCBs, increasing the exposure duration for EU 16 surface water would result in no new conclusions drawn by the BRA. Additionally, since the EU 16 pipelines are plugged at the site boundaries, they do not pose an off-site migration risk. Aroclor is also present in Bldg 401 drains (EU 13) but based on SESOIL modeling, Aroclor does not leach to groundwater in EU 13. Therefore, the pipeline surface water would not have to be removed/treated.

CTE ILCR for soil does not exceed 1×10^{-4} for the construction worker; therefore, no carcinogenic COCs are identified. RME HI does not exceed 1.0 for the construction worker; therefore, no non-carcinogenic COCs are identified.

CTE ILCR for sediment does not exceed 1×10^{-4} for the construction worker; therefore, no carcinogenic COCs are identified. CTE HI does not exceed 1.0 for the construction worker; therefore, no non-carcinogenic COCs are identified. The lead EPC concentration in sediment exceeds the construction worker PRG for soil; therefore, lead is retained as a COC.

CTE ILCR for surface water exceeds 1×10^{-4} for the construction worker. In addition, CTE HI exceeds 1.0 for the construction worker. Aroclor-1254 is a COC in surface water based on both carcinogenic and non-carcinogenic risk.

EU 16 Radiological HHRA Summary

RME risks and doses for soil and sediment are estimated to be below 1×10^{-4} and 25 mrem/yr, respectively. The EU 16 construction worker is assumed to be exposed to contaminated sediment one workday per week for one year resulting in a radiological dose rate of 1.3 mrem/yr. Revising the EU 16 outdoor occupancy times to be consistent with that of the LOOW BRA, would increase the outdoor occupancy for radiological exposures by a factor of five. That is, occupancy would change from one 8-hour workday per week to five 8-hour workdays per week. Dose scales linearly with outdoor occupancy so the revised dose would be 6.5 mrem/yr. No ROCs would be added based on this revision and no new conclusions would be drawn by the BRA. Even with full-time outdoor occupancy by the construction worker, consistent with assumptions used for LOOW pipeline exposures, risk levels would still be within the acceptable risk range. CTE risks and doses for all media are estimated to be below 1×10^{-4} and 25 mrem/yr, respectively. No EU 16 ROPCs are identified for surface soil or surface water. Risk and dose estimates for all receptors reach maximums at year 1,000.

5.4.17 Exposure Unit 17 – Risk Summary

EU 17 is a "site-wide" EU and consists of data collected in all other EUs. EU 17 contains soil, sediment, surface water, and groundwater.

EU 17 Chemical HHRA Summary

Seven COPCs were identified in EU 17 surface water; however, none have toxicity criteria. As a result, risks from surface water exposures could not be calculated. The summaries below discuss risks from exposures to soil, groundwater, and sediment.

RME ILCRs for soil exceed 1 x 10^{-4} for subsistence farmers and residents. Carcinogenic COCs identified in soil (including food pathways) are aroclor-1260, benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, indeno(1,2,3-cd)pyrene, arsenic and tetrachloroethene. RME HIs exceeded 1.0 for subsistence farmer (adult and child) and resident (child). Aroclor-1260 is a COC for direct contact with soil and food pathways.

RME ILCRs for groundwater exceed 1 x 10^{-4} for subsistence farmers and residents. Arsenic, bis(2-ethylhexyl)phthalate, tetrachloroethene, and methylene chloride are COCs for exposure to groundwater. RME HIs exceeded 1.0 for subsistence farmer (adult and child), resident (adult and child), and construction worker. Tetrachloroethene, aluminum, arsenic, manganese, and vanadium are COCs for exposure to groundwater. Lead EPC exceeds the drinking water action level and also is a COC.

RME ILCRs for sediment do not exceed 1 x 10^{-4} for any receptors; therefore, no carcinogenic COCs are identified. RME HIs exceed 1.0 for subsistence farmer (child), resident (child), and trespasser/recreational visitor (adolescent). Aroclor-1254 is a COC in sediment based on non-carcinogenic risk.

CTE ILCRs for soil exceed 1 x 10^{-4} for subsistence farmers and residents. Carcinogenic COCs in soil include aroclor-1260, benzo(a)pyrene, benzo(b)fluoranthene, and indeno(1,2,3-cd)pyrene. CTE HIs exceeded 1.0 for subsistence farmer (adult and child). Aroclor-1260 is a COC for direct contact with soil.

CTE ILCRs for groundwater exceed 1 x 10^{-4} for subsistence farmers, residents, and construction workers. Tetrachloroethene and arsenic are COCs for exposure to groundwater. CTE HIs exceeded 1.0 for subsistence farmer (adult and child) and resident (adult and child). Tetrachloroethene, arsenic, and manganese are COCs for exposure to groundwater. Lead EPC exceeds the drinking water action level and also is a COC.

CTE ILCRs for sediment do not exceed 1 x 10^{-4} for any receptors; therefore, no carcinogenic COCs are identified. RME HIs do not exceed 1.0 for any receptors; therefore, no non-carcinogenic COCs are identified.

EU 17 Radiological HHRA Summary

RME risks at or above 1 x 10^{-4} and RME doses at or above 25 mrem/yr are estimated for soil, surface soil, and groundwater, while RME risks and doses for sediment are estimated to be below 1 x 10^{-4} and 25 mrem/yr, respectively. Risk driving radionuclides are Ra-226 and Pb-210 with the Pb-210 contribution to risk being primarily through the plant ingestion pathway. CTE risks at or above 1 x 10^{-4} and CTE doses at or above 25 mrem/yr are estimated for soil and groundwater, while CTE risks and doses for sediment are estimated to be below 1 x 10^{-4} and 25 mrem/yr, respectively. Risk and dose estimates for all receptors reach maximums at year 0.

EU 17 Chemical SERA Summary

Ecological risks from soil exceed an HQ of 1 for six SVOCs [benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(k)fluoranthene, chrysene, and indeno(1,2,3-cd)pyrene] and 17 inorganics (aluminum, antimony, arsenic, barium, beryllium, boron, cadmium, chromium, copper, lead, lithium, mercury, nickel, selenium, uranium, vanadium, and zinc). Seven of the ecological receptors (all except hawks) had at least one HQ greater than 1 for one or more chemicals. The highest HQs ranged in magnitude from 1.1 (barium HQs for foxes) to 22,000 [aluminum HQ for shrews]. These HQs are conservative because of assumed high bioavailability and other high exposure and effects values used in the mathematical risk computations; this is explained in the uncertainty (Section 4.5) and weight-of-evidence (Section 4.6).

Ecological risks from chemicals in sediment and surface water exceeded the HQ of 1 for 19 inorganics (aluminum, arsenic, barium, boron, cadmium, cobalt, copper, iron, lead, lithium, manganese, mercury, nickel, selenium, silver, thallium, uranium, vanadium, and zinc). All five aquatic receptors had at least one HQ greater than 1 for one or more chemicals. The HQs that exceeded 1 ranged in magnitude from 1.1 (barium HQ for herons) to 9,300 (lead HQ for raccoons).

EU 17 Radiological SERA Summary

The ecological risks from radionuclides in soil were negligible because the sum of fractions did not exceed 1. Likewise, the ecological risks from radionuclides in sediment and surface water were negligible because the radionuclides did not carry forward from the earlier screening steps.

5.5 POTENTIAL RISK TO OFF-SITE GROUNDWATER RECEPTORS

Future risks to off-site receptors from groundwater contamination at NFSS could come from two sources: 1) movement of current groundwater contamination off-site, or 2) leaching of contaminants to groundwater, followed by movement of that groundwater contamination off-site. This section uses predictions from the groundwater modeling effort to discuss potential future risks to off-site receptors from these two sources, specifically, from migration of existing organic and metal groundwater contamination, from leaching and migration of contaminants from within the IWCS, and from existing radionuclide groundwater contamination in combination with continued leaching of radionuclides from site soils and potential ingrowth of contaminants.

Groundwater modeling results indicate that only minor dispersion of a VOC plume in EU 4 is expected and this plume is not predicted to migrate off-site. VOCs within this plume (PCE, TCE, cis-1,2-DCE, and vinyl chloride) are expected to degrade to levels less than the screening values within 300 years in the Brown Clay Till. However, according to modeling results, these VOCs continue to migrate downward into the Glacio-Lacustrine Clay. TCE and vinyl chloride further migrate to the Alluvial Sand and Gravel and Queenston Formation in the first 150 years. Vinyl chloride is predicted to degrade to below screening levels by 200 years.

According to groundwater fate and transport modeling results, the bis(2-ethylhexyl)phthalate plume in EU 10 exhibits only minor dispersion within the Brown Clay Till within 1,000 years, and the maximum concentration of this organic compound in groundwater is not expected to increase above the current concentrations of the plume.

The groundwater flow and transport model indicates that concentrations of boron and manganese, the only two metals plumes identified in the UWBZ, are not expected to increase above the current concentrations of the plumes in EUs 3, 4, and 13. Concentrations of boron and manganese that exceed the screening levels are not expected to migrate vertically below the base of the Brown Clay Till.

Over 1,000 years, the groundwater model does predict leaching from the IWCS to groundwater directly below the IWCS; however, it does not show much lateral movement of the leached contaminants. Moreover, the leached contaminants do not reach the site boundary within the 1,000-yr modeling period. Specifically, the seven modeled metals (arsenic, barium, boron, iron, lead, molybdenum and manganese) present in residues within the IWCS will not migrate off-site in groundwater at concentrations above screening levels in the vicinity of the IWCS. Similarly, leaching of radionuclides is predicted, but lateral movement towards the site boundary does not occur to any appreciable extent. Because minimal dispersion of the existing groundwater plumes in the area adjacent to the IWCS is predicted, no additional risk beyond what is present due to current groundwater contamination is expected in this area. A more detailed discussion of future contaminant concentrations below the IWCS in groundwater can be found in the RI Report (SAIC 2007).

Visual interpretations of groundwater fate and transport modeling results appear to indicate that off-site migration of radionuclides may occur at four site areas within the 1,000-year evaluation period of the BRA. The four locations include the northwest corner of EU 1, the west side of EU 7, the east side of EU 8, and the south side of EU 11. To more accurately evaluate this potential off-site migration, groundwater modeling results using data obtained from the model post-processor were used to predict maximum uranium isotope concentrations at these four boundary locations within 1,000 years. (HGL 2007). The table below (Exhibit 5.1) summarizes the predicted maximum concentrations for uranium isotopes at these four locations within 1,000 years. The MCL for each isotope (as correlated to the MCL of 30 pCi/L for total uranium) and the 10^{-5} risk level PRG are also provided for comparison to the predicted concentrations.

Exhibit 5.1 Predicted Maximum Uranium Isotope Concentrations at NFSS Site Boundary within 1,000 Years

Uranium Isotope	MCL (pCi/L)	10^{-5} Risk PRG (pCi/L)	Northwest Corner of EU 1 * (pCi/L)	West Side of EU 7 * (pCi/L)	East Side of EU 8 * (pCi/L)	South Side of EU 11 * (pCi/L)
U-234	13.2	6.72	15.35	2.49	5.18	180.07
U-235	0.6	6.62	0.08	0.14	0.35	117.78
U-238	13.2	5.46	12.02	1.75	1.34	34.02

* – Uranium isotope concentrations may reach maximum values at different locations and at different elapsed times. Therefore, the expected ratio for the occurrence of the uranium isotopes can not be applied for the uranium data as shown.
pCi/L – picocuries per liter

As data in Exhibit 5.1 indicate, the groundwater model predicts off-site migration of uranium isotopes in the northwest corner of EU 1 and on the south side of EU 11 at concentrations that exceed risk levels and MCLs within 1,000 years. Off-site migration in EUs 1 and 11 is the result of continued migration of existing groundwater contamination with additional contributions predicted from SESOIL modeling. Radionuclide concentrations are not expected to increase significantly in these plumes and contaminant concentrations above screening or risk levels are

not expected to move far beyond the site boundary. Uranium isotope concentrations in the UWBZ on the boundaries of EUs 7 and 8 are expected to remain below screening and risk levels within the next 1,000 years as indicated in Exhibit 5.1.

Conclusions made regarding the fate and transport of radionuclides in site groundwater are somewhat dependant on the conservative K_d value of 3.6 L/kg that was used in the modeling simulations. Use of this K_d value causes the model to predict greater concentrations of radionuclides in groundwater due to increased leaching of site soils. Although predicted off-site migration of radionuclides may indicate a future potential risk to off-site receptors, the evaluation presented in this report only represents a brief, qualitative analysis of future risk. Risk associated with potential off-site migration of contaminants will be further evaluated in the FS.

Another factor to consider for future groundwater risk assessment (other than movement of contaminants) is radioactive decay and ingrowth of contaminants that are already in the GW. This is likely only an issue for thorium contamination resulting in radium ingrowth. Two thorium-230 plumes located near the site boundary (one in EU 4 and one in EU 7/10) were evaluated for future risks due to ingrowth because it is feasible that radium concentrations in groundwater could increase in the presence of parent thorium isotopes: Th-230 for Ra-226 and Th-232 for Ra-228.

Dissolved radium concentrations in the plume in EU 4 are well below the MCL of 5 pCi/L, with a maximum result of approximately 1.0 pCi/L. The total radium (i.e., unfiltered) result is approximately 2.5 pCi/L, or half the MCL. The maximum dissolved and total Th-230 concentrations are 0.64 and 2.5 pCi/L, respectively. The maximum dissolved and total Th-232 concentrations are 0.23 and 2.1 pCi/L, respectively. Therefore, considering potential for radiological ingrowth of radium without the introduction of a secondary source, total radium in the EU 4 plume could not exceed the MCL within 1,000 years. Similar arguments are made for the plume in EU 7/10. The maximum total and dissolved groundwater concentrations for Ra-226, Ra-228, Th-230 or Th-232 are all less than 2.5 pCi/L; thus, combined radium could not exceed the MCL, and ingrowth from thorium would similarly not produce sufficiently high radium concentrations. It is concluded that existing reported radium concentrations in the EU 4 and EU 7/10 plumes are less than the MCL now (considering both total and dissolved results) and the potential for ingrowth would not result in an exceedance over the next 1,000 years without the introduction of a secondary source of contamination.

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