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SUPPLIER DOCUMENT

ECOLOGICAL RISK ASSESSMENT NPD CLOSURE PROJECT

64-509200-ASD-004

Revision 2

Accepted by: ______________________ 2020 December 14

Katie Hogue — Date

NPD Regulatory Approvals Manager

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Nuclear Power Demonstration Closure Project

TECHNICAL SUPPORTING DOCUMENT – ECOLOGICAL RISK ASSESSMENT

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TECHNICAL SUPPORTING DOCUMENT – ECOLOGICAL RISK ASSESSMENT

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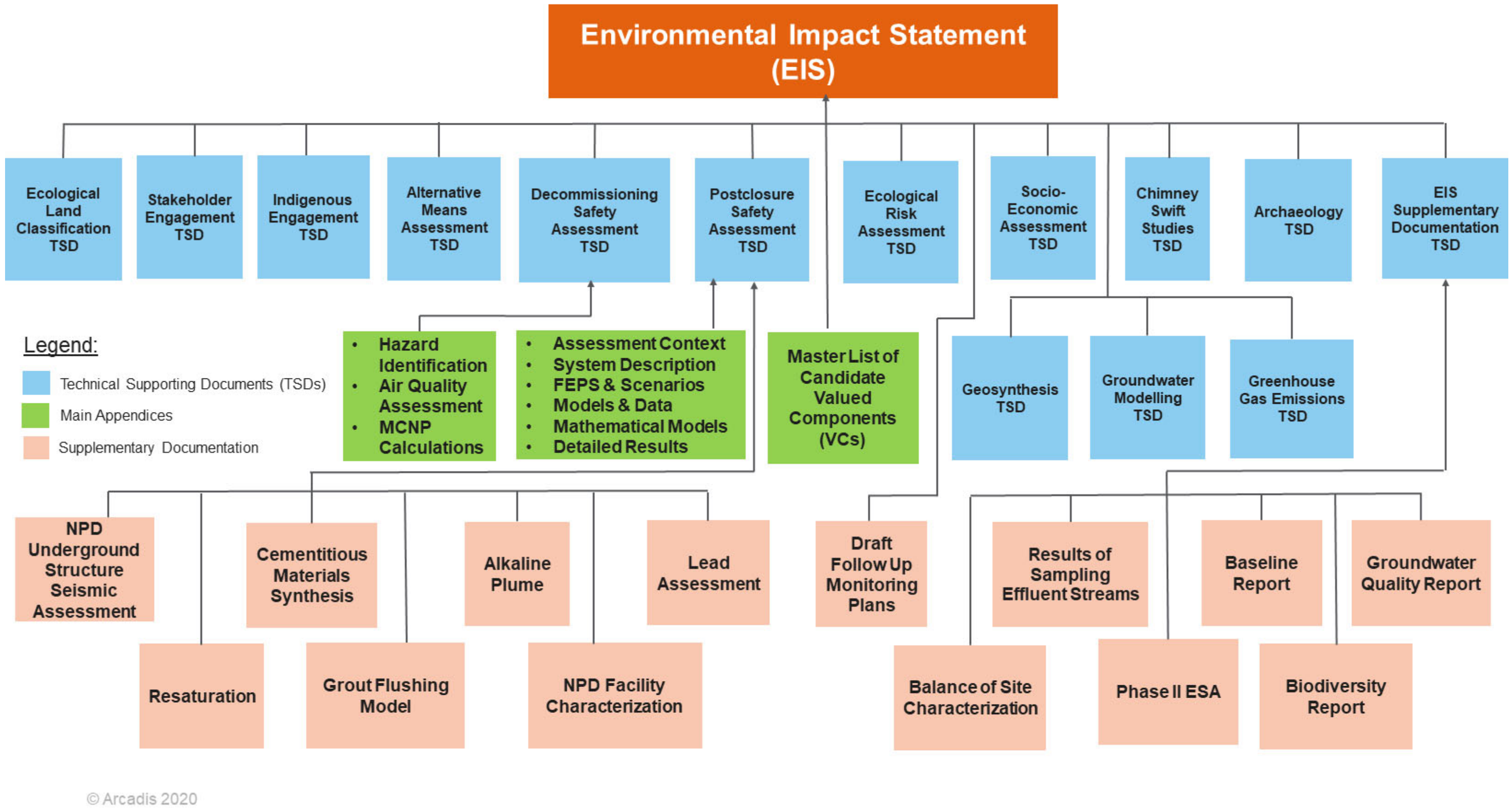
Nuclear Power Demonstration Closure Project
Technical Supporting Document - Ecological Risk Assessment (64-509200-ASD-004 Rev. 2)

This Technical Supporting Document (TSD) has been prepared in support of the Nuclear Power Demonstration (NPD) Closure Project. The project qualifies as a Designated Project under the *Canadian Environmental Assessment Act (2012),* and therefore, an Environmental Impact Statement (EIS) is being prepared as part of the Environmental Assessment process.

The findings of this TSD have been summarized in the NPD Closure Project EIS (CNL Doc #64-509410-ENA-004 Rev 1). The following figure shows the various documents associated with the EIS, and their relationships.


Environmental Impact Statement (EIS)
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Stakeholder Engagement TSD
Indigenous Engagement TSD
Alternative Means Assessment TSD
Decommissioning Safety Assessment TSD
Postclosure Safety Assessment TSD
Ecological Risk Assessment TSD
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Balance of Site Characterization
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Biodiversity Report
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ACRONYMS AND ABBREVIATIONS

ADF	Air Dispersion Factor
AECL	Atomic Energy of Canada Limited
APV	Aquatic Protection Values
BCG	Biota Concentration Guides
BRA	Background Reference Area
CCME	Canadian Council of Ministers of the Environment
CNL	Canadian Nuclear Laboratories
CNSC	Canadian Nuclear Safety Commission
CCOC	Conventional Contaminant of Concern
COPC	Contaminant of Potential Concern
COSEWIC	Committee on the Status of Endangered Wildlife in Canada
CRL	Chalk River Laboratories
CSA	Canadian Standards Association
CSM	Conceptual Site Model
CWF	Canadian Wildlife Foundation
DC	Dose Coefficient
DCC	Dose Conversion Coefficient
DOE	Department of Energy
DecomSA	Decommissioning Safety Assessment
EEC	Environmental Effect Concentration
EcoRA	Ecological Risk Assessment
Eco-SSL	Ecological Soil Screening Level
EIS	Environmental Impact Statement
EMC	Environmental Media Concentrations
END	Endangered
EPA	Environmental Protection Agency
ESA	Environmental Site Assessment
ET	Ecotox Threshold
FASSET	Framework for Assessment of Environmental Impact
FCSAP	Federal Contaminated Sites Assessment Guidance
HHRA	Human Health Risk Assessment
HQ	Hazard Quotient
HSA	Historical Site Assessment
HSDB	Hazardous Substances Database
HT	Elemental Tritium
HTO	Tritiated Water Vapour
IAEA	International Atomic Energy Agency
ICRP	International Commission on Radiological Protection Publication

ISQG	Interim Sediment Quality Guideline
LEL	Lowest Effect Level
LOAEC	Lowest-Observed-Adverse-Effect Concentration
LOAEL	Lowest-Observed-Adverse-Effect Level
LOEC	Lowest-Observed-Effect-Concentration
LOEL	Lowest-Observed-Effect Level
MATC	Maximum Acceptable Toxicant Concentration
MARSSIM	Multi-Agency Radiation Survey and Site Investigation Manual
MECP	Ministry of Environment, Conservation and Parks
MELCC	Ministère de l'Environnement et de la Lutte contre les Changements Climatiques
MOE	Ministry of the Environment
MOEE	Ministry of the Environment and Energy
MPF	Mo-99 Production Facility
NAWQC	National Ambient Water Quality Criteria
NCRP	National Council on Radiation Protection and Measurements
NEC	No-Effect Concentration
NES	Normal Evolution Scenario
NOAEC	No-Observed-Adverse-Effect Concentration
NOAEL	No-Observed-Adverse-Effect Level
NOEC	No-Observed-Effect-Concentration
NPD	Nuclear Power Demonstration
NPDNGS	Nuclear Power Demonstration Nuclear Generating Station
NPDWF	Nuclear Power Demonstration Waste Facility
OBT	Organically Bound Tritium
OF	Occupancy Factor
OSWER	Office of Solid Waste and Emergency Response
PCB	Polychlorinated Biphenyl
PEL	Probable Effect Level
PHC	Petroleum Hydrocarbon
PostSA	Postclosure Safety Assessment
PWQMN	Provincial Water Quality Monitoring Network
PWQO	Provincial Water Quality Objective
RBE	Relative Biological Effectiveness
RTECS	Registry of Toxic Effects of Chemical Substances
SA	Sensitivity Analysis
SAR	Species at Risk
SARA	Species at Risk Act
SC	Special Concern
SEL	Severe Effect Level

SI	Screening Index
SLRA	Screening Level Risk Assessment
SPW	Soil Pore Water
TF	Transfer Factor
THR	Threatened
TRV	Toxicity Reference Value
TSD	Technical Supporting Document
TSP	Total Suspended Particulate
ULB	Upper Limit Background
UNSCEAR	United Nations Scientific Committee on the Effects of Atomic Radiation
VC	Valued Component
WNS	White-nose Syndrome

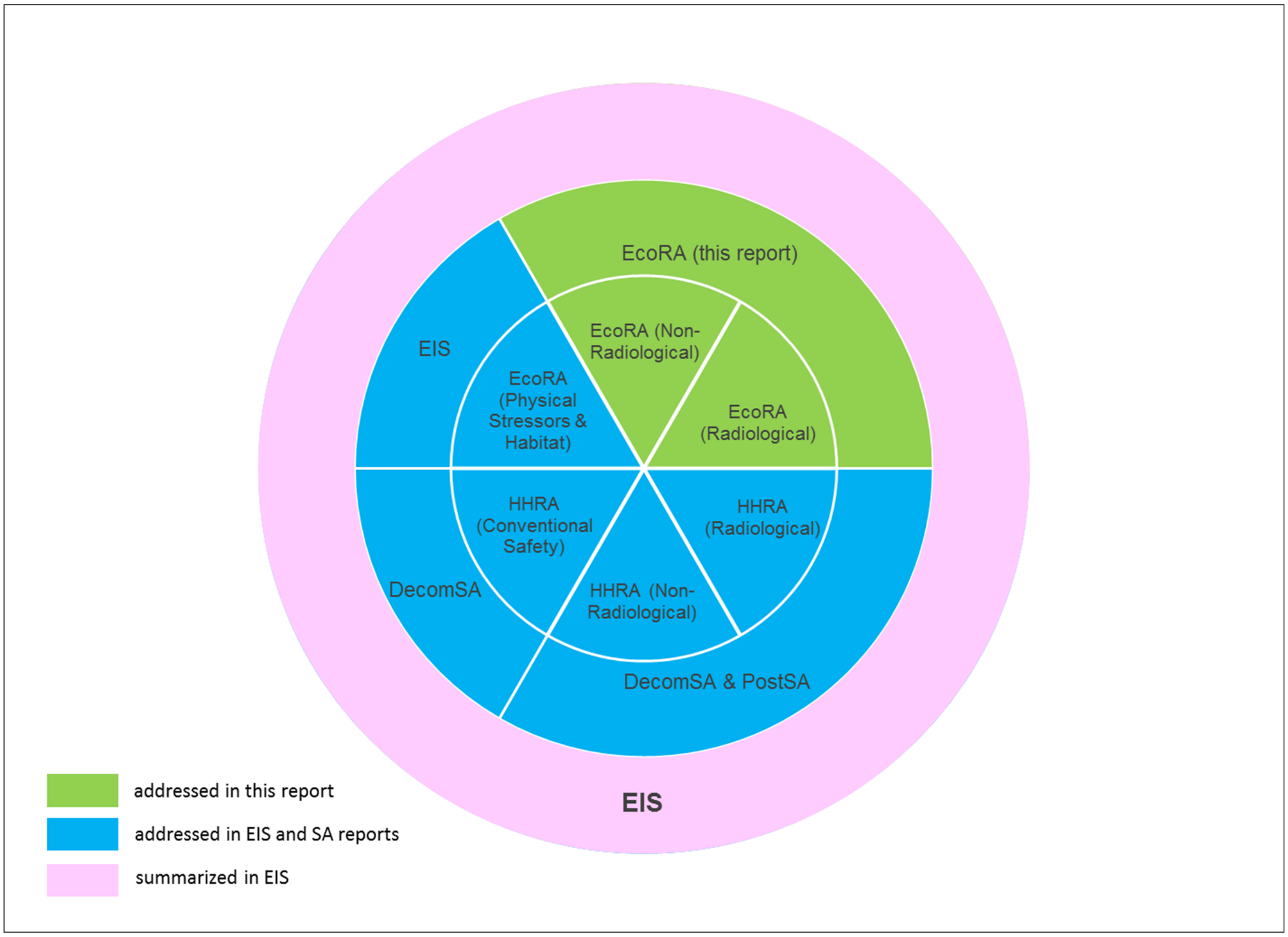
1.0 INTRODUCTION

Canadian Nuclear Laboratories (CNL) is undertaking the decommissioning of the Nuclear Power Demonstration (NPD) reactor, which was the first Canadian nuclear power reactor. The reactor operated from 1962 to 1987 and is currently in a “Storage-with-Surveillance” phase. The preferred approach to decommissioning the NPD reactor is **In-Situ Disposal** whereby above grade structures are removed and below grade structures are encased in grout. An impermeable contoured cap is then installed across the area to achieve closure of the NPD site. The NPD system comprises the buildings that contained nuclear materials including the reactor, spent fuel storage bays, and the heat transport system, alongside the radioactive and non-radioactive hazardous contamination that remains within these buildings.

The Ecological Risk Assessment (EcoRA) for the decommissioning project (the Project) has been prepared as a Technical Supporting Document (TSD) to the Environmental Impact Statement (EIS) in accordance with the Canadian Standards Association (CSA) N288.6-12 standard for Class I Nuclear facilities (CSA 2012). This EcoRA is limited to assessing the effects of radiological and non-radiological contaminants on non-human biota. It does not include an assessment of other stressors associated with the decommissioning of the NPD system (e.g., noise, dust, changes in habitat). Other stressors are assessed in the NPD Closure Project EIS (see Figure 1.1). In Figure 1.1, HHRA refers to Human Health Risk Assessment, DecomSA refers to Decommissioning Safety Assessment and PostSA refers to Postclosure Safety Assessment.

Human receptors are assessed in the DecomSA (Garisto *et al.* 2020) and 3rd Iteration PostSA (Penfold *et al*. 2020) for the Decommissioning and Postclosure Phases of the Project, respectively, and the results are discussed in Section 9.8 of the EIS. Physical stressors and habitat effects are both addressed in the EIS. The EIS also includes a summary of the effect assessments from the EcoRA, DecomSA and PostSA reports.

Figure 1.1 Where Effects are Assessed for Various Receptors and Stressors in this Project



1.1 Assessment of Baseline Conditions

The EcoRA described in this report does not include an assessment of radiological and non-radiological baseline conditions at the NPD site and Local and Regional Study Areas. However, studies systematically characterizing baseline conditions at the NPD site, consisting of Phase I and Phase II Environmental Site Assessments (ESAs), were conducted in 2016 and 2017. The ESAs for the NPD property have been documented in the following reports:

a) *Historical Site Assessment (HSA) for the Nuclear Power Demonstration Waste Management Facility, Rolphton, Ontario* (ORAU 2017) (CNL 64-509410-ASD-001, Revision 1)
   - Phase I ESA

b) *Characterization Plan for Nuclear and Conventional Hazards of the Nuclear Power Demonstration Waste Facility Rolphton, Ontario* (ORAU 2016) (CNL 64-509410-PLA-001, Revision 0)
   - Guidance for the Phase II investigation developed based upon findings of the HSA

c) *Environmental Site Assessment REV 3 Sampling Plan for the NPD Site Canadian Nuclear Laboratories* (Golder 2016) (CNL 64-509410-PLA-002, Revision 0)
   - Summarizes the scope of the Phase II field investigation program

d) *Phase Two Environmental Assessment Nuclear Power Demonstration Site, Canadian Nuclear Laboratories* (Golder 2017a) (CNL 64-509410-REPT-006, Revision 0)
   - Phase II ESA – Summarizes the results for Conventional Contaminants of Concern (CCOCs)

e) *NPD Balance of Site Characterisation Report* (McVeigh 2018) (CNL 64-508740-REPT-009, Revision 0)
   - Summarizes the Phase II ESA results for Radionuclides of Concern

The Phase I ESA (ORAU 2017) was conducted based on CSA Standard Z768-01 (CSA 2003; reaffirmed in 2012) and nuclear industry site characterization guidance (Multi-Agency Radiation Survey and Site Investigation Manual, referred to as “MARSSIM”). The Phase II ESA (Golder 2017a; McVeigh 2018) was conducted in accordance with O. Reg 153/04, CSA Standard Z769 (CSA 2000; reaffirmed in 2013) for Phase II ESA, as well as CSA Standard N292.5-11, which provides guidelines for the exemption or clearance from regulatory control of materials that contain, or potentially contain, nuclear substances. The Phase II ESA work was also conducted in accordance with the requirements of the Characterization Plan (ORAU 2016) that was developed from the Phase I ESA, and followed the framework of the CNL NPD Sampling Plan (Golder 2016).

The Phase I and II ESAs (ORAU 2017; Golder 2017a; McVeigh 2018) collectively meet the requirements for a Screening Level Risk Assessment (SLRA) or Tier 1 Risk Assessment, as defined under CSA Standard N288.6-12, and collectively assess baseline conditions at the NPD property.

1.2 Scope of Ecological Risk Assessment

The EcoRA assesses exposures of non-human biota to radiological and non-radiological contaminants during certain phases of the Project. The Project phases, as described in Sections 3.2 and 5.2.1.2 of the EIS, include the following:

- **Decommissioning Execution** (also referred to as Decommissioning), or the first one to two years during which all activities associated with decommissioning of the facility occur, including setup and operation of the batch mixing plant, grouting and demolition activities, installation of the concrete cap and engineered cover, as well as site restoration and demobilization;
- **Institutional Controls** (also referred to as Postclosure), or a period of at least 100 years, but lasting as long as necessary, as determined by regulatory agencies that follows the Decommissioning Execution phase, where long-term care and maintenance, oversight, and

environmental monitoring would be performed by CNL in order to ensure that the disposal system performs as expected, that human safety is ensured until the short lived nuclear wastes decay to below the acceptance criteria and that problems that may impact the long-term stability of the facility can be rectified; and,

- **Post-Institutional Controls** (also referred to as Postclosure), or the period of time following the Institutional Control period, occurring after year ~2125, and continuing indefinitely. The Decommissioning and Postclosure Phases are the focus of this EcoRA. It is noted that the Postclosure Phase includes both the Institutional Control and Post-Institutional Control periods as tritium releases are expected to occur within 100 years of Project initiation.

1.2.1 Decommissioning Phase

For the Decommissioning Phase, the EcoRA is conducted for both normal operating conditions as well as conditions under potential malfunctions and accidents.

1.2.1.1 Normal Operations

Project works and activities for the Decommissioning Phase of the Project are presented in Table 5.2-1 of the EIS where potential project-environment interactions are evaluated. Decommissioning Phase project works and activities are categorized in the DecomSA (Garisto *et al*. 2020) using the following task groupings:

(1) Batch Mixing Plant:
- Designate location, create access, and erect temporary fencing;
- Stockpile grout ingredients;
- Mix grout to required formula;
- Provide slip pipe access to nuclear area; and,
- Preparation and operation of wash out pits.

(2) Grouting of Below Grade Structures (Grouting Scenario):
- Prepare rooms and large vessels; and,
- Fill nuclear area with grout.

(3) Demolition and Grouting of Above Grade Structures (Demolition Scenario):
- Demolish above grade structures;
- Size materials;
- Complete clearance surveys on potentially recyclable material; and,
- Emplace and grout material.

(4) Install Concrete Cap and Engineered Barriers:
- Install concrete cap; and,
- Install engineered barriers.

(5) Final Site Restoration:
- Restore site; and,
- Demobilize site.

The DecomSA (Garisto *et al.* 2020) evaluates the potential exposure-related effects of the above task groupings on several environmental components, including human receptors. The only activities that were found to have the potential for exposure-related effects on non-human biota (and therefore those that are included in this EcoRA) are:

(2) Grouting of below grade structures: During grouting (i.e., pouring of grout to fill the rooms in the nuclear area of the facility), air present within the facility containing low levels of tritium, asbestos and lead will be displaced, potentially releasing these airborne contaminants into the atmosphere. These releases have the potential to affect the terrestrial environment through subsequent deposition to soil; and,

(3) Demolition and grouting of above grade structures: During the demolition of the above grade structures, radionuclide (tritium, C-14 and Cs-137) surface contaminants from building materials may be released into the atmosphere. In addition, there is the possibility of lead being released into the atmosphere from lead-based paint. These releases have the potential to affect the terrestrial environment through subsequent deposition to soil.

It should be noted that atmospheric evaluations in the DecomSA (Garisto *et al.* 2020) included dust (total suspended particulate (TSP), PM_{10} and $PM_{2.5}$), NO_x, and SO_2, and the results predicted non-measurable effects of these emissions on the atmospheric environment precluding the need for further assessment.

In addition, the DecomSA also considered polychlorinated biphenyls (PCBs), mercury and petroleum hydrocarbons (PHCs). The primary source of PCBs in the NPD facility is light ballasts and these will all be removed either prior to the start of decommissioning if safely accessible, or by the time decommissioning is complete (from the Boiler Room and Condenser Pit). PCB levels in paint and caulking from the NPD facility were found to be below regulatory levels. PCBs and their combustion products (Dioxins and Furans) were not considered in the EcoRA as there are no anticipated releases during the decommissioning phase (Garisto *et al*. 2020).

The only anticipated source of residual mercury throughout the NPD facility is the Boiler Room where <0.01 kg of mercury is currently estimated to remain based on measurements in the wells area sump (Garisto *et al.* 2020). Areas of PHC contamination identified at the NPD facility have been remediated. PHCs related to decommissioning activities are anticipated to be small (<100 L), and will be subject to spill response procedures. For these reasons, PHCs were not considered in the EcoRA.

All other activities are not expected to have an interaction with the environmental components that could lead to exposure pathways for non-human biota.

1.2.1.2 Malfunctions and Accidents Case

The accidents assessment included in the DecomSA (Garisto *et al.* 2020) considered the following bounding scenarios:

(6) **Forest Fire and Release of Radioactivity:** A large forest fire is assumed to occur that engulfs the facility and affects the above grade facility. A fire is then ignited at the facility that releases radioactivity as radioactive contaminants within the walls become airborne;

(7) **Forest Fire and Release of Chemicals:** A large forest fire is assumed to occur that engulfs the facility and affects the above grade facility. A fire is then ignited at the facility that releases hazardous non-radiological chemicals;

(8) **Tornado and Release of Radioactivity:** A category EF-2 tornado is assumed to occur that affects the aboveground structure. Radioactivity is released due to damage to the building and subsequent mobilization and release of radionuclides;

(9) **Tornado and Release of Chemicals:** A category EF-2 tornado is assumed to occur that affects the aboveground structure. Hazardous non-radiological chemicals are released due to damage to the building;

(10) **Underground (Indoor) Fire and Release of Radioactivity:** An underground (indoor) fire is assumed to occur following a spill of combustible material (i.e., small fuel spill). Volatile radionuclides, radioactive contamination embedded in combustible materials, and loose surface contamination become partially airborne;

(11) **Underground (Indoor) Fire and Release of Chemicals:** An underground (indoor) fire is assumed to occur following a spill of combustible material (i.e., small fuel spill). Hazardous non-radiological chemicals become partially airborne;

(12) **Major Flood and Release of Radioactivity:** It is assumed that a large flood occurs, resulting from a precipitation event, causing a large volume of water for enter the facility. The floodwater mobilizes radionuclides which are then released outside the facility;

(13) **Accidental Exposure to Radioactivity:** It is postulated that decommissioning personnel working underground receive a higher than anticipated radiological dose due to a longer exposure time or exposure to higher than anticipated levels of radioactivity;

(14) **Accidental Exposure to Chemicals:** It is postulated that decommissioning personnel working underground receive unanticipated exposure to hazardous chemicals during demolition or cutting activities or through unplanned interaction with chemicals; and,

(15) **Stack Collapse and Release of Radioactivity:** It is postulated that the ventilation stack accidentally fails and falls during demolition, potentially resulting in personnel injuries or fatalities and release of airborne contaminants.

Of the potential malfunctions and accidents scenarios listed above, only scenarios (6) to (12) and (15) have the potential to impact non-human biota and were thus assessed in the EcoRA. More specifically, scenarios (6) to (11) will affect the terrestrial environment via releases to air and subsequent deposition to soil, while scenario (12) will affect the aquatic environment via releases to surface water (Ottawa River). As scenario (12) was assessed qualitatively in the DecomSA (Garisto *et al.* 2020) based on the Safety Analysis Report (Athauda-Arachchige 2015), this scenario was also assessed qualitatively in the EcoRA. Scenarios (13) and (14) have the potential to impact human health only and thus were not considered in the EcoRA. For scenario (15) (accidental stack collapse), while atmospheric emissions of tritium were assessed, radionuclides contained in the ventilation stack water were not assessed, as this source would not be accessible to biota. It is also noted for this scenario that resulting releases would be localized, with exposure pathways limited to on-site biota only, namely, the Chimney Swifts roosting in the stack (Garisto *et al*. 2020). Note that the greatest impact on Chimney Swifts in the case of a stack collapse would be the loss of their habitat and not exposure to contaminants from inside the stack. See Section 9.12.4.4 of the EIS for a description of the safeguards to be taken during structural demolition to prevent a stack collapse.

1.2.2 Postclosure Phase

A number of different scenarios were considered in the PostSA (Penfold *et al.* 2020), including a reference case or Normal Evolution Scenario (NES) that describes the most likely, expected, evolution of the facility and its surrounding environment, along with a set of alternatives describing potential deviations from the expected evolution of the system. Included in the alternative scenarios were sensitivity calculations examining the effect on key performance measures of important uncertainties in the models and data used in the NES. The PostSA also assessed a number of Disruptive Event, Defence-in-Depth, and “What-If” scenarios, all of which are briefly described below. For more thorough descriptions of the scenarios and information on how they were defined and developed, the reader is referred to the PostSA document (Penfold *et al.* 2020).

The facility during the Postclosure Phase will comprise the radioactive material within the Nuclear Power Demonstration Waste Facility (NPDWF) structure, the grout backfill within the structure, and the structure itself. It will also include the infill between the NPDWF structure and the surrounding bedrock and overburden. The majority of the radioactivity is assumed to be associated with the pressure tubes, Calandria, and associated structures, including activation products present within the matrix of materials. In addition, there is a large mass of lead shielding in the Fuelling Room and Reactor Vault, present predominantly as solid metal.

(1) **<u>Normal Evolution Scenario (NES):</u>** Under normal evolution, the facility is closed as planned with no unforeseen events after which a period of Institutional Controls is initiated, lasting for at least 100 years while the facility remains under surveillance. The NES represents a reference description of the most likely, expected, evolution of the facility and its surrounding environment. It examines the evolution of the in-situ disposal system in the postclosure period under normal conditions where changes in the

contaminants and waste, facility, geosphere and biosphere and effects of seismicity (1-in-2,500 and 1-in-10,000 years) and climate change (increased temperature and precipitation) are considered. Following closure, the facility will gradually become saturated with groundwater at which time wastes will corrode and radionuclides and other contaminants will be released into the groundwater. Thus, the main contaminant release pathway to the biosphere is via groundwater, which is assumed to discharge to springs close to the shore and riverbed sediments adjacent to the site from where contamination may pass into water in the Ottawa River. Contaminants released into the Ottawa River may sorb to sediments or be taken up by aquatic flora and fauna. Contaminants may also be transferred to land through crop irrigation (garden soil) with river water and animals drinking river water and then excreting it onto the land (grazing soil).

Sensitivity/Uncertainty Cases: these scenarios explore various factors in the models and data used for the NES that are uncertain and, to which the performance of the system may be sensitive.

(1a) **Radioactive Inventory:** An upper estimate of the contaminant inventory is cautiously used for the reference calculations in the NES. The importance of the inventory is illustrated with this alternative calculation case in which the radioactive inventory is based, where possible, on sampling data, which generally indicate a significantly lower inventory than the theoretical estimates.

(1b) **Sorption:** The key role of the grout is to provide conditions in which sorption of radionuclides is enhanced, reducing their mobility. However, sorption coefficients are both difficult to measure, and strongly influence the rate of release of contaminants. In this calculation, reference values of sorption coefficients used in the NES are reduced to illustrate the consequent effect of greater than anticipated contaminant mobility.

(1c) **Resaturation Rate – Faster:** Following closure, groundwater will gradually seep through the concrete walls and the concrete cap until the facility is saturated to a level above the surrounding water table. However, the rate of resaturation is uncertain as it simultaneously depends on the properties of the facility, the backfill and the surrounding hydrogeology. The estimates obtained through groundwater modelling varied greatly from a few decades to centuries. This calculation case quantifies the significance of uncertainties in resaturation in terms of the overall safety performance of the disposal system. Specifically, it examines the effect of a faster resaturation rate of 25 years compared to 40 years in the NES.

(1d) **Resaturation Rate – Slower:** This case is the same as (1c) but examines the effects of a slower resaturation rate of 400 years compared to 40 years in the NES.

(1e) **Surface Erosion:** This case assumes that a flood scours the surface and exposes contaminated overburden and rock through which groundwater flows, and that a person subsequently lives next to, and uses, the contaminated area in the same way as a site resident is assumed to in the NES. The erosion of the facility itself by floodwaters is considered extremely unlikely, but would result in a surge of river water up to the elevation of the facility surface structures. This scenario also covers the consequences of other events that could erode the overburden (e.g., loss of vegetation coupled with much greater rainfall and/or rapid snowmelt).

(1f) Indigenous Receptor: The habits of people define their level of exposure to contaminants, but such habits are uncertain. This sensitivity case considers a self-sufficient Indigenous receptor group that follows a traditional lifestyle. The group is represented by adults and children using the area around the facility, including the Ottawa River for hunting and gathering.

(1g) Engineering Degradation: The concrete structure of the facility, and the grout backfill that will be added, provide a key engineered barrier to the release of contaminants. This scenario examines the potential consequences of less than anticipated physical performance by this barrier, due for example to unexpected performance of grout or cracking in the concrete, or damage resulting from seismic activity.

(2) <u>Disruptive Event Scenarios:</u> These scenarios are modifications to the NES where the underlying conceptual model in most cases is the same, but different values are selected for scenario-related parameters or there are some limited modifications to the model structure.

(2a) Site Investigation (Human Intrusion): Following the Institutional Controls period, an investigation borehole is drilled through the cap, grout and structure, into the waste. The process of drilling, extracting and examining the core could lead to internal/external exposures. The drilling waste left on site subsequently becomes mixed with surface soil that is used by the resident for small-scale farming and is available for uptake by plants and animals.

(2b) Extreme Degradation of Engineered Structures: This disruptive event scenario addresses the potential effects of the facility experiencing a much more severe earthquake than in the NES. This is assumed to correspond to a 1-in-50,000-year seismic event, which would likely result in substantial cracking to the above-ground portion of the facility. Cautiously, this scenario is assumed to occur only 1,000 years after closure.

(3) <u>Defence-in-Depth Scenarios:</u> These scenarios test the performance of the engineered barriers such as the grout, existing structure and waste forms, in preventing contaminant release from the facility. These cases demonstrate the postclosure safety performance benefits of the engineered barriers by quantifying the performance in their absence, and thus involve somewhat artificial conditions.

(3a) Role of Waste Form: This scenario examines the significance of the rate of release of contaminants from the activated structures of the Calandria. The significance of corrosion in controlling the releases and thus environmental effects of the contaminants is examined by increasing the corrosion rates for carbon steel, stainless steel and Zircaloy by a factor of 10.

(3b) Role of Existing Facility Structure: This calculation case tests the significance of the existing facility concrete structure as part of the multi-barrier system preventing contaminant release. The absence of the existing facility concrete would mean that there is less material to which contaminants can sorb, although sorption to the grout fill within the facility could still occur.

(3c) Role of Grout: This scenario examines the significance of the grout as a substrate for sorption by testing the performance of the facility while assuming the grout is absent from all rooms, which are then free to resaturate and fill with water. The absence of grout in the rooms would mean that no material is available to which contaminants can sorb, although sorption in the concrete walls of the facility could still occur.

(4) <u>“What-if” Cases:</u> Each “What-if” case represents a deliberately <u>extreme</u> set of assumptions that can be used to understand the absolute limits to safety performance. “What-if” calculations have a very low probability of occurrence.

(4a) Mass Excavation: This case considers the complete excavation of the entire facility and then the dispersal of the excavated material in soil. The excavated material is assumed to be spread on land with very limited dilution, and then used for farming by a resident.

(4b) River Level Fall: A fall in the level of the Ottawa River, which in the future is the main recipient of groundwater containing contaminants from the facility, would only occur in response to a major environmental change such as glaciation. A fall in the river level could permit all potentially contaminated groundwater to be released directly to the surface without being diluted with uncontaminated river water, as is the case in the NES. This calculation case evaluates the potential consequences of the direct release of contaminated groundwater from the facility to the surface. The conceptual model is the same as the NES with the exception that groundwater released from the geosphere is directed into the shoreline sediments, rather than the riverbed sediments.

(4c) Well into Contaminated Plume: This case evaluates the potentially highest doses that could be received by a person exposed to contaminated groundwater. It assumes the placement of a well between the facility and the river that intersects the channel associated with the cooling pipes. The contaminated groundwater is pumped out and used for drinking and irrigation.

All of the postclosure scenarios described above were assessed in the EcoRA. It is noted that although scenario (2a) focuses on exposures to people, it was assessed in the EcoRA because the drilling waste is left on site where it becomes mixed with soil that could represent an exposure pathway for biota. Also, despite the extreme assumptions and low probability of occurrence, “What-if” cases were also assessed in the EcoRA.

Table 1.1 below outlines which decommissioning and postclosure scenarios were assessed in the EcoRA.

Table 1.1 Summary of Decommissioning and Postclosure Scenarios and those Assessed in the EcoRA

No.	Scenario	Description	Assessed in EcoRA?
Decommissioning Phase – Normal Operations			
1	Batch Mixing Plant	Decommissioning activities include: designating location, creating access and erecting temporary fencing; stockpiling grout ingredients; mixing grout to required formula; providing slip pipe access to nuclear area; and, preparing and operating wash out pits.	No
2	Grouting Below Grade Structures (Grouting Scenario)	Decommissioning activities include: preparing rooms and large vessels; and, filling nuclear area with grout.	Yes
3	Demolition and Grouting of Above Grade Structures (Demolition Scenario)	Decommissioning activities include: demolishing above grade structures; sizing materials; completing clearance surveys on potentially recyclable material; and, emplacing and grouting material.	Yes
4	Install Concrete Cap and Engineered Barriers	Decommissioning activities include: installing concrete cap; and, installing engineered barriers.	No
5	Final Site Restoration	Decommissioning activities include: restoring the site; and, demobilizing the site.	No
Decommissioning Phase – Malfunctions & Accidents			
6	Forest Fire and Release of Radioactivity	Release of radionuclides that are mobilized and released during a forest fire that spreads to the above grade facility.	Yes
7	Forest Fire and Release of Chemicals	Release of hazardous non-radiological chemicals that are mobilized and released during a forest fire that spreads to the above grade facility.	Yes
8	Tornado (category EF2) and Release of Radioactivity	Release of radionuclides due to damage to the aboveground structure resulting from a category EF-2 tornado.	Yes
9	Tornado (category EF2) and Release of Chemicals	Release of hazardous non-radiological chemicals due to damage to the aboveground structure resulting from a category EF-2 tornado.	Yes
10	Underground (Indoor) Fire and Release of Radioactivity	Release of radionuclides due to an underground (indoor) fire that occurs following a spill of combustible material.	Yes
11	Underground (Indoor) Fire and Release of Chemicals	Release of hazardous non-radiological chemicals due to an underground (indoor) fire that occurs following a spill of combustible material.	Yes
12	Major Flood and Release of Radioactivity	Release of radioactivity due to water ingress during a large flood that mobilizes radionuclides that are released outside the facility.	Yes - qualitative
13	Accidental Exposure to Radioactivity	Decommissioning personnel working underground receive a higher than anticipated radiological dose due to a longer exposure time or higher than anticipated levels of radioactivity.	No
14	Accidental Exposure to Chemicals	Decommissioning personnel working underground receive unanticipated exposure to hazardous non-radiological	No

No.	Scenario	Description	Assessed in EcoRA?
		chemicals during demolition or cutting activities or through unplanned interactions with chemicals.	
15	Stack Collapse and Release of Radioactivity	Accidental failure and fall of the ventilation stack during demolition, potentially resulting in personnel injuries and or fatalities and release of airborne contaminants.	Yes
Postclosure Phase – Normal Evolution Scenario and Sensitivity Analyses (SAs)			
1	Normal Evolution Scenario (NES)	Examines the most likely, expected, evolution of the in-situ disposal system in the postclosure period under normal conditions where changes in the contaminants and waste, facility, geosphere and biosphere and effects of seismicity (1-in-2,500 years and 1-in-10,000 years) and climate change (increased temperature and precipitation) are considered. Under normal evolution, the facility is closed as planned with no unforeseen events after which a period of Institutional Controls (100 years) is initiated.	Yes
1a	NES SA: Radioactive Inventory	The radioactive inventory is based on sampling data, which generally indicate a significantly lower inventory than the theoretical estimates used in the NES.	Yes
1b	NES SA: Sorption	Reference values of sorption coefficients used in the NES are reduced to illustrate the consequent effect of greater than anticipated contaminant mobility.	Yes
1c	NES SA: Resaturation Rate - Faster	Quantifies the significance of uncertainties in resaturation in terms of the overall safety performance of the disposal system. Specifically, it examines the effects of a faster resaturation rate of 25 years compared to 40 years in the NES.	Yes
1d	NES SA: Resaturation Rate - Slower	Quantifies the significance of uncertainties in resaturation in terms of the overall safety performance of the disposal system. Specifically, it examines the effects of a slower resaturation rate of 400 years compared to 40 years in the NES.	Yes
1e	NES SA: Surface Erosion	Assumes that a flood scours the surface and exposes contaminated overburden and rock through which groundwater flows, and that a person subsequently lives next to, and uses, the contaminated area in the same way as a site resident in the NES.	Yes
1f	NES SA: Indigenous Receptor	Considers a self-sufficient Indigenous receptor (adult and child) that follows a traditional lifestyle.	No
1g	NES SA: Engineering Degradation	Examines the potential consequences of less than anticipated physical performance by this barrier, due for example to unexpected performance of grout or cracking in concrete, or damage resulting from seismic activity.	Yes
Postclosure Phase – Disruptive Events			
2a	Site Investigation (Human Intrusion)	Following the Institutional Controls period, an investigation borehole is drilled through the cap, grout and structure, into the waste. The drilling waste on site subsequently becomes mixed with surface soil that is	Yes

No.	Scenario	Description	Assessed in EcoRA?
		used by the resident for small-scale farming and is available for uptake by plants and animals.	
2b	Extreme Degradation of Engineered Structures	The facility experiences a much more severe earthquake than in the NES, corresponding to a 1-in-50,000-year event, only 1,000 years after closure. As a consequence, substantial cracking to the above ground portion of the facility is assumed to occur.	Yes
Postclosure Phase – Defence-in-Depth Cases			
3a	Role of Waste Form	The significance of corrosion in controlling contaminant releases from the activated structures of the Calandria and environmental effects is examined by increasing the corrosion rates for carbon steel, stainless steel and Zircaloy.	Yes
3b	Role of Existing Facility Structure	Tests the significance of the existing facility concrete structure as part of the multi-barrier system preventing contaminant release. In the absence of the existing facility concrete there would be less material available for contaminant sorption.	Yes
3c	Role of Grout	Examines the significance of the grout as a substrate for sorption by testing the performance of the facility while assuming the grout absent from all rooms, in which case the rooms would be free to resaturate and fill with water.	Yes
Postclosure Phase – "What-If" Cases			
4a	Mass Excavation	This case considers the complete excavation of the entire facility and then the dispersal, in soil of the excavated material. The excavated material is assumed to be spread on land with very limited dilution, then used for farming by a resident.	Yes
4b	River Level Fall	A fall in the level of the Ottawa River could permit all contaminated groundwater from the facility to be released to the surface without being diluted with uncontaminated river water. In this case, groundwater released from the geosphere is directed into the shoreline sediments as opposed to the riverbed sediments.	Yes
4c	Well into Contaminated Plume	Assumes the placement of a well between the facility and the river that intersects the channel associated with the cooling pipes in order to evaluate the highest possible doses that could be received by a person exposed to contaminated groundwater.	No

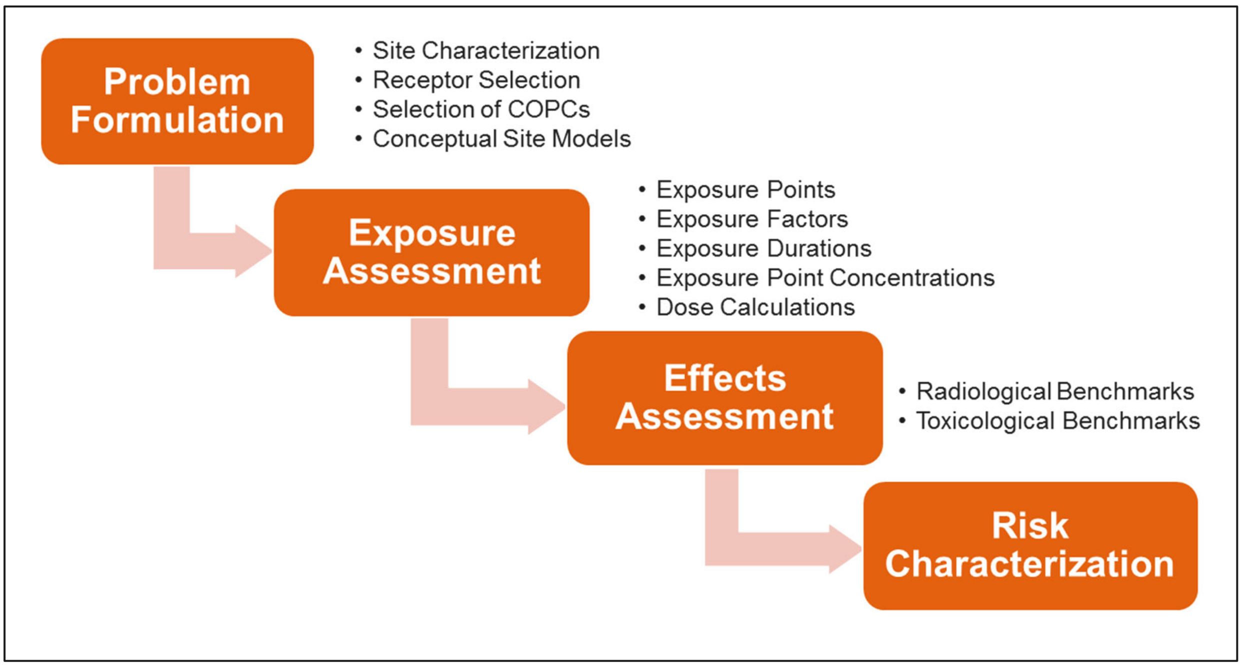
1.2.3 Report Outline

For each project phase, the EcoRA used data/model predictions available from the DecomSA (Garisto *et al.* 2020) and 3rd iteration of the PostSA (Penfold *et al*. 2020) as of December 31, 2019. The EcoRA follows the N288.6-12 (CSA 2012) process/framework as shown in Figure 1.2. In this report, the steps outlined in the figure are addressed in the following sections:

- **Problem Formulation** – Section 2.0
- **Exposure Assessment** – Section 3.0
- **Effects Assessment** – Section 4.0
- **Risk Characterization** – Section 5.0

In addition, uncertainties are discussed in Section 6.0 as per N288.6-12 (Section 8, CSA 2012), conclusions are summarized in Section 7.0, and references cited in the report are compiled in Section 8.0.

Figure 1.2 EcoRA Technical Components in Accordance with N288.6-12 Framework



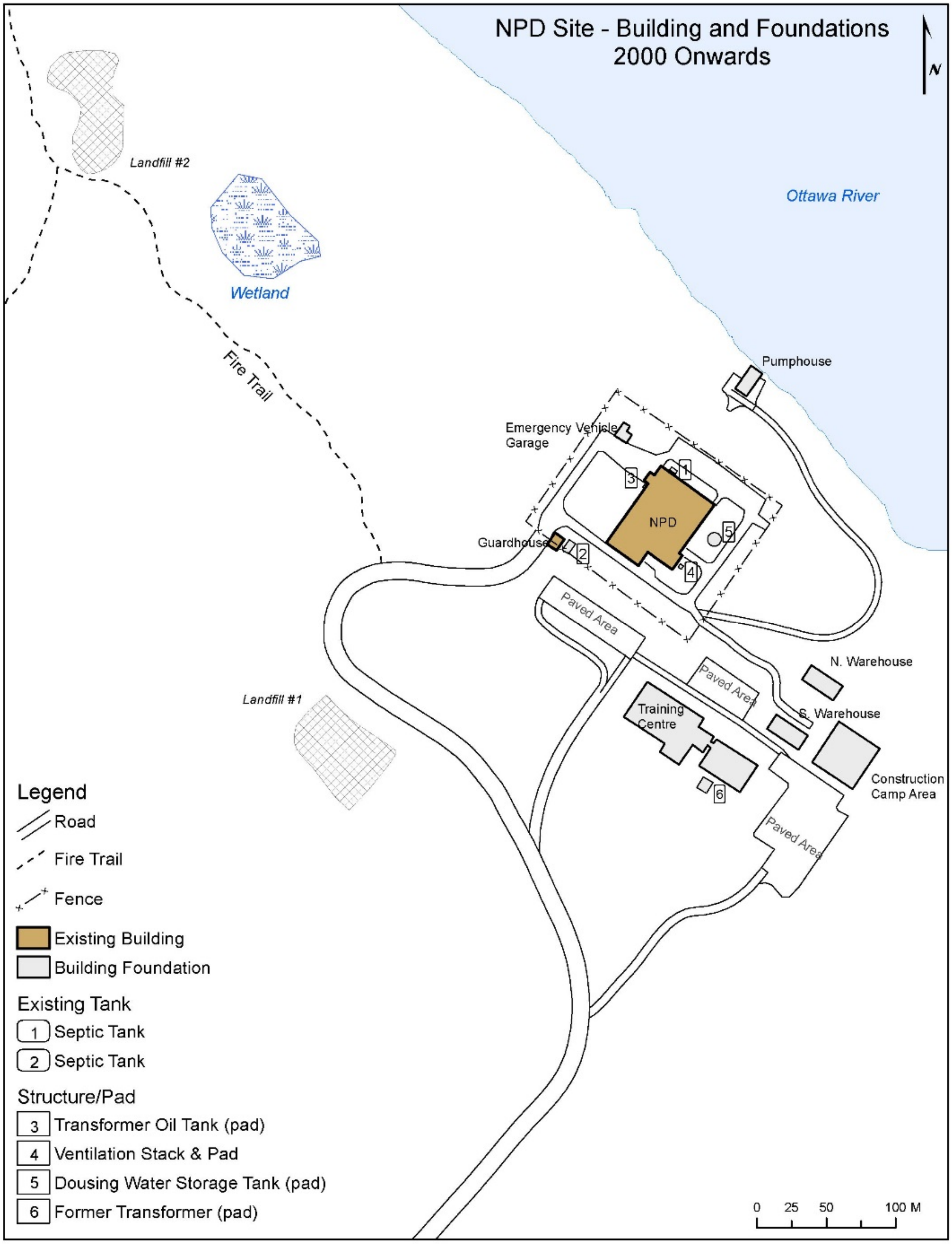
2.0 PROBLEM FORMULATION

The objective of this report is to address the question of exposure related ecological effects during the Decommissioning and Postclosure phases of the Project. This section provides aspects of the assessment related to problem formulation, such as site characterization, identification and characterization of valued components (VCs), identification of assessment endpoints and environmental stressors, selection of exposure pathways and presentation of the site conceptual models. A problem formulation checklist is also provided in Section 2.7. As outlined in N288.6-12 (CSA 2012), the purpose of the problem formulation is to identify contaminants, pathways, and receptors, and their relationships to the site, in order to focus the assessment on relevant aspects.

2.1 Site Characterization

The NPD Nuclear Generating Station (NPDNGS) was operated by Ontario Hydro from 1962 until 1987. Following permanent shutdown of the NPDNGS in 1987, the operating and compliance responsibilities were transferred from Ontario Hydro to Atomic Energy of Canada Limited (AECL), a federal crown corporation, and the facility was renamed the NPDWF. This Class I nuclear facility is presently in the "Storage-with-Surveillance" phase of decommissioning and has a Decommissioning Waste Facility License that was issued in 2014. All fuel and most removable equipment have been removed from the site and transferred to Chalk River Laboratories (CRL) for waste storage and eventual disposal. At present, the former power station consists of the former powerhouse with its associated air effluent stack. The guardhouse is also still present. Outside of the facility, but within the NPD site, there are also two closed landfills (see Figure 2.1). In addition, three underground storage tanks, used for diesel, furnace oil, and radiological liquid waste, were located on the NPD site, but have since been removed and the surrounding soil remediated (Titterington 2016).

Figure 2.1 NPD Site with Structures & Features (Titterington 2016)



The NPD site is located on the southern bank of the Ottawa River in the town of Laurentian Hills (Renfrew County, Ontario), which is approximately 200 km northwest of Ottawa and approximately 25 km upstream of CRL. The site is in a remote area, with a relatively low population density. The surrounding land is primarily used for recreational activities. Agricultural activities in the area are limited to garden plots managed by residents. Sport fishing is carried out on lakes outside the NPD site, as well as the Ottawa River, but there is no commercial fishing in the area (Wills 2013).

Section 8 of the EIS provides a thorough description of the existing environment at the NPD site, which includes information on the following:

- Atmospheric Environment (Section 8.2) – climatic data, air emissions, air quality and ambient noise;
- Surface Water Environment (Section 8.3) – hydrology, surface water emissions, surface water quality, and sediment quality;
- Aquatic Environment (Section 8.4) – physical aquatic habitat and aquatic biota;
- Geological and Hydrogeological Environment (Section 8.5) – geology, soil quality, vegetation quality, hydrogeology and groundwater quality;
- Terrestrial Environment (Section 8.6) – forest/vegetation communities, vegetation species, wildlife species, Species at Risk; regional provincial parks and protected areas;
- Ambient Radioactivity (Section 8.7);
- Human Health (Section 8.8);
- Indigenous Land and Resource Use (Section 8.9) – traditional land use and cultural resources;
- Indigenous Socio-Economic and Health (Section 8.10);
- Socio-Economic Environment (Section 8.11) – socio-economic conditions, land use, archaeology; and,
- Natural Disasters (Section 8.12) - seismicity, tornadoes, floods, potential for natural fires or explosions.

Information on the site characterization is not repeated in the EcoRA and the reader is referred to Section 8 of the EIS for this information. The information in the EIS covers the CSA N288.6-12 (CSA 2012) requirements provided in Appendix C, Section C.2.

2.2 Receptor Selection

The ecological receptors for the site were selected based on the list of VCs identified for the site in the EIS (Section 5.2.4), as well as selection criteria outlined in CSA N288.6-12 (CSA 2012). The VCs that were selected for each environmental component along with a brief rationalization for their selection are summarized in Table 2.1 where species designations under the *Species at Risk Act* (*SARA* 2002) are also included (*shaded cells represent pathways to VCs in other environmental components*). Although *SARA* was originally legislated in 2002, the species list is updated frequently based on recommendations from the Committee on the Status of Endangered Wildlife in Canada (COSEWIC). Further details on the VC selection process are provided in Section 5.2.4 of the EIS.

Table 2.1 Valued Components and Pathways for the NPD Closure Project, Listed by Environmental Component

a) Atmospheric Environment

Environmental Component	Pathway	Rationale
Atmospheric Environment	Pathway to non-human biota health	The effects on non-human biota associated with changes in atmospheric conditions (radiological and chemical releases and concentrations) are considered in the Non-Human Biota Health component.
	Pathway to Valued Components (VCs) in other environmental components	The effects on VCs in other environmental components associated with changes in atmospheric conditions (noise) are considered in the applicable environmental components. These will include effects on Aquatic Environment and Terrestrial Environment VCs.

b) Surface Water Environment

Environmental Component	Pathway	Rationale
Surface Water Environment	Pathway to non-human biota health	The effects on non-human biota associated with changes in site drainage and surface water quality (radiological and chemical releases and concentrations) are considered in the Non-Human Biota components.
	Pathway to Valued Components (VCs) in other environmental components	The effects on VCs in other environmental components associated with changes in site drainage and surface water quality (e.g., water levels) are considered in the applicable environmental components. These will include effects on Aquatic Environment and Terrestrial Environment VCs.

c) Aquatic Environment

Environmental Component	Sub-Category		Valued Component (VC)	Effects Assessed		Rationale
				Habitat	Exposure	
Aquatic Environment	Aquatic Invertebrates		Benthic Invertebrates		x	Macroinvertebrates occupy the sediment and are an important food source for benthivorous fish species. They are used to evaluate overall ecosystem health.
	Aquatic Vegetation		Aquatic Vegetation (e.g. Cranberries)		x	Represents a fundamental element of ecosystem health and function.
	Fish	Small	Emerald Shiner		x	Numerically important pelagic forage species.
		Large	White Sucker		x	Abundant benthivorous, bottom dwelling fish, an important component of that community with available data.
		Large	Lake Sturgeon		x	Benthivorous, bottom-dwelling fish. Lake Sturgeon has been subject to fishery exploitation in the past, before population declines. It is the largest, longest-living freshwater fish in Ontario. In the stretch of the Ottawa River that includes the NPD site, Lake Sturgeon is more abundant than elsewhere in the river.

d) Geological and Hydrogeological Environment

In addition to serving as a pathway to human health, non-human biota and VCs in other components, specific VCs have also been identified for the Geological and Hydrogeological Environment.

Environmental Component	Pathway or Valued Component (VC)	Rationale
Geological and Hydrogeological Environment	Pathway to non-human biota health	The effects on non-human biota associated with changes in soil and groundwater conditions (radiological and chemical releases and concentrations, and noise) as well as groundwater flow and other physical parameters are considered in the Non-Human Biota component.
	Pathway to VCs in other environmental components	The effects on VCs in other environmental components associated with changes in soil and groundwater conditions (radiological and chemical releases and concentrations, and noise) as well as groundwater flow and other physical parameters are considered in the applicable environmental components. These include effects on Surface Water Environment, Aquatic Environment and Terrestrial Environment VCs.
	VC: Soil quality	Potential to affect the Geological and Hydrogeological environment, as soil quality may be affected during construction activities (e.g., release of contaminated particulate matter during removal of above-grade structure). Soil contamination may also occur during the Institutional Controls and Post-Institutional Controls phases, e.g., via surface water and irrigation.
	VC: Groundwater quality	Potential to affect the Geological and Hydrogeological environment, as groundwater quality will come into contact with contamination during the Institutional Controls phase (i.e., via contact with contamination) and Post-Institutional Controls phase (i.e., via contact with an alkaline plume from the grouted structure).
	VC: Groundwater flow	Potential to affect the Geological and Hydrogeological environment during the Institutional Controls phase: groundwater flow will be affected in a localized area, as groundwater starts to enter the grouted structure.

e) Terrestrial Environment

Environmental Component	Sub-Category	Valued Component (VC)	Effects Assessed		Rationale
			Habitat	Exposure	
Terrestrial Environment	Terrestrial Invertebrates	Soil Invertebrates		x	Soil-dwelling invertebrates (e.g., earthworm). Exposure from soil.
		Monarch Butterfly		x	**SC** (*SARA* status) – Monarchs are found in the Site Study Area.
	Terrestrial Vegetation	Red Maple		x	Upland/wetland deciduous tree common at the NPD site.

Environmental Component	Sub-Category	Valued Component (VC)		Effects Assessed		Rationale
				Habitat	Exposure	
	Berries	Berries (e.g., Blueberries, Chokeberries, Raspberries, Serviceberries)			x	Identified through Indigenous engagement.
	Fungi	Mushrooms			x	Identified through Indigenous engagement.
	Birds	Small-Medium, aerial	Chimney Swift	x	x	THR (*SARA* status) - migratory insectivorous bird. There is a Chimney Swift super roost in the vent stack at the NPD site, which is in close proximity to site activities and may be impacted.
		Large, aerial	Bald Eagle	x	x	Large raptor. Cultural and ecological significance. Known nest in the Local Study Area.
		Medium, ground-dwelling	Ruffed Grouse		x	Ground-dwelling non-migratory omnivorous bird. Present at NPD.
		Medium, semi-aquatic	Mallard		x	The Ottawa River is in the heart of the Atlantic Flyway, and is an important stopover for migrating waterfowl such as the Mallard. Regional presence.
		Large, semi-aquatic	Great Blue Heron		x	Large wading piscivorous bird. Great Blue Herons are sensitive to human disturbance. Regional presence. Great Blue Herons often return to their nesting colonies for many consecutive years, and are sensitive to habitat destruction or disturbance.

Environmental Component	Sub-Category	Valued Component (VC)		Effects Assessed		Rationale
				Habitat	Exposure	
	Mammals	Small, insectivorous	**Little Brown Myotis** Eastern Small-footed Myotis Northern Myotis Tri-coloured Bat	x	x	Bat species known to be present at the NPD site. All are listed as **END** under *SARA* except for the Eastern Small-footed Myotis, which is unlisted. While each listed species is a VC, the Little Brown Myotis (in bold) is used as a surrogate for the others.
		Small, herbivorous	Meadow Vole	x	x	Soil-dwelling, small herbivore. Burrowing is an important exposure pathway.
		Small, omnivorous	Short-tailed Shrew		x	Abundant, mostly-carnivorous small mammal feeding primarily on soil invertebrates. Burrowing is an important exposure pathway. Sufficient data availability.
		Small, carnivorous	American Mink		x	Small carnivorous mammal with both terrestrial and aquatic prey. Identified through Indigenous engagement.
			Northern River Otter		x	Small carnivorous mammal feeding primarily on fish. Identified through Indigenous engagement.
			Short-tailed Weasel		x	Sufficient data availability. Carnivorous small mammal. Burrowing is an important exposure pathway. No habitat impact is expected.

Environmental Component	Sub-Category	Valued Component (VC)		Effects Assessed		Rationale
				Habitat	Exposure	
						Identified through Indigenous engagement.
		Medium, omnivorous	Red Fox		x	Sufficient data availability. Omnivorous, medium-sized mammal. No habitat impact is expected. Identified through Indigenous engagement.
		Large, herbivorous	Moose		x	Large herbivore consuming terrestrial and aquatic vegetation. Identified through Indigenous engagement.
		Large, omnivorous	Black Bear		x	Large terrestrial omnivore. Cultural significance and public interest.
		Large, carnivorous	Eastern Wolf		x	**SC** (*SARA* status) - large terrestrial carnivore. Regional presence.
		Small-Medium, semi-aquatic	Muskrat		x	Aquatic piscivore/herbivore. Regional presence.
	Reptiles and Amphibians	Reptile	Blanding's Turtle		x	Sighting at NPD. **THR** (*SARA* status) - turtle present at the NPD site, travels greater distances over land relative to other turtles in Ontario.
			Eastern Milksnake	x	x	**SC** (*SARA* status) - snake present at the NPD site.
		Amphibian	Green Frog		x	The green frog is abundant and is present in wetlands at the NPD site.

SARA Status: **THR** – Threatened, **SC** – Special Concern, **END** – Endangered.

f) Radiation and Radioactivity Environment

Environmental Component	Pathway	Rationale
Radiation and Radioactivity Environment	Pathway to non-human biota health	The effects on non-human biota associated with changes in radioactivity in the environment are considered in the Non-Human Biota Health component.

g) Socio-Economic Environment

Environmental Component	Valued Component (VC)	Rationale
Socio-Economic Environment	Land Use and Planning Regime	The proposed project may allow for redesignation of some or all of the NPD property for another use during the Institutional Controls phase.
	Landscape and Visual Setting	The proposed project may affect the quality of views from the Ottawa River. It is not visible from Highway 17.
	Highway 17	Highway 17 is the main vehicular artery in the area. Project-related increases in traffic may affect capacity and safety of the Highway and represents a risk to human health and safety (e.g., accidents), as well as a risk to the natural environment (e.g., spills, wildlife mortality from increased volume, sensory disturbance from increased noise, increased emissions).
	Walleye	Socio-economic importance as a sportfish.
	White-tailed Deer	Socio-economic importance as a game species.

As mentioned previously, criteria outlined in the CSA N288.6-12 standard (Table 7.1, CSA 2012) were also considered in the ecological receptor selection process. These criteria are described below:

(1) **Represents a major plant or animal group –** including at least one receptor from each of the following groups:
   (a) Aquatic and terrestrial plant species;
   (b) Small and large mammals;
   (c) Bird species with terrestrial and aquatic habitats;
   (d) Soil and benthic invertebrates;
   (e) Amphibians or reptiles;
   (f) Zooplankton; and,
   (g) Fish.

(2) **Receptor of interest to facility –** the candidate receptor can be of interest to the facility because of its use in previous monitoring studies (e.g., whitefish (Réseau ZEC 2016)) or of concern for other reasons (e.g., white-tailed deer can be of interest because their high numbers have impacts on site revegetation efforts, and because they are involved in numerous vehicle collisions).

(3) **Identified by a stakeholder –** this criterion encourages selection of receptors that are of interest to stakeholders.

(4) **Potential to conduct a population effects study –** this criterion relies on a sensitive yet sufficiently robust population available to undertake a reliable survey that is able to distinguish facility-related effects from natural fluctuations and from the effects of other confounding factors.
(5) **Potential for detectable exposure to a contaminant or physical stressor –** the receptor is potentially exposed to a contaminant or physical stressor of potential concern and the exposure can likely be quantified by measurement (e.g., a contaminant likely to accumulate in tissues to a detectable level).
(6) **Potential for significant exposure to a contaminant or physical stressor –** the receptor is potentially exposed to a contaminant or physical stressor of potential concern and the exposure is potentially significant (e.g., approaching levels of concern). Organisms in the early life stages can be more likely than adults to receive significant exposure if their critical habitat is present in the exposure area.
(7) **Receptor has ecological significance –** a receptor with a well-defined and understood importance to ecosystem structure, process, or function would meet this criterion as well as a species of conservation status (e.g., a vulnerable, threatened or endangered species).
(8) **Receptor has socio-economic significance –** the receptor does not play a large ecological role but has important intrinsic or economic value to humans.
(9) **Scientific literature, a database, or other information exists on populations and stressor levels at the facility or in a reference area**.

As potential effects to ecological receptors are assessed in both the aquatic and terrestrial environments, the following major biota groups warrant consideration in the EcoRA:

- Freshwater aquatic environment:
  - Fish (benthic and pelagic);
  - Benthic invertebrates;
  - Aquatic vegetation;
  - Zooplankton;
  - Aquatic birds;
  - Amphibians;
  - Aquatic mammals; and,
  - Aquatic reptiles.
- Terrestrial environment:
  - Soil invertebrates;
  - Terrestrial vegetation;
  - Terrestrial birds;
  - Terrestrial small and large mammals;
  - Terrestrial reptiles; and,
  - Insects.

For each of the major biota groups mentioned above, a representative ecological receptor was selected from the VC list presented in Table 2.1 and assessed against the selection criteria presented in Table 2.2 and Table 2.3 for the aquatic and terrestrial environments, respectively. Input from stakeholders and Indigenous engagement activities also contributes to the selection of ecological receptors, which ensures that ecosystem components that are valued by the local community are considered as receptors. With respect to zooplankton listed above under the freshwater environment it is noted that this biota group was not assessed in the EcoRA because it is not included as a VC in the EIS. However, the radiological exposure to zooplankton would be bounded by that to benthic invertebrates as the exposure to each group is estimated using the same transfer factors, dose coefficients and benchmark with the exception that benthic invertebrates receive an additional external dose from exposure to sediment. Lead exposure to aquatic biota is assessed directly against surface water concentrations and because the same lead toxicity reference value (TRV) is applied to all aquatic biota groups, the exposure to zooplankton would be similar to that of other biota groups.

Table 2.2 Ecological Receptors Identified for the Aquatic Environment

Selection Criteria for Valued Components	Fish (forage/ benthic fish)	Fish (predator/ pelagic fish)	Aquatic Invertebrates	Aquatic Vegetation	Aquatic Birds	Amphibians	Aquatic Reptiles	Aquatic Mammals
Valued Component (VC) (from Table 2.1)	Lake Sturgeon, White Sucker	Emerald Shiner	Benthic Invertebrates	Aquatic Vegetation	Great Blue Heron, Mallard	Green Frog	Blanding's Turtle	Muskrat American Mink Northern River Otter
Receptor of interest to facility	Lake Sturgeon	-	-	-	-	Green Frog	Blanding's Turtle	-
Identified by a stakeholder or Indigenous Community[1]	Bait fish, Burbot, Catfish, Lake Whitefish, White Sucker	Bait fish, Bass species, Brook Trout, Brown Bullhead (Mud Pout), Chub, Lake Trout, Muskellunge, Northern Pike (Jackfish), Sauger, Speckled Trout, Sunfish, Walleye (Pickerel), Yellow Perch	-	Cranberries	Ducks, Goose, Waterfowl	-	Blanding's Turtle	Beaver, American Mink, Muskrat, Northern River Otter, Raccoon
Potential to conduct a population effects study	NR	NR	NR	NR	NR	NR	NR	NR
Potential for detectable or significant exposure to a contaminant or physical stressor	Bait fish, Burbot, Catfish, Lake Sturgeon, Lake Whitefish, White Sucker	Bait fish, Bass species, Brook Trout, Brown Bullhead (Mud Pout), Chub, Emerald Shiner, Lake Trout, Muskellunge, Northern Pike (Jackfish), Sauger, Speckled Trout, Sunfish, Walleye (Pickerel), Yellow Perch	Benthic Invertebrates	Cranberries	Ducks, Great Blue Heron, Goose, Mallard, Waterfowl	Green Frog	Blanding's Turtle	Beaver, American Mink, Muskrat, Northern River Otter, Raccoon

Selection Criteria for Valued Components	Fish (forage/ benthic fish)	Fish (predator/ pelagic fish)	Aquatic Invertebrates	Aquatic Vegetation	Aquatic Birds	Amphibians	Aquatic Reptiles	Aquatic Mammals
Receptor has ecological significance	Lake Sturgeon, White Sucker	-	-	-	-	-	Blanding's Turtle (THR)	-
Receptor has socio-economic significance	-	Walleye	-	-	-	-	-	American Mink
Scientific literature, a database, or other information exists on populations and stressor levels at the facility or in a reference area	Lake Sturgeon, White Sucker	Walleye	-	-	-	Green Frog	-	-
Selected Ecological Receptor	Forage/Benthic Fish (assessed as a biota group that includes Bait fish, Burbot, Catfish, Lake Sturgeon, Lake Whitefish, White Sucker)	Predator/ Pelagic Fish (assessed as a biota group that includes Bait fish, Bass species, Brook Trout, Brown Bullhead (Mud Pout), Chub, Emerald Shiner, Lake Trout, Muskellunge, Northern Pike (Jackfish), Sauger, Speckled Trout, Sunfish, Walleye (Pickerel), Yellow Perch)	Benthic Invertebrates (assessed as a biota group; also represents insect larvae)	Aquatic Vegetation (assessed as a biota group that includes Cranberries)	Great Blue Heron, Mallard (also represents, Ducks, Goose Waterfowl)	Green Frog (assessed as tadpole (fish) to capture sensitive early life stage)	Blanding's Turtle (assessed qualitatively for chemical exposure)	Muskrat (also represents Beaver and Raccoon), Northern River Otter, American Mink

Notes:

(1) Indigenous engagement and identification of valued components (VCs) is an ongoing process.

NR = not relevant at present; status under *Species at Risk Act:* THR = threatened; SC = special concern; END = endangered.

Table 2.3 Ecological Receptors Identified for the Terrestrial Environment

Selection Criteria for Valued Components	Terrestrial Invertebrates & Insects	Terrestrial Vegetation	Berries	Fungi	Terrestrial Birds	Terrestrial Small Mammals	Terrestrial Large Mammals	Terrestrial Reptiles
Valued Component (VC) (from Table 2.1)	Soil Invertebrates, Monarch Butterfly	Red Maple	Berries	Mushrooms	Bald Eagle, Chimney Swift, Ruffed Grouse	Little Brown Myotis, Meadow Vole, Red Fox, Short-tailed Shrew, Short-tailed Weasel	Black Bear, Eastern Wolf, Moose, White-tailed Deer	Eastern Milksnake
Receptor of interest to facility	Monarch Butterfly	Red Maple	-	-	Chimney Swift, Ruffed Grouse	-	White-tailed Deer	-
Identified by a stakeholder or Indigenous Community[1]	-	Birch, Cedar, Oak, Pine, Poplar, Spruce, Tamarack, Willow, Wintergreen, Cattails, Dandelions, Fiddleheads, Juniper Bush, Labrador Tea, Wiken (Muskrat Root or Sweet Flag), Prickly Ash, Red Willow, Gzibimkshk (Scouring Rush), Magajim Mashkiai (Sweet Fern), Wild Leek/Onion	Blueberries, Chokeberries, Raspberries, Serviceberries	Chaga, Mushrooms	Bald Eagle, Barn Swallow, Ruffed Grouse, Partridge, Turkey	Badger, Fisher, Marten, Rabbit/Hare, Red Fox, Short-tailed Weasel, Squirrel	Algonquin Wolf, Black Bear, Coyote, Elk, Moose, White-tailed Deer	-
Potential to conduct a population effects study	NR	NR	NR	NR	NR	NR	NR	NR

Selection Criteria for Valued Components	Terrestrial Invertebrates & Insects	Terrestrial Vegetation	Berries	Fungi	Terrestrial Birds	Terrestrial Small Mammals	Terrestrial Large Mammals	Terrestrial Reptiles
Potential for detectable or significant exposure to a contaminant or physical stressor	Earthworm, Monarch Butterfly	Birch, Cedar, Oak, Pine, Poplar, Spruce, Tamarack, Willow, Wintergreen Cattails, Dandelions, Fiddleheads, Juniper Bush, Labrador Tea, Wiken (Muskrat Root or Sweet Flag), Prickly Ash, Red Maple, Red Willow, Gzibimkshk (Scouring Rush), Magajim Mashkiai (Sweet Fern), Wild Leek/Onion	Blueberries, Chokeberries, Raspberries, Serviceberries	Chaga, Mushrooms	Bald Eagle, Barn Swallow Chimney Swift, Partridge, Ruffed Grouse, Turkey	Badger, Fisher, Little Brown Myotis, Marten, Meadow Vole, Rabbit/Hare, Red Fox Short-tailed Shrew, Short-tailed Weasel, Squirrel	Algonquin Wolf, Black Bear, Coyote, Eastern Wolf, Moose, White-tailed Deer (Elk not present in NPD area)	Eastern Milksnake
Receptor has ecological significance	Monarch Butterfly (SC)	-	-	-	Bald Eagle, Chimney Swift (THR)	Little Brown Myotis (END)	Eastern Wolf (SC)	Eastern Milksnake (SC)
Receptor has socio-economic significance	-	-	-		Bald Eagle, Ruffed Grouse	Marten	White-tailed Deer	-
Scientific literature, a database, or other information exists on populations and stressor levels at the facility or in a reference area	-	-	-	-	Chimney Swift	-	-	-

Selection Criteria for Valued Components	Terrestrial Invertebrates & Insects	Terrestrial Vegetation	Berries	Fungi	Terrestrial Birds	Terrestrial Small Mammals	Terrestrial Large Mammals	Terrestrial Reptiles
Selected Ecological Receptor	Earthworm (the Monarch Butterfly is assessed qualitatively)	Terrestrial Vegetation (assessed as a biota group that includes Birch, Cedar, Oak, Pine, Poplar, Spruce, Tamarack, Willow, Wintergreen, Cattails, Dandelions, Fiddleheads, Juniper Bush, Labrador Tea, Wiken (Muskrat Root or Sweet Flag), Prickly Ash, Red Maple, Red Willow, Gzibimkshk (Scouring Rush), Magajim Mashkiai (Sweet Fern) and Wild Leek/Onion)	Berries (assessed as a biota group that includes Blueberries, Chokeberries, Raspberries, Serviceberries)	Mushrooms (assessed as a biota group that includes Chaga and other Mushrooms)	Bald Eagle, Chimney Swift (also represents Barn Swallow), Ruffed Grouse (also represents Partridge and Turkey)	Little Brown Myotis, Meadow Vole (also represents Rabbit/Hare, Squirrel), Red Fox, Short-tailed Shrew (also represents Badger), Short-tailed Weasel (also represents Fisher and Marten)	Black Bear, Eastern Wolf (also represents Algonquin Wolf and Coyote), Moose, White-tailed Deer (also represents Elk)	Eastern Milksnake (assessed qualitatively)

Notes: NR = not relevant at present; status under *Species at Risk Act:* THR = threatened; SC = special concern; END = endangered.

(1) Indigenous engagement and identification of valued components (VCs) is an ongoing process.

Based on the VC list and rationale provided in Table 2.2 and Table 2.3, the representative ecological receptors summarized in Table 2.4 were selected for inclusion in the EcoRA. As seen from Table 2.4, not all ecological receptors considered in Table 2.2 and Table 2.3 were explicitly assessed. Species of aquatic and terrestrial vegetation, terrestrial and benthic invertebrates, and benthic and pelagic fish, and mushrooms are collectively assessed as major biota groups as required information to assess individual species is typically not available. In addition, in some cases, species of mammals and birds of similar trophic level and dietary characteristics were also grouped for assessment using one species as a surrogate for another (e.g., Chimney Swift as a surrogate for Barn Swallow; Eastern Wolf as a surrogate for Algonquin Wolf and Coyote; Mallard as a surrogate for Ducks, Goose and other Waterfowl; Meadow Vole as a surrogate for Rabbit/Hare and Squirrel; Muskrat as a surrogate for Beaver and Raccoon; Short-tailed Shrew as a surrogate for Badger; Short-Tailed Weasel as a surrogate for Fisher and Marten; Ruffed Grouse as a surrogate for Turkey and Partridge; White-tailed Deer as a surrogate for Elk).

While the Eastern Milksnake was identified as a receptor, there is not sufficient information (e.g., transfer factors or toxicity reference values) to assess risk to snake species and thus was not evaluated quantitatively in the EcoRA; however, an estimate of their radiological exposure is discussed in Section 5.3.1. Blanding's Turtle is assessed quantitatively in the EcoRA for radiological dose but there is not enough information for a quantitative assessment of exposure to lead or mercury, although some inferences of the exposure are made in Section 5.3.3. Also, there is not sufficient information to quantitatively assess the Monarch Butterfly but some inferences about its exposure are made in Section 5.3.4.

Overall, the selected indicator species are appropriate because they reflect a variety of diets/feeding habits, cover a variety of trophic levels, are representative of the biota expected to be found in the study area, and are of interest to the facility and stakeholders. In addition, the indicator species include several species at risk (SAR) under *SARA* that have been observed or are potentially present on site (CNL 2015), including:

- Monarch Butterfly (SC);
- Little Brown Myotis (END);
- Chimney Swift (THR);
- Eastern Wolf (SC);
- Blanding's Turtle (THR); and
- Eastern Milksnake (SC).

Tables summarizing receptor characteristics have been developed for each ecological receptor included in the pathways model. It is important to understand that fish (benthic and pelagic), amphibians (tadpole), invertebrates (benthic invertebrates and earthworms), and vegetation (aquatic and terrestrial) are assessed directly based on environmental concentrations. As such, pathways of exposure (e.g., ingestion, inhalation, etc.) are not explicitly modelled (or needed) for these receptors and profiles have not been developed for these receptors. The ecological profiles were developed based on Federal Contaminated Sites Assessment Guidance (FCSAP; Environment Canada 2012a, 2012b) and Ontario Ministry of the Environment (MOE 2011) guidance where available, and supplemented with information from United States

Environmental Protection Agency (U.S. EPA 1993) and on-line sources. The profiles are presented in Appendix A and include receptor-specific information related to:

- Trophic level or ecosystem role (e.g., predators or prey species);
- Life history;
- Importance to humans;
- Size and body weight;
- Dietary composition;
- Food intake rate;
- Habitat;
- Habitat/home range spatial distribution and size;
- Time spent in area;
- Important behaviour and population dynamics (e.g., migratory); and
- Other useful information.

Table 2.4 Summary of Ecological Receptors Selected for Inclusion in the EcoRA

Major Biota Group	Ecological Receptor	Description	Comment	SARA Status
Aquatic Environment				
Aquatic Vegetation	Aquatic Vegetation, Cranberries	emergent/submergent macrophytes, cranberries	assessed as a major biota group	
Benthic Invertebrate Community	Benthic Invertebrates	sediment-dwelling macroinvertebrates	assessed as a major biota group	
Benthic Fish	Bait fish Burbot Catfish Lake Sturgeon Lake Whitefish White Sucker	benthivorous/bottom-dwelling fish	assessed as a major biota group	
Pelagic Fish	Bait fish Bass species Brook Trout Brown Bullhead (Mud Pout) Chub Emerald Shiner Lake Trout Muskellunge Northern Pike (Jackfish) Sauger Speckled Trout Sunfish Walleye (Pickerel) Yellow Perch	pelagic forage species	assessed as a major biota group	

Major Biota Group	Ecological Receptor	Description	Comment	SARA Status
Birds	Great Blue Heron	piscivore/carnivore; large wading bird		
	Mallard	omnivore; migrating waterfowl; important for hunting	surrogate for Ducks, Goose and other Waterfowl	
Mammals	Muskrat	omnivore consuming mostly plants	surrogate for Beaver and Raccoon	
	Northern River Otter	piscivore/carnivore; important for trapping		
	American Mink	Carnivore; important for trapping		
	Moose	herbivore; important for hunting		
Reptiles	Blanding's Turtle	omnivore; turtle present at the NPD site	assessed qualitatively for chemical exposure	THR
Amphibians	Green Frog	carnivore; present in wetlands at the NPD site	assessed as tadpole (fish) to represent most sensitive life stage	
Terrestrial Environment				
Terrestrial Vegetation	Birch (tea and topical medicine) Cedar (in medicinal pouches) Oak Pine Poplar (tea and topical medicine) Spruce Tamarack (tea and topical medicine) Willow (teething release) Wintergreen Cattails (medicinal rub) Dandelions Fiddleheads Juniper Bush (medicinal tea) Labrador Tea Wiken (Muskrat Root or Sweet Flag) Prickly Ash Red Maple Red Willow Gzibimkshk (Scouring Rush) Magajim Mashkiai (Sweet Fern) (medicinal and ceremonial) Wild Leek/Onion	trees, shrubs, herbs, flowers, ferns and mosses	assessed as a major biota group	

Major Biota Group	Ecological Receptor	Description	Comment	SARA Status
Berries	Chokeberries Blueberries Raspberries Serviceberries	important for gathering	assessed as a major biota group	
Fungi	Chaga Mushrooms	Important for gathering	assessed as a major biota group	
Soil Invertebrates	Earthworm	soil-dwelling invertebrate		
Insects	Monarch Butterfly	flying insect; present in the study area	assessed qualitatively	SC
Birds	Bald Eagle	piscivore/carnivore; large raptor known to nest in the study area		
	Chimney Swift	insectivore; Chimney Swift super roost in the NPD vent stack	surrogate for Barn Swallow	THR
	Ruffed Grouse	Omnivore consuming mostly plants; ground-dwelling non-migratory bird present at the NPD site; important for hunting	surrogate for Partridge and turkey	
Small Mammals	Little Brown Myotis	insectivore; bat species present at the NPD site	surrogate for Eastern Small-footed Myotis, Northern Myotis and Tri-coloured Bat	END
	Meadow Vole	herbivore; burrowing animal; important for hunting	surrogate for Rabbit/Hare and Squirrel; important for hunting	
	Short-tailed Shrew	insectivore; burrowing mammal	surrogate for Badger	
	Short-tailed Weasel	carnivore; burrowing mammal	surrogate for Fisher and Marten	
	Red Fox	omnivore		
Large Mammals	Black Bear	omnivore; important for hunting		
	Eastern Wolf	carnivore	surrogate for Algonquin Wolf and Coyote	SC
	Moose	herbivore; important for hunting		
	White-tailed Deer	herbivore; important for hunting	surrogate for Elk	
Reptiles	Eastern Milksnake	carnivore; snake present at NPD site	assessed qualitatively	SC

Notes:

SARA – *Species at Risk Act*; THR – threatened, END – endangered, SC – special concern.

2.3 Assessment and Measurement Endpoints

Assessment Endpoints

Indicator species are assessed using "assessment endpoints", which are expressions of the actual environmental values to be protected. In general, the assessment endpoints selected in this study were healthy populations of the identified indicator species within the study area. Species at risk were considered on an individual level.

Measurement Endpoints

Typically, assessment endpoints (such as those outlined above) are qualitative in nature and do not lend themselves to direct measurement or quantification. Therefore, measurement endpoints are outlined, which are measurable or predictable expressions of the assessment endpoint. The values of measurement endpoints are dependent not only upon the species being protected, but also upon the level of protection provided. For example, a measurement endpoint suitable for ensuring reproductive success of a population may not be adequate to ensure the protection of each member of the population. Consistent with N288.6-12 (CSA 2012), measurement endpoints were based on survival, growth, and reproduction in order to more closely link the endpoints with population success.

In this study, measurement endpoints are represented by the screening index (SI): the ratio of an estimated exposure level (or an environmental concentration) divided by a corresponding toxicity reference value (TRV). The SI measurement endpoint is at the population level. As a result, when the chosen TRV encompasses long-term effects based on survival (mortality), growth, or reproduction, then the measurement endpoint is closely linked to the assessment endpoint (healthy populations) and the necessary inferences can be made (i.e., one can infer the 'healthiness' of the population). So, where an estimated exposure level is less than the corresponding TRV (i.e., SI less than 1), effects on a population of biota are not expected; however, where an estimated exposure level is greater than the corresponding criterion (i.e., SI greater than 1), deleterious effects on the population of biota may or may not occur and further study may be required to determine potential effects.

The assessment of species at risk is different in that these species are assessed at the individual rather than the population level. The SI is calculated in the same way but the TRVs are adjusted to be protective at the individual level. For instance, for terrestrial wildlife, No-Observed-Adverse-Effect-Level (NOAEL) rather than Lowest-Observed-Adverse-Effect-Level (LOAEL) TRVs were used when available or a 10% safety factor was applied to the LOAEL TRV.

2.4 Selection of Radiological and Non-Radiological Contaminants of Potential Concern

Concentrations of radiological and non-radiological contaminants in environmental media were predicted in the DecomSA (Garisto *et al.* 2020) and PostSA (Penfold *et al.*, 2020) for the Decommissioning and Postclosure Phases of the Project, respectively. The environmental data provided for each decommissioning and postclosure scenario were screened against applicable environmental quality criteria to identify radiological and non-radiological constituents of potential concern (COPCs) for inclusion in the EcoRA. This approach is consistent with Clauses 7.2.5.3.1 and 7.2.5.3.3 of N288.6-12 (CSA 2012). Radiological and non-radiological contaminants relevant to the Decommissioning and Postclosure Phases of the Project that were subsequently screened for inclusion in the EcoRA are summarized below in Table 2.5.

Table 2.5 Radiological and Non-radiological Contaminants Screened in the EcoRA

Project Phase	Radiological Contaminants	Non-radiological Contaminants
Decommissioning Phase	H-3 (tritium), C-14, Co-60, Cs-137	Pb, Hg
Postclosure Phase	H-3 (tritium), C-14, Cl-36, Ca-41, Co-60, Ni-59, Ni-63, Se-79, Sr-90, Zr-93, Nb-93m, Nb-94, Mo-93, Tc-99, Ag-108m, Cd-113m, Sn-121m, Sn-126, Sb-125, I-129, Ba-133, Cs-135, Cs-137, Sm-151, Eu-152, Eu-154, Ho-166m, Hf-182, Pt-193, Th-229, Th-230, Th-232, U-233, U-234, U-235, U-236, U-238, Np-237, Pu-238, Pu-239, Pu-240, Pu-241, Pu-242, Am-241, Am-242m, Am-243, Cm-243, Cm-244, Cm-245, Cm-246	Pb, Hg

2.4.1 Screening Procedure

2.4.1.1 Decommissioning Phase

In decommissioning scenarios, radiological and non-radiological contaminants are emitted directly into air, or surface water in the case of the major flood scenario (assessed qualitatively). All contaminants emitted into air were assumed to deposit to soil from where potential impacts to the terrestrial environment were assessed in the EcoRA. In the screening process, radionuclide concentrations in air were first converted to corresponding soil concentrations using either air-to-soil transfer factors for loam for the CRL site (Cs-137 and Co-60) from N288.1-14 (CSA 2018) or in the case of tritium and carbon-14, using specific activity models from N288.1-14 (CSA 2018) (see Section 2.4.2.1). Specific activity models are based on the concept of isotope exchange between tissues and ambient media. For example, tritium in airborne water vapour exchanges rapidly with hydrogen in plant tissue water until equilibrium is established (CSA 2018). The air concentrations of chemicals (lead and mercury) were converted to corresponding soil concentrations using an air-to-soil transfer model described in Section 2.4.2.1.4.

The DecomSA (Garisto *et al.* 2020) predicted one set of radiological and non-radiological contaminant concentrations at each receptor location considered in the assessment. Contaminant concentrations from the most sensitive receptor location with the highest (maximum) concentrations were used in the screening process. For emissions to air, this location was typically the Guardhouse (see Figure 2.1), representing the location closest to the facility for which valid concentrations could be obtained through air modelling. For the tornado scenario however, maximum radionuclide concentrations in air were predicted for the Rapides de Joachims and Rolphton locations. Radionuclide concentrations in soil were then screened against Environmental Effect Concentration (EEC) levels developed for the CRL site (EcoMetrix and AECL 2013; CNL 2019a). These criteria are site-specific and derived based on radiological benchmarks recommended by the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR 2008)

(2.4 mGy/d for terrestrial organisms and 9.6 mGy/d for aquatic organisms). However, a soil EEC for carbon-14 was not available and instead the carnob-14 No-Effect Concentration (NEC) from SENES (2008) was used. In SENES (2008), the soil NEC for carbon-14 was derived based on a benchmark of 1 mGy/d and was thus multiplied by a factor 2.4 to make it consistent with the benchmark recommended by UNSCEAR (2008) (see Table 2.6). The screening of radionuclide concentrations and sources of environmental screening criteria are consistent with N288.6-12 (CSA 2012, Clauses 7.2.5.2.1 and 7.2.5.3.3).

In the case of non-radiological contaminants, the total concentration of the contaminant in soil, i.e., the incremental concentration predicted in the DecomSA (Garisto *et al.* 2020) added to the baseline concentration shown in Table 2.10, was compared to the screening criterion, consistent with N288.6-12 (CSA 2012) guidance. Total lead and mercury concentrations in soil were screened against the most conservative soil quality criterion from the Ontario Ministry of the Environment (MOE 2011) full depth generic site condition standard for use within 30 m of a water body in a potable groundwater condition (coarse textured soil for residential/parkland/institutional/industrial/commercial and community land uses), and the Canadian Council of Ministers of the Environment (CCME 2020) for the protection of environmental and human health (residential/parkland land use) (see Table 2.6).

Table 2.6 Soil Screening Criteria used in the COPC Screen for the Decommissioning Phase

Contaminant	Soil Screening Criterion [1,2]	Value	Reference
H-3 (HTO)	EEC	3.20E+06 Bq/kg	EcoMetrix and AECL 2013; CNL 2019a
C-14	NEC	5.74E+02 Bq/kg	SENES 2008
Cs-137	EEC	5.54E+04 Bq/kg	EcoMetrix and AECL 2013; CNL 2019a
Co-60	EEC	9.05E+04 Bq/kg	EcoMetrix and AECL 2013; CNL 2019a
Lead	MOE	120 µg/g	MOE 2011
	CCME	140 µg/g	CCME 2020
Mercury	MOE	0.27 µg/g	MOE 2011
	CCME	6.6 µg/g	CCME 2020

Notes:

(1) Environmental Effect Concentration (EEC) levels derived for the Chalk River Laboratories site (Table 5.1, EcoMetrix and AECL 2013) based on a benchmark of 2.4 mGy/d as recommended by UNSCEAR (2008); a soil EEC for C-14 was not available and a No-Effect Concentration (NEC) from SENES (2008) was used - SENES (2008) derived the value based on a benchmark of 1 mGy/d for terrestrial biota (UNSCEAR 1996) and thus a factor of 2.4 was applied to make it consistent with UNSCEAR (2008).

(2) MOE (2011) for soil (coarse textured for all land uses) from Table 8 - Full Depth Generic Site Condition Standards for Use within 30 m of a Water Body in a Potable Ground Water Condition under a residential/ parkland/ institutional/ industrial/ commercial or community land use scenario; Canadian Council of Ministers of the Environment (CCME 2020; accessed online) – Environmental Quality Guidelines for the Protection of Environmental and Human Health under a residential/ parkland land use scenario for soil.

The screening procedure led to the following possible outcomes:

- If the radionuclide or total lead or mercury concentration was below the soil screening criterion, then that contaminant was 'screened out' or excluded from the assessment for the particular scenario being screened (Outcome 1).
- If the contaminant concentration was greater than the soil screening criterion, then the contaminant was 'screened in', i.e., included for assessment in the EcoRA (Outcome 2).
- If a soil screening criterion was not available, then the contaminant was 'screened in' (Outcome 3).

The procedure to select radiological COPCs for inclusion in the EcoRA is summarized in Table 2.7. The first column lists the sequence of criteria that are considered in arriving at the screening decision shown in the final row of the table. The subsequent columns summarize the possible screening outcomes for each contaminant based on the responses to each screening criterion.

Table 2.7 Screening Procedure for the Selection of Radiological and Non-radiological COPCs for Inclusion in the EcoRA for the Decommissioning Phase of the Project

COPC Screening Criteria	Outcome 1	Outcome 2	Outcome 3
Soil screening criterion available?	Yes	Yes	No
Contaminant concentration > soil screening criterion?	No	Yes	-
Screening decision	Screen Out	Screen In	Screen In

Sum of Fractions Analysis

As noted in Section 2.4.2, all radionuclides screened for decommissioning phase scenarios were 'screened-out' meaning that they would be excluded from the radiological assessment. While concentrations were below screening criteria, there is still a possibility of a potential effect because the sum of all radioactivities could be of sufficient cumulative value to pose a risk. In order to assess this possibility, a sum of fractions approach was used following U.S. Department of Energy (U.S. DOE 2019) methodology. For each scenario, the concentration of each radionuclide was divided by the corresponding environmental screening criterion and the fractions were summed for that medium. A sum of fractions value of < 1 indicates no significant ecological impact and a value ≥ 1 requires further assessment. The sum of fractions results are summarized in Table 2.17.

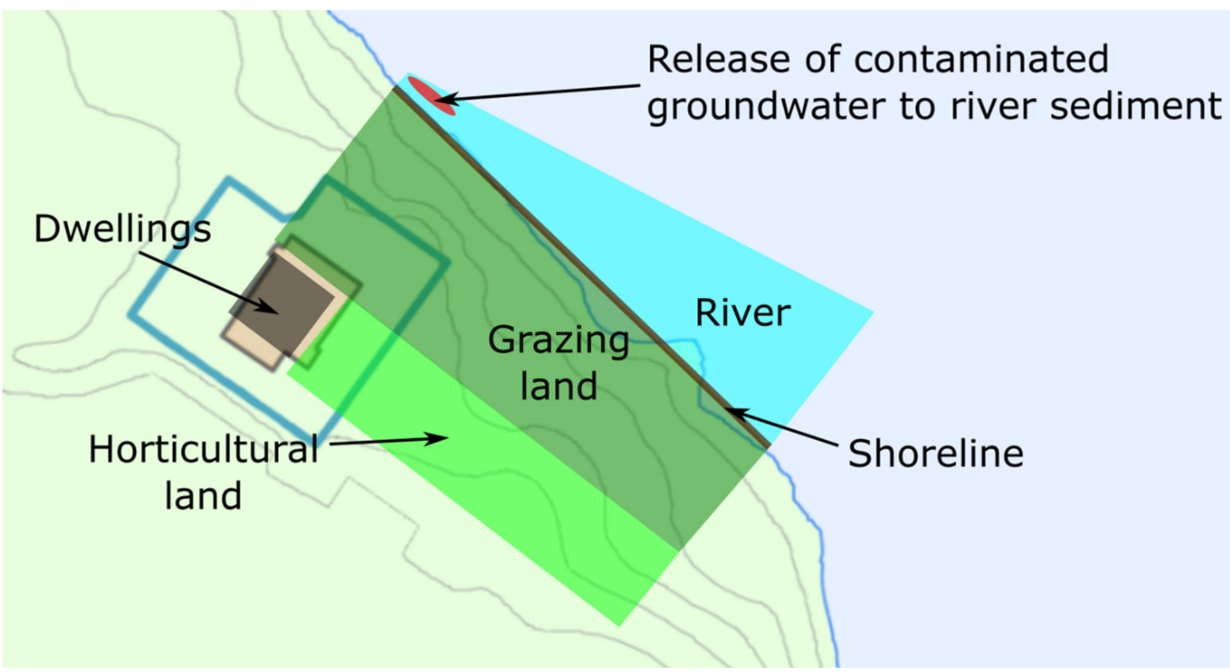
2.4.1.2 Postclosure Phase

In postclosure scenarios, radiological and non-radiological contaminants are emitted directly into groundwater. Contaminants emitted into groundwater were assumed to impact the aquatic environment through groundwater discharge into riverbed or shoreline sediments of the Ottawa River, and the terrestrial environment through the deposition of contaminated surface water onto soil during irrigation or from excretions of animals drinking contaminated river water.

The PostSA (Penfold *et al*. 2020) predicted concentrations of radiological and non-radiological contaminants over time (i.e., 10,000-year assessment timeframe) in all affected environmental media (i.e., garden and grazing areas soil, shoreline and riverbed sediments, river water and spring water (shallow groundwater)) considered in each scenario. For each scenario, the maximum concentration of each contaminant in each environmental medium that was predicted over the entire assessment period (10,000 years) was used in the screening process. Thus, the timing of each peak concentration differed between contaminants and environmental media. Use of these combined maximum concentrations for each scenario is a very conservative approach.

For each postclosure scenario, predicted contaminant concentrations in Ottawa River water (surface water), Spring water (groundwater), Ottawa River Riverbed sediments and Garden Area (Horticultural Land) soil were screened against environmental criteria (see Figure 2.2). Concentrations were also predicted for Grazing Area soil but since all maximum contaminant concentrations in soil were predicted for the Garden Area, only Garden Area soil concentrations were screened and included in the EcoRA assessment. For scenario (4b) What-If – River Level Fall, contaminant concentrations were predicted in shoreline sediments instead of riverbed sediments.

Figure 2.2 Illustrative Location of the Site Resident House, Garden/Horticultural Area and Grazing/Forage Area for Postclosure Phase Scenarios (Penfold *et al.* 2020)



For each scenario, radionuclide concentrations in each environmental medium were screened against EEC levels developed for the CRL site (EcoMetrix and AECL 2013; CNL 2019a). As noted in Section 2.4.1.1, these criteria are site-specific and derived based on radiological benchmarks recommended by UNSCEAR (2008) (2.4 mGy/d for terrestrial organisms and 9.6 mGy/d for aquatic organisms). However, EECs have been derived for a very limited set of radionuclides, and thus where criteria were missing, Environmental Media Concentrations (EMCs) from the ERICA Tool (2019) were used and further infilled with Biota Concentration Guides (BCGs) from U.S. DOE (2019). Environmental screening criteria for Zr-93 were not available from these sources and instead, No-Effect Concentrations (NECs) from SENES (2008) were used for Zr-93. Groundwater screening criteria were generally not available from any of the aforementioned sources and thus surface water criteria were conservatively used to screen groundwater quality. The radiological screening criteria used in the postclosure COPC screen are summarized in Table 2.8. As discussed in the notes to Table 2.8, the screening criteria from the various sources were adjusted so that they reflect the UNSCEAR (2008) dose benchmarks. The screening of radionuclide concentrations and sources of screening criteria are consistent with CSA N288.6-12 (CSA 2012 Clauses 7.2.5.2.1 and 7.2.5.3.3). Radionuclides lacking dose coefficients (DCs) were not assessed in the EcoRA (i.e., Ag-108m, Am-242m, Am-243, Ba-133, Cm-245, Cm-246, Ho-166m, Pt-193, Sm-151 and Sn-121m).

In the case of non-radiological contaminants, the total concentration of the contaminant in each environmental medium, i.e., the incremental concentration predicted in the PostSA (Penfold *et al.* 2020) added to the baseline concentration shown in Table 2.10, was compared to the screening criterion, consistent with N288.6-12 (CSA 2012) guidance. Total lead and mercury concentrations in environmental media were primarily screened against the most conservative environmental quality guidelines from the MOE (2011), MOEE (1994) and CCME (2020) (see Table 2.9). In addition, lead and mercury concentrations in Ottawa River surface water were also screened against Quebec criteria from the Ministère de l'Environnement et de la Lutte contre les changements climatiques (MELCC 2020) because part of the Ottawa River within the expanded study area is located in the Province of Quebec.

Table 2.8 Environmental Screening Criteria for Radionuclides used in the COPC Screen for the Postclosure Phase

Radionuclide	Screening Criterion		
	Surface Water & Groundwater (Bq/L)	Soil (Bq/kg)	Sediment (Bq/kg)
Am-241	3.85E-01	8.62E+02	8.28E+03
C-14	1.64E+02	5.74E+02	5.45E+03
Ca-41	N/A	N/A	N/A
Cd-113m	N/A	N/A	N/A
Cl-36	1.31E+03	9.02E-01	1.06E+02
Cm-243	8.24E-01	8.00E+02	2.07E+01
Cm-244	8.28E-01	8.00E+02	2.07E+01
Co-60	1.35E+02	9.05E+04	1.03E+06
Cs-135	3.48E+02	1.97E+05	4.36E+06
Cs-137	7.27E+01	5.54E+04	7.12E+05
Eu-152	1.18E+02	1.72E+05	4.13E+04
Eu-154	7.74E+01	1.55E+05	2.72E+04

Radionuclide	Screening Criterion		
	Surface Water & Groundwater (Bq/L)	Soil (Bq/kg)	Sediment (Bq/kg)
H-3	1.74E+07	3.20E+06	2.60E+07
Hf-182	N/A	N/A	N/A
I-129	7.63E+01	1.59E+06	1.57E+06
Mo-93	N/A	N/A	N/A
Nb-93m	N/A	N/A	N/A
Nb-94	1.95E+02	1.15E+05	3.08E+03
Ni-59	2.56E+03	1.24E+07	4.30E+07
Ni-63	9.09E+03	8.77E+06	3.25E+07
Np-237	1.83E+01	1.00E+03	5.12E+00
Pu-238	6.36E-01	7.52E+03	2.42E+04
Pu-239	6.79E-01	8.00E+03	2.58E+04
Pu-240	6.78E-01	8.00E+03	2.58E+04
Pu-241	2.50E+03	2.94E+07	9.48E+07
Pu-242	N/A	N/A	N/A
Sb-125	3.28E+01	4.41E+05	6.86E+05
Se-79	9.73E+02	5.29E+05	2.37E+05
Sn-126	N/A	N/A	N/A
Sr-90	1.83E+02	1.18E+06	1.14E+05
Tc-99	2.47E+04	4.61E+04	3.39E+04
Th-229	N/A	N/A	N/A
Th-230	3.81E-02	2.66E+03	4.10E+02
Th-232	4.49E-02	3.11E+03	4.81E+02
U-233	6.72E+00	1.20E+04	1.92E+06
U-234	1.01E+01	1.17E+03	4.94E+02
U-235	1.09E+01	1.26E+03	5.37E+02
U-236	N/A	N/A	N/A
U-238	1.18E+01	1.33E+03	5.76E+02
Zr-93	1.68E+01	2.01E+05	8.06E+07

Notes: N/A – not available

(blue)	Environmental Effect Concentrations (EECs) for the Chalk River Laboratories site (EcoMetrix and AECL 2013; CNL 2019a); derived based on UNSCEAR (2008) - 100 µGy/h (2.4 mGy/d) for terrestrial organisms (Soil) and 400 µGy/h (9.6 mGy/d) for aquatic organisms (Water & Sediment).
(yellow)	Environmental Media Concentrations (EMCs) (ERICA Tool 2019); derived based on incremental dose rate of 10 µGy/h (0.24 mGy/d) for all ecosystems and adjusted to be consistent with UNSCEAR (2008) by applying a factor of 40 to Water & Sediment EMCs and a factor of 10 to Soil EMCs.
(orange)	Biota Concentration Guides (BCGs) (U.S. DOE 2019); derived based on incremental dose rate of 10 mGy/d for aquatic biota and 1 mGy/d for terrestrial and riparian biota and adjusted to be consistent with UNSCEAR (2008) by applying a factor of 0.96 to Surface Water BCGs, 2.4 to Soil BCGs, and 9.6 to Sediment BCGs.
(green)	No-Effect Concentrations (NECs), Upper Estimate, all ecosystems; derived based on EC/HC (2003) - 0.6 mGy/d (benthic fish) for sediment and UNSCEAR (1996) - 1 mGy/d (terrestrial biota) for surface water and soil (UNSCEAR 1996) and adjusted to be consistent with UNSCEAR (2008) by applying a factor of 2.4 to Soil NECs, 9.6 to Surface Water NECs, and 16 to Sediment NECs.

Table 2.9 Environmental Screening Criteria for Non-radiological Contaminants used in the COPC Screen for the Postclosure Phase

	Environmental Quality Guideline		
	MECP [1,2]	CCME/FCSAP [3,4]	Quebec MELCC [5]
Lead			
Groundwater (mg/L)	0.01	0.001	-
Soil (mg/kg)	120	140	-
Surface Water (mg/L)	0.001	0.001	0.00017
Sediment (mg/kg)	31	35	-
Mercury			
Groundwater (mg/L)	0.00029	0.000026	-
Soil (mg/kg)	0.27	6.6	-
Surface Water (mg/L)	0.0002	0.000026	0.000941
Sediment (mg/kg)	0.2	0.17	-

Notes:
MECP – Ministry of the Environment, Conservation and Parks; formerly known as Ministry of the Environment (MOE) and Ministry of the Environment and Energy (MOEE).
CCME – Canadian Council of Ministers of the Environment.
FCSAP – Federal Contaminated Sites Action Plan.
MELCC – Quebec Ministère de l'Environnement et de la Lutte contre les changements climatiques.
(1) MOE (2011) for groundwater, soil (coarse textured for all land uses) and sediment; Table 8 - Full Depth Generic Site Condition Standards for Use within 30 m of a Water Body in a Potable Ground Water Condition.
(2) MOEE (1994) for surface water; Provincial Surface Water Quality Objectives (PWQOs).
(3) CCME (2020; online) – Environmental Quality Guidelines for the Protection of Environmental and Human Health under a residential/parkland land use scenario for soil and for the protection of freshwater aquatic life for surface water (chronic exposure; lead default value of 0.001 mg/L for unknown water hardness).
(4) FCSAP (2016) – Table 2 Federal Interim Groundwater Quality Guidelines Generic Guidelines for residential/parkland land use for the protection of freshwater life and soil organisms in direct contact.
(5) MELCC (2020; online) - Surface Water Quality Criteria for the protection of aquatic organisms (chronic exposure; lead value for a hardness of 10 mg/L $CaCO_3$); retrieved from the MELCC webpage: http://www.environnement.gouv.qc.ca/eau/criteres_eau/index.asp.

For each postclosure scenario, the screening procedure led to the following possible outcomes (also see Table 2.7:

- If the radionuclide or total lead or mercury concentration was below the screening criterion in all environmental media, then that contaminant was 'screened out' or excluded from the assessment (Outcome 1).
- If the contaminant concentration was greater than the screening criterion in at least one environmental medium, then the contaminant was 'screened in' or included for assessment in the EcoRA (Outcome 2).
- If environmental screening criteria were not available, then the contaminant was 'screened in' for assessment (Outcome 3).

Sum of Fractions Analysis

As noted in Section 2.4.3, many of the radionuclides listed in Table 2.8 'screened-out' for all scenarios meaning that they would be excluded from the radiological assessment. While concentrations were below screening criteria, there is still a possibility of a potential effect because the sum of a large number of low concentrations that individually do not cause an effect, could still be of sufficient cumulative value to pose a risk. In order to assess this possibility, a sum of fractions approach was used following U.S. DOE (2019) methodology. For each environmental medium associated with each scenario, the concentration of each radionuclide was divided by the corresponding environmental screening criterion and the fractions were summed for that medium. The sum of fractions were then summed across environmental media for aquatic and terrestrial systems. In the assessment, aquatic based organisms obtain their drinking water from the Ottawa River and sediment exposure from either riverbed sediments or shoreline sediments of the Ottawa River, depending on the scenario. Terrestrial based organisms are exposed to soil from the Garden Area and obtain drinking water from either the Ottawa River or Springs. A sum of fractions value of < 1 indicates no significant ecological impact and a value ≥ 1 requires further assessment. In the case where the sum of fractions for one or more media associated with a particular scenario was > 1, the top five radionuclides contributing to the sum of fractions in each medium were identified and assessed in the EcoRA for the corresponding scenario in addition to the radionuclides identified from the COPC screen. The detailed sum of fractions analysis for the postclosure phase scenarios showing the fractions of individual radionuclides is included in Appendix C. The results of the sum of fractions analysis are discussed in Section 2.4.3.

2.4.1.3 Baseline Contaminant Concentrations

This section summarizes available and relevant environmental baseline concentrations of radiological and non-radiological contaminants at the NPD site.

A Phase II ESA was completed in the fall of 2016 and May 2017 to characterize the environmental condition of soil and groundwater at the NPD site in terms of conventional contaminants (metals in soil only, hydrocarbons, and PCBs) as well as sediment in the Ottawa River upstream and downstream of the NPD site (Golder 2017a; 2017b). Samples were collected from Class 1, 2, and 3 and Background Reference Area (BRA) sample locations as defined in the Characterization Plan (ORAU 2016). Class 1 locations are located within the licensed area, Class 2 locations are located within the exclusion zone adjacent to the licensed area, Class 3 in the undeveloped lands surrounding the Class 2 area, and BRA locations are located at the boundaries of the Site where there is assumed to be no impacts. Golder (2017a) summarized baseline concentrations (minimum, maximum, mean and 90th percentile (P90); Tables 2 and 3) in soil and sediment from Class 3 and BRA areas. These included P90 concentrations of lead in soil (30 mg/kg) and sediment (10 mg/kg), and mercury in soil/sediment (0.05 mg/kg), which were used in the EcoRA. The P90 concentrations of mercury in soil and sediment reported by Golder (2017a) were equivalent to the method detection limit. The Phase II ESA did not assess metal concentrations in groundwater or surface water. As such, baseline concentrations in groundwater were used from MOE (2011) (0.00085 mg/L for lead, 0.00002 mg/L for mercury; P95). Data from the Provincial Water Quality Monitoring Network (PWQMN) were used for lead in Ottawa River surface, measured at the closest active station upstream of the NPD site (Otto Holden Dam, mean for the period 2012-2016; MECP 2018) but data were not available for mercury. For mercury, the upper limit background (ULB) level in the Ottawa River (0.00002 mg/L) was used (CNL 2018, 2019).

In a parallel study, the Balance of Site Characterization study (McVeigh 2018), radiological soil quality was also characterized in the four characterization units discussed above. Available radionuclide data from this study are presented in Table 2.11.

Table 2.10 Environmental Baseline Concentrations of Non-Radiological Contaminants

Environmental Medium	Background Concentration	Unit	Summary Statistic	Reference
Lead				
Soil	30	mg/kg	P90	Table 2; Golder 2017a
Sediment	10	mg/kg	P90	Table 3; Golder 2017a
Groundwater	0.00085	mg/L	P95	Table 8.4; MOE 2011
Surface Water	0.0000974	mg/L	P90	PWQMN Otto Holden Dam 2012-2016 (closest active upstream station); MECP 2018
Mercury				
Soil	0.05	mg/kg	P90*	Table 2; Golder 2017a
Sediment	0.05	mg/kg	P90*	Table 3; Golder 2017a
Groundwater	0.00002	mg/L	P95	Table 8.5; MOE 2011
Surface Water	0.00002	mg/L	ULB	Table 4-7 CNL 2019a; CNL 2018

Notes:

* P90 equivalent to the method detection limit.

PWQMN – Provincial Water Quality Monitoring Network (mercury concentrations were not available from the PWQMN); ULB – Upper Limit Background for Ottawa River.

Table 2.11 Average Radionuclide Concentrations in Soil in Various Characterization Units at the NPD Site (McVeigh 2018)

Radionuclide	Unit	DCGL[1]	BRA		Class 1		Class 2		Class 3	
			Mean	95% UCL	Mean	95% UCL	Mean	95% UCL	Mean	95% UCL
Am-241	Bq/kg	0.1	2.56	3.36	2.72	3.36	2.84	3.20	3.06	3.73
Co-60	Bq/kg	0.1	0.26	0.37	0.26	0.31	0.21	0.24	0.28	0.39
Cs-137	Bq/kg	0.1	30.85	45.83	3.81	6.03	7.77	9.90	23.17	26.71
Eu-152	Bq/kg	0.1	1.26	1.85	2.38	2.88	2.46	2.75	1.52	1.90
U-235	Bq/kg	1	2.59	3.60	2.96	3.71	2.41	2.82	3.55	4.55
U-238	Bq/kg	1	21.38	34.09	22.23	25.58	20.99	22.46	17.22	21.17
H-3	Bq/kg	100	55.44	79.51	30.58	40.09	18.8	24.07	27.49	35.60
C-14	Bq/kg	1	17.51	25.6	16.2	25.60	19.52	23.42	20.73	24.94
Sr-90	Bq/kg	1	30	30.00	14.13	16.60	27.19	27.19	31.6	36.85
Tc-99 [2]	Bq/kg	1	<200	<200	<100	<100	<100	<100	<200	<200

Note: BRA – Background Reference Area; UCL – Upper Confidence Limit.

(1) Unconditional Clearance Levels, Schedule 1, SOR2000-207 Nuclear Substances and Radiation Device Regulations.

(2) All measured Tc-99 soil concentrations were below the method detection limit.

2.4.2 Screening Results - Decommissioning Phase

During the Decommissioning Phase of the Project, two activities included under normal operations are expected to produce emissions: grouting and demolition. During grouting, air present within the facility will be displaced by grout when grout is poured into the facility. Air within the facility contains low levels of tritium, as well as asbestos and lead, which could be released into the atmosphere during the grouting process (Garisto *et al*. 2020). Demolition of the above grade structures may release surface contamination into the atmosphere that could potentially affect the environment and the public (Garisto *et al.* 2020). The highest radionuclide concentrations released into the atmosphere during grouting and demolition activities are expected at the Guardhouse location.

The following four scenarios under potential malfunctions and accidents are expected to result in emissions to air:

- Forest Fire and Release of Radioactivity;
- Tornado and Release of Radioactivity;
- Underground (Indoor) Fire and Release of Radioactivity;
- Stack Collapse and Release of Radioactivity.

With the exception of the tornado scenario, the highest radionuclide concentrations released into the atmosphere during the malfunctions and accidents scenarios listed above are expected at the Guardhouse location. For the tornado scenario, the highest emissions to air are expected at Rapides de Joachims and Rolphton. Expected air emissions during the decommissioning phase of the Project are summarized in Table 2.17 for radiological contaminants and Table 2.18 for non-radiological contaminants.

2.4.2.1 Contaminant Concentrations in Soil

2.4.2.1.1 Tritium

The tritium model in N288.1-14 (CSA 2018) differs from that of other radionuclides because unlike other radionuclides, which can be transported through the environment using a transfer model, tritium is extremely mobile and readily exchanges with hydrogen in water. As a result, N288.1-14 uses a specific activity model that accounts for this mobility. The model also accounts for the incorporation of inorganic tritium into OBT (organically bound tritium).

To calculate tritium concentrations in the environment, tritium release rates were taken from the DecomSA (Garisto *et al*. 2020). The release rate for each scenario is shown in Table 2.12. These scenarios only consider the atmospheric release of tritium, and as such waterborne releases were not considered in the model. As there are no waterborne releases, and the effects of atmospheric deposition on lakes and rivers is negligible (as per N288.1-14; CSA 2018), the aquatic animals, aquatic plants, and sediment compartments, and all pathways associated with them, were not included. However, the water compartment from the N288.1-14 model was included in the form of a pond as wild animals (e.g., deer) are assumed to water at a pond. While inclusion of the pond completes the N288.1-14 model and calculations, it is not relevant to the EcoRA as there is no specific pond known to occur at this location. The hypothetical pond was only included as a water pathway to the deer and was assessed only for tritium to account for the high mobility of tritium in the environment. However, it is noted that the screening of tritium in the hypothetical pond is based on maximum tritium concentrations in air close to the facility at the Guardhouse location and thus bounds any tritium concentrations in wetlands further away from the NPD facility.

The model was run assuming that the entire release of tritium was in the form of tritiated water vapour (HTO), which is a conservative assumption. Figure 2.3 illustrates the model using the Grouting scenario as an example.

Table 2.12 Tritium Release Rates for Decommissioning Phase Scenarios

Scenario	Source	Volume	Duration	Release Rate
Normal - Grouting	1.04E+06 (Bq/m^3)	19,000 m^3	139 days	4.94E+03 Bq/s
Normal - Demolition	-	-	-	5.37E+04 Bq/s
M&A – Forest Fire	4.64E+10 (Bq)	-	1 hour	1.29E+07 Bq/s
M&A – Tornado	1.88E+10 (Bq)	-	1 hour	5.22E+06 Bq/s
M&A – Stack Collapse	6.10E+08 (Bq)	-	1 minute	1.00E+07 Bq/s

The results of the tritium model for each decommissioning scenario with tritium releases are summarized in Table 2.13.

Table 2.13 Tritium Levels in Environmental Components at Locations with Maximum Releases for Decommissioning Scenarios

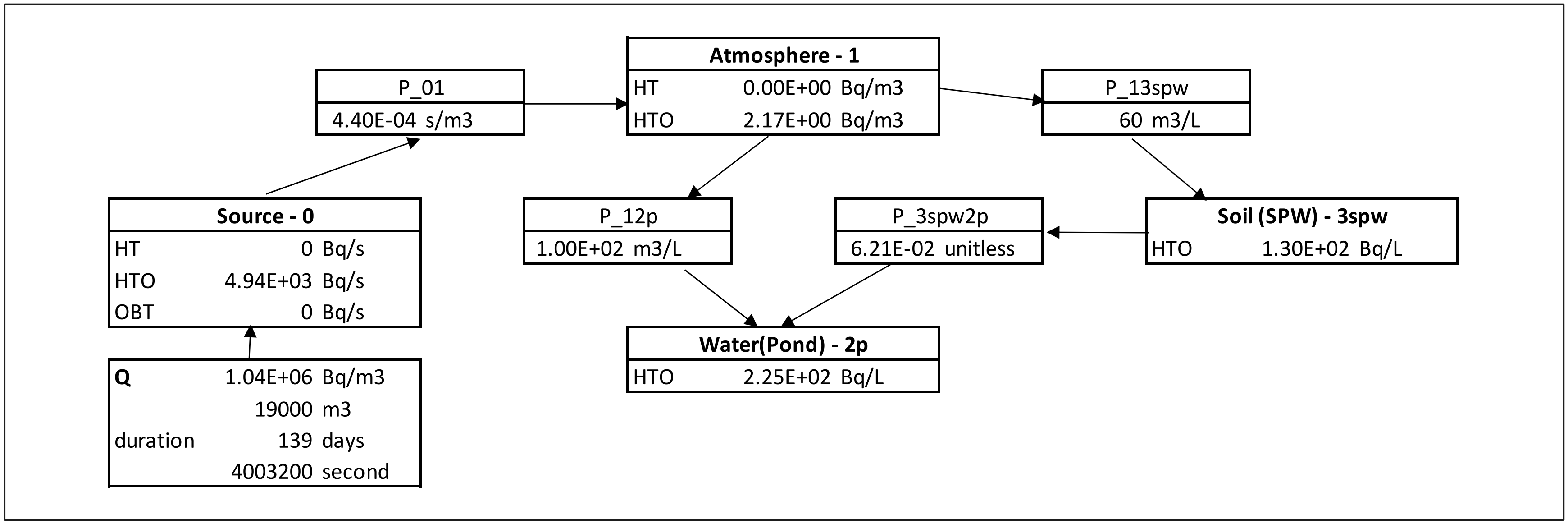
Compartment	HTO Concentration
Normal Operations - Grouting Scenario (Guardhouse)	
Atmosphere (Bq/m^3)	2.17E+00
Water – pond (Bq/L) [1]	2.25E+02
Soil (SPW) (Bq/L) [2]	1.30E+02
Soil (Bq/kg) [3]	2.00E+01
Normal Operations - Demolition Scenario (Guardhouse)	
Atmosphere (Bq/m^3)	2.36E+01
Water – pond (Bq/L) [1]	2.45E+03
Soil (SPW) (Bq/L) [2]	1.42E+03
Soil (Bq/kg) [3]	2.18E+02
Malfunctions & Accidents – Forest Fire (Guardhouse)	
Atmosphere (Bq/m^3)	6.70E+01
Water – pond (Bq/L) [1]	6.95E+03
Soil (SPW) (Bq/L) [2]	4.02E+03
Soil (Bq/kg) [3]	6.19E+02
Malfunctions & Accidents – Tornado (EF-2) (Rapides des Joachims & Rolphton)	
Atmosphere (Bq/m^3)	2.35E+01
Water – pond (Bq/L) [1]	2.44E+03
Soil (SPW) (Bq/L) [2]	1.41E+03
Soil (Bq/kg) [3]	2.17E+02
Malfunctions & Accidents – Stack Collapse	
Atmosphere (Bq/m^3)	1.50E+05
Water – pond (Bq/L) [1]	1.56E+07
Soil (SPW) (Bq/L) [2]	9.02E+06
Soil (Bq/kg) [3]	1.39E+06

Notes:

(1) The pond is a generic 0.5-hectare farm pond, as per N288.1-14 (CSA 2018).
(2) Note that tritium in the soil compartment is purely in the form of pore water, and the transit of tritium from soil to plants, animals and humans, through ingestion, is accounted for in the air compartment.
(3) Calculated from soil pore water (SPW) using Equation (2-1).

HTO – tritiated water; SPW – soil pore water.

Figure 2.3 N288.1-14 Model of HTO in the Environment in the Vicinity of the Guardhouse for the Decommissioning Phase – Normal Case, Grouting Scenario Assuming an Entire Release of HTO



Notes:

(1) Maximum air dispersion factors (ADFs) from CALPUFF were used, taken from Tables 6-5, 6-6, 6-7 and 6-10 of the DecomSA report (Garisto *et al.* 2020):

Scenario	Air Dispersion Factor (ADF)	Location with Maximum ADF
Normal Operations - Grouting	4.4E-04 s/m^3	Guardhouse
Normal Operations – Demolition	4.4E-04 s/m^3	Guardhouse
Malfunctions & Accidents – Forest Fire	5.2E-06 s/m^3	Guardhouse
Malfunctions & Accidents – Tornado	4.5E-06 s/m^3	Rapides de Joachims & Rolphton
Malfunctions & Accidents – Stack Collapse	1.5E-02 s/m^3	Guardhouse

(2) The pond is a generic 0.5 hectare farm pond, as per N288.1-14 (CSA 2018).

(3) Note that tritium in the soil compartment is purely in the form of pore water, and the transit of tritium from soil to plants, animals and humans, through ingestion, is accounted for in the air compartment.

(4) All of the transfer factors used were the default factors included in N288.1-14 (CSA 2018).

HTO – tritiated water; SPW – soil pore water.

The risk to non-human biota was determined by comparing the HTO concentrations found in the environment to the benchmark value. In order to compare the calculated HTO concentrations to screening criteria, the concentration in the soil pore water (SPW) was converted into a soil mass concentration using the following equation:

$$\boldsymbol{C_{soil(mass)}} = \frac{\boldsymbol{C_{soil(spw)}\ x\ 1000\left(\frac{L}{m^3}\right) x\ \theta}}{\boldsymbol{\rho}} \qquad (2\text{-}1)$$

where

$C_{soil(mass)}$ = concentration in the soil by mass (Bq/kg);

$C_{soil(spw)}$ = concentration in the soil pore water (Bq/L);

θ = soil water content (m^3 water/m^3 soil), 0.2 for loam (CSA 2018, Clause 6.3.4.3);

ρ = soil density (kg/m^3), 1300 for loam (CSA 2018, Clause 6.3.2.2);

1000 (L/m^3) = conversion factor from L to m^3.

The mass soil HTO concentrations are included in Table 2.13.

2.4.2.1.2 Carbon-14

In N288.1-14 (CSA 2018), the specific activity model for C-14 was used to determine the transfer of C-14 from air to plants and animals based on the air concentration, where the transfer also accounted for the contribution from soil (N288.1-14, Clause 6.4.9.1; CSA 2018).

To determine the C-14 concentration in soil from the air concentration, an alternative approach described by Yu *et al.* (2001; as cited in IAEA 2009) was used. The flux of C-14 from the soil to the atmosphere is given by:

$$\boldsymbol{F = C_{soil} \times E_c \times \rho_b \times d_s} \qquad (2\text{-}2)$$

where

F = flux of C-14 from soil to air ($Bq/m^2/d$);

C_{soil} = C-14 concentration in soil (Bq/kg dw);

E_c = C-14 evasion loss rate (per d), 0.033 for loam (IAEA 2009);

ρ_b = soil dry bulk density (kg dw/m^3), 1300 for loam (CSA 2018, Clause 6.3.2.2 and IAEA 2009);

d_s = soil depth (m); assumed 0.2 (CSA 2018, Clause 6.3.1.1).

The specific activity of the carbon evading the soil (*SAe*, Bq/gC) is given by:

$$SA_e = \frac{F}{F_c} \tag{2-3}$$

where

F = flux of C-14 from soil to air (Bq/m^2/d), estimated in equation (2-2);

F_c = average production of stable carbon by decomposition of crop residues (gC/m^2/d); suggested value is 0.66 (IAEA 2009).

Assuming that the specific activity of air in the plant canopy is the same as that in the soil gas, the specific activity of air is modified as follows to account for dilution with uncontaminated air:

$$SA_{air} = CD_c \times SA_e \tag{2-4}$$

where,

SA_{air} = C-14 specific activity in air (Bq/gC);

CD_c = canopy dilution factor for C-14 (unitless), 0.15 for crops with an open canopy (forage) (IAEA 2009).

By definition,

$$SA_{air} = \frac{C_{air}}{S_{air}} \tag{2-5}$$

where

S_{air} = concentration of stable carbon in air (gC/m^3), 0.21 (CSA 2018, Clause 6.4.9.3);

C_{air} = concentration of C-14 in air (Bq/m^3).

Hence, C_{soil} (concentration of C-14 in soil) can be estimated from C_{air} (concentration of C-14 in air) by re-arranging the above equations:

$$C_{soil} = (C_{air} \times F_c) \,/\, (E_c \times \rho_b \times d_s \times CD_c \times S_{air}) \tag{2-6}$$

2.4.2.1.3 Other Radionuclides

In addition to tritium and C-14, airborne releases of Co-60 and Cs-137 are also expected during some decommissioning scenarios. Corresponding concentrations in soil were calculated by applying air-to-soil transfer factors to the air concentrations. The air-to-soil transfer factors for loam for the CRL site were taken from CSA N288.1-14 (CSA 2018) and are summarized in Table 2.14.

Table 2.14 Air-to-Soil Transfer Factors for Radionuclides Emitted During the Decommissioning Phase

Radionuclide	Air-to-Soil Transfer Factor [1]
Co-160	4.17E+04
Cs-137	1.33E+05

Notes:
(1) Air-to-soil transfer factors were taken from CSA N288.1-14, Table A.4c for loam at the Chalk River Laboratories site (CSA 2018).

2.4.2.1.4 Lead and Mercury

As with the radionuclides, airborne releases of chemicals from the NPD facility can be transported through the air and deposited on the soil around the facility. This section describes the method used to predict the concentration of lead and mercury in soil resulting from airborne releases.

Soil concentrations depend on the deposition velocity, the duration of deposition, and natural mechanisms that remove the contaminant from the soil. Lead and mercury are naturally removed from the soil by many mechanisms including soil erosion, leaching and surface run-off. For this assessment, the only contaminant removal mechanism from soil was leaching, which is conservative.

Deposition from the atmosphere occurs both by washout during periods of precipitation and by interaction with the surface when precipitation is not falling. A combined wet and dry deposition velocity *Vg* (m/s) is calculated following Clause 6.3.3.1 in N288.1-14 (CSA 2018):

$$\boldsymbol{V_g = V_d + V_w} \qquad (2\text{-}7)$$

where

V_g = combined deposition velocity (m/s);

V_d = dry deposition velocity (m/s);

V_w = wet deposition velocity (m/s).

Wet deposition velocity is different for soil that is exposed to both snow and rain. In such cases deposition velocity can be calculated as follows (see CSA 2018, Clause 6.3.3.1):

$$\boldsymbol{V_w = f_{pj} \times W_r \times P} \qquad (2\text{-}8)$$

where

V_w = wet deposition velocity (m/s);

f_{pj} = fraction of the time precipitation falls when the wind blows from sector j (unitless);

W_r = washout ratio (unitless);

P = long-term average precipitation rate (m/s).

Table 2.15 Default Values for Deposition Velocity Calculation

Parameter	Value	Reference
f_{pj} (unitless)	0.36	N288.1-14, Clause 6.3.3.3; CSA 2018.
W_r (unitless)	5.5E+06	N288.1-14, Table 14; CSA 2018.
P (m/s)	3.03E-08	N288.1-14, Clause 6.3.3.4, value for eastern Ontario; CSA 2018
V_w (m/s)	6E-02	= $f_{pj} \times W_r \times P$ (from values above)
V_d (m/s)	1.4E-03	N288.1-14, Table 14; CSA 2018.
V_g (m/s)	0.0614	= $V_d + V_w$ (from values above)

The soil loss constant due to leaching form the soil is calculated using the following equation, which merges equations 6-32 and 6-33 of CSA N288.1-14 (CSA 2018):

$$k_{leaching} = \frac{q_{infil}}{Z_{soil}[\theta + (\rho \times K_d)]} \quad (2\text{-}9)$$

where

$k_{leaching}$ = soil loss coefficient due to leaching (1/yr);

q_{infil} = net infiltration rate of water through the soil (m/yr);

Z_{soil} = depth of the top mixed soil layer (m);

ρ = bulk soil density (kg/m^3);

θ = soil water content (m^3 water/m^3 soil);

K_d = equilibrium distribution coefficient (m^3/kg).

Soil concentrations over the desired build-up period were estimated using the following equation:

$$C_{soil}(t) = C_{air} \times \frac{V_g}{Z_{soil} \times \rho} \times \left(\frac{1 - \exp(-kt)}{k}\right) \times \frac{1\ kg}{1000\ g} \times \frac{365\ d}{y} \times \frac{86400\ s}{d} \times \frac{10^6 \mu g}{1 g} \quad (2\text{-}10)$$

where

$C_{soil}(t)$ = soil concentration after t years (µg/g);

t = build-up period (yr);

C_{air} = average air concentration over the t-year time period due to air releases from the facility (g/m^3);

V_g = deposition velocity for soil (m/s);

Z_{soil} = depth of the top mixed soil layer (m);

ρ = bulk soil density (kg/m^3);

k = soil loss coefficient due to leaching (1/yr) [calculated $k_{leaching}$, as above].

Table 2.16 Parameter Values for Soil Concentration Calculations

Parameter	Value	Reference
C_{air} (g/m^3)		Calculated separately for each scenario.
V_g (m/s)	0.0614	Calculated in Table 2.15.
ρ (kg/m^3)	1300	N288.1-14, Clause 6.3.2.2 and 6.3.1.2, for loam (as recommended for eastern Ontario sites); CSA2018.
Z_{soil} (m)	0.2	N288.1-14, Clause 6.3.1.1; CSA 2018
t (yr)	Several	Determined separately for each scenario, based on their release durations. See Table 2.12.
k (1/yr)	9.47E-05 (Pb) 1.95E-04 (Hg)	Calculated (see $k_{leaching}$ Equation 2-9).
q_{infil} (m/yr)	0.32	N288.1-14, Clause 6.3.6.3, value for eastern Ontario sites; CSA 2018.
θ (m^3 water/m^3 soil)	0.2	N288.1-14, Clauses 6.3.4.3 and 6.3.1.2, for loam (as recommended for eastern Ontario sites); CSA 2018.
K_d (m^3/kg)	13 (Pb) 6.3 (Hg)	IAEA (2010), Table 14, mean value for loam (loam soil type is recommended for eastern Ontario sites N288.1-14, Clause 6.2.1.2; CSA 2018).

2.4.2.2 Screening Results

The results of the radiological and non-radiological COPC screens for the decommissioning phase are shown in Table 2.17 and Table 2.18, respectively. As seen from the tables, the soil concentrations of all radionuclides and chemical contaminants released during each decommissioning scenario under both normal operations and potential malfunctions & accidents were below applicable soil criteria. As such all radiological and non-radiological contaminants 'screened-out' for the decommissioning phase and were not assessed further in the EcoRA. In addition, the sum of fractions analysis for radionuclides included in Table 2.17 shows that all radionuclide fractions are well below a value of 1, indicating no significant impact. With the exception of the Malfunctions & Accidents – Stack Collapse and Release of Radioactivity scenario for which the sum of fractions was 0.43, all sums were several orders of magnitude below a value of 1.

Table 2.17 Results of Radiological COPC Screen for the Decommissioning Phase

Radionuclide	Maximum Concentration in Air (Bq/m^3)[1]	Air-to-Soil Transfer Factor (Loam) (m^3/kg dw)[2]	Estimated Concentration in Soil (Bq/kg dw)[3]	Soil Screening Criterion (Bq/kg)[4]	Dose Conversion Coefficient Available?	Screening Decision	Fraction (Concentration/ Criterion)	Sum of Fractions
(2) Normal Operations - Grouting of Below Grade Structures (Grouting Scenario) - Guardhouse								
H-3	2.16E+00	NA	2.00E+01	3.20E+06	Y	Screen-out	6.26E-06	6.26E-06
(3) Normal Operations - Removal and Grouting of Above Grade Structures (Demolition Scenario) - Guardhouse								
H-3	2.36E+01	NA	2.18E+02	3.20E+06	Y	Screen-out	6.82E-05	2.36E-03
Cs-137	7.08E-04	1.33E+05	9.42E+01	5.54E+04	Y	Screen-out	1.70E-03	
C-14	1.39E-01	NA	3.39E-01	5.74E+02	Y	Screen-out	5.91E-04	
(6) Malfunctions & Accidents - Forest Fire and Release of Radioactivity - Guardhouse								
H-3	6.70E+01	NA	6.19E+02	3.20E+06	Y	Screen-out	1.93E-04	1.87E-03
Cs-137	1.20E-07	1.33E+05	1.60E-02	5.54E+04	Y	Screen-out	2.88E-07	
C-14	3.93E-01	NA	9.60E-01	5.74E+02	Y	Screen-out	1.67E-03	
(8) Malfunctions & Accidents - Tornado (Category EF-2) and Release of Radioactivity - Rapides de Joachims & Rolphton								
H-3	5.23E-07	NA	2.17E+02	3.20E+06	Y	Screen-out	6.78E-05	6.78E-05
Cs-137	1.82E-19	1.33E+05	2.42E-14	5.54E+04	Y	Screen-out	4.37E-19	
C-14	7.56E-12	NA	1.85E-11	5.74E+02	Y	Screen-out	3.22E-14	
(10) Malfunctions & Accidents - Underground (Indoor) Fire and Release of Radioactivity - Guardhouse								
Cs-137	1.13E-04	1.33E+05	1.50E+01	5.54E+04	Y	Screen-out	2.71E-04	2.79E-04
Co-60	1.78E-05	4.17E+04	7.42E-01	9.05E+04	Y	Screen-out	8.20E-06	
(15) Malfunctions & Accidents - Stack Collapse and Release of Radioactivity - Guardhouse								
H-3	1.50E+05	NA	1.39E+06	3.20E+06	Y	Screen-out	4.34E-01	4.34E-01

Notes:

(1) Radionuclide concentrations in air for each scenario were estimated in the DecomSA and taken from Tables 8-9, 8-19, 9-20, 9-22, 9-25 and 9-28 (Garisto *et al.* 2020); data from the location with the maximum air emissions were used for each scenario.

(2) Air-to-soil transfer factors were taken from N288.1-14, Table A.4c for loam at the Chalk River Laboratories site (CSA 2018).

(3) Radionuclide concentrations in soil were calculated by applying the air-to-soil transfer factor to the air concentration except for H-3 and C-14 for which soil concentrations were estimated using specific activity models as per N288.1-14 (CSA 2018) (See Section 2.4.2.1.1 for tritium and Section 2.4.2.1.2 for C-14).

(4) Environmental Effect Concentration (EEC) Levels derived for the Chalk River Laboratories site (Table 5.1, EcoMetrix and AECL 2013) based on a benchmark of 2.4 mGy/d as recommended by UNSCEAR (2008); a soil EEC for C-14 was not available and a No-Effect Concentration (NEC) from SENES (2008) was used - SENES (2008) derived the value based on a benchmark of 1 mGy/d for terrestrial biota from UNSCEAR (1996) and thus a factor of 2.4 was applied to make it consistent with UNSCEAR (2008).

Table 2.18 Results of Non-radiological COPC Screen for the Decommissioning Phase

Contaminant	Maximum Concentration in Air (g/m^3)[1]	Concentration in Soil (µg/g)[2]	Baseline Soil Concentration (µg/g)[3]	Total Soil Concentration (Incremental + Baseline) (µg/g)	Soil Screening Criterion (µg/g)		Screening Decision
					MOE[4]	CCME[5]	
(2) Normal Operations - Grouting of Below Grade Structures (Grouting Scenario) - Guardhouse							
Lead	2.09E-11	5.93E-05	30	30	120	140	Screen-out
(3) Normal Operations - Removal and Grouting of Above Grade Structures (Demolition Scenario) - Guardhouse							
Lead	1.71E-08	1.05E-02	30	30	120	140	Screen-out
(7) Malfunctions & Accidents - Forest Fire and Release of Chemicals - Guardhouse							
Lead	2.42E-07	2.06E-04	30	30	120	140	Screen-out
(9) Malfunctions & Accidents - Tornado (Category EF-2) and Release of Chemicals - Rapides de Joachims & Rolphton							
Lead	4.19E-07	3.56E-04	30	30	120	140	Screen-out
(11) Malfunctions & Accidents - Underground (Indoor) Fire and Release of Chemicals - Guardhouse							
Lead	9.08E-09	7.72E-06	30	30	120	140	Screen-out
Mercury	1.44E-09	1.22E-06	0.05	0.05	0.27	6.6	Screen-out

Notes:

(1) Concentrations of lead and mercury in air for each scenario were estimated in the DecomSA and taken from Tables 8-5, 8-16, 9-21, 9-23 and 9-26 for lead and Table 9-27 for mercury; data from the location with the maximum emissions were used for each scenario (Garisto *et al.* 2020).

(2) Concentrations of lead and mercury in soil were calculated using the air-to-soil transfer model described in Section 2.4.2.1.4.

(3) Baseline concentrations of lead and mercury are summarized in Table 2.10; site-specific baseline soil concentrations were taken from Table 2 of Golder (2017a).

(4) MOE (2011) for soil (coarse textured for all land uses) from Table 8 - Full Depth Generic Site Condition Standards for Use within 30 m of a Water Body in a Potable Ground Water Condition.

(5) CCME (2020; online) – Environmental Quality Guidelines for the Protection of Environmental and Human Health under a residential/parkland land use scenario for soil.

2.4.3 Screening Results – Postclosure Phase

The following postclosure scenarios from the PostSA (Penfold *et al.* 2020) were screened to identify radiological and non-radiological COPCs for inclusion in the EcoRA:

(1) Normal Evolution Scenario (NES)
(1a) NES Sensitivity Analysis – Radioactive Inventory
(1b) NES Sensitivity Analysis – Sorption
(1c) NES Sensitivity Analysis – Resaturation Rate – Faster
(1d) NES Sensitivity Analysis – Resaturation Rate - Slower
(1e) NES Sensitivity Analysis – Surface Erosion
(1g) NES Sensitivity Analysis – Engineering Degradation
(2a) Disruptive Event – Site Investigation (Human Intrusion)
(2b) Disruptive Event – Extreme Degradation of Engineered Structures
(3a) Defence-in-Depth – Role of Waste Form
(3b) Defence-in-Depth – Role of Existing Facility Structure
(3c) Defence-in-Depth – Role of Grout
(4a) What-If – Mass Excavation
(4b) What-If – River Level Fall

Following closure, the NPD facility will gradually become saturated with groundwater at which time wastes will corrode and radionuclides and other contaminants will be released into the groundwater. Thus, the main contaminant release pathway to the biosphere during the postclosure phase is via groundwater, which is assumed to discharge to springs close to the shore and riverbed (or shoreline) sediments adjacent to the site from where contamination may pass into water in the Ottawa River. Contaminants released into the Ottawa River may sorb to sediments or be taken up by aquatic flora and fauna. Contaminants may also be transferred to land through crop irrigation (garden soil) with river water and animals drinking river water and then excreting it onto the land (grazing soil).

For each postclosure scenario, predicted contaminant concentrations in Ottawa River water (surface water), Spring water (groundwater), Ottawa River Riverbed or Shoreline sediments, and Garden Area soil were screened against the environmental criteria presented in Section 2.4.1.

2.4.3.1 Radiological COPC Screen

The maximum environmental radionuclide (incremental) concentrations for each scenario, along with the environmental screening criteria and the screening decision, are summarized in Table 2.19 to Table 2.32. If a radionuclide exceeded the environmental criterion in at least one environmental medium then it was ‘screened-in’ (i.e., assessed) for that scenario and assessed in all media.

Table 2.19 Maximum Radionuclide Concentrations Predicted in Environmental Media Over 10,000 Year Postclosure Period and COPC Selection for Scenario (1) Normal Evolution Scenario (NES)

Radionuclide	Spring Water	Ottawa River	Garden Area	Riverbed	Screening Criterion			Screened In?	Comments
	Groundwater	Surface Water	Soil	Sediment	Surface Water & Groundwater	Soil	Sediment		
	(Bq/L)	(Bq/L)	(Bq/kg)	(Bq/kg)	(Bq/L)	(Bq/kg)	(Bq/kg)		
(1) Normal Evolution Scenario (NES)									
Am-241	1.05E-08	2.30E-11	1.47E-08	1.31E-08	3.85E-01	8.62E+02	8.28E+03		
C-14	2.76E-02	9.57E-05	2.16E-04	3.21E+01	1.64E+02	5.74E+02	5.45E+03		
Ca-41	4.92E-03	3.94E-05	3.38E-04	2.11E+02	N/A	N/A	N/A	**Yes**	No environmental screening criteria
Cd-113m	5.42E-22	5.36E-22	4.56E-21	7.87E-25	N/A	N/A	N/A	**Yes**	No environmental screening criteria
Cl-36	6.88E-04	1.59E-05	3.63E-03	2.65E+01	1.31E+03	9.02E-01	1.06E+02		
Cm-243	2.73E-33	1.08E-32	1.22E-31	1.07E-34	8.24E-01	8.00E+02	2.07E+01		
Cm-244	8.44E-32	4.62E-30	5.18E-29	4.49E-32	8.28E-01	8.00E+02	2.07E+01		
Co-60	7.33E-10	4.59E-13	2.59E-12	1.44E-14	1.35E+02	9.05E+04	1.03E+06		
Cs-135	4.45E-08	5.42E-10	3.05E-06	4.07E-01	3.48E+02	1.97E+05	4.36E+06		
Cs-137	1.74E-05	5.10E-08	1.48E-06	2.09E-09	7.27E+01	5.54E+04	7.12E+05		
Eu-152	5.94E-18	3.30E-13	2.41E-12	1.25E-16	1.18E+02	1.72E+05	4.13E+04		
Eu-154	1.92E-19	1.17E-14	4.60E-14	3.03E-18	7.74E+01	1.55E+05	2.72E+04		
H-3	1.80E+02	6.57E-01	4.56E+00	9.01E+03	1.74E+07	3.20E+06	2.60E+07		
Hf-182	3.75E-15	1.28E-17	1.97E-15	5.78E-11	N/A	N/A	N/A	**Yes**	No environmental screening criteria
I-129	4.92E-08	2.42E-10	9.07E-09	7.08E-02	7.63E+01	1.59E+06	1.57E+06		
Mo-93	3.46E-05	1.47E-07	7.57E-05	1.08E+00	N/A	N/A	N/A	**Yes**	No environmental screening criteria
Nb-93m	1.61E-06	7.88E-09	7.53E-05	9.79E-01	N/A	N/A	N/A	**Yes**	No environmental screening criteria
Nb-94	8.34E-12	2.81E-14	3.47E-12	3.98E-08	1.95E+02	1.15E+05	3.08E+03		
Ni-59	2.27E-03	7.28E-05	7.05E-02	7.67E+03	2.56E+03	1.24E+07	4.30E+07		
Ni-63	8.64E-07	2.94E-09	3.80E-07	1.24E-08	9.09E+03	8.77E+06	3.25E+07		
Np-237	9.12E-15	4.78E-14	4.95E-13	4.58E-08	1.83E+01	1.00E+03	5.12E+00		
Pu-238	2.83E-08	3.02E-11	1.39E-09	2.43E-11	6.36E-01	7.52E+03	2.42E+04		
Pu-239	1.22E-06	4.32E-08	2.19E-04	7.43E+02	6.79E-01	8.00E+03	2.58E+04		
Pu-240	1.45E-13	1.89E-14	2.83E-12	3.58E-04	6.78E-01	8.00E+03	2.58E+04		
Pu-241	1.85E-13	8.70E-16	1.28E-12	1.79E-06	2.50E+03	2.94E+07	9.48E+07		
Pu-242	8.36E-13	1.64E-12	2.64E-10	3.11E-02	N/A	N/A	N/A	**Yes**	No environmental screening criteria
Sb-125	4.00E-27	1.27E-26	2.92E-26	2.73E-29	3.28E+01	4.41E+05	6.86E+05		
Se-79	3.37E-06	2.24E-08	6.41E-06	9.58E-01	9.73E+02	5.29E+05	2.37E+05		
Sn-126	8.94E-11	1.11E-12	9.28E-11	8.35E-05	N/A	N/A	N/A	**Yes**	No environmental screening criteria
Sr-90	7.05E-07	2.37E-09	2.54E-08	1.47E-09	1.83E+02	1.18E+06	1.14E+05		
Tc-99	1.00E-03	3.39E-06	2.99E-04	6.61E-01	2.47E+04	4.61E+04	3.39E+04		
Th-229	1.41E-09	1.09E-11	1.13E-07	9.41E-02	N/A	N/A	N/A	**Yes**	No environmental screening criteria
Th-230	2.14E-07	7.35E-10	5.53E-04	2.13E-01	3.81E-02	2.66E+03	4.10E+02		
Th-232	7.21E-11	2.42E-13	3.28E-11	1.92E-07	4.49E-02	3.11E+03	4.81E+02		
U-233	3.07E-09	1.19E-09	4.17E-07	4.87E-03	6.72E+00	1.20E+04	1.92E+06		
U-234	1.73E-09	1.83E-10	4.10E-08	7.32E-04	1.01E+01	1.17E+03	4.94E+02		
U-235	7.67E-07	2.93E-09	2.58E-04	8.48E-03	1.09E+01	1.26E+03	5.37E+02		
U-236	1.17E-13	6.12E-13	4.26E-11	2.52E-06	N/A	N/A	N/A	**Yes**	No environmental screening criteria
U-238	1.24E-05	4.62E-08	3.75E-03	1.37E-01	1.18E+01	1.33E+03	5.76E+02		
Zr-93	2.91E-10	1.16E-12	2.52E-10	1.41E-05	1.68E+01	2.01E+05	8.06E+07		

Notes: see Table 2.8 for notes on environmental screening criteria. N/A – not available.

Table 2.20 Maximum Radionuclide Concentrations Predicted in Environmental Media Over 10,000 Year Postclosure Period and COPC Selection for Scenario (1a) NES Sensitivity Analysis – Radioactive Inventory

Radionuclide	Spring Water Groundwater (Bq/L)	Ottawa River Surface Water (Bq/L)	Garden Area Soil (Bq/kg)	Riverbed Sediment (Bq/kg)	Screening Criteria Surface Water & Groundwater (Bq/L)	Screening Criteria Soil (Bq/kg)	Screening Criteria Sediment (Bq/kg)	Screened In?	Comments
(1a) NES Sensitivity Analysis – Radioactive Inventory									
Am-241	9.88E-08	2.10E-10	7.54E-07	1.35E-09	3.85E-01	8.62E+02	8.28E+03		
C-14	8.50E-06	3.02E-08	8.23E-07	5.02E-02	1.64E+02	5.74E+02	5.45E+03		
Ca-41	4.84E-03	3.43E-05	3.04E-04	1.83E+02	N/A	N/A	N/A	**Yes**	No environmental screening criteria
Cd-113m	0.00E+00	0.00E+00	0.00E+00	0.00E+00	N/A	N/A	N/A	**Yes**	No environmental screening criteria
Cl-36	3.30E-05	5.18E-07	2.03E-06	8.31E-01	1.31E+03	9.02E-01	1.06E+02		
Cm-243	6.13E-17	4.93E-16	7.03E-15	5.97E-18	8.24E-01	8.00E+02	2.07E+01		
Cm-244	1.23E-16	2.47E-15	2.51E-14	2.17E-17	8.28E-01	8.00E+02	2.07E+01		
Co-60	1.34E-08	8.41E-12	4.74E-11	2.63E-13	1.35E+02	9.05E+04	1.03E+06		
Cs-135	3.84E-07	1.29E-09	3.82E-06	5.34E-01	3.48E+02	1.97E+05	4.36E+06		
Cs-137	1.05E-04	3.08E-07	1.38E-05	1.24E-08	7.27E+01	5.54E+04	7.12E+05		
Eu-152	6.02E-18	3.31E-13	2.42E-12	1.25E-16	1.18E+02	1.72E+05	4.13E+04		
Eu-154	0.00E+00	0.00E+00	0.00E+00	0.00E+00	7.74E+01	1.55E+05	2.72E+04		
H-3	3.48E+02	1.27E+00	8.27E+00	1.74E+04	1.74E+07	3.20E+06	2.60E+07		
Hf-182	0.00E+00	0.00E+00	0.00E+00	0.00E+00	N/A	N/A	N/A	**Yes**	No environmental screening criteria
I-129	1.05E-06	3.86E-09	1.70E-07	9.63E-01	7.63E+01	1.59E+06	1.57E+06		
Mo-93	0.00E+00	0.00E+00	0.00E+00	0.00E+00	N/A	N/A	N/A	**Yes**	No environmental screening criteria
Nb-93m	1.31E-22	1.44E-17	1.41E-16	3.72E-20	N/A	N/A	N/A	**Yes**	No environmental screening criteria
Nb-94	5.41E-14	1.83E-16	2.25E-14	1.49E-10	1.95E+02	1.15E+05	3.08E+03		
Ni-59	5.02E-05	1.29E-06	1.48E-03	1.36E+02	2.56E+03	1.24E+07	4.30E+07		
Ni-63	4.93E-06	1.66E-08	4.26E-07	1.11E-09	9.09E+03	8.77E+06	3.25E+07		
Np-237	3.08E-11	5.32E-13	5.78E-12	4.27E-07	1.83E+01	1.00E+03	5.12E+00		
Pu-238	1.95E-09	2.09E-12	1.81E-10	1.68E-12	6.36E-01	7.52E+03	2.42E+04		
Pu-239	2.67E-06	8.64E-09	8.56E-03	5.32E+00	6.79E-01	8.00E+03	2.58E+04		
Pu-240	3.90E-09	1.29E-11	3.16E-09	9.16E-04	6.78E-01	8.00E+03	2.58E+04		
Pu-241	1.71E-08	5.06E-12	6.88E-11	8.12E-13	2.50E+03	2.94E+07	9.48E+07		
Pu-242	3.01E-10	2.48E-12	7.35E-09	3.67E-02	N/A	N/A	N/A	**Yes**	No environmental screening criteria
Sb-125	6.19E-18	2.20E-19	4.65E-19	4.34E-22	3.28E+01	4.41E+05	6.86E+05		
Se-79	1.19E-05	4.05E-08	3.29E-05	8.04E-02	9.73E+02	5.29E+05	2.37E+05		
Sn-126	8.83E-08	2.98E-10	2.25E-08	3.65E-04	N/A	N/A	N/A	**Yes**	No environmental screening criteria
Sr-90	4.19E-05	1.41E-07	1.25E-06	2.16E-08	1.83E+02	1.18E+06	1.14E+05		
Tc-99	5.35E-04	2.56E-06	3.01E-06	9.86E-01	2.47E+04	4.61E+04	3.39E+04		
Th-229	3.93E-10	1.34E-12	8.29E-07	4.45E-04	N/A	N/A	N/A	**Yes**	No environmental screening criteria
Th-230	1.96E-11	6.70E-14	2.98E-10	1.65E-05	3.81E-02	2.66E+03	4.10E+02		
Th-232	1.93E-16	6.79E-19	1.87E-15	4.46E-10	4.49E-02	3.11E+03	4.81E+02		
U-233	6.51E-10	6.91E-12	6.66E-07	1.94E-05	6.72E+00	1.20E+04	1.92E+06		
U-234	1.49E-10	6.19E-12	1.78E-09	2.42E-05	1.01E+01	1.17E+03	4.94E+02		
U-235	1.49E-11	6.11E-14	1.86E-10	1.45E-07	1.09E+01	1.26E+03	5.37E+02		
U-236	1.21E-10	5.63E-12	1.71E-09	2.21E-05	N/A	N/A	N/A	**Yes**	No environmental screening criteria
U-238	3.86E-10	3.72E-12	4.90E-09	1.17E-05	1.18E+01	1.33E+03	5.76E+02		
Zr-93	3.08E-09	1.04E-11	1.77E-09	1.71E-06	1.68E+01	2.01E+05	8.06E+07		

Notes: see Table 2.8 for notes on environmental screening criteria. N/A – not available.

Table 2.21 Maximum Radionuclide Concentrations Predicted in Environmental Media Over 10,000 Year Postclosure Period and COPC Selection for Scenario (1b) NES Sensitivity Analysis - Sorption

Radionuclide	Spring Water	Ottawa River	Garden Area	Riverbed	Screening Criteria			Screened In?	Comments
	Groundwater	Surface Water	Soil	Sediment	Surface Water & Groundwater	Soil	Sediment		
	(Bq/L)	(Bq/L)	(Bq/kg)	(Bq/kg)	(Bq/L)	(Bq/kg)	(Bq/kg)		
(1b) NES Sensitivity Analysis - Sorption									
Am-241	1.42E-07	3.81E-10	1.26E-06	1.37E-06	3.85E-01	8.62E+02	8.28E+03		
C-14	2.67E-01	9.01E-04	1.83E-02	3.84E+02	1.64E+02	5.74E+02	5.45E+03		
Ca-41	5.83E-02	1.97E-04	7.69E-03	5.33E+02	N/A	N/A	N/A	**Yes**	No environmental screening criteria
Cd-113m	7.06E-17	5.56E-18	6.38E-17	1.02E-20	N/A	N/A	N/A	**Yes**	No environmental screening criteria
Cl-36	1.83E-02	1.68E-04	1.30E-02	2.11E+02	1.31E+03	9.02E-01	1.06E+02	**Yes**	Exceeded sediment (River Bed) criterion
Cm-243	1.26E-25	7.51E-26	8.85E-25	7.67E-28	8.24E-01	8.00E+02	2.07E+01		
Cm-244	4.92E-24	3.22E-23	3.74E-22	3.24E-25	8.28E-01	8.00E+02	2.07E+01		
Co-60	7.26E-09	6.31E-12	3.74E-11	2.04E-13	1.35E+02	9.05E+04	1.03E+06		
Cs-135	5.15E-07	1.78E-09	1.27E-06	4.46E-01	3.48E+02	1.97E+05	4.36E+06		
Cs-137	1.04E-04	3.07E-07	2.72E-05	1.27E-08	7.27E+01	5.54E+04	7.12E+05		
Eu-152	5.91E-15	3.29E-11	2.40E-10	1.24E-14	1.18E+02	1.72E+05	4.13E+04		
Eu-154	1.92E-17	1.16E-13	4.59E-13	3.02E-17	7.74E+01	1.55E+05	2.72E+04		
H-3	1.80E+02	6.57E-01	4.56E+00	9.01E+03	1.74E+07	3.20E+06	2.60E+07		
Hf-182	8.15E-11	2.75E-13	2.25E-09	2.12E-08	N/A	N/A	N/A	**Yes**	No environmental screening criteria
I-129	5.06E-07	5.30E-10	1.38E-07	1.48E-01	7.63E+01	1.59E+06	1.57E+06		
Mo-93	3.82E-04	1.29E-06	7.56E-04	1.35E+00	N/A	N/A	N/A	**Yes**	No environmental screening criteria
Nb-93m	2.60E-05	8.86E-08	7.57E-04	1.22E+00	N/A	N/A	N/A	**Yes**	No environmental screening criteria
Nb-94	1.92E-08	6.51E-11	3.03E-07	5.56E-05	1.95E+02	1.15E+05	3.08E+03		
Ni-59	1.35E-02	1.64E-04	1.30E-01	1.31E+04	2.56E+03	1.24E+07	4.30E+07		
Ni-63	8.66E-06	3.09E-08	3.29E-05	1.21E-06	9.09E+03	8.77E+06	3.25E+07		
Np-237	2.96E-11	6.53E-12	9.99E-11	6.24E-06	1.83E+01	1.00E+03	5.12E+00		
Pu-238	2.83E-07	3.02E-10	1.61E-08	2.42E-10	6.36E-01	7.52E+03	2.42E+04		
Pu-239	8.86E-05	1.14E-06	7.94E-02	1.72E+04	6.79E-01	8.00E+03	2.58E+04		
Pu-240	9.78E-10	3.74E-12	2.00E-07	2.87E-02	6.78E-01	8.00E+03	2.58E+04		
Pu-241	2.21E-10	1.15E-13	1.24E-08	3.19E-04	2.50E+03	2.94E+07	9.48E+07		
Pu-242	1.94E-09	1.35E-10	1.94E-06	2.44E+00	N/A	N/A	N/A	**Yes**	No environmental screening criteria
Sb-125	3.97E-24	1.26E-24	2.90E-24	2.70E-27	3.28E+01	4.41E+05	6.86E+05		
Se-79	4.38E-06	2.24E-08	2.72E-05	9.51E-01	9.73E+02	5.29E+05	2.37E+05		
Sn-126	5.17E-09	6.94E-11	2.77E-08	5.42E-03	N/A	N/A	N/A	**Yes**	No environmental screening criteria
Sr-90	7.04E-06	2.37E-08	1.52E-06	1.27E-07	1.83E+02	1.18E+06	1.14E+05		
Tc-99	3.70E-03	1.25E-05	4.13E-04	1.85E+00	2.47E+04	4.61E+04	3.39E+04		
Th-229	4.30E-08	2.53E-10	2.93E-05	1.66E+00	N/A	N/A	N/A	**Yes**	No environmental screening criteria
Th-230	4.78E-07	1.64E-09	1.14E-03	6.13E-01	3.81E-02	2.66E+03	4.10E+02		
Th-232	5.38E-09	1.81E-11	2.74E-09	2.95E-04	4.49E-02	3.11E+03	4.81E+02		
U-233	8.57E-08	1.32E-08	5.15E-05	5.32E-02	6.72E+00	1.20E+04	1.92E+06		
U-234	2.28E-08	7.13E-09	1.30E-05	2.92E-02	1.01E+01	1.17E+03	4.94E+02		
U-235	7.26E-06	2.45E-08	1.46E-03	1.80E-02	1.09E+01	1.26E+03	5.37E+02		
U-236	1.04E-10	3.35E-11	5.93E-08	1.37E-04	N/A	N/A	N/A	**Yes**	No environmental screening criteria
U-238	1.17E-04	3.96E-07	2.12E-02	2.92E-01	1.18E+01	1.33E+03	5.76E+02		
Zr-93	5.05E-06	1.71E-08	4.50E-04	4.94E-03	1.68E+01	2.01E+05	8.06E+07		

Notes: see Table 2.8 for notes on environmental screening criteria. N/A – not available.

Table 2.22 Maximum Radionuclide Concentrations Predicted in Environmental Media Over 10,000 Year Postclosure Period and COPC Selection for Scenario (1c) NES Sensitivity Analysis – Resaturation Rate - Faster

Radionuclide	Spring Water	Ottawa River	Garden Area	Riverbed	Screening Criteria			Screened In?	Comments
	Groundwater	Surface Water	Soil	Sediment	Surface Water & Groundwater	Soil	Sediment		
	(Bq/L)	(Bq/L)	(Bq/kg)	(Bq/kg)	(Bq/L)	(Bq/kg)	(Bq/kg)		
(1c) NES Sensitivity Analysis - Resaturation Rate - Faster									
Am-241	1.05E-08	2.30E-11	1.47E-08	1.31E-08	3.85E-01	8.62E+02	8.28E+03		
C-14	2.76E-02	9.57E-05	2.16E-04	3.21E+01	1.64E+02	5.74E+02	5.45E+03		
Ca-41	4.92E-03	3.94E-05	3.38E-04	2.11E+02	N/A	N/A	N/A	**Yes**	No environmental screening criteria
Cd-113m	6.36E-22	8.41E-22	6.73E-21	1.13E-24	N/A	N/A	N/A	**Yes**	No environmental screening criteria
Cl-36	6.88E-04	1.59E-05	3.63E-03	2.65E+01	1.31E+03	9.02E-01	1.06E+02		
Cm-243	2.73E-33	1.08E-32	1.23E-31	1.07E-34	8.24E-01	8.00E+02	2.07E+01		
Cm-244	8.45E-32	4.62E-30	5.19E-29	4.50E-32	8.28E-01	8.00E+02	2.07E+01		
Co-60	7.34E-10	6.35E-13	3.52E-12	1.93E-14	1.35E+02	9.05E+04	1.03E+06		
Cs-135	4.45E-08	5.42E-10	3.05E-06	4.07E-01	3.48E+02	1.97E+05	4.36E+06		
Cs-137	2.04E-05	6.03E-08	1.65E-06	2.42E-09	7.27E+01	5.54E+04	7.12E+05		
Eu-152	7.47E-18	4.43E-13	3.72E-12	1.95E-16	1.18E+02	1.72E+05	4.13E+04		
Eu-154	3.00E-19	2.97E-14	1.55E-13	9.06E-18	7.74E+01	1.55E+05	2.72E+04		
H-3	1.80E+02	6.57E-01	8.21E+00	9.01E+03	1.74E+07	3.20E+06	2.60E+07		
Hf-182	3.75E-15	1.28E-17	1.97E-15	5.78E-11	N/A	N/A	N/A	**Yes**	No environmental screening criteria
I-129	4.94E-08	2.43E-10	9.09E-09	7.10E-02	7.63E+01	1.59E+06	1.57E+06		
Mo-93	3.52E-05	1.47E-07	7.59E-05	1.08E+00	N/A	N/A	N/A	**Yes**	No environmental screening criteria
Nb-93m	1.64E-06	7.89E-09	7.55E-05	9.80E-01	N/A	N/A	N/A	**Yes**	No environmental screening criteria
Nb-94	8.34E-12	2.81E-14	3.47E-12	3.99E-08	1.95E+02	1.15E+05	3.08E+03		
Ni-59	2.27E-03	7.28E-05	7.05E-02	7.67E+03	2.56E+03	1.24E+07	4.30E+07		
Ni-63	9.75E-07	3.29E-09	3.83E-07	1.25E-08	9.09E+03	8.77E+06	3.25E+07		
Np-237	9.12E-15	4.79E-14	4.95E-13	4.58E-08	1.83E+01	1.00E+03	5.12E+00		
Pu-238	3.14E-08	3.19E-11	1.46E-09	2.55E-11	6.36E-01	7.52E+03	2.42E+04		
Pu-239	1.22E-06	4.32E-08	2.19E-04	7.43E+02	6.79E-01	8.00E+03	2.58E+04		
Pu-240	1.45E-13	1.89E-14	2.84E-12	3.58E-04	6.78E-01	8.00E+03	2.58E+04		
Pu-241	1.85E-13	1.76E-15	1.28E-12	1.79E-06	2.50E+03	2.94E+07	9.48E+07		
Pu-242	8.36E-13	1.64E-12	2.64E-10	3.11E-02	N/A	N/A	N/A	**Yes**	No environmental screening criteria
Sb-125	4.00E-27	4.10E-25	1.00E-24	9.20E-28	3.28E+01	4.41E+05	6.86E+05		
Se-79	3.42E-06	2.25E-08	6.54E-06	9.57E-01	9.73E+02	5.29E+05	2.37E+05		
Sn-126	8.95E-11	1.11E-12	9.28E-11	8.35E-05	N/A	N/A	N/A	**Yes**	No environmental screening criteria
Sr-90	7.53E-07	2.97E-09	3.27E-08	1.59E-09	1.83E+02	1.18E+06	1.14E+05		
Tc-99	1.00E-03	3.39E-06	2.99E-04	6.64E-01	2.47E+04	4.61E+04	3.39E+04		
Th-229	1.41E-09	1.09E-11	1.13E-07	9.41E-02	N/A	N/A	N/A	**Yes**	No environmental screening criteria
Th-230	2.14E-07	7.35E-10	5.53E-04	2.13E-01	3.81E-02	2.66E+03	4.10E+02		
Th-232	7.21E-11	2.42E-13	3.28E-11	1.92E-07	4.49E-02	3.11E+03	4.81E+02		
U-233	3.07E-09	1.19E-09	4.17E-07	4.87E-03	6.72E+00	1.20E+04	1.92E+06		
U-234	1.73E-09	1.83E-10	4.10E-08	7.32E-04	1.01E+01	1.17E+03	4.94E+02		
U-235	7.67E-07	2.93E-09	2.58E-04	8.48E-03	1.09E+01	1.26E+03	5.37E+02		
U-236	1.17E-13	6.12E-13	4.26E-11	2.52E-06	N/A	N/A	N/A	**Yes**	No environmental screening criteria
U-238	1.24E-05	4.62E-08	3.75E-03	1.37E-01	1.18E+01	1.33E+03	5.76E+02		
Zr-93	2.91E-10	1.16E-12	2.52E-10	1.41E-05	1.68E+01	2.01E+05	8.06E+07		

Notes: see Table 2.8 for notes on environmental screening criteria. N/A – not available.

Table 2.23 Maximum Radionuclide Concentrations Predicted in Environmental Media Over 10,000 Year Postclosure Period and COPC Selection for Scenario (1d) NES Sensitivity Analysis – Resaturation Rate - Slower

Radionuclide	Spring Water	Ottawa River	Garden Area	Riverbed	Screening Criteria			Screened In?	Comments
	Groundwater	Surface Water	Soil	Sediment	Surface Water & Groundwater	Soil	Sediment		
	(Bq/L)	(Bq/L)	(Bq/kg)	(Bq/kg)	(Bq/L)	(Bq/kg)	(Bq/kg)		
(1d) NES Sensitivity Analysis - Resaturation Rate - Slower									
Am-241	1.05E-08	2.30E-11	1.47E-08	1.31E-08	3.85E-01	8.62E+02	8.28E+03		
C-14	2.76E-02	9.57E-05	2.16E-04	3.21E+01	1.64E+02	5.74E+02	5.45E+03		
Ca-41	4.94E-03	3.94E-05	3.38E-04	2.11E+02	N/A	N/A	N/A	**Yes**	No environmental screening criteria
Cd-113m	1.84E-22	6.01E-25	6.71E-24	1.09E-27	N/A	N/A	N/A	**Yes**	No environmental screening criteria
Cl-36	6.90E-04	1.58E-05	3.66E-03	2.64E+01	1.31E+03	9.02E-01	1.06E+02		
Cm-243	1.16E-33	4.26E-36	9.18E-35	0.00E+00	8.24E-01	8.00E+02	2.07E+01		
Cm-244	2.39E-32	1.34E-34	1.31E-33	0.00E+00	8.28E-01	8.00E+02	2.07E+01		
Co-60	7.33E-10	4.59E-13	2.59E-12	1.43E-14	1.35E+02	9.05E+04	1.03E+06		
Cs-135	4.53E-08	5.41E-10	3.09E-06	4.06E-01	3.48E+02	1.97E+05	4.36E+06		
Cs-137	1.33E-05	3.90E-08	8.12E-07	1.53E-09	7.27E+01	5.54E+04	7.12E+05		
Eu-152	2.06E-18	1.02E-20	8.84E-20	3.75E-24	1.18E+02	1.72E+05	4.13E+04		
Eu-154	1.58E-19	5.17E-22	4.52E-21	2.37E-25	7.74E+01	1.55E+05	2.72E+04		
H-3	1.80E+02	6.57E-01	6.65E-02	9.01E+03	1.74E+07	3.20E+06	2.60E+07		
Hf-182	3.72E-15	1.27E-17	1.95E-15	5.74E-11	N/A	N/A	N/A	**Yes**	No environmental screening criteria
I-129	4.71E-08	2.30E-10	8.62E-09	6.75E-02	7.63E+01	1.59E+06	1.57E+06		
Mo-93	2.23E-05	1.44E-07	7.15E-05	1.05E+00	N/A	N/A	N/A	**Yes**	No environmental screening criteria
Nb-93m	1.03E-06	7.70E-09	7.11E-05	9.54E-01	N/A	N/A	N/A	**Yes**	No environmental screening criteria
Nb-94	8.33E-12	2.81E-14	3.47E-12	3.95E-08	1.95E+02	1.15E+05	3.08E+03		
Ni-59	2.26E-03	7.28E-05	7.04E-02	7.67E+03	2.56E+03	1.24E+07	4.30E+07		
Ni-63	5.94E-07	2.00E-09	1.91E-07	9.74E-09	9.09E+03	8.77E+06	3.25E+07		
Np-237	9.06E-15	4.76E-14	4.93E-13	4.56E-08	1.83E+01	1.00E+03	5.12E+00		
Pu-238	1.90E-08	1.80E-11	8.01E-10	1.41E-11	6.36E-01	7.52E+03	2.42E+04		
Pu-239	1.22E-06	4.32E-08	2.19E-04	7.43E+02	6.79E-01	8.00E+03	2.58E+04		
Pu-240	1.38E-13	1.88E-14	2.81E-12	3.55E-04	6.78E-01	8.00E+03	2.58E+04		
Pu-241	1.84E-13	1.57E-16	1.27E-12	1.79E-06	2.50E+03	2.94E+07	9.48E+07		
Pu-242	8.30E-13	1.63E-12	2.63E-10	3.09E-02	N/A	N/A	N/A	**Yes**	No environmental screening criteria
Sb-125	4.00E-27	8.01E-30	2.62E-29	2.47E-32	3.28E+01	4.41E+05	6.86E+05		
Se-79	2.31E-06	2.24E-08	4.00E-06	9.62E-01	9.73E+02	5.29E+05	2.37E+05		
Sn-126	8.93E-11	1.11E-12	9.22E-11	8.28E-05	N/A	N/A	N/A	**Yes**	No environmental screening criteria
Sr-90	7.05E-07	2.37E-09	2.02E-08	9.75E-10	1.83E+02	1.18E+06	1.14E+05		
Tc-99	1.02E-03	3.45E-06	3.15E-04	6.04E-01	2.47E+04	4.61E+04	3.39E+04		
Th-229	1.41E-09	1.09E-11	1.13E-07	9.41E-02	N/A	N/A	N/A	**Yes**	No environmental screening criteria
Th-230	2.14E-07	7.35E-10	5.53E-04	2.13E-01	3.81E-02	2.66E+03	4.10E+02		
Th-232	7.21E-11	2.42E-13	3.28E-11	1.92E-07	4.49E-02	3.11E+03	4.81E+02		
U-233	3.07E-09	1.19E-09	4.17E-07	4.87E-03	6.72E+00	1.20E+04	1.92E+06		
U-234	1.73E-09	1.82E-10	4.10E-08	7.28E-04	1.01E+01	1.17E+03	4.94E+02		
U-235	7.68E-07	2.92E-09	2.58E-04	8.48E-03	1.09E+01	1.26E+03	5.37E+02		
U-236	1.16E-13	6.07E-13	4.23E-11	2.50E-06	N/A	N/A	N/A	**Yes**	No environmental screening criteria
U-238	1.24E-05	4.62E-08	3.75E-03	1.37E-01	1.18E+01	1.33E+03	5.76E+02		
Zr-93	2.88E-10	1.15E-12	2.50E-10	1.40E-05	1.68E+01	2.01E+05	8.06E+07		

Notes: see Table 2.8 for notes on environmental screening criteria. N/A – not available.

Table 2.24 Maximum Radionuclide Concentrations Predicted in Environmental Media Over 10,000 Year Postclosure Period and COPC Selection for Scenario (1) NES Sensitivity Analysis – Surface Erosion

Radionuclide	Spring Water	Ottawa River	Garden Area	Riverbed	Screening Criteria			Screened In?	Comments
	Groundwater (Bq/L)	Surface Water (Bq/L)	Soil (Bq/kg)	Sediment (Bq/kg)	Surface Water & Groundwater (Bq/L)	Soil (Bq/kg)	Sediment (Bq/kg)		
(1e) NES Sensitivity Analysis - Surface Erosion									
Am-241	1.05E-08	2.30E-11	3.10E-05	1.31E-08	3.85E-01	8.62E+02	8.28E+03		
C-14	2.76E-02	9.57E-05	6.60E-01	3.21E+01	1.64E+02	5.74E+02	5.45E+03		
Ca-41	4.92E-03	3.94E-05	4.29E+01	2.11E+02	N/A	N/A	N/A	**Yes**	No environmental screening criteria
Cd-113m	5.42E-22	5.36E-22	1.03E-19	7.87E-25	N/A	N/A	N/A	**Yes**	No environmental screening criteria
Cl-36	6.88E-04	1.59E-05	4.60E-03	2.65E+01	1.31E+03	9.02E-01	1.06E+02		
Cm-243	2.73E-33	1.08E-32	1.81E-26	1.07E-34	8.24E-01	8.00E+02	2.07E+01		
Cm-244	8.44E-32	4.62E-30	9.67E-25	4.49E-32	8.28E-01	8.00E+02	2.07E+01		
Co-60	7.33E-10	4.59E-13	1.07E-09	1.44E-14	1.35E+02	9.05E+04	1.03E+06		
Cs-135	4.45E-08	5.42E-10	2.78E-02	4.07E-01	3.48E+02	1.97E+05	4.36E+06		
Cs-137	1.74E-05	5.10E-08	9.83E-03	2.09E-09	7.27E+01	5.54E+04	7.12E+05		
Eu-152	5.94E-18	3.30E-13	2.41E-12	1.25E-16	1.18E+02	1.72E+05	4.13E+04		
Eu-154	1.92E-19	1.17E-14	1.09E-11	3.03E-18	7.74E+01	1.55E+05	2.72E+04		
H-3	1.80E+02	6.57E-01	4.56E+00	9.01E+03	1.74E+07	3.20E+06	2.60E+07		
Hf-182	3.75E-15	1.28E-17	5.24E-06	5.78E-11	N/A	N/A	N/A	**Yes**	No environmental screening criteria
I-129	4.92E-08	2.42E-10	7.23E-08	7.08E-02	7.63E+01	1.59E+06	1.57E+06		
Mo-93	3.46E-05	1.47E-07	2.34E+00	1.08E+00	N/A	N/A	N/A	**Yes**	No environmental screening criteria
Nb-93m	1.61E-06	7.88E-09	2.34E+00	9.79E-01	N/A	N/A	N/A	**Yes**	No environmental screening criteria
Nb-94	8.34E-12	2.81E-14	5.73E-04	3.98E-08	1.95E+02	1.15E+05	3.08E+03		
Ni-59	2.27E-03	7.28E-05	4.81E+02	7.67E+03	2.56E+03	1.24E+07	4.30E+07		
Ni-63	8.64E-07	2.94E-09	4.67E-04	1.24E-08	9.09E+03	8.77E+06	3.25E+07		
Np-237	9.12E-15	4.78E-14	1.14E-07	4.58E-08	1.83E+01	1.00E+03	5.12E+00		
Pu-238	2.83E-08	3.02E-11	3.38E-07	2.43E-11	6.36E-01	7.52E+03	2.42E+04		
Pu-239	1.22E-06	4.32E-08	7.32E+00	7.43E+02	6.79E-01	8.00E+03	2.58E+04		
Pu-240	1.45E-13	1.89E-14	3.26E-06	3.58E-04	6.78E-01	8.00E+03	2.58E+04		
Pu-241	1.85E-13	8.70E-16	5.39E-07	1.79E-06	2.50E+03	2.94E+07	9.48E+07		
Pu-242	8.36E-13	1.64E-12	6.41E-05	3.11E-02	N/A	N/A	N/A	**Yes**	No environmental screening criteria
Sb-125	4.00E-27	1.27E-26	2.92E-26	2.73E-29	3.28E+01	4.41E+05	6.86E+05		
Se-79	3.37E-06	2.24E-08	2.20E-01	9.58E-01	9.73E+02	5.29E+05	2.37E+05		
Sn-126	8.94E-11	1.11E-12	7.74E-04	8.35E-05	N/A	N/A	N/A	**Yes**	No environmental screening criteria
Sr-90	7.05E-07	2.37E-09	7.38E-06	1.47E-09	1.83E+02	1.18E+06	1.14E+05		
Tc-99	1.00E-03	3.39E-06	1.98E-02	6.61E-01	2.47E+04	4.61E+04	3.39E+04		
Th-229	1.41E-09	1.09E-11	1.91E-03	9.41E-02	N/A	N/A	N/A	**Yes**	No environmental screening criteria
Th-230	2.14E-07	7.35E-10	2.77E-03	2.13E-01	3.81E-02	2.66E+03	4.10E+02		
Th-232	7.21E-11	2.42E-13	3.80E-07	1.92E-07	4.49E-02	3.11E+03	4.81E+02		
U-233	3.07E-09	1.19E-09	3.21E-03	4.87E-03	6.72E+00	1.20E+04	1.92E+06		
U-234	1.73E-09	1.83E-10	3.46E-04	7.32E-04	1.01E+01	1.17E+03	4.94E+02		
U-235	7.67E-07	2.93E-09	4.60E-03	8.48E-03	1.09E+01	1.26E+03	5.37E+02		
U-236	1.17E-13	6.12E-13	1.23E-06	2.52E-06	N/A	N/A	N/A	**Yes**	No environmental screening criteria
U-238	1.24E-05	4.62E-08	7.44E-02	1.37E-01	1.18E+01	1.33E+03	5.76E+02		
Zr-93	2.91E-10	1.16E-12	2.72E-01	1.41E-05	1.68E+01	2.01E+05	8.06E+07		

Notes: see Table 2.8 for notes on environmental screening criteria. N/A – not available.

Table 2.25 Maximum Radionuclide Concentrations Predicted in Environmental Media Over 10,000 Year Postclosure Period and COPC Selection for Scenario (1g) NES Sensitivity Analysis – Engineering Degradation

Radionuclide	Spring Water	Ottawa River	Garden Area	Riverbed	Screening Criteria			Screened In?	Comments
	Groundwater	Surface Water	Soil	Sediment	Surface Water & Groundwater	Soil	Sediment		
	(Bq/L)	(Bq/L)	(Bq/kg)	(Bq/kg)	(Bq/L)	(Bq/kg)	(Bq/kg)		
(1g) NES Sensitivity Analysis – Engineering Degradation									
Am-241	4.41E-08	9.66E-11	2.64E-08	4.14E-08	3.85E-01	8.62E+02	8.28E+03		
C-14	3.09E-02	1.07E-04	2.20E-04	3.50E+01	1.64E+02	5.74E+02	5.45E+03		
Ca-41	1.40E-03	4.07E-05	3.15E-04	2.19E+02	N/A	N/A	N/A	Yes	No environmental screening criteria
Cd-113m	8.91E-20	5.36E-22	4.56E-21	7.87E-25	N/A	N/A	N/A	Yes	No environmental screening criteria
Cl-36	6.68E-04	1.60E-05	4.44E-03	2.70E+01	1.31E+03	9.02E-01	1.06E+02		
Cm-243	7.24E-30	2.26E-32	6.14E-31	1.18E-31	8.24E-01	8.00E+02	2.07E+01		
Cm-244	2.21E-28	4.62E-30	5.18E-29	1.82E-31	8.28E-01	8.00E+02	2.07E+01		
Co-60	7.33E-10	4.59E-13	2.59E-12	1.44E-14	1.35E+02	9.05E+04	1.03E+06		
Cs-135	4.16E-08	5.41E-10	3.13E-06	4.06E-01	3.48E+02	1.97E+05	4.36E+06		
Cs-137	7.42E-05	2.18E-07	5.14E-06	8.57E-09	7.27E+01	5.54E+04	7.12E+05		
Eu-152	8.08E-16	3.30E-13	2.41E-12	1.25E-16	1.18E+02	1.72E+05	4.13E+04		
Eu-154	5.91E-19	1.17E-14	4.60E-14	3.03E-18	7.74E+01	1.55E+05	2.72E+04		
H-3	1.80E+02	6.57E-01	4.56E+00	9.01E+03	1.74E+07	3.20E+06	2.60E+07		
Hf-182	3.68E-15	1.26E-17	1.96E-15	6.89E-11	N/A	N/A	N/A	Yes	No environmental screening criteria
I-129	2.52E-09	1.99E-10	3.03E-09	6.62E-02	7.63E+01	1.59E+06	1.57E+06		
Mo-93	1.66E-05	1.48E-07	6.98E-05	1.09E+00	N/A	N/A	N/A	Yes	No environmental screening criteria
Nb-93m	7.63E-07	7.92E-09	6.94E-05	9.84E-01	N/A	N/A	N/A	Yes	No environmental screening criteria
Nb-94	8.58E-12	2.90E-14	3.58E-12	4.73E-08	1.95E+02	1.15E+05	3.08E+03		
Ni-59	2.42E-03	7.47E-05	7.19E-02	7.90E+03	2.56E+03	1.24E+07	4.30E+07		
Ni-63	3.49E-05	1.17E-07	1.74E-05	1.50E-06	9.09E+03	8.77E+06	3.25E+07		
Np-237	9.41E-15	4.72E-14	4.89E-13	4.52E-08	1.83E+01	1.00E+03	5.12E+00		
Pu-238	1.03E-06	9.88E-10	4.54E-08	7.76E-10	6.36E-01	7.52E+03	2.42E+04		
Pu-239	1.29E-06	4.98E-08	2.23E-04	8.62E+02	6.79E-01	8.00E+03	2.58E+04		
Pu-240	1.19E-13	1.97E-14	2.88E-12	3.73E-04	6.78E-01	8.00E+03	2.58E+04		
Pu-241	1.87E-13	8.70E-16	1.35E-12	1.89E-06	2.50E+03	2.94E+07	9.48E+07		
Pu-242	7.96E-13	1.73E-12	2.68E-10	3.27E-02	N/A	N/A	N/A	Yes	No environmental screening criteria
Sb-125	4.00E-27	1.27E-26	2.92E-26	2.73E-29	3.28E+01	4.41E+05	6.86E+05		
Se-79	3.38E-07	2.25E-08	3.75E-06	9.57E-01	9.73E+02	5.29E+05	2.37E+05		
Sn-126	9.89E-11	1.16E-12	9.74E-11	8.54E-05	N/A	N/A	N/A	Yes	No environmental screening criteria
Sr-90	7.87E-06	2.65E-08	4.32E-07	5.31E-08	1.83E+02	1.18E+06	1.14E+05		
Tc-99	1.63E-03	5.50E-06	3.02E-04	3.55E-01	2.47E+04	4.61E+04	3.39E+04		
Th-229	1.52E-09	1.18E-11	1.38E-07	1.02E-01	N/A	N/A	N/A	Yes	No environmental screening criteria
Th-230	2.15E-07	7.38E-10	5.58E-04	2.18E-01	3.81E-02	2.66E+03	4.10E+02		
Th-232	7.57E-11	2.54E-13	3.45E-11	1.97E-07	4.49E-02	3.11E+03	4.81E+02		
U-233	3.22E-09	1.22E-09	4.91E-07	4.98E-03	6.72E+00	1.20E+04	1.92E+06		
U-234	1.74E-09	1.69E-10	4.50E-08	6.73E-04	1.01E+01	1.17E+03	4.94E+02		
U-235	7.72E-07	2.90E-09	2.53E-04	8.38E-03	1.09E+01	1.26E+03	5.37E+02		
U-236	1.16E-13	5.64E-13	3.95E-11	2.32E-06	N/A	N/A	N/A	Yes	No environmental screening criteria
U-238	1.25E-05	4.58E-08	3.71E-03	1.36E-01	1.18E+01	1.33E+03	5.76E+02		
Zr-93	2.89E-10	1.19E-12	2.60E-10	1.68E-05	1.68E+01	2.01E+05	8.06E+07		

Notes: see Table 2.8 for notes on environmental screening criteria. N/A – not available.

Table 2.26 Maximum Radionuclide Concentrations Predicted in Environmental Media Over 10,000 Year Postclosure Period and COPC Selection for Scenario (2a) Disruptive Event – Site Investigation (Human Intrusion)

Radionuclide	Spring Water Groundwater (Bq/L)	Ottawa River Surface Water (Bq/L)	Garden Area Soil (Bq/kg)	Riverbed Sediment (Bq/kg)	Screening Criteria Surface Water & Groundwater (Bq/L)	Screening Criteria Soil (Bq/kg)	Screening Criteria Sediment (Bq/kg)	Screened In?	Comments
(2a) Disruptive Event - Site Investigation (Human Intrusion)									
Am-241	1.05E-08	2.30E-11	1.58E-03	1.31E-08	3.85E-01	8.62E+02	8.28E+03		
C-14	2.76E-02	9.57E-05	7.91E-01	3.21E+01	1.64E+02	5.74E+02	5.45E+03		
Ca-41	4.92E-03	3.94E-05	4.73E-03	2.11E+02	N/A	N/A	N/A	**Yes**	No environmental screening criteria
Cd-113m	5.42E-22	5.36E-22	1.04E-05	7.87E-25	N/A	N/A	N/A	**Yes**	No environmental screening criteria
Cl-36	6.88E-04	1.59E-05	1.80E-02	2.65E+01	1.31E+03	9.02E-01	1.06E+02		
Cm-243	2.73E-33	1.08E-32	4.56E-07	1.07E-34	8.24E-01	8.00E+02	2.07E+01		
Cm-244	8.44E-32	4.62E-30	1.78E-04	4.49E-32	8.28E-01	8.00E+02	2.07E+01		
Co-60	7.33E-10	4.59E-13	1.61E-05	1.44E-14	1.35E+02	9.05E+04	1.03E+06		
Cs-135	4.45E-08	5.42E-10	3.35E-06	4.07E-01	3.48E+02	1.97E+05	4.36E+06		
Cs-137	1.74E-05	5.10E-08	6.54E-03	2.09E-09	7.27E+01	5.54E+04	7.12E+05		
Eu-152	5.94E-18	3.30E-13	3.87E-04	1.25E-16	1.18E+02	1.72E+05	4.13E+04		
Eu-154	1.92E-19	1.17E-14	4.60E-14	3.03E-18	7.74E+01	1.55E+05	2.72E+04		
H-3	1.80E+02	6.57E-01	4.56E+00	9.01E+03	1.74E+07	3.20E+06	2.60E+07		
Hf-182	3.75E-15	1.28E-17	2.39E-06	5.78E-11	N/A	N/A	N/A	**Yes**	No environmental screening criteria
I-129	4.92E-08	2.42E-10	5.37E-08	7.08E-02	7.63E+01	1.59E+06	1.57E+06		
Mo-93	3.46E-05	1.47E-07	1.27E-03	1.08E+00	N/A	N/A	N/A	**Yes**	No environmental screening criteria
Nb-93m	1.61E-06	7.88E-09	2.55E-03	9.79E-01	N/A	N/A	N/A	**Yes**	No environmental screening criteria
Nb-94	8.34E-12	2.81E-14	7.65E-03	3.98E-08	1.95E+02	1.15E+05	3.08E+03		
Ni-59	2.27E-03	7.28E-05	1.82E-01	7.67E+03	2.56E+03	1.24E+07	4.30E+07		
Ni-63	8.64E-07	2.94E-09	1.18E+01	1.24E-08	9.09E+03	8.77E+06	3.25E+07		
Np-237	9.12E-15	4.78E-14	3.18E-08	4.58E-08	1.83E+01	1.00E+03	5.12E+00		
Pu-238	2.83E-08	3.02E-11	5.10E-04	2.43E-11	6.36E-01	7.52E+03	2.42E+04		
Pu-239	1.22E-06	4.32E-08	1.02E-03	7.43E+02	6.79E-01	8.00E+03	2.58E+04		
Pu-240	1.45E-13	1.89E-14	7.20E-04	3.58E-04	6.78E-01	8.00E+03	2.58E+04		
Pu-241	1.85E-13	8.70E-16	1.19E-04	1.79E-06	2.50E+03	2.94E+07	9.48E+07		
Pu-242	8.36E-13	1.64E-12	5.91E-06	3.11E-02	N/A	N/A	N/A	**Yes**	No environmental screening criteria
Sb-125	4.00E-27	1.27E-26	5.52E-13	2.73E-29	3.28E+01	4.41E+05	6.86E+05		
Se-79	3.37E-06	2.24E-08	1.50E-05	9.58E-01	9.73E+02	5.29E+05	2.37E+05		
Sn-126	8.94E-11	1.11E-12	5.42E-07	8.35E-05	N/A	N/A	N/A	**Yes**	No environmental screening criteria
Sr-90	7.05E-07	2.37E-09	2.82E-03	1.47E-09	1.83E+02	1.18E+06	1.14E+05		
Tc-99	1.00E-03	3.39E-06	5.72E-04	6.61E-01	2.47E+04	4.61E+04	3.39E+04		
Th-229	1.41E-09	1.09E-11	6.05E-07	9.41E-02	N/A	N/A	N/A	**Yes**	No environmental screening criteria
Th-230	2.14E-07	7.35E-10	5.56E-04	2.13E-01	3.81E-02	2.66E+03	4.10E+02		
Th-232	7.21E-11	2.42E-13	6.23E-06	1.92E-07	4.49E-02	3.11E+03	4.81E+02		
U-233	3.07E-09	1.19E-09	5.85E-07	4.87E-03	6.72E+00	1.20E+04	1.92E+06		
U-234	1.73E-09	1.83E-10	1.98E-05	7.32E-04	1.01E+01	1.17E+03	4.94E+02		
U-235	7.67E-07	2.93E-09	2.59E-04	8.48E-03	1.09E+01	1.26E+03	5.37E+02		
U-236	1.17E-13	6.12E-13	9.14E-08	2.52E-06	N/A	N/A	N/A	**Yes**	No environmental screening criteria
U-238	1.24E-05	4.62E-08	3.78E-03	1.37E-01	1.18E+01	1.33E+03	5.76E+02		
Zr-93	2.91E-10	1.16E-12	1.25E-01	1.41E-05	1.68E+01	2.01E+05	8.06E+07		

Notes: see Table 2.8 for notes on environmental screening criteria. N/A – not available.

Table 2.27 Maximum Radionuclide Concentrations Predicted in Environmental Media Over 10,000 Year Postclosure Period and COPC Selection for Scenario (2b) Disruptive Event – Extreme Degradation of Engineered Structures

Radionuclide	Spring Water	Ottawa River	Garden Area	Riverbed	Screening Criteria			Screened In?	Comments
	Groundwater	Surface Water	Soil	Sediment	Surface Water & Groundwater	Soil	Sediment		
	(Bq/L)	(Bq/L)	(Bq/kg)	(Bq/kg)	(Bq/L)	(Bq/kg)	(Bq/kg)		
(2b) Disruptive Event - Extreme Degradation of Engineered Structures									
Am-241	1.19E-07	3.21E-10	3.70E-08	1.64E-06	3.85E-01	8.62E+02	8.28E+03		
C-14	1.71E-01	5.86E-04	8.31E-05	1.23E+03	1.64E+02	5.74E+02	5.45E+03		
Ca-41	8.11E-03	1.31E-04	3.98E-04	7.44E+02	N/A	N/A	N/A	**Yes**	No environmental screening criteria
Cd-113m	5.42E-22	5.36E-22	4.56E-21	7.87E-25	N/A	N/A	N/A	**Yes**	No environmental screening criteria
Cl-36	3.27E-03	3.28E-04	3.45E-03	5.63E+02	1.31E+03	9.02E-01	1.06E+02	**Yes**	Exceeded sediment (Riverbed) criterion
Cm-243	4.32E-30	1.36E-32	3.46E-31	9.91E-33	8.24E-01	8.00E+02	2.07E+01		
Cm-244	2.10E-29	4.62E-30	5.18E-29	4.49E-32	8.28E-01	8.00E+02	2.07E+01		
Co-60	7.33E-10	4.59E-13	2.59E-12	1.44E-14	1.35E+02	9.05E+04	1.03E+06		
Cs-135	5.22E-08	6.02E-10	4.52E-08	4.51E-01	3.48E+02	1.97E+05	4.36E+06		
Cs-137	1.74E-05	5.10E-08	1.48E-06	2.09E-09	7.27E+01	5.54E+04	7.12E+05		
Eu-152	5.94E-18	3.30E-13	2.41E-12	1.25E-16	1.18E+02	1.72E+05	4.13E+04		
Eu-154	1.92E-19	1.17E-14	4.60E-14	3.03E-18	7.74E+01	1.55E+05	2.72E+04		
H-3	1.80E+02	6.57E-01	4.56E+00	9.01E+03	1.74E+07	3.20E+06	2.60E+07		
Hf-182	5.58E-09	1.89E-11	2.18E-09	4.52E-05	N/A	N/A	N/A	**Yes**	No environmental screening criteria
I-129	1.25E-08	4.73E-10	3.78E-09	1.62E-01	7.63E+01	1.59E+06	1.57E+06		
Mo-93	1.23E-04	4.17E-07	1.32E-05	1.44E+00	N/A	N/A	N/A	**Yes**	No environmental screening criteria
Nb-93m	5.25E-06	1.80E-08	1.12E-05	1.30E+00	N/A	N/A	N/A	**Yes**	No environmental screening criteria
Nb-94	1.50E-05	5.07E-08	6.25E-06	1.27E-01	1.95E+02	1.15E+05	3.08E+03		
Ni-59	9.68E-03	2.31E-04	9.81E-03	2.49E+04	2.56E+03	1.24E+07	4.30E+07		
Ni-63	8.30E-06	2.80E-08	9.29E-06	5.79E-07	9.09E+03	8.77E+06	3.25E+07		
Np-237	7.22E-10	2.00E-10	2.06E-09	1.89E-04	1.83E+01	1.00E+03	5.12E+00		
Pu-238	2.12E-07	2.05E-10	1.02E-08	1.65E-10	6.36E-01	7.52E+03	2.42E+04		
Pu-239	1.32E-04	3.16E-05	3.41E-03	5.99E+05	6.79E-01	8.00E+03	2.58E+04	**Yes**	Exceeded sediment (Riverbed) criterion
Pu-240	1.32E-06	4.93E-09	5.54E-07	7.77E+01	6.78E-01	8.00E+03	2.58E+04		
Pu-241	3.84E-09	1.70E-12	9.30E-10	2.13E-03	2.50E+03	2.94E+07	9.48E+07		
Pu-242	5.56E-08	2.50E-09	2.71E-07	4.65E+01	N/A	N/A	N/A	**Yes**	No environmental screening criteria
Sb-125	4.00E-27	1.27E-26	2.92E-26	2.73E-29	3.28E+01	4.41E+05	6.86E+05		
Se-79	4.90E-07	2.17E-08	1.23E-06	9.42E-01	9.73E+02	5.29E+05	2.37E+05		
Sn-126	7.60E-09	1.69E-10	1.37E-08	1.71E-02	N/A	N/A	N/A	**Yes**	No environmental screening criteria
Sr-90	7.05E-07	2.37E-09	2.54E-08	1.47E-09	1.83E+02	1.18E+06	1.14E+05		
Tc-99	8.89E-04	3.08E-06	7.16E-05	1.52E+00	2.47E+04	4.61E+04	3.39E+04		
Th-229	3.80E-09	3.87E-11	9.44E-09	5.43E-01	N/A	N/A	N/A	**Yes**	No environmental screening criteria
Th-230	1.13E-07	3.83E-10	5.33E-08	1.07E+00	3.81E-02	2.66E+03	4.10E+02		
Th-232	2.44E-08	8.42E-11	1.15E-08	3.17E-02	4.49E-02	3.11E+03	4.81E+02		
U-233	2.22E-08	4.16E-09	2.87E-07	1.69E-02	6.72E+00	1.20E+04	1.92E+06		
U-234	5.06E-07	2.91E-08	2.01E-06	1.20E-01	1.01E+01	1.17E+03	4.94E+02		
U-235	3.67E-06	1.24E-08	1.15E-06	1.77E-02	1.09E+01	1.26E+03	5.37E+02		
U-236	2.13E-09	1.23E-10	8.52E-09	5.08E-04	N/A	N/A	N/A	**Yes**	No environmental screening criteria
U-238	5.94E-05	2.00E-07	1.79E-05	2.96E-01	1.18E+01	1.33E+03	5.76E+02		
Zr-93	3.27E-04	1.11E-06	1.45E-04	4.15E+00	1.68E+01	2.01E+05	8.06E+07		

Notes: see Table 2.8 for notes on environmental screening criteria. N/A – not available.

Table 2.28 Maximum Radionuclide Concentrations Predicted in Environmental Media Over 10,000 Year Postclosure Period and COPC Selection for Scenario (3a) Defence-in-Depth – Role of Waste Form

Radionuclide	Spring Water	Ottawa River	Garden Area	Riverbed	Screening Criteria			Screened In?	Comments
	Groundwater	Surface Water	Soil	Sediment	Surface Water & Groundwater	Soil	Sediment		
	(Bq/L)	(Bq/L)	(Bq/kg)	(Bq/kg)	(Bq/L)	(Bq/kg)	(Bq/kg)		
(3a) Defence-in-Depth Cases - Role of Waste Form									
Am-241	1.05E-08	2.30E-11	1.47E-08	1.31E-08	3.85E-01	8.62E+02	8.28E+03		
C-14	2.76E-02	9.57E-05	2.16E-04	3.21E+01	1.64E+02	5.74E+02	5.45E+03		
Ca-41	4.92E-03	4.15E-05	3.46E-04	2.22E+02	N/A	N/A	N/A	**Yes**	No environmental screening criteria
Cd-113m	5.42E-22	5.36E-22	4.56E-21	7.87E-25	N/A	N/A	N/A	**Yes**	No environmental screening criteria
Cl-36	1.87E-03	3.12E-05	3.63E-03	5.22E+01	1.31E+03	9.02E-01	1.06E+02		
Cm-243	2.76E-33	1.08E-32	1.23E-31	1.07E-34	8.24E-01	8.00E+02	2.07E+01		
Cm-244	8.48E-32	4.63E-30	5.18E-29	4.50E-32	8.28E-01	8.00E+02	2.07E+01		
Co-60	7.33E-10	4.59E-13	2.59E-12	1.44E-14	1.35E+02	9.05E+04	1.03E+06		
Cs-135	8.06E-08	8.23E-10	2.84E-06	6.18E-01	3.48E+02	1.97E+05	4.36E+06		
Cs-137	1.74E-05	5.10E-08	1.48E-06	2.09E-09	7.27E+01	5.54E+04	7.12E+05		
Eu-152	5.94E-18	3.30E-13	2.41E-12	1.25E-16	1.18E+02	1.72E+05	4.13E+04		
Eu-154	1.92E-19	1.17E-14	4.60E-14	3.03E-18	7.74E+01	1.55E+05	2.72E+04		
H-3	1.80E+02	6.57E-01	4.56E+00	9.01E+03	1.74E+07	3.20E+06	2.60E+07		
Hf-182	3.36E-14	1.15E-16	1.79E-14	4.52E-10	N/A	N/A	N/A	**Yes**	No environmental screening criteria
I-129	1.12E-07	9.25E-10	2.30E-08	2.96E-01	7.63E+01	1.59E+06	1.57E+06		
Mo-93	3.07E-04	1.03E-06	7.43E-04	5.94E+00	N/A	N/A	N/A	**Yes**	No environmental screening criteria
Nb-93m	1.43E-05	4.87E-08	7.39E-04	5.37E+00	N/A	N/A	N/A	**Yes**	No environmental screening criteria
Nb-94	8.49E-12	2.86E-14	3.54E-12	1.27E-07	1.95E+02	1.15E+05	3.08E+03		
Ni-59	4.89E-03	1.28E-04	1.45E-01	1.35E+04	2.56E+03	1.24E+07	4.30E+07		
Ni-63	8.64E-07	2.94E-09	3.80E-07	1.24E-08	9.09E+03	8.77E+06	3.25E+07		
Np-237	2.09E-14	9.92E-14	1.02E-12	9.51E-08	1.83E+01	1.00E+03	5.12E+00		
Pu-238	2.83E-08	3.02E-11	1.39E-09	2.43E-11	6.36E-01	7.52E+03	2.42E+04		
Pu-239	1.22E-06	4.33E-08	2.19E-04	7.44E+02	6.79E-01	8.00E+03	2.58E+04		
Pu-240	7.57E-13	3.71E-14	6.22E-12	7.02E-04	6.78E-01	8.00E+03	2.58E+04		
Pu-241	8.21E-13	8.70E-16	6.16E-12	8.76E-06	2.50E+03	2.94E+07	9.48E+07		
Pu-242	3.11E-12	7.24E-12	1.10E-09	1.37E-01	N/A	N/A	N/A	**Yes**	No environmental screening criteria
Sb-125	4.00E-27	1.27E-26	2.92E-26	2.73E-29	3.28E+01	4.41E+05	6.86E+05		
Se-79	3.27E-05	1.11E-07	6.15E-05	1.67E+00	9.73E+02	5.29E+05	2.37E+05		
Sn-126	1.76E-10	2.77E-12	2.31E-10	2.24E-04	N/A	N/A	N/A	**Yes**	No environmental screening criteria
Sr-90	7.05E-07	2.37E-09	2.54E-08	1.47E-09	1.83E+02	1.18E+06	1.14E+05		
Tc-99	1.62E-03	9.23E-06	3.01E-04	4.38E+00	2.47E+04	4.61E+04	3.39E+04		
Th-229	1.41E-09	1.09E-11	1.13E-07	9.41E-02	N/A	N/A	N/A	**Yes**	No environmental screening criteria
Th-230	2.14E-07	7.35E-10	5.53E-04	2.14E-01	3.81E-02	2.66E+03	4.10E+02		
Th-232	7.21E-11	2.42E-13	3.28E-11	1.98E-07	4.49E-02	3.11E+03	4.81E+02		
U-233	3.07E-09	1.19E-09	4.17E-07	4.87E-03	6.72E+00	1.20E+04	1.92E+06		
U-234	1.73E-09	2.73E-10	4.37E-08	1.10E-03	1.01E+01	1.17E+03	4.94E+02		
U-235	7.67E-07	2.93E-09	2.58E-04	8.50E-03	1.09E+01	1.26E+03	5.37E+02		
U-236	2.24E-13	1.11E-12	7.72E-11	4.56E-06	N/A	N/A	N/A	**Yes**	No environmental screening criteria
U-238	1.24E-05	4.63E-08	3.75E-03	1.38E-01	1.18E+01	1.33E+03	5.76E+02		
Zr-93	2.55E-09	1.00E-11	2.25E-09	1.11E-04	1.68E+01	2.01E+05	8.06E+07		

Notes: see Table 2.8 for notes on environmental screening criteria. N/A – not available.

Table 2.29 Maximum Radionuclide Concentrations Predicted in Environmental Media Over 10,000 Year Postclosure Period and COPC Selection for Scenario (3a) Defence-in-Depth – Role of Existing Facility Structure

Radionuclide	Spring Water	Ottawa River	Garden Area	Riverbed	Screening Criteria			Screened In?	Comments
	Groundwater	Surface Water	Soil	Sediment	Surface Water & Groundwater	Soil	Sediment		
	(Bq/L)	(Bq/L)	(Bq/kg)	(Bq/kg)	(Bq/L)	(Bq/kg)	(Bq/kg)		
(3b) Defence-in-Depth Cases - Role of Existing Facility Structure									
Am-241	1.37E-08	3.18E-11	1.54E-08	1.15E-07	3.85E-01	8.62E+02	8.28E+03		
C-14	3.18E-02	1.09E-04	2.87E-04	3.92E+01	1.64E+02	5.74E+02	5.45E+03		
Ca-41	1.36E-02	4.68E-05	7.83E-04	2.37E+02	N/A	N/A	N/A	Yes	No environmental screening criteria
Cd-113m	1.11E-14	5.18E-17	5.69E-16	9.24E-20	N/A	N/A	N/A	Yes	No environmental screening criteria
Cl-36	2.88E-03	2.29E-05	3.34E-03	2.94E+01	1.31E+03	9.02E-01	1.06E+02		
Cm-243	2.93E-25	7.63E-26	9.61E-25	8.31E-28	8.24E-01	8.00E+02	2.07E+01		
Cm-244	1.46E-23	3.28E-23	4.07E-22	3.52E-25	8.28E-01	8.00E+02	2.07E+01		
Co-60	1.68E-08	1.05E-11	5.94E-11	3.29E-13	1.35E+02	9.05E+04	1.03E+06		
Cs-135	2.12E-07	7.06E-10	1.20E-06	3.72E-01	3.48E+02	1.97E+05	4.36E+06		
Cs-137	1.60E-04	4.72E-07	1.07E-05	1.91E-08	7.27E+01	5.54E+04	7.12E+05		
Eu-152	4.76E-16	6.76E-13	4.94E-12	2.55E-16	1.18E+02	1.72E+05	4.13E+04		
Eu-154	1.58E-17	1.17E-14	4.60E-14	3.03E-18	7.74E+01	1.55E+05	2.72E+04		
H-3	2.39E+02	8.77E-01	3.85E+00	1.22E+04	1.74E+07	3.20E+06	2.60E+07		
Hf-182	5.20E-11	1.76E-13	2.13E-11	8.92E-10	N/A	N/A	N/A	Yes	No environmental screening criteria
I-129	5.75E-08	2.88E-10	2.61E-08	6.25E-02	7.63E+01	1.59E+06	1.57E+06		
Mo-93	2.20E-04	7.43E-07	1.77E-04	1.02E+00	N/A	N/A	N/A	Yes	No environmental screening criteria
Nb-93m	1.05E-05	3.60E-08	1.75E-04	9.22E-01	N/A	N/A	N/A	Yes	No environmental screening criteria
Nb-94	3.58E-09	1.21E-11	1.50E-09	8.16E-07	1.95E+02	1.15E+05	3.08E+03		
Ni-59	1.52E-02	6.45E-05	8.76E-02	5.54E+03	2.56E+03	1.24E+07	4.30E+07		
Ni-63	1.37E-05	4.59E-08	1.12E-06	6.79E-06	9.09E+03	8.77E+06	3.25E+07		
Np-237	2.64E-11	4.19E-13	4.68E-12	3.26E-07	1.83E+01	1.00E+03	5.12E+00		
Pu-238	4.44E-07	4.29E-10	1.92E-08	3.37E-10	6.36E-01	7.52E+03	2.42E+04		
Pu-239	2.62E-06	1.06E-07	2.18E-04	1.85E+03	6.79E-01	8.00E+03	2.58E+04		
Pu-240	2.40E-09	7.95E-12	2.73E-09	3.31E-03	6.78E-01	8.00E+03	2.58E+04		
Pu-241	7.39E-11	3.29E-14	6.32E-11	6.81E-06	2.50E+03	2.94E+07	9.48E+07		
Pu-242	2.11E-09	2.32E-11	4.51E-08	3.05E-01	N/A	N/A	N/A	Yes	No environmental screening criteria
Sb-125	2.50E-25	1.44E-26	3.32E-26	3.10E-29	3.28E+01	4.41E+05	6.86E+05		
Se-79	7.23E-06	2.45E-08	1.60E-05	8.77E-01	9.73E+02	5.29E+05	2.37E+05		
Sn-126	5.28E-09	2.55E-11	2.73E-09	7.90E-04	N/A	N/A	N/A	Yes	No environmental screening criteria
Sr-90	1.63E-05	5.50E-08	4.78E-07	2.07E-07	1.83E+02	1.18E+06	1.14E+05		
Tc-99	5.45E-04	1.90E-06	1.41E-04	5.30E-01	2.47E+04	4.61E+04	3.39E+04		
Th-229	3.10E-09	1.70E-11	1.12E-07	1.02E-01	N/A	N/A	N/A	Yes	No environmental screening criteria
Th-230	2.80E-07	9.48E-10	4.81E-04	1.07E-01	3.81E-02	2.66E+03	4.10E+02		
Th-232	5.30E-10	1.78E-12	2.41E-10	1.02E-06	4.49E-02	3.11E+03	4.81E+02		
U-233	6.68E-09	1.23E-09	4.15E-07	4.99E-03	6.72E+00	1.20E+04	1.92E+06		
U-234	3.21E-08	1.23E-09	4.18E-07	4.69E-03	1.01E+01	1.17E+03	4.94E+02		
U-235	8.91E-07	3.01E-09	2.41E-04	3.96E-03	1.09E+01	1.26E+03	5.37E+02		
U-236	1.48E-10	5.51E-12	1.85E-09	2.12E-05	N/A	N/A	N/A	Yes	No environmental screening criteria
U-238	1.44E-05	4.85E-08	3.49E-03	6.54E-02	1.18E+01	1.33E+03	5.76E+02		
Zr-93	3.52E-06	1.19E-08	1.77E-06	2.16E-04	1.68E+01	2.01E+05	8.06E+07		

Notes: see Table 2.8 for notes on environmental screening criteria. N/A – not available.

Table 2.30 Maximum Radionuclide Concentrations Predicted in Environmental Media Over 10,000 Year Postclosure Period and COPC Selection for Scenario (3c) Defence-in-Depth – Role of Grout

Radionuclide	Spring Water	Ottawa River	Garden Area	Riverbed	Screening Criteria			Screened In?	Comments
	Groundwater	Surface Water	Soil	Sediment	Surface Water & Groundwater	Soil	Sediment		
	(Bq/L)	(Bq/L)	(Bq/kg)	(Bq/kg)	(Bq/L)	(Bq/kg)	(Bq/kg)		
(3c) Defence-in-Depth Cases - Role of Grout									
Am-241	1.10E-08	2.47E-11	6.97E-08	4.26E-08	3.85E-01	8.62E+02	8.28E+03		
C-14	2.73E-02	9.43E-05	2.45E-03	3.18E+01	1.64E+02	5.74E+02	5.45E+03		
Ca-41	2.00E-02	6.76E-05	2.56E-03	2.32E+02	N/A	N/A	N/A	**Yes**	No environmental screening criteria
Cd-113m	6.91E-21	3.65E-21	3.12E-20	5.41E-24	N/A	N/A	N/A	**Yes**	No environmental screening criteria
Cl-36	1.26E-03	2.32E-05	8.47E-03	3.59E+01	1.31E+03	9.02E-01	1.06E+02		
Cm-243	3.18E-31	5.47E-31	6.24E-30	5.43E-33	8.24E-01	8.00E+02	2.07E+01		
Cm-244	1.01E-29	2.35E-28	2.64E-27	2.29E-30	8.28E-01	8.00E+02	2.07E+01		
Co-60	7.33E-10	5.18E-13	3.23E-12	1.79E-14	1.35E+02	9.05E+04	1.03E+06		
Cs-135	6.98E-08	5.32E-10	5.06E-06	3.98E-01	3.48E+02	1.97E+05	4.36E+06		
Cs-137	1.77E-05	5.22E-08	2.23E-06	2.16E-09	7.27E+01	5.54E+04	7.12E+05		
Eu-152	1.47E-16	3.21E-12	2.35E-11	1.21E-15	1.18E+02	1.72E+05	4.13E+04		
Eu-154	1.00E-18	2.10E-14	8.27E-14	5.44E-18	7.74E+01	1.55E+05	2.72E+04		
H-3	1.79E+02	6.55E-01	4.72E+00	8.98E+03	1.74E+07	3.20E+06	2.60E+07		
Hf-182	6.70E-14	2.26E-16	4.07E-13	1.13E-10	N/A	N/A	N/A	**Yes**	No environmental screening criteria
I-129	1.00E-07	3.37E-10	8.46E-08	7.03E-02	7.63E+01	1.59E+06	1.57E+06		
Mo-93	1.38E-04	4.67E-07	6.41E-04	1.06E+00	N/A	N/A	N/A	**Yes**	No environmental screening criteria
Nb-93m	6.52E-06	2.23E-08	6.39E-04	9.60E-01	N/A	N/A	N/A	**Yes**	No environmental screening criteria
Nb-94	3.05E-11	1.03E-13	6.68E-11	7.64E-08	1.95E+02	1.15E+05	3.08E+03		
Ni-59	6.15E-03	8.00E-05	1.20E+00	7.71E+03	2.56E+03	1.24E+07	4.30E+07		
Ni-63	8.67E-07	3.05E-09	1.31E-06	4.43E-08	9.09E+03	8.77E+06	3.25E+07		
Np-237	8.00E-14	8.49E-14	1.11E-12	8.11E-08	1.83E+01	1.00E+03	5.12E+00		
Pu-238	2.83E-08	3.02E-11	1.43E-09	2.43E-11	6.36E-01	7.52E+03	2.42E+04		
Pu-239	1.33E-05	1.91E-07	2.55E-02	2.77E+03	6.79E-01	8.00E+03	2.58E+04		
Pu-240	7.11E-13	3.57E-14	1.41E-10	6.72E-04	6.78E-01	8.00E+03	2.58E+04		
Pu-241	1.67E-12	1.57E-15	9.44E-11	2.21E-06	2.50E+03	2.94E+07	9.48E+07		
Pu-242	7.30E-12	3.10E-12	1.37E-08	5.82E-02	N/A	N/A	N/A	**Yes**	No environmental screening criteria
Sb-125	1.16E-25	1.25E-25	2.88E-25	2.69E-28	3.28E+01	4.41E+05	6.86E+05		
Se-79	4.04E-06	2.29E-08	2.97E-05	8.82E-01	9.73E+02	5.29E+05	2.37E+05		
Sn-126	9.33E-10	3.72E-12	5.20E-10	5.91E-05	N/A	N/A	N/A	**Yes**	No environmental screening criteria
Sr-90	7.06E-07	2.38E-09	8.18E-08	5.90E-09	1.83E+02	1.18E+06	1.14E+05		
Tc-99	1.19E-03	4.03E-06	3.43E-04	7.03E-01	2.47E+04	4.61E+04	3.39E+04		
Th-229	9.31E-09	5.64E-11	8.43E-06	3.85E-01	N/A	N/A	N/A	**Yes**	No environmental screening criteria
Th-230	1.36E-07	4.76E-10	1.30E-03	2.79E-01	3.81E-02	2.66E+03	4.10E+02		
Th-232	3.92E-10	1.31E-12	1.79E-10	2.17E-07	4.49E-02	3.11E+03	4.81E+02		
U-233	2.29E-08	4.26E-09	1.80E-05	1.72E-02	6.72E+00	1.20E+04	1.92E+06		
U-234	1.45E-09	2.94E-10	6.16E-07	1.20E-03	1.01E+01	1.17E+03	4.94E+02		
U-235	7.67E-07	2.87E-09	5.53E-04	8.48E-03	1.09E+01	1.26E+03	5.37E+02		
U-236	5.52E-13	1.15E-12	4.50E-10	4.73E-06	N/A	N/A	N/A	**Yes**	No environmental screening criteria
U-238	1.24E-05	4.51E-08	8.10E-03	1.34E-01	1.18E+01	1.33E+03	5.76E+02		
Zr-93	5.02E-09	1.73E-11	8.49E-08	2.76E-05	1.68E+01	2.01E+05	8.06E+07		

Notes: see Table 2.8 for notes on environmental screening criteria. N/A – not available.

Table 2.31 Maximum Radionuclide Concentrations Predicted in Environmental Media Over 10,000 Year Postclosure Period and COPC Selection for Scenario (4a) What-If Cases – Mass Excavation

Radionuclide	Spring Water Groundwater (Bq/L)	Ottawa River Surface Water (Bq/L)	Garden Area Soil (Bq/kg)	Riverbed Sediment (Bq/kg)	Screening Criteria Surface Water (Bq/L)	Screening Criteria Soil (Bq/kg)	Screening Criteria Sediment (Bq/kg)	Screened In?	Comments
(4a) What-If Cases - Mass Excavation									
Am-241	1.05E-08	2.30E-11	9.36E+02	1.31E-08	3.85E-01	8.62E+02	8.28E+03	**Yes**	Exceeded soil (Garden) criterion
C-14	2.76E-02	9.57E-05	1.42E+04	3.21E+01	1.64E+02	5.74E+02	5.45E+03	**Yes**	Exceeded soil (Garden) criterion
Ca-41	4.92E-03	3.94E-05	7.80E+01	2.11E+02	N/A	N/A	N/A	**Yes**	No environmental screening criteria
Cd-113m	5.42E-22	5.36E-22	1.64E-01	7.87E-25	N/A	N/A	N/A	**Yes**	No environmental screening criteria
Cl-36	6.88E-04	1.59E-05	2.30E+02	2.65E+01	1.31E+03	9.02E-01	1.06E+02	**Yes**	Exceeded soil (Garden) criterion
Cm-243	2.73E-33	1.08E-32	7.19E-03	1.07E-34	8.24E-01	8.00E+02	2.07E+01		
Cm-244	8.44E-32	4.62E-30	2.81E+00	4.49E-32	8.28E-01	8.00E+02	2.07E+01		
Co-60	7.33E-10	4.59E-13	2.65E-01	1.44E-14	1.35E+02	9.05E+04	1.03E+06		
Cs-135	4.45E-08	5.42E-10	1.66E-02	4.07E-01	3.48E+02	1.97E+05	4.36E+06		
Cs-137	1.74E-05	5.10E-08	1.47E+02	2.09E-09	7.27E+01	5.54E+04	7.12E+05		
Eu-152	5.94E-18	3.30E-13	6.11E+00	1.25E-16	1.18E+02	1.72E+05	4.13E+04		
Eu-154	1.92E-19	1.17E-14	3.49E-02	3.03E-18	7.74E+01	1.55E+05	2.72E+04		
H-3	1.80E+02	6.57E-01	2.61E+02	9.01E+03	1.74E+07	3.20E+06	2.60E+07		
Hf-182	3.75E-15	1.28E-17	3.42E-02	5.78E-11	N/A	N/A	N/A	**Yes**	No environmental screening criteria
I-129	4.92E-08	2.42E-10	7.36E-04	7.08E-02	7.63E+01	1.59E+06	1.57E+06		
Mo-93	3.46E-05	1.47E-07	2.01E+01	1.08E+00	N/A	N/A	N/A	**Yes**	No environmental screening criteria
Nb-93m	1.61E-06	7.88E-09	4.02E+01	9.79E-01	N/A	N/A	N/A	**Yes**	No environmental screening criteria
Nb-94	8.34E-12	2.81E-14	1.21E+02	3.98E-08	1.95E+02	1.15E+05	3.08E+03		
Ni-59	2.27E-03	7.28E-05	2.87E+03	7.67E+03	2.56E+03	1.24E+07	4.30E+07		
Ni-63	8.64E-07	2.94E-09	1.89E+05	1.24E-08	9.09E+03	8.77E+06	3.25E+07		
Np-237	9.12E-15	4.78E-14	4.66E-04	4.58E-08	1.83E+01	1.00E+03	5.12E+00		
Pu-238	2.83E-08	3.02E-11	5.29E+01	2.43E-11	6.36E-01	7.52E+03	2.42E+04		
Pu-239	1.22E-06	4.32E-08	1.02E+03	7.43E+02	6.79E-01	8.00E+03	2.58E+04		
Pu-240	1.45E-13	1.89E-14	1.14E+01	3.58E-04	6.78E-01	8.00E+03	2.58E+04		
Pu-241	1.85E-13	8.70E-16	6.81E+01	1.79E-06	2.50E+03	2.94E+07	9.48E+07		
Pu-242	8.36E-13	1.64E-12	9.33E-02	3.11E-02	N/A	N/A	N/A	**Yes**	No environmental screening criteria
Sb-125	4.00E-27	1.27E-26	8.71E-09	2.73E-29	3.28E+01	4.41E+05	6.86E+05		
Se-79	3.37E-06	2.24E-08	1.42E-01	9.58E-01	9.73E+02	5.29E+05	2.37E+05		
Sn-126	8.94E-11	1.11E-12	8.56E-03	8.35E-05	N/A	N/A	N/A	**Yes**	No environmental screening criteria
Sr-90	7.05E-07	2.37E-09	7.89E+01	1.47E-09	1.83E+02	1.18E+06	1.14E+05		
Tc-99	1.00E-03	3.39E-06	4.49E+00	6.61E-01	2.47E+04	4.61E+04	3.39E+04		
Th-229	1.41E-09	1.09E-11	6.84E-02	9.41E-02	N/A	N/A	N/A	**Yes**	No environmental screening criteria
Th-230	2.14E-07	7.35E-10	1.34E-01	2.13E-01	3.81E-02	2.66E+03	4.10E+02		
Th-232	7.21E-11	2.42E-13	8.86E-02	1.92E-07	4.49E-02	3.11E+03	4.81E+02		
U-233	3.07E-09	1.19E-09	7.35E-02	4.87E-03	6.72E+00	1.20E+04	1.92E+06		
U-234	1.73E-09	1.83E-10	3.13E-01	7.32E-04	1.01E+01	1.17E+03	4.94E+02		
U-235	7.67E-07	2.93E-09	1.05E-01	8.48E-03	1.09E+01	1.26E+03	5.37E+02		
U-236	1.17E-13	6.12E-13	1.30E-03	2.52E-06	N/A	N/A	N/A	**Yes**	No environmental screening criteria
U-238	1.24E-05	4.62E-08	1.70E+00	1.37E-01	1.18E+01	1.33E+03	5.76E+02		
Zr-93	2.91E-10	1.16E-12	1.85E+03	1.41E-05	1.68E+01	2.01E+05	8.06E+07		

Notes: see Table 2.8 for notes on environmental screening criteria. N/A – not available.

Table 2.32 Maximum Radionuclide Concentrations Predicted in Environmental Media Over 10,000 Year Postclosure Period and COPC Selection for Scenario (4b) What-If Cases – River Level Fall

Radionuclide	Spring Water Groundwater (Bq/L)	Ottawa River Surface Water (Bq/L)	Garden Area Soil (Bq/kg)	Rivershore Sediment (Bq/kg)	Screening Criteria Surface Water & Groundwater (Bq/L)	Screening Criteria Soil (Bq/kg)	Screening Criteria Sediment (Bq/kg)	Screened In?	Comments
(4b) What-If Cases - River Level Fall									
Am-241	1.05E-08	2.31E-11	1.47E-08	1.43E-03	3.85E-01	8.62E+02	8.28E+03		
C-14	2.76E-02	9.57E-05	2.16E-04	1.47E+00	1.64E+02	5.74E+02	5.45E+03		
Ca-41	4.92E-03	3.94E-05	3.38E-04	8.40E-01	N/A	N/A	N/A	Yes	No environmental screening criteria
Cd-113m	5.42E-22	5.36E-22	4.56E-21	1.75E-16	N/A	N/A	N/A	Yes	No environmental screening criteria
Cl-36	6.88E-04	1.59E-05	3.63E-03	1.04E-01	1.31E+03	9.02E-01	1.06E+02		
Cm-243	2.73E-33	1.08E-32	1.22E-31	1.60E-26	8.24E-01	8.00E+02	2.07E+01		
Cm-244	8.44E-32	4.62E-30	5.18E-29	6.85E-24	8.28E-01	8.00E+02	2.07E+01		
Co-60	7.33E-10	4.59E-13	2.59E-12	5.85E-06	1.35E+02	9.05E+04	1.03E+06		
Cs-135	4.45E-08	5.43E-10	3.05E-06	1.52E-03	3.48E+02	1.97E+05	4.36E+06		
Cs-137	1.74E-05	5.10E-08	1.48E-06	1.43E-01	7.27E+01	5.54E+04	7.12E+05		
Eu-152	5.94E-18	3.30E-13	2.41E-12	4.92E-08	1.18E+02	1.72E+05	4.13E+04		
Eu-154	1.92E-19	1.17E-14	4.60E-14	1.74E-09	7.74E+01	1.55E+05	2.72E+04		
H-3	1.80E+02	6.57E-01	4.56E+00	3.82E+02	1.74E+07	3.20E+06	2.60E+07		
Hf-182	3.75E-15	1.28E-17	1.97E-15	1.71E-11	N/A	N/A	N/A	Yes	No environmental screening criteria
I-129	4.92E-08	3.21E-10	9.24E-09	4.18E-04	7.63E+01	1.59E+06	1.57E+06		
Mo-93	3.46E-05	1.47E-07	7.57E-05	4.43E-03	N/A	N/A	N/A	Yes	No environmental screening criteria
Nb-93m	1.61E-06	6.79E-09	7.53E-05	3.41E-03	N/A	N/A	N/A	Yes	No environmental screening criteria
Nb-94	8.34E-12	2.81E-14	3.47E-12	1.41E-08	1.95E+02	1.15E+05	3.08E+03		
Ni-59	2.27E-03	7.29E-05	7.05E-02	3.02E+01	2.56E+03	1.24E+07	4.30E+07		
Ni-63	8.64E-07	2.94E-09	3.80E-07	1.22E-03	9.09E+03	8.77E+06	3.25E+07		
Np-237	9.12E-15	4.78E-14	4.95E-13	1.71E-10	1.83E+01	1.00E+03	5.12E+00		
Pu-238	2.83E-08	3.03E-11	1.39E-09	2.15E-03	6.36E-01	7.52E+03	2.42E+04		
Pu-239	1.22E-06	7.57E-08	2.23E-04	5.37E+00	6.79E-01	8.00E+03	2.58E+04		
Pu-240	1.45E-13	2.73E-14	3.74E-12	1.93E-06	6.78E-01	8.00E+03	2.58E+04		
Pu-241	1.85E-13	8.70E-16	1.29E-12	6.19E-08	2.50E+03	2.94E+07	9.48E+07		
Pu-242	8.36E-13	2.37E-12	3.43E-10	1.68E-04	N/A	N/A	N/A	Yes	No environmental screening criteria
Sb-125	4.00E-27	1.27E-26	2.92E-26	1.89E-20	3.28E+01	4.41E+05	6.86E+05		
Se-79	3.37E-06	2.25E-08	6.41E-06	3.73E-03	9.73E+02	5.29E+05	2.37E+05		
Sn-126	8.94E-11	1.11E-12	9.29E-11	4.29E-07	N/A	N/A	N/A	Yes	No environmental screening criteria
Sr-90	7.05E-07	2.37E-09	2.54E-08	1.35E-04	1.83E+02	1.18E+06	1.14E+05		
Tc-99	1.00E-03	3.39E-06	2.99E-04	7.14E-03	2.47E+04	4.61E+04	3.39E+04		
Th-229	1.41E-09	1.55E-11	1.13E-07	8.69E-04	N/A	N/A	N/A	Yes	No environmental screening criteria
Th-230	2.14E-07	7.37E-10	5.53E-04	4.14E-02	3.81E-02	2.66E+03	4.10E+02		
Th-232	7.21E-11	2.42E-13	3.28E-11	1.36E-05	4.49E-02	3.11E+03	4.81E+02		
U-233	3.07E-09	1.19E-09	4.17E-07	1.84E-05	6.72E+00	1.20E+04	1.92E+06		
U-234	1.73E-09	1.83E-10	4.10E-08	2.82E-06	1.01E+01	1.17E+03	4.94E+02		
U-235	7.67E-07	2.92E-09	2.58E-04	4.50E-05	1.09E+01	1.26E+03	5.37E+02		
U-236	1.17E-13	6.12E-13	4.26E-11	9.42E-09	N/A	N/A	N/A	Yes	No environmental screening criteria
U-238	1.24E-05	4.62E-08	3.75E-03	7.11E-04	1.18E+01	1.33E+03	5.76E+02		
Zr-93	2.91E-10	1.16E-12	2.52E-10	3.43E-07	1.68E+01	2.01E+05	8.06E+07		

Notes: see Table 2.8 for notes on environmental screening criteria. N/A – not available.

It is noted from Table 2.19 to Table 2.32 that for all scenarios:

- 9 radionuclides 'screened-in' due to a lack of screening criteria for all environmental media (Ca-41, Cd-113m, Hf-182, Mo-93, Nb-93m, Pu-242, Sn-126, Th-229, U-236);
- Cl-36 'screened-in' for scenario (1b) because the concentration in riverbed sediments exceeded the screening criterion;
- Cl-36 and Pu-239 'screened-in' for scenario (2b) because their concentrations in riverbed sediments exceeded the screening criteria;
- Am-241, C-14 and Cl-36 'screened-in' for scenario (4a) because their concentrations in garden soil exceeded the screening criteria.

The results of the sum of fractions analysis are presented in Table 2.33 and the reader is referred to Appendix C for the detailed results showing the fractions for each individual radionuclide by scenario/environmental medium. In the assessment, aquatic based organisms obtain their drinking water from the Ottawa River and sediment exposure from either riverbed sediments or shoreline sediments of the Ottawa River, depending on the scenario. Terrestrial based organisms are exposed to soil from the Garden Area and obtain drinking water from either the Ottawa River or Springs. As seen from the table, the sum of fractions were summed across relevant environmental media/exposure pathways for aquatic based (Ottawa River surface water + riverbed sediment or shoreline sediment) and terrestrial (Garden Area soil + Ottawa River water or Spring water) receptors. A sum of fractions value of < 1 indicates no significant ecological impact and a value ≥ 1 requires further assessment. A value > 1 was obtained for aquatic pathways (Ottawa River surface water + riverbed sediment) for scenarios (1b) and (2b) and for terrestrial pathways (Garden Area soil + Ottawa River surface water or Spring water) for scenario (4a). For these scenarios, the top five radionuclides contributing to the sum of fractions in each associated medium (e.g., Ottawa River surface water and riverbed sediment) were identified and added to the COPC list identified through the screen for assessment in the EcoRA for that scenario. These radionuclides are shown in Table 2.34. The sum of fractions for the remaining radionuclides in each environmental medium was < 0.030 while the cumulative sum of the top five radionuclides was > 97%.

Radionuclides selected as COPCs for each scenario based on the COPC screen and sum of fractions analysis are summarized in Table 2.35.

Table 2.33 Results of Sum of Fractions Analysis for Aquatic and Terrestrial Pathways

Scenario	Sum of Fractions - for Environmental Media				Sum of Fractions - for Aquatic and Terrestrial Pathways		
	Spring Water	Ottawa River	Garden Area	Riverbed or Rivershore	Aquatic Pathways	Terrestrial Pathways	
	Groundwater	Surface Water	Soil	Sediment	Ottawa River (Surface Water + Sediment)	Garden Area (Soil) + Ottawa River (Surface Water)	Garden Area (Soil) + Spring Water
(1) Normal Evolution Scenario (NES)	1.88E-04	1.65E-06	4.03E-03	2.85E-01	0.28	0.00	0.00
(1a) NES Sensitivity Analysis: Radioactive Inventory	2.60E-05	9.26E-08	5.91E-06	8.73E-03	0.01	0.00	0.00
(1b) NES Sensitivity Analysis: Sorption	1.81E-03	7.49E-06	1.45E-02	**2.72E+00**	**2.72**	0.01	0.02
(1c) NES Sensitivity Analysis: Resaturation Rate - Faster	1.89E-04	7.50E-07	4.03E-03	2.85E-01	0.28	0.00	0.00
(1d) NES Sensitivity Analysis: Resaturation Rate - Slower	1.89E-04	7.50E-07	4.06E-03	2.84E-01	0.28	0.00	0.00
(1e) NES Sensitivity Analysis: Surface Erosion	1.89E-04	7.50E-07	7.27E-03	2.85E-01	0.28	0.01	0.01
(1g) NES Sensitivity Analysis: Engineering Degradation	2.12E-04	8.34E-07	4.93E-03	2.95E-01	0.29	0.00	0.01
(2a) Disruptive Event: Site Investigation (Human Intrusion)	1.89E-04	7.50E-07	2.14E-02	2.85E-01	0.28	0.02	0.02
(2b) Disruptive Event: Extreme Degradation of Engineered Structures	1.29E-03	5.06E-05	3.82E-03	**2.87E+01**	**28.7**	0.00	0.01
(3a) Defence-in-Depth: Role of Waste Form	1.91E-04	7.84E-07	4.03E-03	5.27E-01	0.53	0.00	0.00
(3b) Defence-in-Depth: Role of Existing Facility Structure	2.31E-04	9.52E-07	3.71E-03	3.56E-01	0.36	0.00	0.00
(3c) Defence-in-Depth: Role of Grout	2.05E-04	9.60E-07	9.40E-03	4.52E-01	0.45	0.01	0.01
(4a) What-If: Mass Excavation	1.89E-04	7.50E-07	**2.81E+02**	2.85E-01	0.28	**281**	**281**
(4b) What-If: River Level Fall	1.89E-04	7.98E-07	4.03E-03	1.57E-03	0.00	0.00	0.00

Notes: Highlighted values exceed the unity rule (>1).

Table 2.34 Top Five Radionuclides Contributing Activity to Aquatic and Terrestrial Pathways with a Sum of Fractions > 1

	Aquatic Pathways		Aquatic Pathways		Terrestrial Pathways		
	Ottawa River - Surface Water	Ottawa River - Riverbed Sediment	Ottawa River - Surface Water	Ottawa River - Riverbed Sediment	Garden Area (Soil)	Ottawa River - Surface Water	Spring Water
	Scenario (1b)		Scenario (2b)		Scenario (4a)		
Top 5 Radionuclides Contributing to Sum of Fractions	C-14 Pu-239 Cl-36 Ni-59 Th-230	Cl-36 Pu-239 C-14 Th-230 U-238	Pu-239 C-14 Cl-36 Ni-59 Zr-93	Pu-239 Cl-36 C-14 Pu-240 Th-230	Cl-36 C-14 Am-241 Pu-239 Ni-63	C-14 Pu-239 H-3 Ni-59 Th-230	C-14 H-3 Th-230 Pu239 U-238
Cumulative Sum (%)	98.88%	99.97%	99.84%	99.99%	99.99%	97.67%	99.03%
Sum of Fractions for Remaining Radionuclides	0.000	0.001	0.000	0.002	0.027	0.000	0.000

Table 2.35 Summary of Radiological COPCs Selected for Inclusion in the EcoRA

Radionuclide COPCs		Comment
All Scenarios		
Ca-41 Cd-113m Hf-182 Mo-93 Nb-93m	Pu-242 Sn-126 Th-229 U236	These radionuclides 'screened-in' for all scenarios due to a lack of available screening criteria for all environmental media.
(1b) NES Sensitivity Analysis – Sorption		
C-14 Ca-41 Cd-113m Cl-36 Hf-182 Mo-93 Nb-93m Ni-59	Pu-239 Pu-242 Sn-126 Th-229 Th-230 U-236 U-238	In addition to the radionuclides listed above that 'screened-in' for all scenarios due to a lack of screening criteria, Cl-36 'screened-in' because its concentration in riverbed sediments of the Ottawa River exceeded the sediment criterion. In addition, as the sum of fractions exceeded 1 for the aquatic pathway (Ottawa River water + riverbed sediment) in this scenario, the top five radionuclides contributing to the dose in surface water and in riverbed sediment (cumulatively representing >98% of total dose in each medium) were also included as COPC in this scenario.
(2b) Disruptive Events - Extreme Degradation of Engineered Structures		
C-14 Ca-41 Cd-113m Cl-36 Hf-182 Mo-93 Nb-93m Ni-59	Pu-239 Pu-240 Pu-242 Sn-126 Th-229 Th-230 U-236 Zr-93	In addition to the radionuclides listed above that 'screened-in' for all scenarios due to a lack of screening criteria, Cl-36 and Pu-239 'screened-in' because their concentrations in riverbed sediments of the Ottawa River exceeded the sediment criterion. In addition, as the sum of fractions exceeded 1 for the aquatic pathway (Ottawa River water + riverbed sediment) in this scenario, the top five radionuclides contributing to the dose in surface water and in riverbed sediment (cumulatively representing >99% of total dose in each medium) were also included as COPC in this scenario.
(4a) What-If Cases - Mass Excavation		
Am-241 C-14 Ca-41 Cd-113m Cl-36 H-3 Hf-182 Mo-93 Nb-93m	Ni-59 Ni-63 Pu-239 Pu-242 Sn-126 Th-229 Th-230 U-236 U-238	In addition to the radionuclides listed above that 'screened-in' for all scenarios due to a lack of screening criteria, Am-241, C-14 and Cl-36 'screened-in' because their concentrations in soil in the garden area exceeded the soil criterion. In addition, as the sum of fractions exceeded 1 for terrestrial pathways (Ottawa River water + garden soil & spring water + garden soil) in this scenario, the top five radionuclides contributing to the dose in surface water, spring water and garden soil (cumulatively representing >97% of total dose in each medium) were also included as COPC in this scenario.

2.4.3.2 Non-radiological COPC Screen

The total (maximum incremental + baseline) environmental concentrations of lead and mercury for each scenario, along with the environmental screening criteria and screening decisions, are summarized in Table 2.36. If a total contaminant concentration exceeded the environmental criterion in at least one environmental medium then it was ‘screened-in’ for that scenario and assessed in all media.

As seen from Table 2.36, mercury concentrations were below the screening criteria in all environmental media for all scenarios. Mercury was ‘screened-out’ for all scenarios and was not assessed in the EcoRA.

With the exception of one scenario, (4a) What-If – Mass Excavation, lead concentrations were also below the screening criteria in all environmental media. Thus lead ‘screened-out’ for all scenarios except scenario (4a). In scenario (4a), while the lead concentrations in surface water, spring water and sediment were below criteria, the lead concentration in soil exceeded the soil quality guideline. It should be noted that while lead was assessed for scenario (4a), this What-If scenario is a highly improbable scenario representing an extreme set of conditions.

Table 2.36 Total Lead and Mercury Concentrations (Maximum Incremental + Baseline) Predicted in Environmental Media Over 10,000 Year Postclosure Period and COPC Selection

Scenario, Environmental Medium & Contaminant	Incremental Concentration	Baseline Concentration	Total Concentration (Incremental + Baseline)	Environmental Screening Criterion			Total Concentration > Environmental Screening Criterion	Screening Decision
				MOE[1,2]	CCME/FCSAP[3,4]	MELCC[5]		
(1) Normal Evolution Scenario (NES)								
Lead (Pb)								Screen-Out
Spring Water - Groundwater (mg/L)	3.87E-07	8.50E-04	8.50E-04	0.01	0.001		No	
Ottawa River - Surface Water (mg/L)	1.31E-09	9.74E-05	9.74E-05	0.001	0.001	0.00017	No	
Shallow Groundwater - Groundwater (mg/L)	3.89E-07	8.50E-04	8.50E-04	0.01	0.001		No	
Garden Area - Soil (mg/kg)	7.80E-03	3.00E+01	3.00E+01	120	140		No	
Ottawa River - Riverbed Sediment (mg/kg)	8.05E-03	1.00E+01	1.00E+01	31	35		No	
Ottawa River - Rivershore Sediment (mg/kg)	N/A							
Mercury (Hg)								Screen-Out
Spring Water - Groundwater (mg/L)	1.58E-14	2.00E-05	2.00E-05	0.00029	0.000026		No	
Ottawa River - Surface Water (mg/L)	5.34E-17	2.00E-05	2.00E-05	0.0002	0.000026	0.000941	No	
Shallow Groundwater - Groundwater (mg/L)	1.64E-14	2.00E-05	2.00E-05	0.00029	0.000026		No	
Garden Area - Soil (mg/kg)	1.39E-14	5.00E-02	5.00E-02	0.27	6.6		No	
Ottawa River - Riverbed Sediment (mg/kg)	8.15E-14	5.00E-02	5.00E-02	0.2	0.17		No	
Ottawa River - Rivershore Sediment (mg/kg)	N/A							
(1a) NES Sensitivity Analysis: Radioactive Inventory								
Lead (Pb)								Screen-Out
Spring Water - Groundwater (mg/L)	3.87E-07	8.50E-04	8.50E-04	0.01	0.001		No	
Ottawa River - Surface Water (mg/L)	1.31E-09	9.74E-05	9.74E-05	0.001	0.001	0.00017	No	
Shallow Groundwater - Groundwater (mg/L)	3.89E-07	8.50E-04	8.50E-04	0.01	0.001		No	
Garden Area - Soil (mg/kg)	7.80E-03	3.00E+01	3.00E+01	120	140		No	
Ottawa River - Riverbed Sediment (mg/kg)	8.05E-03	1.00E+01	1.00E+01	31	35		No	
Ottawa River - Rivershore Sediment (mg/kg)	N/A							
Mercury (Hg)								Screen-Out
Spring Water - Groundwater (mg/L)	1.58E-14	2.00E-05	2.00E-05	0.00029	0.000026		No	
Ottawa River - Surface Water (mg/L)	5.34E-17	2.00E-05	2.00E-05	0.0002	0.000026	0.000941	No	
Shallow Groundwater - Groundwater (mg/L)	1.64E-14	2.00E-05	2.00E-05	0.00029	0.000026		No	
Garden Area - Soil (mg/kg)	1.39E-14	5.00E-02	5.00E-02	0.27	6.6		No	
Ottawa River - Riverbed Sediment (mg/kg)	8.15E-14	5.00E-02	5.00E-02	0.2	0.17		No	
Ottawa River - Rivershore Sediment (mg/kg)	N/A	5.00E-02	5.00E-02	0.2	0.17		No	
(1b) NES Sensitivity Analysis: Sorption								
Lead (Pb)								Screen-Out
Spring Water - Groundwater (mg/L)	9.87E-06	8.50E-04	8.60E-04	0.01	0.001		No	
Ottawa River - Surface Water (mg/L)	3.33E-08	9.74E-05	9.74E-05	0.001	0.001	0.00017	No	
Shallow Groundwater - Groundwater (mg/L)	9.81E-06	8.50E-04	8.60E-04	0.01	0.001		No	
Garden Area - Soil (mg/kg)	1.18E-01	3.00E+01	3.01E+01	120	140		No	
Ottawa River - Riverbed Sediment (mg/kg)	2.50E-01	1.00E+01	1.03E+01	31	35		No	
Ottawa River - Rivershore Sediment (mg/kg)	N/A							
Mercury (Hg)								Screen-Out
Spring Water - Groundwater (mg/L)	1.13E-11	2.00E-05	2.00E-05	0.00029	0.000026		No	
Ottawa River - Surface Water (mg/L)	3.80E-14	2.00E-05	2.00E-05	0.0002	0.000026	0.000941	No	
Shallow Groundwater - Groundwater (mg/L)	1.14E-11	2.00E-05	2.00E-05	0.00029	0.000026		No	
Garden Area - Soil (mg/kg)	3.81E-10	5.00E-02	5.00E-02	0.27	6.6		No	
Ottawa River - Riverbed Sediment (mg/kg)	7.16E-12	5.00E-02	5.00E-02	0.2	0.17		No	
Ottawa River - Rivershore Sediment (mg/kg)	N/A							

Scenario, Environmental Medium & Contaminant	Incremental Concentration	Baseline Concentration	Total Concentration (Incremental + Baseline)	Environmental Screening Criterion			Total Concentration > Environmental Screening Criterion	Screening Decision
				MOE[1,2]	CCME/FCSAP[3,4]	MELCC[5]		
(1c) NES Sensitivity Analysis: Resaturation Rate - Faster								
Lead (Pb)								Screen-Out
Spring Water - Groundwater (mg/L)	3.87E-07	8.50E-04	8.50E-04	0.01	0.001	-	No	
Ottawa River - Surface Water (mg/L)	1.31E-09	9.74E-05	9.74E-05	0.001	0.001	0.00017	No	
Shallow Groundwater - Groundwater (mg/L)	3.89E-07	8.50E-04	8.50E-04	0.01	0.001	-	No	
Garden Area - Soil (mg/kg)	7.80E-03	3.00E+01	3.00E+01	120	140	-	No	
Ottawa River - Riverbed Sediment (mg/kg)	8.05E-03	1.00E+01	1.00E+01	31	35	-	No	
Ottawa River - Rivershore Sediment (mg/kg)	N/A							
Mercury (Hg)								Screen-Out
Spring Water - Groundwater (mg/L)	1.58E-14	2.00E-05	2.00E-05	0.00029	0.000026	-	No	
Ottawa River - Surface Water (mg/L)	5.34E-17	2.00E-05	2.00E-05	0.0002	0.000026	0.000941	No	
Shallow Groundwater - Groundwater (mg/L)	1.64E-14	2.00E-05	2.00E-05	0.00029	0.000026	-	No	
Garden Area - Soil (mg/kg)	1.39E-14	5.00E-02	5.00E-02	0.27	6.6	-	No	
Ottawa River - Riverbed Sediment (mg/kg)	8.15E-14	5.00E-02	5.00E-02	0.2	0.17	-	No	
Ottawa River - Rivershore Sediment (mg/kg)	N/A							
(1d) NES Sensitivity Analysis: Resaturation Rate - Slower								
Lead (Pb)								Screen-Out
Spring Water - Groundwater (mg/L)	3.87E-07	8.50E-04	8.50E-04	0.01	0.001	-	No	
Ottawa River - Surface Water (mg/L)	1.30E-09	9.74E-05	9.74E-05	0.001	0.001	0.00017	No	
Shallow Groundwater - Groundwater (mg/L)	3.89E-07	8.50E-04	8.50E-04	0.01	0.001	-	No	
Garden Area - Soil (mg/kg)	7.80E-03	3.00E+01	3.00E+01	120	140	-	No	
Ottawa River - Riverbed Sediment (mg/kg)	8.05E-03	1.00E+01	1.00E+01	31	35	-	No	
Ottawa River - Rivershore Sediment (mg/kg)	N/A							
Mercury (Hg)								Screen-Out
Spring Water - Groundwater (mg/L)	1.58E-14	2.00E-05	2.00E-05	0.00029	0.000026	-	No	
Ottawa River - Surface Water (mg/L)	5.34E-17	2.00E-05	2.00E-05	0.0002	0.000026	0.000941	No	
Shallow Groundwater - Groundwater (mg/L)	1.64E-14	2.00E-05	2.00E-05	0.00029	0.000026	-	No	
Garden Area - Soil (mg/kg)	1.39E-14	5.00E-02	5.00E-02	0.27	6.6	-	No	
Ottawa River - Riverbed Sediment (mg/kg)	8.15E-14	5.00E-02	5.00E-02	0.2	0.17	-	No	
Ottawa River - Rivershore Sediment (mg/kg)	N/A							
(1e) NES Sensitivity Analysis: Surface Erosion								
Lead (Pb)								Screen-Out
Spring Water - Groundwater (mg/L)	3.87E-07	8.50E-04	8.50E-04	0.01	0.001	-	No	
Ottawa River - Surface Water (mg/L)	1.31E-09	9.74E-05	9.74E-05	0.001	0.001	0.00017	No	
Shallow Groundwater - Groundwater (mg/L)	3.89E-07	8.50E-04	8.50E-04	0.01	0.001	-	No	
Garden Area - Soil (mg/kg)	2.53E-04	3.00E+01	3.00E+01	120	140	-	No	
Ottawa River - Riverbed Sediment (mg/kg)	8.05E-03	1.00E+01	1.00E+01	31	35	-	No	
Ottawa River - Rivershore Sediment (mg/kg)	N/A							
Mercury (Hg)								Screen-Out
Spring Water - Groundwater (mg/L)	1.58E-14	2.00E-05	2.00E-05	0.00029	0.000026	-	No	
Ottawa River - Surface Water (mg/L)	5.34E-17	2.00E-05	2.00E-05	0.0002	0.000026	0.000941	No	
Shallow Groundwater - Groundwater (mg/L)	1.64E-14	2.00E-05	2.00E-05	0.00029	0.000026	-	No	
Garden Area - Soil (mg/kg)	3.10E-06	5.00E-02	5.00E-02	0.27	6.6	-	No	
Ottawa River - Riverbed Sediment (mg/kg)	8.15E-14	5.00E-02	5.00E-02	0.2	0.17	-	No	
Ottawa River - Rivershore Sediment (mg/kg)	N/A							

Scenario, Environmental Medium & Contaminant	Incremental Concentration	Baseline Concentration	Total Concentration (Incremental + Baseline)	Environmental Screening Criterion			Total Concentration > Environmental Screening Criterion	Screening Decision
				MOE[1,2]	CCME/FCSAP[3,4]	MELCC[5]		
(1g) NES Sensitivity Analysis: Engineering Degradation								
Lead (Pb)								Screen-Out
Spring Water - Groundwater (mg/L)	3.38E-07	8.50E-04	8.50E-04	0.01	0.001	-	No	
Ottawa River - Surface Water (mg/L)	1.14E-09	9.74E-05	9.74E-05	0.001	0.001	0.00017	No	
Shallow Groundwater - Groundwater (mg/L)	3.39E-07	8.50E-04	8.50E-04	0.01	0.001	-	No	
Garden Area - Soil (mg/kg)	1.29E-02	3.00E+01	3.00E+01	120	140	-	No	
Ottawa River - Riverbed Sediment (mg/kg)	7.58E-03	1.00E+01	1.00E+01	31	35	-	No	
Ottawa River - Rivershore Sediment (mg/kg)	N/A							
Mercury (Hg)								Screen-Out
Spring Water - Groundwater (mg/L)	1.58E-14	2.00E-05	2.00E-05	0.00029	0.000026	-	No	
Ottawa River - Surface Water (mg/L)	5.34E-17	2.00E-05	2.00E-05	0.0002	0.000026	0.000941	No	
Shallow Groundwater - Groundwater (mg/L)	1.64E-14	2.00E-05	2.00E-05	0.00029	0.000026	-	No	
Garden Area - Soil (mg/kg)	1.39E-14	5.00E-02	5.00E-02	0.27	6.6	-	No	
Ottawa River - Riverbed Sediment (mg/kg)	8.55E-14	5.00E-02	5.00E-02	0.2	0.17	-	No	
Ottawa River - Rivershore Sediment (mg/kg)	N/A							
(2a) Disruptive Event: Site Investigation (Human Intrusion)								
Lead (Pb)								Screen-Out
Spring Water - Groundwater (mg/L)	3.87E-07	8.50E-04	8.50E-04	0.01	0.001	-	No	
Ottawa River - Surface Water (mg/L)	1.31E-09	9.74E-05	9.74E-05	0.001	0.001	0.00017	No	
Shallow Groundwater - Groundwater (mg/L)	3.89E-07	8.50E-04	8.50E-04	0.01	0.001	-	No	
Garden Area - Soil (mg/kg)	2.13E-02	3.00E+01	3.00E+01	120	140	-	No	
Ottawa River - Riverbed Sediment (mg/kg)	8.05E-03	1.00E+01	1.00E+01	31	35	-	No	
Ottawa River - Rivershore Sediment (mg/kg)	N/A							
Mercury (Hg)								Screen-Out
Spring Water - Groundwater (mg/L)	1.58E-14	2.00E-05	2.00E-05	0.00029	0.000026	-	No	
Ottawa River - Surface Water (mg/L)	5.34E-17	2.00E-05	2.00E-05	0.0002	0.000026	0.000941	No	
Shallow Groundwater - Groundwater (mg/L)	1.64E-14	2.00E-05	2.00E-05	0.00029	0.000026	-	No	
Garden Area - Soil (mg/kg)	1.10E-12	5.00E-02	5.00E-02	0.27	6.6	-	No	
Ottawa River - Riverbed Sediment (mg/kg)	8.15E-14	5.00E-02	5.00E-02	0.2	0.17	-	No	
Ottawa River - Rivershore Sediment (mg/kg)	N/A							
(2b) Disruptive Event: Extreme Degradation of Engineered Barriers								
Lead (Pb)								Screen-Out
Spring Water - Groundwater (mg/L)	1.13E-05	8.50E-04	8.61E-04	0.01	0.001	-	No	
Ottawa River - Surface Water (mg/L)	3.92E-08	9.74E-05	9.74E-05	0.001	0.001	0.00017	No	
Shallow Groundwater - Groundwater (mg/L)	1.13E-05	8.50E-04	8.61E-04	0.01	0.001	-	No	
Garden Area - Soil (mg/kg)	3.29E-04	3.00E+01	3.00E+01	120	140	-	No	
Ottawa River - Riverbed Sediment (mg/kg)	4.07E-01	1.00E+01	1.04E+01	31	35	-	No	
Ottawa River - Rivershore Sediment (mg/kg)	N/A							
Mercury (Hg)								Screen-Out
Spring Water - Groundwater (mg/L)	5.84E-13	2.00E-05	2.00E-05	0.00029	0.000026	-	No	
Ottawa River - Surface Water (mg/L)	1.97E-15	2.00E-05	2.00E-05	0.0002	0.000026	0.000941	No	
Shallow Groundwater - Groundwater (mg/L)	5.94E-13	2.00E-05	2.00E-05	0.00029	0.000026	-	No	
Garden Area - Soil (mg/kg)	2.49E-13	5.00E-02	5.00E-02	0.27	6.6	-	No	
Ottawa River - Riverbed Sediment (mg/kg)	1.14E-11	5.00E-02	5.00E-02	0.2	0.17	-	No	
Ottawa River - Rivershore Sediment (mg/kg)	N/A							

Scenario, Environmental Medium & Contaminant	Incremental Concentration	Baseline Concentration	Total Concentration (Incremental + Baseline)	Environmental Screening Criterion			Total Concentration > Environmental Screening Criterion	Screening Decision
				MOE[1,2]	CCME/FCSAP[3,4]	MELCC[5]		
(3a) Defence-in-Depth: Role of Waste Form								
Lead (Pb)								Screen-Out
Spring Water - Groundwater (mg/L)	3.87E-07	8.50E-04	8.50E-04	0.01	0.001	-	No	
Ottawa River - Surface Water (mg/L)	1.31E-09	9.74E-05	9.74E-05	0.001	0.001	0.00017	No	
Shallow Groundwater - Groundwater (mg/L)	3.89E-07	8.50E-04	8.50E-04	0.01	0.001	-	No	
Garden Area - Soil (mg/kg)	7.80E-03	3.00E+01	3.00E+01	120	140	-	No	
Ottawa River - Riverbed Sediment (mg/kg)	8.05E-03	1.00E+01	1.00E+01	31	35	-	No	
Ottawa River - Rivershore Sediment (mg/kg)	N/A							
Mercury (Hg)								Screen-Out
Spring Water - Groundwater (mg/L)	1.58E-14	2.00E-05	2.00E-05	0.00029	0.000026	-	No	
Ottawa River - Surface Water (mg/L)	5.34E-17	2.00E-05	2.00E-05	0.0002	0.000026	0.000941	No	
Shallow Groundwater - Groundwater (mg/L)	1.64E-14	2.00E-05	2.00E-05	0.00029	0.000026	-	No	
Garden Area - Soil (mg/kg)	1.39E-14	5.00E-02	5.00E-02	0.27	6.6	-	No	
Ottawa River - Riverbed Sediment (mg/kg)	8.15E-14	5.00E-02	5.00E-02	0.2	0.17	-	No	
Ottawa River - Rivershore Sediment (mg/kg)	N/A							
(3b) Defence-in-Depth: Role of Existing Facility Structure								
Lead (Pb)								Screen-Out
Spring Water - Groundwater (mg/L)	1.31E-05	8.50E-04	8.63E-04	0.01	0.001	-	No	
Ottawa River - Surface Water (mg/L)	4.43E-08	9.74E-05	9.74E-05	0.001	0.001	0.00017	No	
Shallow Groundwater - Groundwater (mg/L)	1.31E-05	8.50E-04	8.63E-04	0.01	0.001	-	No	
Garden Area - Soil (mg/kg)	7.80E-03	3.00E+01	3.00E+01	120	140	-	No	
Ottawa River - Riverbed Sediment (mg/kg)	1.74E-01	1.00E+01	1.02E+01	31	35	-	No	
Ottawa River - Rivershore Sediment (mg/kg)	N/A							
Mercury (Hg)								Screen-Out
Spring Water - Groundwater (mg/L)	3.13E-14	2.00E-05	2.00E-05	0.00029	0.000026	-	No	
Ottawa River - Surface Water (mg/L)	1.06E-16	2.00E-05	2.00E-05	0.0002	0.000026	0.000941	No	
Shallow Groundwater - Groundwater (mg/L)	3.23E-14	2.00E-05	2.00E-05	0.00029	0.000026	-	No	
Garden Area - Soil (mg/kg)	4.76E-14	5.00E-02	5.00E-02	0.27	6.6	-	No	
Ottawa River - Riverbed Sediment (mg/kg)	4.01E-13	5.00E-02	5.00E-02	0.2	0.17	-	No	
Ottawa River - Rivershore Sediment (mg/kg)	N/A							
(3c) Defence-in-Depth: Role of Grout								
Lead (Pb)								Screen-Out
Spring Water - Groundwater (mg/L)	1.62E-06	8.50E-04	8.52E-04	0.01	0.001	-	No	
Ottawa River - Surface Water (mg/L)	5.46E-09	9.74E-05	9.74E-05	0.001	0.001	0.00017	No	
Shallow Groundwater - Groundwater (mg/L)	1.63E-06	8.50E-04	8.52E-04	0.01	0.001	-	No	
Garden Area - Soil (mg/kg)	7.08E-02	3.00E+01	3.01E+01	120	140	-	No	
Ottawa River - Riverbed Sediment (mg/kg)	3.12E-02	1.00E+01	1.00E+01	31	35	-	No	
Ottawa River - Rivershore Sediment (mg/kg)	N/A							
Mercury (Hg)								Screen-Out
Spring Water - Groundwater (mg/L)	7.14E-13	2.00E-05	2.00E-05	0.00029	0.000026	-	No	
Ottawa River - Surface Water (mg/L)	2.41E-15	2.00E-05	2.00E-05	0.0002	0.000026	0.000941	No	
Shallow Groundwater - Groundwater (mg/L)	7.37E-13	2.00E-05	2.00E-05	0.00029	0.000026	-	No	
Garden Area - Soil (mg/kg)	3.60E-12	5.00E-02	5.00E-02	0.27	6.6	-	No	
Ottawa River - Riverbed Sediment (mg/kg)	2.04E-13	5.00E-02	5.00E-02	0.2	0.17	-	No	
Ottawa River - Rivershore Sediment (mg/kg)	N/A							

Scenario, Environmental Medium & Contaminant	Incremental Concentration	Baseline Concentration	Total Concentration (Incremental + Baseline)	Environmental Screening Criterion			Total Concentration > Environmental Screening Criterion	Screening Decision
				MOE[1,2]	CCME/FCSAP[3,4]	MELCC[5]		
(4a) What-If: Mass Excavation								
Lead (Pb)								**Screen-In**
Spring Water - Groundwater (mg/L)	3.87E-07	8.50E-04	8.50E-04	0.01	0.001	-	No	
Ottawa River - Surface Water (mg/L)	1.31E-09	9.74E-05	9.74E-05	0.001	0.001	0.00017	No	
Shallow Groundwater - Groundwater (mg/L)	3.89E-07	8.50E-04	8.50E-04	0.01	0.001	-	No	
Garden Area - Soil (mg/kg)	1.73E+03	3.00E+01	1.76E+03	120	140	-	**Yes**	
Ottawa River - Riverbed Sediment (mg/kg)	8.05E-03	1.00E+01	1.00E+01	31	35	-	No	
Ottawa River - Rivershore Sediment (mg/kg)	N/A							
Mercury (Hg)								Screen-Out
Spring Water - Groundwater (mg/L)	1.58E-14	2.00E-05	2.00E-05	0.00029	0.000026	-	No	
Ottawa River - Surface Water (mg/L)	5.34E-17	2.00E-05	2.00E-05	0.0002	0.000026	0.000941	No	
Shallow Groundwater - Groundwater (mg/L)	1.64E-14	2.00E-05	2.00E-05	0.00029	0.000026	-	No	
Garden Area - Soil (mg/kg)	1.93E-04	5.00E-02	5.02E-02	0.27	6.6	-	No	
Ottawa River - Riverbed Sediment (mg/kg)	8.15E-14	5.00E-02	5.00E-02	0.2	0.17	-	No	
Ottawa River - Rivershore Sediment (mg/kg)	N/A							
(4b) What-If: River Level Fall								
Lead (Pb)								Screen-Out
Spring Water - Groundwater (mg/L)	3.87E-07	8.50E-04	8.50E-04	0.01	0.001	-	No	
Ottawa River - Surface Water (mg/L)	1.31E-09	9.74E-05	9.74E-05	0.001	0.001	0.00017	No	
Shallow Groundwater - Groundwater (mg/L)	3.89E-07	8.50E-04	8.50E-04	0.01	0.001	-	No	
Garden Area - Soil (mg/kg)	7.80E-03	3.00E+01	3.00E+01	120	140	-	No	
Ottawa River - Riverbed Sediment (mg/kg)	N/A							
Ottawa River - Rivershore Sediment (mg/kg)	1.04E-03	1.00E+01	1.00E+01	31	35	-	No	
Mercury (Hg)								Screen-Out
Spring Water - Groundwater (mg/L)	1.58E-14	2.00E-05	2.00E-05	0.00029	0.000026	-	No	
Ottawa River - Surface Water (mg/L)	5.34E-17	2.00E-05	2.00E-05	0.0002	0.000026	0.000941	No	
Shallow Groundwater - Groundwater (mg/L)	1.64E-14	2.00E-05	2.00E-05	0.00029	0.000026	-	No	
Garden Area - Soil (mg/kg)	1.39E-14	5.00E-02	5.00E-02	0.27	6.6	-	No	
Ottawa River - Riverbed Sediment (mg/kg)	N/A							
Ottawa River - Rivershore Sediment (mg/kg)	2.55E-12	5.00E-02	5.00E-02	0.2	0.17	-	No	

Notes:
(1) MOE (2011) for groundwater, soil (coarse textured for all land uses) and sediment; Table 8 - Full Depth Generic Site Condition Standards for Use within 30 m of a Water Body in a Potable Ground Water Condition.
(2) MOE (1994) for surface water; Provincial Surface Water Quality Objectives (PWQOs).
(3) CCME (2020; online) – Environmental Quality Guidelines for the Protection of Environmental and Human Health under a residential/parkland land use scenario for soil and for the protection of freshwater aquatic life for surface water (default value of 0.001 mg/L for unknown water hardness).
(4) FCSAP (2016) – Table 2 Federal Interim Groundwater Quality Guidelines Generic Guidelines for residential/parkland land use for the protection of freshwater life and soil organisms in direct contact.
(5) MELCC (2020; online) – Surface Water Quality Criteria for the protection of aquatic organisms (chronic exposure; lead value for water hardness of 10 mg/L $CaCO_3$).

2.5 Selection of Exposure Pathways

Table 2.37 and Table 2.38 present the active exposure pathways of radiological and non-radiological COPCs for the ecological receptors identified in Section 2.2. The exposure pathways are based on the known habitat needs, mobility, and diets of the ecological receptors, along with knowledge of the location of their respective habitats within the study area.

Terrestrial vegetation and terrestrial invertebrates (earthworms) are directly exposed to contaminated soil and are assessed against contaminant concentrations in soil. Consequently, pathways of exposure (e.g., ingestion, inhalation, etc.) are not explicitly modelled (or needed) for these receptors.

Similarly, aquatic vegetation, benthic invertebrates, benthic and pelagic fish are directly exposed to contaminated surface water and are assessed against contaminant concentrations in surface water and sediment. Thus, pathways of exposure (e.g., ingestion, inhalation, etc.) are not explicitly modelled (or needed) for these receptors. Terrestrial mammals and birds are exposed through ingestion of food, including terrestrial vegetation and earthworms, as well as incidental ingestion of soil and ingestion of surface water. Higher trophic species (such as the bald eagle) will also consume lower trophic species (such as voles and shrews), as part of their diet. Terrestrial mammals will also receive an external dose from soil (radiological only from being on or in soil (e.g., burrowing animals such as the shrew and vole)). It is assumed that terrestrial mammals and birds obtain all of their food from the site, which is very conservative, given that many species have larger home ranges or forage areas than provided by the site.

Aquatic birds are exposed through ingestion of food, including aquatic vegetation and benthic invertebrates, as well as ingestion of sediment and surface water. Aquatic birds will also receive an external dose from radionuclides in surface water. Higher trophic species such as the bald eagle consume fish as part of their diet.

Aquatic mammals (e.g., muskrat) are exposed through ingestion of food as well as ingestion of water and sediment (through the ingestion of aquatic vegetation). The muskrat will also receive an external dose from surface water, sediment and vegetation as it spends the majority of its time in its lodge, which comprises sediment and vegetation.

The following pathways have been identified as inactive, or are otherwise not applicable:

1. *Inhalation*

As discussed in N288.6-12 (CSA 2012), inhalation exposures are typically minor in relation to soil and food ingestion exposures and can therefore be excluded from assessments. For particulate substances released to air and accumulation in soil over time, the steady-state soil concentrations are usually high enough that soil and food ingestion components of dose are dominant.

2. *Dermal uptake*

Dermal exposure is generally not a significant pathway of exposure for wildlife as fur and feathers are effective at blocking direct contact with skin. Water, dietary items, and incidental ingestion of soil and sediment are usually by far the most important pathways of exposure for wildlife and inclusion of dermal exposure and inhalation pathways is rarely necessary (Environment Canada 2012a, 2012b).

3. *Immersion in air (radiological only)*

External dose from immersion in air is minor relative to soil and food ingestion exposure and can be ignored (particularly since noble gases are not identified as COPCs) (CSA 2012).

Table 2.37 Summary of Exposure Pathways for Radiological Contaminants

Receptor	Environmental Media Exposed	Modes of Exposure to Radiological COPCs	Risk Calculation Method
			Radiation
Aquatic Vegetation	• surface water	• uptake from surface water • immersion in surface water	• internal dose from surface water • external dose from surface water
Benthic Invertebrates	• surface water • sediment	• uptake from surface water • immersion in surface water • immersion in sediment	• internal dose from surface water • external dose from surface water (50%) • external dose from sediment (50%)
Pelagic Fish (various species; see Table 2.4) and Benthic Fish (various species; see Table 2.4) & Green Frog (tadpole)	• surface water • sediment	Pelagic fish: • uptake from surface water • immersion in surface water Benthic fish & Green Frog (tadpole): • uptake from surface water • immersion in surface water • exposure to sediment	Pelagic fish: • internal dose from surface water • external dose from surface water Benthic fish & Green Frog (tadpole): • internal dose from surface water • external dose from surface water (50%) • external dose from sediment (50%)
Aquatic Birds (Great Blue Heron and Mallard)	• surface water • sediment	• ingestion (as appropriate): - surface water (all) - sediment (all) - fish (all) - benthic invertebrates (Great Blue Heron, Mallard) - terrestrial invertebrates/insects (Mallard) - aquatic & terrestrial vegetation (Mallard) - small mammals (Great Blue Heron) • immersion in surface water (all)	• internal dose from ingestion • external dose from surface water
Aquatic Reptiles (Blanding's Turtle)	• surface water • sediment	• ingestion - surface water - sediment - fish - aquatic vegetation - benthic invertebrates • immersion in surface water • exposure to sediment	• internal dose from ingestion • external dose from surface water (50%) • external dose from sediment (50%)
Aquatic Mammals (American Mink, Moose,	• surface water • sediment	• ingestion (as appropriate): - surface water (all)	• internal dose from ingestion • external dose from sediment

Receptor	Environmental Media Exposed	Modes of Exposure to Radiological COPCs	Risk Calculation Method
			Radiation
Muskrat, Northern River Otter)		- sediment (all) - aquatic vegetation (Moose, Muskrat) - terrestrial vegetation (Moose) - benthic invertebrates (Northern River Otter, Muskrat, American Mink) - fish (Northern River Otter, Muskrat, American Mink) - small mammals/birds (Northern River Otter, American Mink)	
Terrestrial Invertebrates (Earthworm)	• soil	• uptake from soil • immersion in soil	• internal dose from soil • external dose from soil
Terrestrial Plants, Berries and Mushrooms (various species; see Table 2.4)	• soil	• uptake from soil (root uptake) • exposure to soil	• internal dose from soil • external dose from soil
Terrestrial Birds (Bald Eagle, Chimney Swift, and Ruffed Grouse)	• surface water • soil	• ingestion (as appropriate): - surface water (all) - soil (Bald Eagle, Ruffed Grouse) - terrestrial vegetation (Ruffed Grouse) - terrestrial invertebrates/insects (Chimney Swift, Ruffed Grouse) - small mammals/birds (Bald Eagle) - fish (Bald Eagle) • direct exposure to soil (all)	• internal dose from ingestion • external dose from soil
Terrestrial Mammals (Black Bear, Eastern Wolf, Little Brown Myotis, Meadow Vole, Red Fox, Short-tailed Shrew, Short-tailed Weasel, White-tailed Deer)	• surface water • soil	• ingestion (as appropriate): - surface water (all) - soil (all) - terrestrial invertebrates/insects (Black Bear, Little Brown Myotis, Red Fox, Short-tailed Shrew, Short-tailed Weasel) - terrestrial vegetation (Black Bear, Meadow Vole, Red Fox, White-tailed Deer) - small mammals (Black Bear, Eastern Wolf, Red Fox, Short-tailed Weasel) - birds (Red Fox, Short-tailed Weasel) - deer (Eastern Wolf) - fish (Black Bear) - aquatic & terrestrial invertebrates/insects (Little Brown Myotis) • direct exposure to soil (all)	• internal dose from ingestion • external dose from soil

Note: The Monarch Butterfly and Eastern Milksnake are not included in the table as they were assessed qualitatively.

Table 2.38 Summary of Exposure Pathways for Non-Radiological Contaminants

Receptor	Environmental Media Exposed	Modes of Exposure to Non-radiological COPC	Risk Calculation Method
			Non-Radioactive
Aquatic Vegetation	• surface water	• uptake from surface water	Comparison of surface water concentrations with benchmark values.
Benthic Invertebrates	• surface water	• uptake from surface water	Comparison of surface water concentrations with benchmark values.
Pelagic Fish (various species; see Table 2.4) and *Benthic Fish (various species; see Table 2.4) & Green Frog (tadpole)*	• surface water	• uptake from surface water	Comparison of surface water concentrations with corresponding benchmark values.
Aquatic Birds (Great Blue Heron and Mallard)	• surface water • sediment	• ingestion (as appropriate): - surface water (all) - sediment (all) - fish (fish) - benthic invertebrates (Great Blue Heron, Mallard) - terrestrial invertebrates/insects (Mallard) - aquatic & terrestrial vegetation (Mallard) - small mammals (Great Blue Heron)	Comparison of dose from intake with benchmark values.
Aquatic Mammals (American Mink, Moose, Muskrat, Northern River Otter)	• surface water • sediment	• ingestion (as appropriate): - surface water (all) - sediment (all) - aquatic vegetation (Moose, Muskrat) - terrestrial vegetation (Moose) - benthic invertebrates (Northern River Otter, Muskrat, American Mink) - fish (Northern River Otter, Muskrat, American Mink) - small mammals/birds (Northern River Otter, American Mink)	Comparison of dose from intake with benchmark values.
Terrestrial Invertebrates (Earthworm)	• soil • groundwater	• uptake from soil • uptake from groundwater	Comparison of soil or groundwater concentrations with benchmark values.

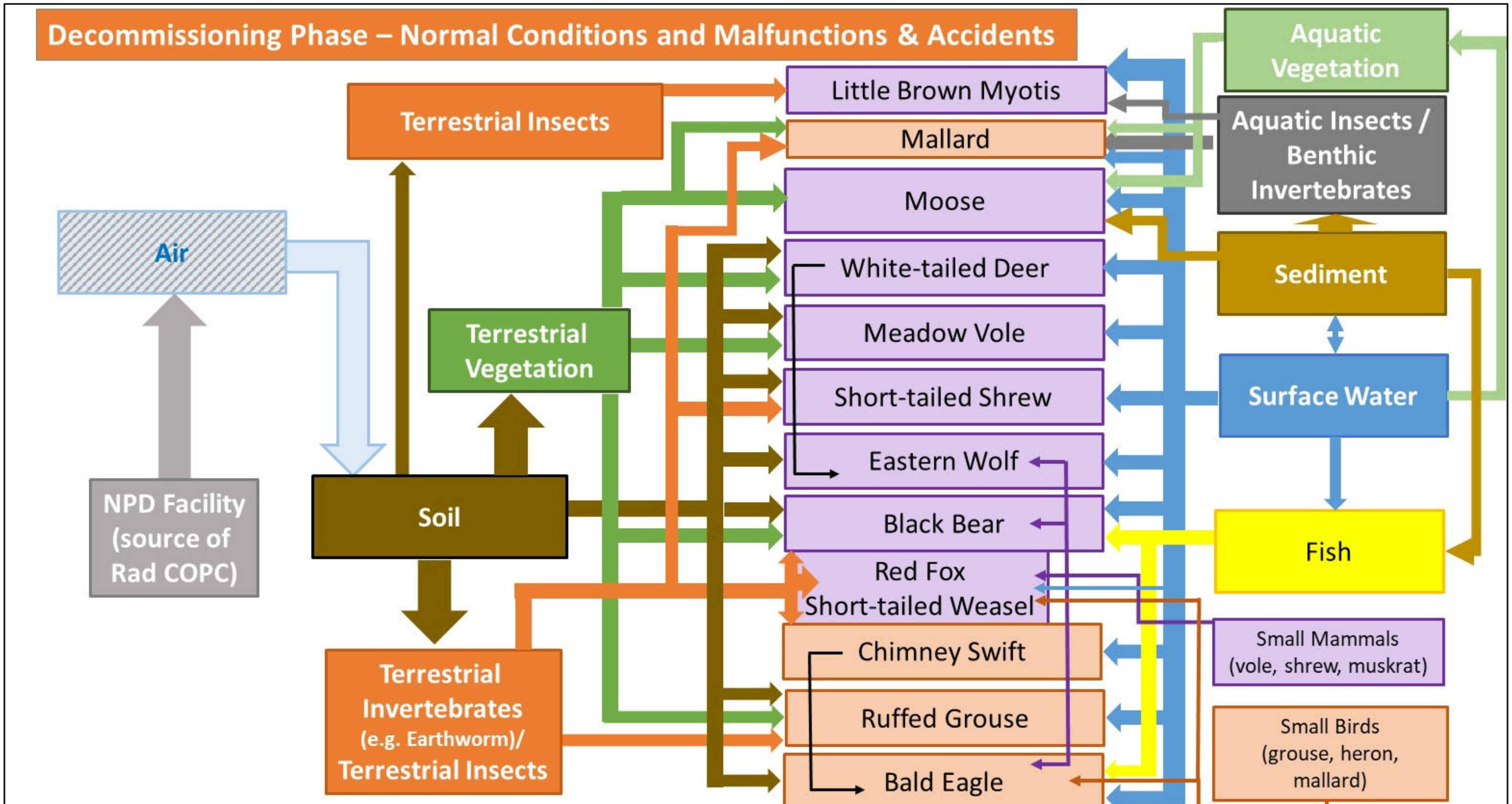
Receptor	Environmental Media Exposed	Modes of Exposure to Non-radiological COPC	Risk Calculation Method
			Non-Radioactive
Terrestrial Plants, Berries and Mushrooms (various species; see Table 2.4)	• *soil*	• uptake from soil (root uptake)	Comparison of soil concentrations with benchmark values.
Terrestrial Birds (Bald Eagle, Chimney Swift and Ruffed Grouse)	• surface water • soil	• ingestion (as appropriate): - surface water (all) - soil (Bald Eagle, Ruffed Grouse) - terrestrial vegetation (Ruffed Grouse) - terrestrial invertebrates/insects (Chimney Swift, Ruffed Grouse) - small mammals/birds (Bald Eagle) - fish (Bald Eagle)	Comparison of dose from intake with benchmark values.
Terrestrial Mammals (Black Bear, Eastern Wolf, Little Brown Myotis, Meadow Vole, Red Fox, Short-tailed Shrew, Short-tailed Weasel, White-tailed Deer)	• surface water • soil	• ingestion (as appropriate): - surface water (all) - soil (all) - terrestrial invertebrates/insects (Black Bear, Little Brown Myotis, Red Fox, Short-tailed Shrew, Short-tailed Weasel) - terrestrial vegetation (Black Bear, Meadow Vole, Red Fox, White-tailed Deer) - small mammals (Black Bear, Eastern Wolf, Red Fox, Short-tailed Weasel) - birds (Red Fox, Short-tailed Weasel) - fish (Black Bear) - aquatic & terrestrial invertebrates/insects (Little Brown Myotis)	Comparison of dose from intake with benchmark values.

Note: The Monarch butterfly, Blanding's Turtle, and Eastern Milksnake are not included in the table as they were assessed qualitatively.

2.6 Conceptual Site Models

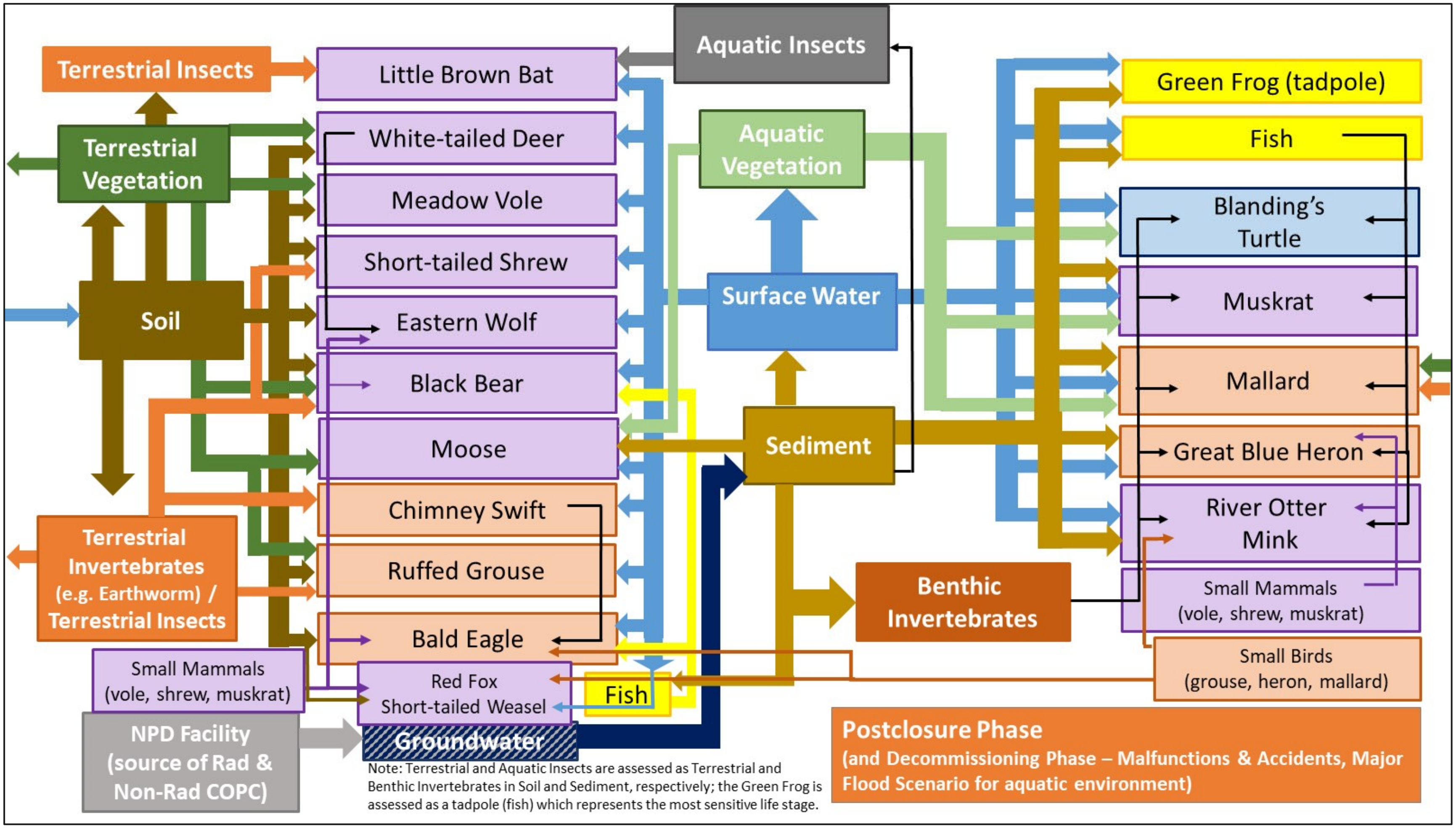
Conceptual site models are shown in Figure 2.4 for the Decommissioning Phase – Normal Operating Conditions and Malfunctions & Accidents (impacts to the terrestrial environment) and Figure 2.5 for the Postclosure Phase (impacts to both the aquatic and terrestrial environments).

Figure 2.4 Conceptual Site Model for the Decommissioning Phase under Normal Operating Conditions and Malfunctions & Accidents



Note: Terrestrial and Aquatic Insects are assessed as Terrestrial and Benthic Invertebrates in Soil and Sediment, respectively.
The Green Frog is assessed as a tadpole (benthic fish) which represents the most sensitive life stage.

Figure 2.5 Conceptual Site Model for the Postclosure Phase for All Scenarios



2.7 Problem Formulation Checklist

Table 2.39 provides the problem formulation checklist for the EcoRA.

Table 2.39 Problem Formulation Checklist – Ecological Risk Assessment

Land use	Receptor Group	Exposure Pathways – Contact/Ingestion			
		Soil	Surface Water	Sediment	Food
Residential/ Parkland	Soil invertebrates	✓[1]	NR	NR	NR[4]
	Terrestrial plants	✓[1]	NR	NR	NR[4]
	Aquatic birds	NR	✓	✓	✓
	Terrestrial birds	✓	✓	NR	✓
	Aquatic mammals	NR	✓	✓	✓
	Terrestrial mammals	✓	✓	NR	✓
	Amphibians	NR	✓[2,3]	✓	NR[4]
	Reptiles[5]	NA	✓	✓	✓
	Fish	NR	✓[2]	✓	NR[4]
	Aquatic plants	NR	✓[2]	✓	NR[4]
	Aquatic invertebrates	NR	✓[2]	✓	NR[4]

Note: NA – not assessed; NR – not relevant; ✓ - assessed.

(1) Directly exposed to contaminated soil and assessed against contaminant concentrations in soil.
(2) Directly exposed to contaminated surface water and assessed against contaminant concentrations in surface water.
(3) Green Frog assessed at the tadpole stage as a fish.
(4) Food chain modelling not conducted for these receptors; food consumption is included in the assessment of effects on the base abiotic environmental component (soil or surface water).
(5) Radiological assessment only as there is a lack of available information on toxicity effects for the non-radiological assessment of reptiles (Blanding's Turtle).

3.0 EXPOSURE ASSESSMENT

3.1 Exposure Points

This assessment relies on the conservative use of maximum COPC concentrations predicted based on modelling for the most sensitive receptor location in the DecomSA (Garisto *et al*. 2020) and over the postclosure assessment period in the PostSA (Penfold *et al.* 2020). While guidance suggests the use of the 95th percentile upper confidence limit on the arithmetic mean, use of the maximum concentration is a typical approach when less than 10 measurements are available (CSA 2012).

During the decommissioning phase, emissions are made to air and assumed to deposit to soil (Garisto *et al.* 2020). For each scenario, only one concentration per receptor location was available and the location with the maximum concentration was used in the EcoRA. This location was typically the Guardhouse, the location closest to the facility for which valid air concentrations could be obtained through air modelling. For the tornado scenarios, maximum concentrations of radiological and non-radiological contaminants emitted to air were predicted for both Rapides de Joachims and Rolphton. Thus, terrestrial receptors were assumed to receive all of their exposure from soil, invertebrates, terrestrial vegetation, etc. from the Garden Area and from Rapides de Joachims/Rolphton for the tornado scenarios (decommissioning scenarios (8) and (9)).

During the postclosure phase, emissions are made to groundwater, which is assumed to discharge to springs close to the shore and riverbed sediments adjacent to the site from where contamination may pass into water in the Ottawa River. Contaminants released into the Ottawa River may sorb to sediments or be taken up by aquatic flora and fauna. Contaminants may also be transferred to land through crop irrigation (garden soil) with river water and animals drinking river water and then excreting it onto the land (grazing soil). The maximum contaminant concentrations predicted over the entire PostSA (Penfold *et al.* 2020) assessment period (10,000 years) in each environmental medium (i.e., groundwater, garden soil, spring water, Ottawa River water and Ottawa River riverbed or shoreline sediments) were used in the EcoRA. Terrestrial receptors were assumed to reside in the Garden Area and to obtain their drinking water/exposure to surface water from either the Ottawa River adjacent to the site or from Spring. Aquatic receptors were assumed to reside along the Ottawa River adjacent to the site and to obtain their exposure to terrestrial components from the Garden Area.

Table 3.1 shows the exposure point locations of aquatic and terrestrial biota assessed against environmental concentrations during the postclosure phase. It is noted that aquatic biota are assessed using both surface water and sediment quality and that aquatic biota are assessed using both Ottawa River surface water and Spring water. Table 3.2 shows the exposure point locations of aquatic and terrestrial mammals and birds assessed for postclosure scenarios. It is noted that there are two sets of terrestrial receptors denoted by (1) and (2). The exposures between the two sets of receptors are the same except that receptor (1) receives its drinking water/exposure to surface water from the Ottawa River and receptor (2) from Spring water. This was meant to assess the effect of Spring water on terrestrial receptors, which are assumed the most likely receptors to drink Spring water, because Spring water generally has higher contaminant concentrations than Ottawa River surface water. In addition, the Great Blue Heron, Moose and Muskrat were also assumed to drink Spring water.

Table 3.1 Exposure Point Locations of Aquatic and Terrestrial Receptors Assessed Against Environmental Concentrations for the Postclosure Scenarios

Major Biota Group	Representative Receptor	Ottawa River			Garden Area
		Surface Water	Sediment - Riverbed or Shoreline *	Spring water	Soil
Aquatic Receptors					
Aquatic Invertebrates	Benthic Invertebrates	X	X		
Aquatic Vegetation	Aquatic Vegetation	X	X		
Benthic Fish	Various species; see Table 2.4	X	X		
Pelagic Fish	Various species; see Table 2.4	X	X	X	
Amphibians	Green Frog (tadpole)	X	X		
Terrestrial Receptors					
Soil Invertebrates	Earthworm (exposed to soil)				X
Terrestrial Vegetation, Berries, Mushrooms	Various species; see Table 2.4				X

Note:

* Shoreline sediments as opposed to Riverbed sediments are assessed only for scenario (4b) What-If – River Level Fall.

Table 3.2 Exposure Point Locations of Aquatic and Terrestrial Receptors Assessed for Postclosure Scenarios

Parameter	Aquatic Based Receptors							Terrestrial Based Receptors										
	American Mink	Blanding's Turtle	Great Blue Heron	Mallard	Moose	Muskrat	Northern River Otter	Bald Eagle	Black Bear	Chimney Swift	Eastern Wolf	Little Brown Myotis	Meadow Vole	Red Fox	Ruffed Grouse	Short-tailed Shrew	Short-tailed Weasel	White-tailed Deer
Postclosure Phase																		
Aquatic Environment																		
Ottawa River near NPD Site																		
Surface Water	X	X	X (1)	X	X (1)	X (1)	X											
Sediment - Riverbed or Shoreline *	X	X	X (1)(2)	X	X (1)(2)	X (1)(2)	X											
Aquatic Vegetation		X		X	X (1)(2)	X (1)(2)												
Benthic Invertebrates & Insects	X	X	X (1)(2)	X		X (1)(2)	X					X (1)(2)						
Fish (Pelagic or Benthic)	X		X (1)(2)	X		X (1)(2)	X	X (1)(2)	X (1)(2)									
Terrestrial Environment																		
Garden Area																		
Surface Water - Ottawa River								X (1)	X (1)	X (1)	X (1)	X (1)	X (1)	X (1)	X (1)	X (1)	X (1)	X (1)
Soil								X (1)	X (1)		X (1)		X (1)	X (1)	X (1)	X (1)	X (1)	X (1)
Terrestrial Invertebrates & Insects									X (1)	X (1)		X (1)		X (1)	X (1)	X (1)	X (1)	
Terrestrial Vegetation				X	X (1)(2)				X (1)				X (1)	X (1)	X (1)			X (1)
Small Mammals (Vole, Shrew, Muskrat)	X		X (1)(2)				X	X (1)	X (1)		X (1)			X (1)			X (1)	
Birds (Heron, Grouse, Mallard)	X						X	X (1)						X (1)			X (1)	
Deer											X (1)							
Garden Area																		
Surface water - Spring Water			X (2)		X (1)(2)	X (2)		X (2)	X (2)	X (2)	X (2)	X (2)	X (2)	X (2)	X (2)	X (2)	X (2)	X (2)
Soil								X (2)	X (2)		X (2)		X (2)	X (2)	X (2)	X (2)	X (2)	X (2)
Terrestrial Invertebrates & Insects									X (2)	X (2)		X (2)		X (2)	X (2)	X (2)	X (2)	
Terrestrial Vegetation									X (2)				X (2)	X (2)	X (2)			X (2)
Small Mammals (Vole, Shrew, Muskrat)								X (2)	X (2)		X (2)			X (2)			X (2)	
Birds (Heron, Grouse, Mallard)								X (2)						X (2)			X (2)	
Deer											X (2)							

Notes:

** The Monarch Butterfly and Eastern Milksnake were assessed qualitatively as well as Blanding's Turtle for non-radiological exposure.*

( ) - indicates that the receptor is assessed in more than one exposure point location; for example, Black Bear (1) drinks water from the Ottawa River and Black Bear (2) drinks Spring water (and consumes small mammals drinking Spring water), but all other exposures are consistent between the two Black Bears.

3.2 Exposure Factors for Receptors

Table 3.4 presents an overview of key exposure factors among the ecological receptors identified and described in Section 2.2. Ecological profiles for each receptor are included in Appendix A.

The exposure factors for ecological receptors were obtained preferentially from Module C (*Standardization of Wildlife Receptor Characteristics*) of the Environment Canada *Federal Contaminated Sites Action Plan (FCSAP) Ecological Risk Assessment Guidance* (Environment Canada 2012a, 2012b). Standard profiles from FCSAP were available for the American Mink, Black Bear, Bald Eagle, Great Blue Heron, Mallard, Meadow Vole, Moose, Muskrat, Northern River Otter, Red Fox, Ruffed Grouse, Short-tailed Weasel and White-tailed Deer. Standard profiles for the Short-tailed Shrew and Green Frog were available from MOE (2011) and U.S. EPA (1993), respectively, although the Green Frog was assessed as a tadpole/fish to capture the most sensitive life stage and thus was not modelled explicitly. Standard profiles were not available for Blanding's Turtle, Chimney Swift, Eastern Wolf and Little Brown Myotis (bat) and other sources noted in Table 3.4 were consulted to infill information mainly on body weights and dietary characteristics.

Soil and sediment ingestion rates, if not available from the FCSAP document (Environment Canada 2012a, 2012b), were for the most part obtained from a wildlife soil ingestion study completed by Beyer *et al.* (1994) in which the fractional soil composition of the diets (i.e., percentage of the dry weight food ingestion rate) of 28 wildlife species was estimated.

When food and water intake rates were not available directly from the FCSAP guidance (Environment Canada 2012a, 2012b), the following allometric equations from the United States Environmental Protection Agency (U.S. EPA 1993) were used:

Dry Weight Food Ingestion (g dw/d):

Birds = $0.648 * BW^{0.651}$ (body weight (BW) in g)

Mammals = $0.235 * BW^{0.822}$ (BW in g)

Water Intake (L/d):

Birds = $0.059 * BW^{0.67}$ (BW in kg)

Mammals = $0.099 * BW^{0.9}$ (BW in kg)

In converting food ingestion rates from dry weight to wet weight, the average weighted water content of the diet was calculated using the water contents shown for various food items in Table 3.3.

Table 3.3 Water Content of Dietary Components

Dietary Component	Water Content	Reference
Fish	71.5%	US EPA 1993, Table 4-1 and 4-2
Benthic Invertebrates	78.5%	US EPA 1993, Table 4-1 and 4-2
Earthworms	84.0%	US EPA 1993, Table 4-1 and 4-2
Mammals	68.0%	US EPA 1993, Table 4-1 and 4-2
Birds	67.5%	US EPA 1993, Table 4-1 and 4-2
Terrestrial Vegetation	80.0%	CSA 2018 Table G.5 Forage
Aquatic Vegetation	75.0%	CSA 2018, Clause 7.7.4.2

For this high-level assessment, the fraction of time spent on-site consuming food and water was assumed to be 1 for all receptors regardless of their migratory patterns or home ranges. This is a very conservative assumption as many bird species (e.g., Chimney Swift, Great Blue Heron, Mallard) migrate to southern destinations for the winter, large mammals (e.g., Black Bear, Bald Eagle) have home ranges larger than the area of the NPD site, and other species hibernate in the winter time (e.g., Little Brown Myotis).

Table 3.4 Overview of Exposure Factors for Ecological Receptors

Parameter	Units	American Mink	Bald Eagle	Black Bear	Blanding's Turtle	Chimney Swift	Eastern Wolf	Great Blue Heron	Little Brown Myotis	Mallard	Meadow Vole	Moose	Muskrat	Northern River Otter	Red Fox	Ruffed Grouse	Short-tailed Shrew	Short-tailed Weasel	Ruffed Grouse	White-tailed Deer
Body Weight	kg	0.82 (1)	4.7 (1)	68 (1)	1.3 (4)	0.021 (6)	43 (7)	2.3 (1)	0.0095 (10)(11)	1.2 (1)	0.0349 (1)	400 (1)	1 (1)	7.5 (1)	3.8 (1)	0.552 (1)	0.015 (13)	0.089 (1)	0.552 (1)	75 (1)
Water Intake Rate	L/d	0.0246 (1)	0.188 (1)	4.08 (1)	0.026 (2)	0.004 (2)	2.92 (2)	0.092 (1)	0.0015 (2)	0.072 (1)	0.007 (1)	20 (1)	0.099 (1)	0.6 (1)	0.342 (1)	0.0386 (1)	0.00226 (2)	0.01157 (1)	0.0386 (1)	4.5 (1)
Soil Ingestion Rate	g(dw)/d	-	3.36 (1)	40.8 (1)	-	negligible	49.3 (3)	-	negligible	-	0.083 (1)	-	-	-	2.14 (1)	3.26 (3)	0.187 (13)	0.196 (1)	3.26 (3)	45.0 (1)
Sediment Ingestion Rate	g(dw)/d	0.62 (1)	-	-	0.47 (3)	-	-	2.37 (3)	-	1.98 (1)	-	160 (1)	1.4 (1)	4.5 (1)	-	-	-	-	-	-
Food Ingestion Rate	g(ww)/d	114.8 (1)	564 (1)	9522 (1)	32.5 (2)	15.3 (2)	5500 (8)	414 (1)	4.8 (2)	258 (1)	11.5 (1)	38095 (1)	284 (1)	814 (1)	342 (1)	171 (1)	9 (13)	31.7 (1)	171 (1)	11250 (1)
Fraction that is fish	-	0.4 (1)	0.65 (1)	0.05 (1)	0.4 (5)	-	-	0.65 (1)	-	0.025 (1)	-	-	0.05 (1)	0.8 (1)	-	-	-	-	-	-
Fraction that is benthic invertebrates/insects	-	0.35 (1)	-	-	0.4 (5)	-	-	0.1 (1)	0.5 (11)*	0.4 (1)	-	-	0.15 (1)	0.15 (1)	-	-	-	-	-	-
Fraction that is aquatic vegetation	-	-	-	-	0.2 (5)	-	-	-	-	0.5 (1)	-	0.2 (1)	0.8 (1)	-	-	-	-	-	-	-
Fraction that is small mammals	-	0.125 (1)	0.2 (1)	0.1 (1)	-	-	0.8 (9)	0.25 (1)	-	-	-	-	-	0.023 (12)	0.4 (1)	-	-	0.7 (1)	-	-
Fraction that is deer	-	-	-	-	-	-	0.2 (9)	-	-	-	-	-	-	-	-	-	-	-	-	-
Fraction that is birds	-	0.125 (1)	0.15 (1)	-	-	-	-	-	-	-	-	-	-	0.027 (12)	0.2 (1)	-	-	0.25 (1)	-	-
Fraction that is soil invertebrates/insects	-	-	-	0.05 (1)	-	1 (14)*	-	-	0.5 (11)*	0.025 (1)	-	-	-	-	0.25 (1)	0.15 (1)	1 (13)	0.05 (1)	0.15 (1)	-
Fraction that is terrestrial vegetation	-	-	-	0.8 (1)	-	-	-	-	-	0.05 (1)	1 (1)	0.8 (1)	-	-	0.15 (1)	0.85 (1)	-	-	0.85 (1)	1 (1)
Fraction of time at site (assumed)	-	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

<u>Notes:</u>
The exposure factors for the Green Frog are not included in Table 3.4 because it was assessed as a fish, directly against COPC concentrations in surface water, to represent the most sensitive early life stage of the frog (tadpole).
* The Little Brown Myotis consumes both flying insects and insects on surface water, which are represented by soil invertebrates and benthic invertebrates, respectively; the Chimney Swift consumes terrestrial insects.

References (also see Appendix A):

(1) Environment Canada (FCSAP) (2012a, 2012b)
(2) U.S. EPA (1993)
(3) Beyer *et al.* (1994)
(4) RCGS (2014)
(5) Assumed based on Kipp (2000)
(6) Chantler and Driessens (2000)
(7) Schmidt and Gilbert (1978)
(8) Fuller and Keith (1980)
(9) Assumed based on Smith (2002)
(10) Havens (2006)
(11) CWF (2016)
(12) Lanszki *et al.* (2016)
(13) MOE (2011)
(14) Palmer and Fowler (1975)

3.3 Exposure Durations and Averaging

It has been conservatively assumed that all aquatic and terrestrial ecological receptors spend their entire exposure duration within their exposure locations. In other words, there is no reduction to account for time spent outside of the exposure location.

For migratory species, risk calculations do *not* average a receptor's exposure based on time away from the site during migration.

3.4 Exposure Point Concentrations

In postclosure scenarios, radiological and non-radiological contaminants are emitted directly into groundwater. Contaminants emitted into groundwater were assumed to impact the aquatic environment through groundwater discharge into riverbed or shoreline sediments of the Ottawa River, and the terrestrial environment through the deposition of contaminated surface water onto soil during irrigation or from excretions of animals drinking contaminated river water.

The PostSA (Penfold *et al*. 2020) predicted concentrations of radiological and non-radiological contaminants over time (i.e., 10,000-year assessment timeframe) in all affected environmental media (i.e., garden and grazing areas soil, shoreline and riverbed sediments, river water and spring water (i.e., shallow groundwater)) considered in each scenario. For each scenario, the maximum concentration of each contaminant in each environmental medium that was predicted over the entire assessment period (10,000 years) was used in the assessment. For radionuclides, the incremental environmental concentrations predicted by the AMBER model were used as exposure point concentrations and the total concentrations consisting of the predicted incremental concentrations summed with baseline concentrations in each environmental medium for lead.

Exposure point concentrations for food items were determined using concentration ratios (CRs) for terrestrial vegetation, earthworm, fish, benthic invertebrates and aquatic vegetation, and food chain modelling for the grouse, heron, mallard, vole, shrew, muskrat and deer.

Table 3.5 and Table 3.6 present the radiological exposure point concentrations for all relevant environmental media and consumed foods, respectively, for all postclosure scenarios assessed, and Table 3.7 and Table 3.8 present the non-radiological exposure point concentrations for all relevant environmental media and consumed foods, respectively, for scenario (4a) What-If – Mass Excavation.

Exposure point concentrations are not presented for decommissioning phase scenarios because as was shown in Section 2.4.2, all radiological and non-radiological contaminants emitted in these scenarios 'screened-out' of the assessment.

Table 3.5 Radiological Environmental Exposure Point Concentrations for Postclosure Scenarios

Radionuclide	Spring Water Groundwater (Bq/L)	Ottawa River Surface Water (Bq/L)	Garden Area Soil (Bq/kg)	Ottawa River - Riverbed Sediment (Bq/kg)	Ottawa River - Rivershore Sediment (Bq/kg)
(1) Normal Evolution Scenario (NES)					
Ca-41	4.92E-03	3.94E-05	3.38E-04	2.11E+02	N/A
Cd-113m	5.42E-22	5.36E-22	4.56E-21	7.87E-25	N/A
Hf-182	3.75E-15	1.28E-17	1.97E-15	5.78E-11	N/A
Mo-93	3.46E-05	1.47E-07	7.57E-05	1.08E+00	N/A
Nb-93m	1.61E-06	7.88E-09	7.53E-05	9.79E-01	N/A
Pu-242	8.36E-13	1.64E-12	2.64E-10	3.11E-02	N/A
Sn-126	8.94E-11	1.11E-12	9.28E-11	8.35E-05	N/A
Th-229	1.41E-09	1.09E-11	1.13E-07	9.41E-02	N/A
U-236	1.17E-13	6.12E-13	4.26E-11	2.52E-06	N/A
(1a) NES Sensitivity Analysis – Radioactive Inventory					
Ca-41	4.84E-03	3.43E-05	3.04E-04	1.83E+02	N/A
Cd-113m	0.00E+00	0.00E+00	0.00E+00	0.00E+00	N/A
Hf-182	0.00E+00	0.00E+00	0.00E+00	0.00E+00	N/A
Mo-93	0.00E+00	0.00E+00	0.00E+00	0.00E+00	N/A
Nb-93m	1.31E-22	1.44E-17	1.41E-16	3.72E-20	N/A
Pu-242	3.01E-10	2.48E-12	7.35E-09	3.67E-02	N/A
Sn-126	8.83E-08	2.98E-10	2.25E-08	3.65E-04	N/A
Th-229	3.93E-10	1.34E-12	8.29E-07	4.45E-04	N/A
U-236	1.21E-10	5.63E-12	1.71E-09	2.21E-05	N/A
(1b) NES Sensitivity Analysis – Sorption					
C-14	2.67E-01	9.01E-04	1.83E-02	3.84E+02	N/A
Ca-41	5.83E-02	1.97E-04	7.69E-03	5.33E+02	N/A
Cd-113m	7.06E-17	5.56E-18	6.38E-17	1.02E-20	N/A
Cl-36	1.83E-02	1.68E-04	1.30E-02	2.11E+02	N/A
Hf-182	8.15E-11	2.75E-13	2.25E-09	2.12E-08	N/A
Mo-93	3.82E-04	1.29E-06	7.56E-04	1.35E+00	N/A
Nb-93m	2.60E-05	8.86E-08	7.57E-04	1.22E+00	N/A
Ni-59	1.35E-02	1.64E-04	1.30E-01	1.31E+04	N/A
Pu-239	8.86E-05	1.14E-06	7.94E-02	1.72E+04	N/A
Pu-242	1.94E-09	1.35E-10	1.94E-06	2.44E+00	N/A

Radionuclide	Spring Water Groundwater (Bq/L)	Ottawa River Surface Water (Bq/L)	Garden Area Soil (Bq/kg)	Ottawa River - Riverbed Sediment (Bq/kg)	Ottawa River - Rivershore Sediment (Bq/kg)
Sn-126	5.17E-09	6.94E-11	2.77E-08	5.42E-03	N/A
Th-229	4.30E-08	2.53E-10	2.93E-05	1.66E+00	N/A
Th-230	4.78E-07	1.64E-09	1.14E-03	6.13E-01	N/A
U-236	1.04E-10	3.35E-11	5.93E-08	1.37E-04	N/A
U-238	1.17E-04	3.96E-07	2.12E-02	2.92E-01	N/A
(1c) NES Sensitivity Analysis - Resaturation Rate - Faster					
Ca-41	4.92E-03	3.94E-05	3.38E-04	2.11E+02	N/A
Cd-113m	6.36E-22	8.41E-22	6.73E-21	1.13E-24	N/A
Hf-182	3.75E-15	1.28E-17	1.97E-15	5.78E-11	N/A
Mo-93	3.52E-05	1.47E-07	7.59E-05	1.08E+00	N/A
Nb-93m	1.64E-06	7.89E-09	7.55E-05	9.80E-01	N/A
Pu-242	8.36E-13	1.64E-12	2.64E-10	3.11E-02	N/A
Sn-126	8.95E-11	1.11E-12	9.28E-11	8.35E-05	N/A
Th-229	1.41E-09	1.09E-11	1.13E-07	9.41E-02	N/A
U-236	1.17E-13	6.12E-13	4.26E-11	2.52E-06	N/A
(1d) NES Sensitivity Analysis - Resaturation Rate - Slower					
Ca-41	4.94E-03	3.94E-05	3.38E-04	2.11E+02	N/A
Cd-113m	1.84E-22	6.01E-25	6.71E-24	1.09E-27	N/A
Hf-182	3.72E-15	1.27E-17	1.95E-15	5.74E-11	N/A
Mo-93	2.23E-05	1.44E-07	7.15E-05	1.05E+00	N/A
Nb-93m	1.03E-06	7.70E-09	7.11E-05	9.54E-01	N/A
Pu-242	8.30E-13	1.63E-12	2.63E-10	3.09E-02	N/A
Sn-126	8.93E-11	1.11E-12	9.22E-11	8.28E-05	N/A
Th-229	1.41E-09	1.09E-11	1.13E-07	9.41E-02	N/A
U-236	1.16E-13	6.07E-13	4.23E-11	2.50E-06	N/A
(1e) NES Sensitivity Analysis - Surface Erosion					
Ca-41	4.92E-03	3.94E-05	4.29E+01	2.11E+02	N/A
Cd-113m	5.42E-22	5.36E-22	1.03E-19	7.87E-25	N/A
Hf-182	3.75E-15	1.28E-17	5.24E-06	5.78E-11	N/A
Mo-93	3.46E-05	1.47E-07	2.34E+00	1.08E+00	N/A
Nb-93m	1.61E-06	7.88E-09	2.34E+00	9.79E-01	N/A
Pu-242	8.36E-13	1.64E-12	6.41E-05	3.11E-02	N/A
Sn-126	8.94E-11	1.11E-12	7.74E-04	8.35E-05	N/A

Radionuclide	Spring Water	Ottawa River	Garden Area	Ottawa River - Riverbed	Ottawa River - Rivershore
	Groundwater	Surface Water	Soil	Sediment	Sediment
	(Bq/L)	(Bq/L)	(Bq/kg)	(Bq/kg)	(Bq/kg)
Th-229	1.41E-09	1.09E-11	1.91E-03	9.41E-02	N/A
U-236	1.17E-13	6.12E-13	1.23E-06	2.52E-06	N/A
(1g) NES Sensitivity Analysis – Engineering Degradation					
Ca-41	1.40E-03	4.07E-05	3.15E-04	2.19E+02	N/A
Cd-113m	8.91E-20	5.36E-22	4.56E-21	7.87E-25	N/A
Hf-182	3.68E-15	1.26E-17	1.96E-15	6.89E-11	N/A
Mo-93	1.66E-05	1.48E-07	6.98E-05	1.09E+00	N/A
Nb-93m	7.63E-07	7.92E-09	6.94E-05	9.84E-01	N/A
Pu-242	7.96E-13	1.73E-12	2.68E-10	3.27E-02	N/A
Sn-126	9.89E-11	1.16E-12	9.74E-11	8.54E-05	N/A
Th-229	1.52E-09	1.18E-11	1.38E-07	1.02E-01	N/A
U-236	1.16E-13	5.64E-13	3.95E-11	2.32E-06	N/A
(2a) Disruptive Event - Site Investigation (Human Intrusion)					
Ca-41	4.92E-03	3.94E-05	4.73E-03	2.11E+02	N/A
Cd-113m	5.42E-22	5.36E-22	1.04E-05	7.87E-25	N/A
Hf-182	3.75E-15	1.28E-17	2.39E-06	5.78E-11	N/A
Mo-93	3.46E-05	1.47E-07	1.27E-03	1.08E+00	N/A
Nb-93m	1.61E-06	7.88E-09	2.55E-03	9.79E-01	N/A
Pu-242	8.36E-13	1.64E-12	5.91E-06	3.11E-02	N/A
Sn-126	8.94E-11	1.11E-12	5.42E-07	8.35E-05	N/A
Th-229	1.41E-09	1.09E-11	6.05E-07	9.41E-02	N/A
U-236	1.17E-13	6.12E-13	9.14E-08	2.52E-06	N/A
(2b) Disruptive Event - Extreme Degradation of Engineered Barriers					
C-14	1.71E-01	5.86E-04	8.31E-05	1.23E+03	N/A
Ca-41	8.11E-03	1.31E-04	3.98E-04	7.44E+02	N/A
Cd-113m	5.42E-22	5.36E-22	4.56E-21	7.87E-25	N/A
Cl-36	3.27E-03	3.28E-04	3.45E-03	5.63E+02	N/A
Hf-182	5.58E-09	1.89E-11	2.18E-09	4.52E-05	N/A
Mo-93	1.23E-04	4.17E-07	1.32E-05	1.44E+00	N/A
Nb-93m	5.25E-06	1.80E-08	1.12E-05	1.30E+00	N/A
Ni-59	9.68E-03	2.31E-04	9.81E-03	2.49E+04	N/A
Pu-239	1.32E-04	3.16E-05	3.41E-03	5.99E+05	N/A
Pu-240	1.32E-06	4.93E-09	5.54E-07	7.77E+01	N/A

Radionuclide	Spring Water	Ottawa River	Garden Area	Ottawa River - Riverbed	Ottawa River - Rivershore
	Groundwater	Surface Water	Soil	Sediment	Sediment
	(Bq/L)	(Bq/L)	(Bq/kg)	(Bq/kg)	(Bq/kg)
Pu-242	5.56E-08	2.50E-09	2.71E-07	4.65E+01	N/A
Sn-126	7.60E-09	1.69E-10	1.37E-08	1.71E-02	N/A
Th-229	3.80E-09	3.87E-11	9.44E-09	5.43E-01	N/A
Th-230	1.13E-07	3.83E-10	5.33E-08	1.07E+00	N/A
U-236	2.13E-09	1.23E-10	8.52E-09	5.08E-04	N/A
Zr-93	3.27E-04	1.11E-06	1.45E-04	4.15E+00	N/A
(3a) Defence-in-Depth Cases - Role of Waste Form					
Ca-41	4.92E-03	4.15E-05	3.46E-04	2.22E+02	N/A
Cd-113m	5.42E-22	5.36E-22	4.56E-21	7.87E-25	N/A
Hf-182	3.36E-14	1.15E-16	1.79E-14	4.52E-10	N/A
Mo-93	3.07E-04	1.03E-06	7.43E-04	5.94E+00	N/A
Nb-93m	1.43E-05	4.87E-08	7.39E-04	5.37E+00	N/A
Pu-242	3.11E-12	7.24E-12	1.10E-09	1.37E-01	N/A
Sn-126	1.76E-10	2.77E-12	2.31E-10	2.24E-04	N/A
Th-229	1.41E-09	1.09E-11	1.13E-07	9.41E-02	N/A
U-236	2.24E-13	1.11E-12	7.72E-11	4.56E-06	N/A
(3b) Defence-in-Depth Cases - Role of Existing Facility Structure					
Ca-41	1.36E-02	4.68E-05	7.83E-04	2.37E+02	N/A
Cd-113m	1.11E-14	5.18E-17	5.69E-16	9.24E-20	N/A
Hf-182	5.20E-11	1.76E-13	2.13E-11	8.92E-10	N/A
Mo-93	2.20E-04	7.43E-07	1.77E-04	1.02E+00	N/A
Nb-93m	1.05E-05	3.60E-08	1.75E-04	9.22E-01	N/A
Pu-242	2.11E-09	2.32E-11	4.51E-08	3.05E-01	N/A
Sn-126	5.28E-09	2.55E-11	2.73E-09	7.90E-04	N/A
Th-229	3.10E-09	1.70E-11	1.12E-07	1.02E-01	N/A
U-236	1.48E-10	5.51E-12	1.85E-09	2.12E-05	N/A
(3c) Defence-in-Depth Cases - Role of Grout					
Ca-41	2.00E-02	6.76E-05	2.56E-03	2.32E+02	N/A
Cd-113m	6.91E-21	3.65E-21	3.12E-20	5.41E-24	N/A
Hf-182	6.70E-14	2.26E-16	4.07E-13	1.13E-10	N/A
Mo-93	1.38E-04	4.67E-07	6.41E-04	1.06E+00	N/A
Nb-93m	6.52E-06	2.23E-08	6.39E-04	9.60E-01	N/A
Pu-242	7.30E-12	3.10E-12	1.37E-08	5.82E-02	N/A

Radionuclide	Spring Water Groundwater (Bq/L)	Ottawa River Surface Water (Bq/L)	Garden Area Soil (Bq/kg)	Ottawa River - Riverbed Sediment (Bq/kg)	Ottawa River - Rivershore Sediment (Bq/kg)
Sn-126	9.33E-10	3.72E-12	5.20E-10	5.91E-05	N/A
Th-229	9.31E-09	5.64E-11	8.43E-06	3.85E-01	N/A
U-236	5.52E-13	1.15E-12	4.50E-10	4.73E-06	N/A
(4a) What-If Cases - Mass Excavation					
Am-241	1.05E-08	2.30E-11	9.36E+02	1.31E-08	N/A
C-14	2.76E-02	9.57E-05	1.42E+04	3.21E+01	N/A
Ca-41	4.92E-03	3.94E-05	7.80E+01	2.11E+02	N/A
Cd-113m	5.42E-22	5.36E-22	1.64E-01	7.87E-25	N/A
Cl-36	6.88E-04	1.59E-05	2.30E+02	2.65E+01	N/A
H-3	1.80E+02	6.57E-01	2.61E+02	9.01E+03	N/A
Hf-182	3.75E-15	1.28E-17	3.42E-02	5.78E-11	N/A
Mo-93	3.46E-05	1.47E-07	2.01E+01	1.08E+00	N/A
Nb-93m	1.61E-06	7.88E-09	4.02E+01	9.79E-01	N/A
Ni-59	2.27E-03	7.28E-05	2.87E+03	7.67E+03	N/A
Ni-63	8.64E-07	2.94E-09	1.89E+05	1.24E-08	N/A
Pu-239	1.22E-06	4.32E-08	1.02E+03	7.43E+02	N/A
Pu-242	8.36E-13	1.64E-12	9.33E-02	3.11E-02	N/A
Sn-126	8.94E-11	1.11E-12	8.56E-03	8.35E-05	N/A
Th-229	1.41E-09	1.09E-11	6.84E-02	9.41E-02	N/A
Th-230	2.14E-07	7.35E-10	1.34E-01	2.13E-01	N/A
U-236	1.17E-13	6.12E-13	1.30E-03	2.52E-06	N/A
U-238	1.24E-05	4.62E-08	1.70E+00	1.37E-01	N/A
(4b) What-If Cases - River Level Fall					
Ca-41	4.92E-03	3.94E-05	3.38E-04	N/A	8.40E-01
Cd-113m	5.42E-22	5.36E-22	4.56E-21	N/A	1.75E-16
Hf-182	3.75E-15	1.28E-17	1.97E-15	N/A	1.71E-11
Mo-93	3.46E-05	1.47E-07	7.57E-05	N/A	4.43E-03
Nb-93m	1.61E-06	6.79E-09	7.53E-05	N/A	3.41E-03
Pu-242	8.36E-13	2.37E-12	3.43E-10	N/A	1.68E-04
Sn-126	8.94E-11	1.11E-12	9.29E-11	N/A	4.29E-07
Th-229	1.41E-09	1.55E-11	1.13E-07	N/A	8.69E-04
U-236	1.17E-13	6.12E-13	4.26E-11	N/A	9.42E-09

Note: N/A – not applicable

Table 3.6 Radiological Exposure Point Concentrations for Consumed Foods in Each Postclosure Scenario (1)

Radionuclide	Terrestrial Vegetation	Earthworm (2)	Fish	Benthic Invertebrates	Aquatic Vegetation	Birds (avg. Grouse, Mallard, Heron)	Birds (avg. Grouse, Mallard, Heron)	Mammals (avg. Vole, Shrew, Muskrat)	Mammals (avg. Vole, Shrew, Muskrat)	White-tailed Deer	White-tailed Deer
	Garden Area	Garden Area	Ottawa River	Ottawa River	Ottawa River	Ottawa River Drinking Water	Spring Drinking Water	Ottawa River Drinking Water	Spring Drinking Water	Ottawa River Drinking Water	Spring Drinking Water
	(Bq/kg ww)	(Bq/kg ww)	(Bq/kg ww)	(Bq/kg ww)	(Bq/kg ww)	(Bq/kg ww)	(Bq/kg ww)	(Bq/kg ww)	(Bq/kg ww)	(Bq/kg ww)	(Bq/kg ww)
(1) Normal Evolution Scenario (NES)											
Ca-41	1.35E-03	1.66E-05	5.52E-02	1.79E-02	1.48E-02	1.61E-02	1.61E-02	1.58E-01	1.58E-01	9.52E-04	2.31E-03
Cd-113m	1.45E-20	2.10E-20	1.23E-19	1.50E-16	3.38E-19	1.62E-17	1.62E-17	1.52E-18	1.52E-18	4.57E-21	4.57E-21
Hf-182	6.31E-18	-	2.69E-14	1.24E-15	1.28E-14	2.49E-14	2.50E-14	4.80E-12	4.83E-12	6.52E-19	5.11E-17
Mo-93	5.45E-06	1.21E-05	3.97E-06	5.29E-07	3.53E-05	3.29E-04	3.29E-04	1.98E-04	1.98E-04	3.11E-07	1.05E-06
Nb-93m	4.37E-07	3.84E-08	2.36E-06	7.88E-07	9.46E-06	4.94E-07	4.94E-07	2.99E-06	2.99E-06	1.03E-11	1.92E-11
Pu-242	7.40E-15	8.19E-12	3.45E-08	1.18E-09	6.56E-09	4.80E-08	4.80E-08	7.88E-08	7.88E-08	1.01E-16	8.23E-17
Sn-126	7.61E-12	-	3.34E-09	6.57E-10	1.11E-10	1.69E-07	1.69E-07	1.70E-08	1.70E-08	4.96E-12	2.58E-11
Th-229	7.45E-11	1.03E-09	2.08E-09	9.83E-09	1.31E-08	1.58E-06	1.58E-06	1.91E-06	1.91E-06	6.52E-12	1.34E-11
U-236	8.52E-14	3.75E-13	1.47E-12	6.06E-11	1.84E-10	3.19E-09	3.19E-09	7.59E-11	7.59E-11	1.04E-14	6.31E-15
(1a) NES Sensitivity Analysis – Radioactive Inventory											
Ca-41	1.22E-03	1.49E-05	4.80E-02	1.55E-02	1.29E-02	1.40E-02	1.40E-02	1.37E-01	1.37E-01	8.56E-04	2.19E-03
Cd-113m	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Hf-182	0.00E+00	-	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Mo-93	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Nb-93m	8.16E-19	7.17E-20	4.32E-15	1.44E-15	1.73E-14	4.64E-19	4.64E-19	8.81E-18	8.81E-18	9.93E-23	1.92E-23
Pu-242	2.06E-13	2.28E-10	5.21E-08	1.79E-09	9.93E-09	5.67E-08	5.67E-08	9.30E-08	9.30E-08	1.80E-15	8.84E-15
Sn-126	1.84E-09	-	8.94E-07	1.76E-07	2.98E-08	8.45E-07	8.48E-07	7.81E-08	7.98E-08	1.21E-09	2.19E-08
Th-229	5.47E-10	7.60E-09	2.55E-10	1.21E-09	1.61E-09	7.52E-09	7.52E-09	9.13E-09	9.14E-09	4.75E-11	4.95E-11
U-236	3.42E-12	1.50E-11	1.35E-11	5.57E-10	1.69E-09	2.79E-08	2.79E-08	6.65E-10	6.65E-10	2.61E-13	1.23E-12
(1b) NES Sensitivity Analysis - Sorption											
C-14	3.57E+00	3.96E+00	5.14E+00	4.69E+00	3.57E+00	1.62E+01	1.62E+01	1.24E+01	1.25E+01	7.17E+00	7.39E+00
Ca-41	3.08E-02	3.78E-04	2.75E-01	8.91E-02	3.08E-02	4.16E-02	4.17E-02	4.07E-01	4.11E-01	2.15E-02	3.76E-02
Cd-113m	2.03E-16	2.93E-16	1.28E-15	1.56E-12	2.03E-16	1.68E-13	1.68E-13	1.57E-14	1.57E-14	6.37E-17	7.18E-17
Cl-36	2.32E-01	2.35E-03	1.60E-02	2.36E-02	2.32E-01	6.99E-01	7.00E-01	3.37E-01	3.40E-01	2.11E-01	2.18E-01
Hf-182	7.19E-12	-	5.77E-10	2.67E-11	7.19E-12	3.12E-11	3.15E-11	6.49E-09	7.14E-09	5.49E-13	1.64E-12
Mo-93	5.45E-05	1.21E-04	3.49E-05	4.65E-06	5.45E-05	4.16E-04	4.18E-04	2.59E-04	2.66E-04	3.10E-06	1.13E-05
Nb-93m	4.39E-06	3.86E-07	2.66E-05	8.86E-06	4.39E-06	6.20E-07	6.20E-07	3.79E-06	3.79E-06	1.04E-10	2.48E-10
Ni-59	1.22E-02	9.33E-03	1.16E-02	1.64E-02	1.22E-02	6.86E+00	6.86E+00	3.29E+00	3.29E+00	3.42E-03	4.85E-03
Pu-239	2.22E-06	2.46E-03	2.39E-02	8.19E-04	2.22E-06	2.65E-02	2.65E-02	4.35E-02	4.35E-02	1.89E-08	2.09E-08
Pu-242	5.42E-11	6.00E-08	2.84E-06	9.75E-08	5.42E-11	3.78E-06	3.78E-06	6.20E-06	6.20E-06	4.62E-13	5.05E-13
Sn-126	2.27E-09	-	2.08E-07	4.10E-08	2.27E-09	1.10E-05	1.10E-05	1.10E-06	1.10E-06	1.42E-09	2.62E-09
Th-229	1.94E-08	2.69E-07	4.81E-08	2.28E-07	1.94E-08	2.78E-05	2.78E-05	3.36E-05	3.36E-05	1.68E-09	1.89E-09
Th-230	7.51E-07	1.04E-05	3.11E-07	1.47E-06	7.51E-07	1.03E-05	1.04E-05	1.26E-05	1.26E-05	6.53E-08	6.76E-08
U-236	1.19E-10	5.22E-10	8.04E-11	3.32E-09	1.19E-10	1.74E-07	1.74E-07	4.15E-09	4.15E-09	7.71E-12	8.30E-12

Radionuclide	Terrestrial Vegetation	Earthworm [2]	Fish	Benthic Invertebrates	Aquatic Vegetation	Birds (avg. Grouse, Mallard, Heron)	Birds (avg. Grouse, Mallard, Heron)	Mammals (avg. Vole, Shrew, Muskrat)	Mammals (avg. Vole, Shrew, Muskrat)	White-tailed Deer	White-tailed Deer
	Garden Area	Garden Area	Ottawa River	Ottawa River	Ottawa River	Ottawa River Drinking Water	Spring Drinking Water	Ottawa River Drinking Water	Spring Drinking Water	Ottawa River Drinking Water	Spring Drinking Water
	(Bq/kg ww)	(Bq/kg ww)	(Bq/kg ww)	(Bq/kg ww)	(Bq/kg ww)	(Bq/kg ww)	(Bq/kg ww)	(Bq/kg ww)	(Bq/kg ww)	(Bq/kg ww)	(Bq/kg ww)
U-238	4.25E-05	1.87E-04	9.50E-07	3.92E-05	4.25E-05	4.29E-04	4.32E-04	1.25E-05	1.29E-05	2.66E-06	3.64E-06
(1c) NES Sensitivity Analysis - Resaturation Rate - Faster											
Ca-41	1.35E-03	1.66E-05	5.52E-02	1.79E-02	1.48E-02	1.61E-02	1.61E-02	1.58E-01	1.58E-01	9.52E-04	2.31E-03
Cd-113m	2.14E-20	3.10E-20	1.93E-19	2.36E-16	5.30E-19	2.54E-17	2.54E-17	2.38E-18	2.38E-18	6.76E-21	6.73E-21
Hf-182	6.32E-18	-	2.69E-14	1.24E-15	1.28E-14	2.49E-14	2.50E-14	4.80E-12	4.83E-12	6.52E-19	5.11E-17
Mo-93	5.46E-06	1.21E-05	3.97E-06	5.30E-07	3.53E-05	3.29E-04	3.30E-04	1.98E-04	1.98E-04	3.12E-07	1.06E-06
Nb-93m	4.38E-07	3.85E-08	2.37E-06	7.89E-07	9.47E-06	4.94E-07	4.94E-07	2.99E-06	2.99E-06	1.03E-11	1.94E-11
Pu-242	7.40E-15	8.19E-12	3.45E-08	1.18E-09	6.57E-09	4.80E-08	4.80E-08	7.88E-08	7.88E-08	1.01E-16	8.23E-17
Sn-126	7.61E-12	-	3.34E-09	6.57E-10	1.11E-10	1.69E-07	1.69E-07	1.70E-08	1.70E-08	4.96E-12	2.58E-11
Th-229	7.45E-11	1.03E-09	2.08E-09	9.83E-09	1.31E-08	1.58E-06	1.58E-06	1.91E-06	1.91E-06	6.52E-12	1.34E-11
U-236	8.52E-14	3.75E-13	1.47E-12	6.06E-11	1.84E-10	3.19E-09	3.19E-09	7.59E-11	7.59E-11	1.04E-14	6.32E-15
(1d) NES Sensitivity Analysis - Resaturation Rate - Slower											
Ca-41	1.35E-03	1.66E-05	5.52E-02	1.79E-02	1.48E-02	1.61E-02	1.61E-02	1.58E-01	1.58E-01	9.52E-04	2.31E-03
Cd-113m	2.13E-23	3.09E-23	1.38E-22	1.68E-19	3.79E-22	1.82E-20	1.82E-20	1.70E-21	1.71E-21	6.71E-24	2.95E-23
Hf-182	6.25E-18	-	2.67E-14	1.23E-15	1.27E-14	2.48E-14	2.48E-14	4.77E-12	4.80E-12	6.45E-19	5.06E-17
Mo-93	5.15E-06	1.14E-05	3.88E-06	5.17E-07	3.45E-05	3.21E-04	3.21E-04	1.93E-04	1.93E-04	2.94E-07	7.69E-07
Nb-93m	4.13E-07	3.63E-08	2.31E-06	7.70E-07	9.24E-06	4.82E-07	4.82E-07	2.91E-06	2.91E-06	9.74E-12	1.54E-11
Pu-242	7.35E-15	8.14E-12	3.43E-08	1.18E-09	6.53E-09	4.78E-08	4.78E-08	7.84E-08	7.84E-08	1.01E-16	8.18E-17
Sn-126	7.56E-12	-	3.32E-09	6.53E-10	1.11E-10	1.68E-07	1.68E-07	1.68E-08	1.68E-08	4.93E-12	2.57E-11
Th-229	7.45E-11	1.03E-09	2.08E-09	9.83E-09	1.31E-08	1.58E-06	1.58E-06	1.91E-06	1.91E-06	6.52E-12	1.34E-11
U-236	8.45E-14	3.72E-13	1.46E-12	6.01E-11	1.82E-10	3.17E-09	3.17E-09	7.53E-11	7.53E-11	1.04E-14	6.26E-15
(1e) NES Sensitivity Analysis - Surface Erosion											
Ca-41	1.72E+02	2.11E+00	5.52E-02	1.79E-02	1.48E-02	1.05E+00	1.05E+00	1.34E+01	1.34E+01	1.20E+02	1.20E+02
Cd-113m	3.27E-19	4.74E-19	1.23E-19	1.50E-16	3.38E-19	1.63E-17	1.63E-17	1.55E-18	1.55E-18	1.02E-19	1.02E-19
Hf-182	1.68E-08	-	2.69E-14	1.24E-15	1.28E-14	6.83E-09	6.83E-09	1.64E-06	1.64E-06	1.27E-09	1.27E-09
Mo-93	1.69E-01	3.75E-01	3.97E-06	5.29E-07	3.53E-05	7.38E-03	7.38E-03	1.50E-02	1.50E-02	9.52E-03	9.52E-03
Nb-93m	1.36E-02	1.19E-03	2.36E-06	7.88E-07	9.46E-06	3.05E-06	3.05E-06	3.35E-05	3.35E-05	3.19E-07	3.19E-07
Pu-242	1.80E-09	1.99E-06	3.45E-08	1.18E-09	6.56E-09	4.82E-08	4.82E-08	8.02E-08	8.02E-08	1.52E-11	1.52E-11
Sn-126	6.35E-05	-	3.34E-09	6.57E-10	1.11E-10	1.30E-05	1.30E-05	1.90E-06	1.90E-06	3.92E-05	3.92E-05
Th-229	1.26E-06	1.76E-05	2.08E-09	9.83E-09	1.31E-08	1.64E-06	1.64E-06	2.11E-06	2.11E-06	1.10E-07	1.10E-07
U-236	2.46E-09	1.08E-08	1.47E-12	6.06E-11	1.84E-10	6.28E-09	6.28E-09	2.64E-10	2.64E-10	1.54E-10	1.54E-10
(1g) NES Sensitivity Analysis - Engineering Degradation											
Ca-41	1.26E-03	1.55E-05	5.70E-02	1.85E-02	1.53E-02	1.67E-02	1.67E-02	1.64E-01	1.64E-01	8.89E-04	1.27E-03
Cd-113m	1.45E-20	2.10E-20	1.23E-19	1.50E-16	3.38E-19	1.62E-17	1.62E-17	1.52E-18	1.52E-18	4.57E-21	1.56E-20
Hf-182	6.27E-18	-	2.65E-14	1.22E-15	1.26E-14	2.96E-14	2.96E-14	5.69E-12	5.71E-12	6.45E-19	5.01E-17
Mo-93	5.03E-06	1.12E-05	3.98E-06	5.31E-07	3.54E-05	3.31E-04	3.31E-04	1.99E-04	1.99E-04	2.87E-07	6.39E-07
Nb-93m	4.03E-07	3.54E-08	2.38E-06	7.92E-07	9.50E-06	4.96E-07	4.96E-07	3.00E-06	3.00E-06	9.51E-12	1.37E-11

Radionuclide	Terrestrial Vegetation	Earthworm [(2)]	Fish	Benthic Invertebrates	Aquatic Vegetation	Birds (avg. Grouse, Mallard, Heron)	Birds (avg. Grouse, Mallard, Heron)	Mammals (avg. Vole, Shrew, Muskrat)	Mammals (avg. Vole, Shrew, Muskrat)	White-tailed Deer	White-tailed Deer
	Garden Area	Garden Area	Ottawa River	Ottawa River	Ottawa River	Ottawa River Drinking Water	Spring Drinking Water	Ottawa River Drinking Water	Spring Drinking Water	Ottawa River Drinking Water	Spring Drinking Water
	(Bq/kg ww)	(Bq/kg ww)	(Bq/kg ww)	(Bq/kg ww)	(Bq/kg ww)	(Bq/kg ww)	(Bq/kg ww)	(Bq/kg ww)	(Bq/kg ww)	(Bq/kg ww)	(Bq/kg ww)
Pu-242	7.51E-15	8.32E-12	3.63E-08	1.24E-09	6.91E-09	5.06E-08	5.06E-08	8.30E-08	8.30E-08	1.04E-16	8.23E-17
Sn-126	7.98E-12	-	3.49E-09	6.87E-10	1.16E-10	1.73E-07	1.73E-07	1.74E-08	1.74E-08	5.20E-12	2.82E-11
Th-229	9.12E-11	1.27E-09	2.24E-09	1.06E-08	1.41E-08	1.71E-06	1.71E-06	2.06E-06	2.06E-06	7.98E-12	1.54E-11
U-236	7.90E-14	3.48E-13	1.35E-12	5.58E-11	1.69E-10	2.94E-09	2.94E-09	6.99E-11	6.99E-11	9.65E-15	5.91E-15
(2a) Disruptive Event - Site Investigation (Human Intrusion)											
Ca-41	1.89E-02	2.32E-04	5.52E-02	1.79E-02	1.48E-02	1.62E-02	1.62E-02	1.59E-01	1.59E-01	1.32E-02	1.45E-02
Cd-113m	3.30E-05	4.77E-05	1.23E-19	1.50E-16	3.38E-19	9.79E-06	9.79E-06	3.47E-06	3.47E-06	1.03E-05	1.03E-05
Hf-182	7.64E-09	-	2.69E-14	1.24E-15	1.28E-14	3.11E-09	3.11E-09	7.49E-07	7.49E-07	5.80E-10	5.80E-10
Mo-93	9.17E-05	2.04E-04	3.97E-06	5.29E-07	3.53E-05	3.33E-04	3.33E-04	2.05E-04	2.06E-04	5.18E-06	5.92E-06
Nb-93m	1.48E-05	1.30E-06	2.36E-06	7.88E-07	9.46E-06	4.97E-07	4.97E-07	3.02E-06	3.02E-06	3.47E-10	3.56E-10
Pu-242	1.65E-10	1.83E-07	3.45E-08	1.18E-09	6.56E-09	4.80E-08	4.80E-08	7.90E-08	7.90E-08	1.40E-12	1.40E-12
Sn-126	4.45E-08	-	3.34E-09	6.57E-10	1.11E-10	1.78E-07	1.78E-07	1.83E-08	1.83E-08	2.75E-08	2.75E-08
Th-229	3.99E-10	5.55E-09	2.08E-09	9.83E-09	1.31E-08	1.58E-06	1.58E-06	1.91E-06	1.91E-06	3.48E-11	4.17E-11
U-236	1.83E-10	8.04E-10	1.47E-12	6.06E-11	1.84E-10	3.42E-09	3.42E-09	8.98E-11	8.98E-11	1.15E-11	1.14E-11
(2b) Disruptive Event - Extreme Degradation of Engineered Structures											
C-14	1.62E-02	1.80E-02	3.34E+00	3.05E+00	3.46E+00	1.96E+01	1.96E+01	1.01E+01	1.02E+01	3.30E-02	1.70E-01
Ca-41	1.59E-03	1.96E-05	1.83E-01	5.92E-02	4.90E-02	5.68E-02	5.68E-02	5.56E-01	5.57E-01	1.15E-03	3.37E-03
Cd-113m	1.45E-20	2.10E-20	1.23E-19	1.50E-16	3.38E-19	1.62E-17	1.62E-17	1.52E-18	1.52E-18	4.57E-21	4.57E-21
Cl-36	6.14E-02	6.24E-04	3.11E-02	4.59E-02	1.64E-02	1.73E+00	1.73E+00	8.16E-01	8.16E-01	5.60E-02	5.70E-02
Hf-182	6.98E-12	-	3.98E-08	1.84E-09	1.89E-08	2.01E-08	2.02E-08	3.89E-06	3.93E-06	7.85E-13	7.57E-11
Mo-93	9.49E-07	2.11E-06	1.13E-05	1.50E-06	1.00E-04	4.39E-04	4.40E-04	2.65E-04	2.67E-04	6.25E-08	2.70E-06
Nb-93m	6.52E-08	5.74E-09	5.39E-06	1.80E-06	2.15E-05	6.58E-07	6.59E-07	3.98E-06	3.99E-06	1.63E-12	3.07E-11
Ni-59	9.22E-04	7.06E-04	1.64E-02	2.31E-02	1.20E-02	1.30E+01	1.30E+01	6.24E+00	6.24E+00	2.82E-04	1.29E-03
Pu-239	9.56E-08	1.06E-04	6.64E-01	2.28E-02	1.26E-01	9.27E-01	9.27E-01	1.52E+00	1.52E+00	1.55E-09	3.93E-09
Pu-240	1.55E-11	1.72E-08	1.04E-04	3.55E-06	1.97E-05	1.20E-04	1.20E-04	1.97E-04	1.97E-04	2.48E-13	3.13E-11
Pu-242	7.58E-12	8.40E-09	5.24E-05	1.80E-06	9.99E-06	7.19E-05	7.19E-05	1.18E-04	1.18E-04	1.23E-13	1.37E-12
Sn-126	1.12E-09	-	5.07E-07	9.97E-08	1.69E-08	3.48E-05	3.48E-05	3.48E-06	3.48E-06	7.32E-10	2.48E-09
Th-229	6.23E-12	8.66E-11	7.36E-09	3.49E-08	4.65E-08	9.13E-06	9.13E-06	1.10E-05	1.10E-05	7.32E-13	1.92E-11
Th-230	3.52E-11	4.89E-10	7.28E-08	3.45E-07	4.60E-07	1.80E-05	1.80E-05	2.18E-05	2.18E-05	4.94E-12	5.57E-10
U-236	1.70E-11	7.50E-11	2.96E-10	1.22E-08	3.70E-08	6.43E-07	6.43E-07	1.53E-08	1.53E-08	2.10E-12	1.88E-11
Zr-93	9.28E-08	1.38E-06	1.05E-04	3.32E-03	3.54E-03	4.45E-07	4.45E-07	2.48E-06	2.50E-06	7.16E-11	8.44E-09
(3a) Defence-in-Depth Cases - Role of Waste Form											
Ca-41	1.39E-03	1.70E-05	5.81E-02	1.88E-02	1.56E-02	1.70E-02	1.70E-02	1.66E-01	1.67E-01	9.76E-04	2.34E-03
Cd-113m	1.45E-20	2.10E-20	1.23E-19	1.50E-16	3.38E-19	1.62E-17	1.62E-17	1.52E-18	1.52E-18	4.57E-21	4.57E-21
Hf-182	5.71E-17	-	2.41E-13	1.11E-14	1.15E-13	1.96E-13	1.96E-13	3.78E-11	3.80E-11	5.88E-18	4.58E-16
Mo-93	5.35E-05	1.19E-04	2.79E-05	3.73E-06	2.48E-04	1.81E-03	1.81E-03	1.09E-03	1.09E-03	3.04E-06	9.59E-06
Nb-93m	4.28E-06	3.77E-07	1.46E-05	4.87E-06	5.85E-05	2.71E-06	2.71E-06	1.64E-05	1.64E-05	1.01E-10	1.80E-10

Radionuclide	Terrestrial Vegetation	Earthworm [2]	Fish	Benthic Invertebrates	Aquatic Vegetation	Birds (avg. Grouse, Mallard, Heron)	Birds (avg. Grouse, Mallard, Heron)	Mammals (avg. Vole, Shrew, Muskrat)	Mammals (avg. Vole, Shrew, Muskrat)	White-tailed Deer	White-tailed Deer
	Garden Area	Garden Area	Ottawa River	Ottawa River	Ottawa River	Ottawa River Drinking Water	Spring Drinking Water	Ottawa River Drinking Water	Spring Drinking Water	Ottawa River Drinking Water	Spring Drinking Water
	(Bq/kg ww)	(Bq/kg ww)	(Bq/kg ww)	(Bq/kg ww)	(Bq/kg ww)	(Bq/kg ww)	(Bq/kg ww)	(Bq/kg ww)	(Bq/kg ww)	(Bq/kg ww)	(Bq/kg ww)
Pu-242	3.09E-14	3.42E-11	1.52E-07	5.22E-09	2.90E-08	2.12E-07	2.12E-07	3.48E-07	3.48E-07	4.32E-16	3.35E-16
Sn-126	1.90E-11	-	8.30E-09	1.63E-09	2.77E-10	4.54E-07	4.54E-07	4.55E-08	4.55E-08	1.24E-11	5.30E-11
Th-229	7.45E-11	1.03E-09	2.08E-09	9.83E-09	1.31E-08	1.58E-06	1.58E-06	1.91E-06	1.91E-06	6.53E-12	1.34E-11
U-236	1.54E-13	6.80E-13	2.66E-12	1.10E-10	3.32E-10	5.78E-09	5.78E-09	1.37E-10	1.37E-10	1.89E-14	1.15E-14
(3b) Defence-in-Depth Cases - Role of Existing Facility Structure											
Ca-41	3.13E-03	3.85E-05	6.56E-02	2.12E-02	1.76E-02	1.82E-02	1.82E-02	1.78E-01	1.79E-01	2.19E-03	5.96E-03
Cd-113m	1.81E-15	2.62E-15	1.19E-14	1.45E-11	3.26E-14	1.57E-12	1.57E-12	1.47E-13	1.47E-13	5.69E-16	1.94E-15
Hf-182	6.81E-14	-	3.69E-10	1.70E-11	1.76E-10	1.28E-11	1.30E-11	2.69E-09	3.10E-09	7.53E-15	7.07E-13
Mo-93	1.27E-05	2.83E-05	2.01E-05	2.67E-06	1.78E-04	3.12E-04	3.13E-04	1.91E-04	1.95E-04	7.35E-07	5.43E-06
Nb-93m	1.02E-06	8.93E-08	1.08E-05	3.60E-06	4.33E-05	4.66E-07	4.66E-07	2.83E-06	2.84E-06	2.41E-11	8.26E-11
Pu-242	1.26E-12	1.40E-09	4.88E-07	1.67E-08	9.29E-08	4.72E-07	4.72E-07	7.75E-07	7.75E-07	1.12E-14	6.05E-14
Sn-126	2.24E-10	-	7.64E-08	1.50E-08	2.55E-09	1.61E-06	1.61E-06	1.61E-07	1.61E-07	1.44E-10	1.38E-09
Th-229	7.39E-11	1.03E-09	3.24E-09	1.53E-08	2.04E-08	1.72E-06	1.72E-06	2.08E-06	2.08E-06	6.51E-12	2.17E-11
U-236	3.70E-12	1.63E-11	1.32E-11	5.46E-10	1.65E-09	2.68E-08	2.68E-08	6.38E-10	6.39E-10	2.78E-13	1.47E-12
(3c) Defence-in-Depth Cases - Role of Grout											
Ca-41	1.03E-02	1.26E-04	9.47E-02	3.06E-02	2.54E-02	1.80E-02	1.80E-02	1.76E-01	1.77E-01	7.16E-03	1.27E-02
Cd-113m	9.94E-20	1.44E-19	8.40E-19	1.02E-15	2.30E-18	1.10E-16	1.10E-16	1.03E-17	1.03E-17	3.13E-20	3.17E-20
Hf-182	1.30E-15	-	4.75E-13	2.19E-14	2.26E-13	6.35E-14	6.37E-14	1.25E-11	1.30E-11	1.02E-16	1.00E-15
Mo-93	4.62E-05	1.03E-04	1.26E-05	1.68E-06	1.12E-04	3.25E-04	3.26E-04	2.00E-04	2.02E-04	2.62E-06	5.57E-06
Nb-93m	3.71E-06	3.26E-07	6.69E-06	2.23E-06	2.68E-05	4.86E-07	4.86E-07	2.95E-06	2.95E-06	8.73E-11	1.24E-10
Pu-242	3.82E-13	4.23E-10	6.50E-08	2.23E-09	1.24E-08	9.01E-08	9.01E-08	1.48E-07	1.48E-07	3.31E-15	3.41E-15
Sn-126	4.26E-11	-	1.12E-08	2.20E-09	3.72E-10	1.21E-07	1.21E-07	1.21E-08	1.21E-08	2.72E-11	2.46E-10
Th-229	5.56E-09	7.73E-08	1.07E-08	5.08E-08	6.77E-08	6.47E-06	6.47E-06	7.81E-06	7.81E-06	4.84E-10	5.29E-10
U-236	8.99E-13	3.96E-12	2.76E-12	1.14E-10	3.44E-10	5.99E-09	5.99E-09	1.42E-10	1.42E-10	6.59E-14	6.09E-14
(4a) What-If Cases - Mass Excavation											
Am-241	1.18E-01	1.68E+02	5.53E-09	2.76E-08	7.14E-08	8.40E-03	8.40E-03	6.86E-02	6.86E-02	1.03E-01	1.03E-01
C-14	2.77E+06	3.07E+06	5.46E-01	4.98E-01	5.65E-01	3.00E+06	3.00E+06	3.71E+06	3.71E+06	5.56E+06	5.56E+06
Ca-41	3.12E+02	3.83E+00	5.52E-02	1.79E-02	1.48E-02	1.89E+00	1.89E+00	2.42E+01	2.42E+01	2.17E+02	2.17E+02
Cd-113m	5.21E-01	7.54E-01	1.23E-19	1.50E-16	3.38E-19	1.54E-01	1.54E-01	5.47E-02	5.47E-02	1.62E-01	1.62E-01
Cl-36	4.09E+03	4.16E+01	1.51E-03	2.22E-03	7.94E-04	9.90E+02	9.90E+02	6.03E+02	6.03E+02	3.72E+03	3.72E+03
H-3	1.40E+03	3.91E+04	4.93E-01	4.93E-01	4.93E-01	7.17E+02	7.18E+02	2.36E+03	2.36E+03	2.93E+02	2.96E+02
Hf-182	1.09E-04	-	2.69E-14	1.24E-15	1.28E-14	4.45E-05	4.45E-05	1.07E-02	1.07E-02	8.30E-06	8.30E-06
Mo-93	1.45E+00	3.22E+00	3.97E-06	5.29E-07	3.53E-05	6.09E-02	6.09E-02	1.27E-01	1.27E-01	8.17E-02	8.17E-02
Nb-93m	2.33E-01	2.05E-02	2.36E-06	7.88E-07	9.46E-06	4.44E-05	4.44E-05	5.26E-04	5.26E-04	5.48E-06	5.48E-06
Ni-59	2.70E+02	2.06E+02	5.17E-03	7.28E-03	3.79E-03	1.95E+01	1.95E+01	1.92E+01	1.92E+01	7.52E+01	7.52E+01
Ni-63	1.78E+04	1.40E+04	2.09E-07	2.94E-07	1.53E-07	1.02E+03	1.02E+03	1.15E+03	1.15E+03	4.96E+03	4.96E+03
Pu-239	2.86E-02	3.17E+01	9.08E-04	3.11E-05	1.73E-04	4.58E-03	4.58E-03	2.33E-02	2.33E-02	2.42E-04	2.42E-04

Radionuclide	Terrestrial Vegetation	Earthworm [2]	Fish	Benthic Invertebrates	Aquatic Vegetation	Birds (avg. Grouse, Mallard, Heron)	Birds (avg. Grouse, Mallard, Heron)	Mammals (avg. Vole, Shrew, Muskrat)	Mammals (avg. Vole, Shrew, Muskrat)	White-tailed Deer	White-tailed Deer
	Garden Area	Garden Area	Ottawa River	Ottawa River	Ottawa River	Ottawa River Drinking Water	Spring Drinking Water	Ottawa River Drinking Water	Spring Drinking Water	Ottawa River Drinking Water	Spring Drinking Water
	(Bq/kg ww)	(Bq/kg ww)	(Bq/kg ww)	(Bq/kg ww)	(Bq/kg ww)	(Bq/kg ww)	(Bq/kg ww)	(Bq/kg ww)	(Bq/kg ww)	(Bq/kg ww)	(Bq/kg ww)
Pu-242	2.61E-06	2.89E-03	3.45E-08	1.18E-09	6.56E-09	3.61E-07	3.61E-07	2.03E-06	2.03E-06	2.21E-08	2.21E-08
Sn-126	7.02E-04	-	3.34E-09	6.57E-10	1.11E-10	1.43E-04	1.43E-04	2.08E-05	2.08E-05	4.34E-04	4.34E-04
Th-229	4.51E-05	6.27E-04	2.07E-09	9.81E-09	1.31E-08	3.76E-06	3.76E-06	8.92E-06	8.92E-06	3.92E-06	3.92E-06
Th-230	8.84E-05	1.23E-03	1.40E-07	6.62E-07	8.82E-07	7.84E-06	7.84E-06	1.81E-05	1.81E-05	7.69E-06	7.69E-06
U-236	2.61E-06	1.15E-05	1.47E-12	6.06E-11	1.84E-10	3.28E-06	3.28E-06	1.99E-07	1.99E-07	1.63E-07	1.63E-07
U-238	3.40E-03	1.50E-02	1.11E-07	4.58E-06	1.39E-05	4.45E-03	4.45E-03	2.63E-04	2.64E-04	2.13E-04	2.13E-04
(4b) What-If Cases - River Level Fall											
Ca-41	1.35E-03	1.66E-05	5.52E-02	1.79E-02	1.48E-02	3.06E-04	3.14E-04	2.68E-03	3.04E-03	9.52E-04	2.31E-03
Cd-113m	1.45E-20	2.10E-20	1.23E-19	1.50E-16	3.38E-19	1.62E-17	1.62E-17	1.52E-18	1.52E-18	4.57E-21	4.57E-21
Hf-182	6.32E-18	-	2.69E-14	1.24E-15	1.28E-14	9.11E-16	9.24E-16	1.92E-13	2.21E-13	6.52E-19	5.11E-17
Mo-93	5.45E-06	1.21E-05	3.97E-06	5.29E-07	3.53E-05	7.04E-07	9.14E-07	1.53E-06	2.15E-06	3.11E-07	1.05E-06
Nb-93m	4.37E-07	3.84E-08	2.04E-06	6.79E-07	8.14E-06	3.01E-10	3.17E-10	5.13E-09	5.62E-09	1.03E-11	1.92E-11
Pu-242	9.60E-15	1.0627E-11	4.97E-08	1.70E-09	9.47E-09	4.49E-12	4.49E-12	5.32E-12	5.32E-12	1.37E-16	1.01E-16
Sn-126	7.62E-12	-	3.34E-09	6.58E-10	1.11E-10	3.97E-10	4.01E-10	1.49E-11	1.67E-11	4.97E-12	2.58E-11
Th-229	7.49E-11	1.04E-09	2.94E-09	1.39E-08	1.86E-08	2.66E-11	2.71E-11	8.21E-11	8.50E-11	6.58E-12	1.35E-11
U-236	8.52E-14	3.75E-13	1.47E-12	6.06E-11	1.84E-10	1.18E-11	1.18E-11	9.51E-13	9.49E-13	1.04E-14	6.31E-15

Notes:

(1) Calculated using the transfer parameters presented in Table 3.12 and the feed-to-flesh transfer factors for tritium in Table 3.14 and carbon-14 in Table 3.17.

(2) Soil-to-earthworm transfer factors are not available for Hf-182 and Sn-126.

Table 3.7 Non-Radiological Environmental Exposure Point Concentrations for the Postclosure Scenarios

Scenario	Contaminant	Spring Water (mg/L)	Ottawa River - Surface Water (mg/L)	Garden Area - Soil (mg/kg)	Ottawa River - Riverbed Sediment (mg/kg)
(4a) What-If: Mass Excavation					
Total Concentration (Incremental + Baseline)	Lead (Pb)	8.50E-04	9.74E-05	1.76E+03	1.00E+01
Baseline Concentration					
Baseline Concentration	Lead (Pb)	8.50E-04	9.74E-05	3.00E+01	1.00E+01

Table 3.8 Non-Radiological Exposure Point Concentrations for Consumed Foods in Postclosure Scenarios (1)

Contaminant	Terrestrial Vegetation	Earthworm	Fish	Benthic Invertebrates	Aquatic Vegetation	Birds (avg. Grouse, Mallard, Heron)	Birds (avg. Grouse, Mallard, Heron)	Mammals (avg. Vole, Shrew, Muskrat)	Mammals (avg. Vole, Shrew, Muskrat)	White-tailed Deer	White-tailed Deer
	Garden Area	Garden Area	Ottawa River	Ottawa River	Ottawa River	Ottawa River Drinking Water	Spring Drinking Water	Ottawa River Drinking Water	Spring Drinking Water	Ottawa River Drinking Water	Spring Drinking Water
	(mg/kg ww)	(mg/kg ww)	(mg/kg ww)	(mg/kg ww)	(mg/kg ww)	(mg/kg ww)	(mg/kg ww)	(mg/kg ww)	(mg/kg ww)	(mg/kg ww)	(mg/kg ww)
(4a) What-If - Mass Excavation											
Lead (Pb)	1.09E+02	8.74E+01	3.60E-02	2.14E-03	1.85E-01	1.75E+01	1.75E+01	1.23E+00	1.23E+00	4.36E+00	4.36E+00

Notes:

(1) Calculated using the transfer parameters presented in Table 3.10.

3.5 Dose Calculation Methods

The COPCs identified through the screening process (see Section 2.4) were quantitatively evaluated for all ecological receptors, based on the identified pathways and environmental media for each scenario. Sufficient data were not available for the quantitative assessment of the Monarch Butterfly and Eastern Milksnake for exposure to both radiological and non-radiological COPCs and Blanding's Turtle for exposure to non-radiological COPCs. However, inferences regarding their exposure are discussed in Section 5.3.

3.5.1 Radiological COPCs

For radiological COPCs, the resulting radiation dose involves both internal and external components, which are calculated separately. The total radiation dose, per radionuclide, is the sum of all internal and external doses. The overall radiation dose is the total sum of all internal/external doses from all radionuclides.

3.5.1.1 Aquatic Biota – Internal & External Radiation Dose

For aquatic biota, the internal dose calculation is performed for each radionuclide, following Equation 3-1 (CSA 2012, Clause 7.3.4.1.2):

$$D_{\text{int}} = DC_{\text{int}} \times C_{tissue} \qquad (3\text{-}1)$$

where

D_{int} = internal radiation dose [μGy/h]

DC_{int} = internal dose coefficient for radionuclide in tissue [μGy/h per Bq/(kg fw)]

C_{tissue} = whole body tissue concentration [Bq/(kg fw)]

The external dose calculation was performed for each radionuclide using the following equation from N288.6-12 (CSA 2012, Clause 7.3.4.1.2), except the external DC for exposure on sediment (OF_{ss}) was not reduced by 0.5 as external DCs for this exposure are now available from ERICA (2019). Previously, the external DC for in sediment exposure was applied and reduced by a factor 0.5 to account for the diminished exposure compared to when immersed in sediment.

$$D_{ext} = DC_{ext}[(OFw + 0.5 \times OFws + OFss) \times Cw + (OFs + OFss) \times Cs] \qquad (3\text{-}2)$$

where

D_{ext} = external radiation dose [μGy/h]

DC_{ext} = external dose coefficient for radionuclide in water or sediment [μGy/h per Bq/kg; or μGy/h per Bq/L]

OF_w = fraction of time spent immersed in surface water [unitless]

OF_s = fraction of time spent immersed in sediment [unitless]

OF_{ws} = fraction of time spent on the water's surface [unitless]

OF_{ss} = fraction of time spent on the sediment's surface [unitless]

C_w = surface water concentration [Bq/L]

C_s = sediment concentration [Bq/kg]

3.5.1.2 Terrestrial Biota – Internal & External Radiation Dose

For terrestrial biota, the internal dose calculation is performed for each radionuclide, following Equation 3-3 (CSA 2012, Clause 7.3.4.1.3):

$$D_{\text{int}} = DC_{\text{int}} \times C_{tissue} \qquad (3\text{-}3)$$

where

D_{int} = internal radiation dose [μGy/h]

DC_{int} = internal dose coefficient for radionuclide in tissue [μGy/h per Bq/(kg fw)]

C_{tissue} = whole body tissue concentration [Bq/(kg fw)]

The external dose calculation is performed for each radionuclide, following Equation 3-4 and Equation 3-5 (CSA 2012, Clause 7.3.4.1.3):

$$D_{ext} = DC_{ext} \times OFs \times Csoil \qquad (3\text{-}4)$$

$$D_{ext} = DC_{ext} \times OFss \times Csoil \qquad (3\text{-}5)$$

where

D_{ext} = external radiation dose [μGy/h]

DC_{ext} = external dose coefficient for radionuclide in soil [μGy/h per Bq/kg]

OF_{sl} = fraction of time spent immersed in soil [unitless]

OF_{ss} = fraction of time spent immersed on soil [unitless]

C_{soil} = soil concentration [Bq/kg]

3.5.1.3 Dose Coefficients

The dose coefficients (DCs) used in the EcoRA calculations were obtained from the ERICA Assessment Tool (version 1.3, ERICA 2019). The DCs in ERICA are adapted from the FASSET (Framework for the Assessment of Environmental Impact) Project (Pröhl 2003). Weighting factors were applied, as described below. Missing DC values were infilled first from the International Commission on Radiological Protection

Publication 136 (ICRP 2017) and then from Amiro (1997). The DCs from Amiro (1997) are more conservative because they neglect organism geometry (i.e., assume infinite size) and therefore assume that all energies emitted by radionuclides from within the biota are absorbed by the biota, regardless of its actual size. The DCs from Amiro (1997) are also unweighted and an RBE factor of 10 was used for the alpha radiation component of internal dose from all alpha emitting radionuclides, following CSA (2012).

3.5.1.3.1 Radiological Weighting Factors

The radioecological weighting factor, also referred to as relative biological effectiveness (RBE), is the ratio of doses from different types of radiation needed to produce the same biological effect. For example:

$$\text{Alpha RBE} = \frac{\text{(Dose of gamma to produce a given effect)}}{\text{(Dose of alpha to produce the same effect)}}.$$

The radiological weighting factors recommended in the ERICA Tool (ERICA 2019) are:

- 10 for alpha radiation;
- 3 for low-energy (i.e., ≤ 10 eV) beta radiation; and
- 1 for high-energy (i.e., >10 eV) beta and gamma radiation.

The ERICA Tool (2019) provided freshwater and terrestrial internal (alpha; beta/gamma; low beta) and external (low beta; beta/gamma) unweighted DCs for each radionuclide/receptor pair. The internal and external DCs were then compiled for each radionuclide/receptor pair by summing the internal and external components, respectively, while applying the appropriate weighting factor to each component.

Use of the ERICA-recommended weighting factors is consistent with other sources. For example, FASSET (Pröhl 2003) applies a weighting factor of 10 to internal dose coefficients for alpha radiation. N288.6-12 (CSA 2012) recommends a value of 1-3 for the tritium (low-energy) absorbed dose for use at Canadian nuclear facilities and a factor of 10 for the alpha component of the internal dose.

3.5.1.3.2 Mapping to Reference Organisms

Each of the ecological receptors identified for this EcoRA was mapped to a representative organism in ERICA and ICRP, in order to select the most appropriate DC value. Table 3.9 shows the occupancy factors assigned to each ecological receptor.

Table 3.9 Mapping of EcoRA Receptors to ERICA and ICRP Representative Organisms and Assumed Occupancy Factors

EcoRA Receptor	OFis	OFos	OFw
American Mink		0.5	0.5
Aquatic Vegetation			1
Bald Eagle		1	
Benthic Fish	0.5		0.5
Benthic Invertebrates	0.5		0.5
Berries		1	
Black Bear		1	
Blanding's Turtle		0.5	0.5
Chimney Swift		1	
Little Brown Myotis (bat)		1	
Earthworm	1		
Eastern Wolf		1	
Great Blue Heron		0.5	0.5
Green Frog (tadpole)	0.5		0.5
Mallard		0.5	0.5
Meadow Vole	0.5	0.5	
Moose		1	
Mushroom		1	
Muskrat		0.5	0.5
Northern River Otter		0.5	0.5
Pelagic Fish			1
Red Fox		1	
Ruffed Grouse		1	
Short-tailed Shrew	0.5	0.5	
Short-tailed Weasel	0.5	0.5	
Terrestrial Vegetation		1	
White-tailed Deer		1	

Notes:
OFis: occupancy factor in soil or sediment
OFos: occupancy factor on soil or sediment surface
OFw: occupancy factor in water

3.5.1.3.3 Dose Coefficients

The DCs used in this assessment are summarized in Table 3.10.

Table 3.10 Dose Coefficients Used in the EcoRA

Radionuclide	Internal (Gy/y per Bq/kg)	Reference	External On-soil (Gy/y per Bq/kg)	Reference	External In-soil (Gy/y per Bq/kg)	Reference	Water (Gy/y per Bq/kg)	Reference
Aquatic Vegetation								
Am-241	2.78E-04	ERICA (2019)	-	-	-	-	1.58E-07	ERICA (2019)
C-14	2.41E-07	ERICA (2019)	-	-	-	-	9.64E-09	ERICA (2019)
Ca-41	1.40E-08	Amiro (1997)	-	-	-	-	1.87E-09	Amiro (1997)
Cd-113m	9.37E-07	Amiro (1997)	-	-	-	-	2.82E-07	Amiro (1997)
Cl-36	9.64E-07	ERICA (2019)	-	-	-	-	4.82E-07	ERICA (2019)
H-3	7.23E-08	ERICA (2019)	-	-	-	-	3.22E-11	ERICA (2019)
Hf-182	1.63E-06	Amiro (1997)	-	-	-	-	1.04E-06	Amiro (1997)
Mo-93	8.22E-08	Amiro (1997)	-	-	-	-	4.97E-08	Amiro (1997)
Nb-93m	1.53E-07	Amiro (1997)	-	-	-	-	8.90E-09	Amiro (1997)
Ni-59	7.63E-08	ERICA (2019)	-	-	-	-	5.70E-09	ERICA (2019)
Ni-63	1.07E-07	ERICA (2019)	-	-	-	-	5.45E-10	ERICA (2019)
Pu-239	2.63E-04	ERICA (2019)	-	-	-	-	3.51E-09	ERICA (2019)
Pu-240	2.63E-04	ERICA (2019)	-	-	-	-	8.06E-09	ERICA (2019)
Pu-242	2.52E-04	Amiro (1997) - RBE 10	-	-	-	-	6.70E-09	Amiro (1997)
Sn-126	1.20E-05	Amiro (1997)	-	-	-	-	7.98E-06	Amiro (1997)
Th-229	2.48E-04	ICRP (2017)	-	-	-	-	4.47E-07	ICRP (2017)
Th-230	2.37E-04	ERICA (2019)	-	-	-	-	8.24E-09	ERICA (2019)
U-236	2.33E-04	Amiro (1997) - RBE 10	-	-	-	-	7.31E-09	Amiro (1997)
U-238	2.10E-04	ERICA (2019)	-	-	-	-	6.31E-09	ERICA (2019)
Zr-93	9.92E-08	Amiro (1997)	-	-	-	-	0.00E+00	Amiro (1997)
Bald Eagle								
Am-241	2.78E-04	ERICA (2019)	2.19E-08	ERICA (2019)	-	-	-	-
C-14	2.59E-07	ERICA (2019)	0.00E+00	ERICA (2019)	-	-	-	-
Ca-41	1.40E-08	Amiro (1997)	2.81E-09	Amiro (1997)	-	-	-	-
Cd-113m	9.37E-07	Amiro (1997)	4.23E-07	Amiro (1997)	-	-	-	-
Cl-36	1.40E-06	ERICA (2019)	2.72E-10	ERICA (2019)	-	-	-	-
H-3	7.23E-08	ERICA (2019)	0.00E+00	ERICA (2019)	-	-	-	-
Hf-182	1.63E-06	Amiro (1997)	1.56E-06	Amiro (1997)	-	-	-	-
Mo-93	8.22E-08	Amiro (1997)	7.46E-08	Amiro (1997)	-	-	-	-
Nb-93m	1.53E-07	Amiro (1997)	1.34E-08	Amiro (1997)	-	-	-	-
Ni-59	8.13E-08	ERICA (2019)	8.77E-42	ERICA (2019)	-	-	-	-

Radionuclide	Internal (Gy/y per Bq/kg)	Reference	External On-soil (Gy/y per Bq/kg)	Reference	External In-soil (Gy/y per Bq/kg)	Reference	Water (Gy/y per Bq/kg)	Reference
Ni-63	1.08E-07	ERICA (2019)	0.00E+00	ERICA (2019)	-	-	-	-
Pu-239	2.63E-04	ERICA (2019)	2.81E-10	ERICA (2019)	-	-	-	-
Pu-240	2.63E-04	ERICA (2019)	5.26E-10	ERICA (2019)	-	-	-	-
Pu-242	2.52E-04	Amiro (1997) - RBE 10	1.01E-08	Amiro (1997)	-	-	-	-
Sn-126	1.20E-05	Amiro (1997)	1.20E-05	Amiro (1997)	-	-	-	-
Th-229	2.48E-04	ICRP (2017)	1.14E-07	ICRP (2017)	-	-	-	-
Th-230	2.37E-04	ERICA (2019)	6.14E-10	ERICA (2019)	-	-	-	-
U-236	2.33E-04	Amiro (1997) - RBE 10	1.10E-08	Amiro (1997)	-	-	-	-
U-238	2.10E-04	ERICA (2019)	4.21E-10	ERICA (2019)	-	-	-	-
Zr-93	9.92E-08	Amiro (1997)	0.00E+00	Amiro (1997)	-	-	-	-
Benthic Fish								
Am-241	2.78E-04	ERICA (2019)	-	-	5.43E-08	ERICA (2019)	9.64E-08	ERICA (2019)
C-14	2.59E-07	ERICA (2019)	-	-	0.00E+00	ERICA (2019)	1.49E-10	ERICA (2019)
Ca-41	1.40E-08	Amiro (1997)	-	-	2.81E-09	Amiro (1997)	1.87E-09	Amiro (1997)
Cd-113m	9.37E-07	Amiro (1997)	-	-	4.23E-07	Amiro (1997)	2.82E-07	Amiro (1997)
Cl-36	1.40E-06	ERICA (2019)	-	-	7.10E-10	ERICA (2019)	1.14E-08	ERICA (2019)
H-3	7.23E-08	ERICA (2019)	-	-	0.00E+00	ERICA (2019)	3.24E-15	ERICA (2019)
Hf-182	1.63E-06	Amiro (1997)	-	-	1.56E-06	Amiro (1997)	1.04E-06	Amiro (1997)
Mo-93	8.22E-08	Amiro (1997)	-	-	7.46E-08	Amiro (1997)	4.97E-08	Amiro (1997)
Nb-93m	1.53E-07	Amiro (1997)	-	-	1.34E-08	Amiro (1997)	8.90E-09	Amiro (1997)
Ni-59	8.13E-08	ERICA (2019)	-	-	8.77E-10	ERICA (2019)	2.02E-10	ERICA (2019)
Ni-63	1.08E-07	ERICA (2019)	-	-	0.00E+00	ERICA (2019)	9.64E-12	ERICA (2019)
Pu-239	2.63E-04	ERICA (2019)	-	-	7.54E-10	ERICA (2019)	6.84E-10	ERICA (2019)
Pu-240	2.63E-04	ERICA (2019)	-	-	1.49E-09	ERICA (2019)	1.14E-09	ERICA (2019)
Pu-242	2.52E-04	Amiro (1997) - RBE 10	-	-	1.01E-08	Amiro (1997)	6.70E-09	Amiro (1997)
Sn-126	1.20E-05	Amiro (1997)	-	-	1.20E-05	Amiro (1997)	7.98E-06	Amiro (1997)
Th-229	2.48E-04	ICRP (2017)	-	-	6.52E-07	Amiro (1997)	3.68E-07	ICRP (2017)
Th-230	2.37E-04	ERICA (2019)	-	-	1.84E-09	ERICA (2019)	2.10E-09	ERICA (2019)
U-236	2.33E-04	Amiro (1997) - RBE 10	-	-	1.10E-08	Amiro (1997)	7.31E-09	Amiro (1997)
U-238	2.10E-04	ERICA (2019)	-	-	1.14E-09	ERICA (2019)	8.33E-10	ERICA (2019)
Zr-93	9.92E-08	Amiro (1997)	-	-	0.00E+00	Amiro (1997)	0.00E+00	Amiro (1997)
Benthic Invertebrates								
Am-241	2.78E-04	ERICA (2019)	-	-	5.43E-08	ERICA (2019)	1.58E-07	ERICA (2019)
C-14	2.50E-07	ERICA (2019)	-	-	0.00E+00	ERICA (2019)	7.89E-09	ERICA (2019)

Radionuclide	Internal (Gy/y per Bq/kg)	Reference	External On-soil (Gy/y per Bq/kg)	Reference	External In-soil (Gy/y per Bq/kg)	Reference	Water (Gy/y per Bq/kg)	Reference
Ca-41	1.40E-08	Amiro (1997)	-	-	2.81E-09	Amiro (1997)	1.87E-09	Amiro (1997)
Cd-113m	9.37E-07	Amiro (1997)	-	-	4.23E-07	Amiro (1997)	2.82E-07	Amiro (1997)
Cl-36	1.40E-06	ERICA (2019)	-	-	7.10E-10	ERICA (2019)	4.73E-07	ERICA (2019)
H-3	7.23E-08	ERICA (2019)	-	-	0.00E+00	ERICA (2019)	1.31E-14	ERICA (2019)
Hf-182	1.63E-06	Amiro	-	-	1.56E-06	Amiro	1.04E-06	Amiro
Mo-93	8.22E-08	Amiro (1997)	-	-	7.46E-08	Amiro (1997)	4.97E-08	Amiro (1997)
Nb-93m	1.53E-07	Amiro (1997)	-	-	1.34E-08	Amiro (1997)	8.90E-09	Amiro (1997)
Ni-59	7.93E-08	ERICA (2019)	-	-	8.77E-10	ERICA (2019)	6.14E-09	ERICA (2019)
Ni-63	1.08E-07	ERICA (2019)	-	-	0.00E+00	ERICA (2019)	5.00E-10	ERICA (2019)
Pu-239	2.63E-04	ERICA (2019)	-	-	7.54E-10	ERICA (2019)	3.51E-09	ERICA (2019)
Pu-240	2.63E-04	ERICA (2019)	-	-	1.49E-09	ERICA (2019)	8.33E-09	ERICA (2019)
Pu-242	2.52E-04	Amiro (1997) - RBE 10	-	-	1.01E-08	Amiro (1997)	6.70E-09	Amiro (1997)
Sn-126	1.20E-05	Amiro (1997)	-	-	1.20E-05	Amiro (1997)	7.98E-06	Amiro (1997)
Th-229	2.48E-04	ICRP (2017)	-	-	6.52E-07	Amiro (1997)	3.68E-07	ICRP (2017)
Th-230	2.37E-04	ERICA (2019)	-	-	1.84E-09	ERICA (2019)	8.06E-09	ERICA (2019)
U-236	2.33E-04	Amiro (1997) - RBE 10	-	-	1.10E-08	Amiro (1997)	7.31E-09	Amiro (1997)
U-238	2.10E-04	ERICA (2019)	-	-	1.14E-09	ERICA (2019)	6.40E-09	ERICA (2019)
Zr-93	9.92E-08	Amiro (1997)	-	-	0.00E+00	Amiro (1997)	0.00E+00	Amiro (1997)
Black Bear								
Am-241	2.78E-04	ERICA (2019)	8.06E-09	ERICA (2019)	-	-	-	-
C-14	2.59E-07	ERICA (2019)	0.00E+00	ERICA (2019)	-	-	-	-
Ca-41	1.40E-08	Amiro (1997)	2.81E-09	Amiro (1997)	-	-	-	-
Cd-113m	9.37E-07	Amiro (1997)	4.23E-07	Amiro (1997)	-	-	-	-
Cl-36	1.40E-06	ERICA (2019)	1.31E-10	ERICA (2019)	-	-	-	-
H-3	7.23E-08	ERICA (2019)	0.00E+00	ERICA (2019)	-	-	-	-
Hf-182	1.04E-09	Amiro (1997)	1.56E-06	Amiro (1997)	-	-	-	-
Mo-93	8.22E-08	Amiro (1997)	7.46E-08	Amiro (1997)	-	-	-	-
Nb-93m	1.53E-07	Amiro (1997)	1.34E-08	Amiro (1997)	-	-	-	-
Ni-59	8.06E-08	ERICA (2019)	3.24E-42	ERICA (2019)	-	-	-	-
Ni-63	1.08E-07	ERICA (2019)	0.00E+00	ERICA (2019)	-	-	-	-
Pu-239	2.63E-04	ERICA (2019)	8.33E-11	ERICA (2019)	-	-	-	-
Pu-240	2.63E-04	ERICA (2019)	1.23E-10	ERICA (2019)	-	-	-	-
Pu-242	2.52E-04	Amiro (1997) - RBE 10	1.01E-08	Amiro (1997)	-	-	-	-
Sn-126	1.20E-05	Amiro (1997)	1.20E-05	Amiro (1997)	-	-	-	-

Radionuclide	Internal (Gy/y per Bq/kg)	Reference	External On-soil (Gy/y per Bq/kg)	Reference	External In-soil (Gy/y per Bq/kg)	Reference	Water (Gy/y per Bq/kg)	Reference
Th-229	2.54E-04	ICRP (2017)	6.14E-08	ICRP (2017)	-	-	-	-
Th-230	2.37E-04	ERICA (2019)	2.19E-10	ERICA (2019)	-	-	-	-
U-236	2.33E-04	Amiro (1997) - RBE 10	1.10E-08	Amiro (1997)	-	-	-	-
U-238	2.10E-04	ERICA (2019)	8.77E-11	ERICA (2019)	-	-	-	-
Zr-93	9.92E-08	Amiro (1997)	0.00E+00	Amiro (1997)	-	-	-	-
Little Brown Myotis (bat)								
Am-241	2.78E-04	ERICA (2019)	2.19E-08	ERICA (2019)	-	-	-	-
C-14	2.59E-07	ERICA (2019)	0.00E+00	ERICA (2019)	-	-	-	-
Ca-41	1.40E-08	Amiro (1997)	2.81E-09	Amiro (1997)	-	-	-	-
Cd-113m	9.37E-07	Amiro (1997)	4.23E-07	Amiro (1997)	-	-	-	-
Cl-36	1.40E-06	ERICA (2019)	2.63E-10	ERICA (2019)	-	-	-	-
H-3	7.23E-08	ERICA (2019)	0.00E+00	ERICA (2019)	-	-	-	-
Hf-182	1.63E-06	Amiro (1997)	1.56E-06	Amiro (1997)	-	-	-	-
Mo-93	8.22E-08	Amiro (1997)	7.46E-08	Amiro (1997)	-	-	-	-
Nb-93m	1.53E-07	Amiro (1997)	1.34E-08	Amiro (1997)	-	-	-	-
Ni-59	8.13E-08	ERICA (2019)	8.77E-42	ERICA (2019)	-	-	-	-
Ni-63	1.08E-07	ERICA (2019)	0.00E+00	ERICA (2019)	-	-	-	-
Pu-239	2.63E-04	ERICA (2019)	2.81E-10	ERICA (2019)	-	-	-	-
Pu-240	2.63E-04	ERICA (2019)	5.17E-10	ERICA (2019)	-	-	-	-
Pu-242	2.52E-04	Amiro (1997) - RBE 10	1.01E-08	Amiro (1997)	-	-	-	-
Sn-126	1.20E-05	Amiro (1997)	1.20E-05	Amiro (1997)	-	-	-	-
Th-229	2.48E-04	ICRP (2017)	1.14E-07	ICRP (2017)	-	-	-	-
Th-230	2.37E-04	ERICA (2019)	6.05E-10	ERICA (2019)	-	-	-	-
U-236	2.33E-04	Amiro (1997) - RBE 10	1.10E-08	Amiro (1997)	-	-	-	-
U-238	2.10E-04	ERICA (2019)	4.12E-10	ERICA (2019)	-	-	-	-
Zr-93	9.92E-08	Amiro (1997)	0.00E+00	Amiro (1997)	-	-	-	-
Chimney Swift								
Am-241	2.78E-04	ERICA (2019)	2.19E-08	ERICA (2019)	-	-	-	-
C-14	2.59E-07	ERICA (2019)	0.00E+00	ERICA (2019)	-	-	-	-
Ca-41	1.40E-08	Amiro (1997)	2.81E-09	Amiro (1997)	-	-	-	-
Cd-113m	9.37E-07	Amiro (1997)	4.23E-07	Amiro (1997)	-	-	-	-
Cl-36	1.40E-06	ERICA (2019)	2.72E-10	ERICA (2019)	-	-	-	-
H-3	7.23E-08	ERICA (2019)	0.00E+00	ERICA (2019)	-	-	-	-
Hf-182	1.63E-06	Amiro (1997)	1.56E-06	Amiro (1997)	-	-	-	-

Radionuclide	Internal (Gy/y per Bq/kg)	Reference	External On-soil (Gy/y per Bq/kg)	Reference	External In-soil (Gy/y per Bq/kg)	Reference	Water (Gy/y per Bq/kg)	Reference
Mo-93	8.22E-08	Amiro (1997)	7.46E-08	Amiro (1997)	-	-	-	-
Nb-93m	1.53E-07	Amiro (1997)	1.34E-08	Amiro (1997)	-	-	-	-
Ni-59	8.13E-08	ERICA (2019)	8.77E-42	ERICA (2019)	-	-	-	-
Ni-63	1.08E-07	ERICA (2019)	0.00E+00	ERICA (2019)	-	-	-	-
Pu-239	2.63E-04	ERICA (2019)	2.81E-10	ERICA (2019)	-	-	-	-
Pu-240	2.63E-04	ERICA (2019)	5.26E-10	ERICA (2019)	-	-	-	-
Pu-242	2.52E-04	Amiro (1997) - RBE 10	1.01E-08	Amiro (1997)	-	-	-	-
Sn-126	1.20E-05	Amiro (1997)	1.20E-05	Amiro (1997)	-	-	-	-
Th-229	2.48E-04	ICRP (2017)	1.14E-07	ICRP (2017)	-	-	-	-
Th-230	2.37E-04	ERICA (2019)	6.14E-10	ERICA (2019)	-	-	-	-
U-236	2.33E-04	Amiro (1997) - RBE 10	1.10E-08	Amiro (1997)	-	-	-	-
U-238	2.10E-04	ERICA (2019)	4.21E-10	ERICA (2019)	-	-	-	-
Zr-93	9.92E-08	Amiro (1997)	0.00E+00	Amiro (1997)	-	-	-	-
Earthworm								
Am-241	2.78E-04	ERICA (2019)	-	-	5.35E-08	ERICA (2019)	-	-
C-14	2.50E-07	ERICA (2019)	-	-	0.00E+00	ERICA (2019)	-	-
Ca-41	1.40E-08	Amiro (1997)	-	-	2.81E-09	Amiro (1997)	-	-
Cd-113m	9.37E-07	Amiro (1997)	-	-	4.23E-07	Amiro (1997)	-	-
Cl-36	1.31E-06	ERICA (2019)	-	-	7.01E-10	ERICA (2019)	-	-
H-3	7.23E-08	ERICA (2019)	-	-	0.00E+00	ERICA (2019)	-	-
Hf-182	1.63E-06	Amiro (1997)	-	-	1.56E-06	Amiro (1997)	-	-
Mo-93	8.22E-08	Amiro (1997)	-	-	7.46E-08	Amiro (1997)	-	-
Nb-93m	1.53E-07	Amiro (1997)	-	-	1.34E-08	Amiro (1997)	-	-
Ni-59	7.93E-08	ERICA (2019)	-	-	8.77E-10	ERICA (2019)	-	-
Ni-63	1.08E-07	ERICA (2019)	-	-	0.00E+00	ERICA (2019)	-	-
Pu-239	2.63E-04	ERICA (2019)	-	-	7.45E-10	ERICA (2019)	-	-
Pu-240	2.63E-04	ERICA (2019)	-	-	1.40E-09	ERICA (2019)	-	-
Pu-242	2.52E-04	Amiro (1997) - RBE 10	-	-	1.01E-08	Amiro (1997)	-	-
Sn-126	1.20E-05	Amiro (1997)	-	-	1.20E-05	Amiro (1997)	-	-
Th-229	2.48E-04	ICRP (2017)	-	-	2.45E-07	ICRP (2017)	-	-
Th-230	2.37E-04	ERICA (2019)	-	-	1.84E-09	ERICA (2019)	-	-
U-236	2.33E-04	Amiro (1997) - RBE 10	-	-	1.10E-08	Amiro (1997)	-	-
U-238	2.10E-04	ERICA (2019)	-	-	1.05E-09	ERICA (2019)	-	-
Zr-93	9.92E-08	Amiro (1997)	-	-	0.00E+00	Amiro (1997)	-	-

Radionuclide	Internal (Gy/y per Bq/kg)	Reference	External On-soil (Gy/y per Bq/kg)	Reference	External In-soil (Gy/y per Bq/kg)	Reference	Water (Gy/y per Bq/kg)	Reference
Great Blue Heron								
Am-241	2.78E-04	ERICA (2019)	2.19E-08	ERICA (2019)	-	-	9.64E-08	ERICA (2019)
C-14	2.59E-07	ERICA (2019)	0.00E+00	ERICA (2019)	-	-	1.58E-10	ERICA (2019)
Ca-41	1.40E-08	Amiro (1997)	2.81E-09	Amiro (1997)	-	-	1.87E-09	Amiro (1997)
Cd-113m	9.37E-07	Amiro (1997)	4.23E-07	Amiro (1997)	-	-	2.82E-07	Amiro (1997)
Cl-36	1.40E-06	ERICA (2019)	2.72E-10	ERICA (2019)	-	-	1.23E-08	ERICA (2019)
H-3	7.23E-08	ERICA (2019)	0.00E+00	ERICA (2019)	-	-	3.16E-15	ERICA (2019)
Hf-182	1.63E-06	Amiro (1997)	1.56E-06	Amiro (1997)	-	-	1.04E-06	Amiro (1997)
Mo-93	8.22E-08	Amiro (1997)	7.46E-08	Amiro (1997)	-	-	4.97E-08	Amiro (1997)
Nb-93m	1.53E-06	Amiro (1997)	1.34E-08	Amiro (1997)	-	-	8.90E-09	Amiro (1997)
Ni-59	8.13E-08	ERICA (2019)	8.77E-42	ERICA (2019)	-	-	2.19E-10	ERICA (2019)
Ni-63	1.08E-07	ERICA (2019)	0.00E+00	ERICA (2019)	-	-	9.64E-12	ERICA (2019)
Pu-239	2.63E-04	ERICA (2019)	2.81E-10	ERICA (2019)	-	-	6.75E-10	ERICA (2019)
Pu-240	2.63E-04	ERICA (2019)	5.26E-10	ERICA (2019)	-	-	1.14E-09	ERICA (2019)
Pu-242	2.52E-04	Amiro (1997) - RBE 10	1.01E-08	Amiro (1997)	-	-	6.70E-09	Amiro (1997)
Sn-126	1.20E-05	Amiro (1997)	1.20E-05	Amiro (1997)	-	-	7.98E-06	Amiro (1997)
Th-229	2.48E-04	ICRP (2017)	1.14E-07	ICRP (2017)	-	-	3.59E-07	ICRP (2017)
Th-230	2.37E-04	ERICA (2019)	6.14E-10	ERICA (2019)	-	-	2.10E-09	ERICA (2019)
U-236	2.33E-04	Amiro (1997) - RBE 10	1.10E-08	Amiro (1997)	-	-	7.31E-09	Amiro (1997)
U-238	2.10E-04	ERICA (2019)	4.21E-10	ERICA (2019)	-	-	8.33E-10	ERICA (2019)
Zr-93	9.92E-08	Amiro (1997)	0.00E+00	Amiro (1997)	-	-	0.00E+00	Amiro (1997)
Green Frog (tadpole)								
Am-241	2.78E-04	ERICA (2019)	-	-	5.43E-08	ERICA (2019)	1.23E-07	ERICA (2019)
C-14	2.50E-07	ERICA (2019)	-	-	0.00E+00	ERICA (2019)	5.17E-10	ERICA (2019)
Ca-41	1.40E-08	Amiro (1997)	-	-	2.81E-09	Amiro (1997)	1.87E-09	Amiro (1997)
Cd-113m	9.37E-07	Amiro (1997)	-	-	4.23E-07	Amiro (1997)	2.82E-07	Amiro (1997)
Cl-36	1.40E-06	ERICA (2019)	-	-	7.10E-10	ERICA (2019)	3.68E-08	ERICA (2019)
H-3	7.23E-08	ERICA (2019)	-	-	0.00E+00	ERICA (2019)	2.19E-14	ERICA (2019)
Hf-182	1.63E-06	Amiro (1997)	-	-	1.56E-06	Amiro (1997)	1.04E-06	Amiro (1997)
Mo-93	8.22E-08	Amiro (1997)	-	-	7.46E-08	Amiro (1997)	4.97E-08	Amiro (1997)
Nb-93m	1.53E-06	Amiro (1997)	-	-	1.34E-08	Amiro (1997)	8.90E-09	Amiro (1997)
Ni-59	8.00E-08	ERICA (2019)	-	-	8.77E-10	ERICA (2019)	7.36E-10	ERICA (2019)
Ni-63	1.08E-07	ERICA (2019)	-	-	0.00E+00	ERICA (2019)	3.33E-11	ERICA (2019)
Pu-239	2.63E-04	ERICA (2019)	-	-	7.54E-10	ERICA (2019)	1.58E-09	ERICA (2019)

Radionuclide	Internal (Gy/y per Bq/kg)	Reference	External On-soil (Gy/y per Bq/kg)	Reference	External In-soil (Gy/y per Bq/kg)	Reference	Water (Gy/y per Bq/kg)	Reference
Pu-240	2.63E-04	ERICA (2019)	-	-	1.49E-09	ERICA (2019)	3.24E-09	ERICA (2019)
Pu-242	2.52E-04	Amiro (1997) - RBE 10	-	-	1.01E-08	Amiro (1997)	6.70E-09	Amiro (1997)
Sn-126	1.20E-05	Amiro (1997)	-	-	1.20E-05	Amiro (1997)	7.98E-06	Amiro (1997)
Th-229	2.48E-04	ICRP (2017)	-	-	6.52E-07	Amiro (1997)	4.21E-07	ICRP (2017)
Th-230	2.37E-04	ERICA (2019)	-	-	1.84E-09	ERICA (2019)	3.59E-09	ERICA (2019)
U-236	2.33E-04	Amiro (1997) - RBE 10	-	-	5.87E-07	Amiro (1997)	7.31E-09	Amiro (1997)
U-238	2.10E-04	ERICA (2019)	-	-	1.10E-08	ERICA (2019)	2.37E-09	ERICA (2019)
Zr-93	9.92E-08	Amiro (1997)	-	-	1.14E-09	Amiro (1997)	0.00E+00	Amiro (1997)
Northern River Otter								
Am-241	2.78E-04	ERICA (2019)	2.19E-08	ERICA (2019)	-	-	7.80E-08	ERICA (2019)
C-14	2.59E-07	ERICA (2019)	0.00E+00	ERICA (2019)	-	-	1.05E-10	ERICA (2019)
Ca-41	1.40E-08	Amiro (1997)	2.81E-09	Amiro (1997)	-	-	1.87E-09	Amiro (1997)
Cd-113m	9.37E-07	Amiro (1997)	4.23E-07	Amiro (1997)	-	-	2.82E-07	Amiro (1997)
Cl-36	1.40E-06	ERICA (2019)	2.63E-10	ERICA (2019)	-	-	8.59E-09	ERICA (2019)
H-3	7.23E-08	ERICA (2019)	0.00E+00	ERICA (2019)	-	-	2.45E-15	ERICA (2019)
Hf-182	1.63E-06	Amiro (1997)	1.56E-06	Amiro (1997)	-	-	1.04E-06	Amiro (1997)
Mo-93	8.22E-08	Amiro (1997)	7.46E-08	Amiro (1997)	-	-	4.97E-08	Amiro (1997)
Nb-93m	1.53E-06	Amiro (1997)	1.34E-08	Amiro (1997)	-	-	8.90E-09	Amiro (1997)
Ni-59	8.13E-08	ERICA (2019)	8.77E-42	ERICA (2019)	-	-	1.49E-10	ERICA (2019)
Ni-63	1.08E-07	ERICA (2019)	0.00E+00	ERICA (2019)	-	-	6.49E-12	ERICA (2019)
Pu-239	2.63E-04	ERICA (2019)	2.81E-10	ERICA (2019)	-	-	5.17E-10	ERICA (2019)
Pu-240	2.63E-04	ERICA (2019)	5.17E-10	ERICA (2019)	-	-	8.06E-10	ERICA (2019)
Pu-242	2.52E-04	Amiro (1997) - RBE 10	1.01E-08	Amiro (1997)	-	-	6.70E-09	Amiro (1997)
Sn-126	1.20E-05	Amiro (1997)	1.20E-05	Amiro (1997)	-	-	7.98E-06	Amiro (1997)
Th-229	2.48E-04	ICRP (2017)	1.14E-07	ICRP (2017)	-	-	3.59E-07	ICRP (2017)
Th-230	2.37E-04	ERICA (2019)	6.05E-10	ERICA (2019)	-	-	1.75E-09	ERICA (2019)
U-236	2.33E-04	Amiro (1997) - RBE 10	1.10E-08	Amiro (1997)	-	-	7.31E-09	Amiro (1997)
U-238	2.10E-04	ERICA (2019)	4.12E-10	ERICA (2019)	-	-	5.79E-10	ERICA (2019)
Zr-93	9.92E-08	Amiro (1997)	0.00E+00	Amiro (1997)	-	-	0.00E+00	Amiro (1997)
Mallard								
Am-241	2.78E-04	ERICA (2019)	2.19E-08	ERICA (2019)	-	-	9.64E-08	ERICA (2019)
C-14	2.59E-07	ERICA (2019)	0.00E+00	ERICA (2019)	-	-	1.58E-10	ERICA (2019)
Ca-41	1.40E-08	Amiro (1997)	2.81E-09	Amiro (1997)	-	-	1.87E-09	Amiro (1997)
Cd-113m	9.37E-07	Amiro (1997)	4.23E-07	Amiro (1997)	-	-	2.82E-07	Amiro (1997)

Radionuclide	Internal (Gy/y per Bq/kg)	Reference	External On-soil (Gy/y per Bq/kg)	Reference	External In-soil (Gy/y per Bq/kg)	Reference	Water (Gy/y per Bq/kg)	Reference
Cl-36	1.40E-06	ERICA (2019)	2.72E-10	ERICA (2019)	-	-	1.23E-08	ERICA (2019)
H-3	7.23E-08	ERICA (2019)	0.00E+00	ERICA (2019)	-	-	3.16E-15	ERICA (2019)
Hf-182	1.63E-06	Amiro (1997)	1.56E-06	Amiro (1997)	-	-	1.04E-06	Amiro (1997)
Mo-93	8.22E-08	Amiro (1997)	7.46E-08	Amiro (1997)	-	-	4.97E-08	Amiro (1997)
Nb-93m	1.53E-06	Amiro (1997)	1.34E-08	Amiro (1997)	-	-	8.90E-09	Amiro (1997)
Ni-59	8.13E-08	ERICA (2019)	8.77E-42	ERICA (2019)	-	-	2.19E-10	ERICA (2019)
Ni-63	1.08E-07	ERICA (2019)	0.00E+00	ERICA (2019)	-	-	9.64E-12	ERICA (2019)
Pu-239	2.63E-04	ERICA (2019)	2.81E-10	ERICA (2019)	-	-	6.75E-10	ERICA (2019)
Pu-240	2.63E-04	ERICA (2019)	5.26E-10	ERICA (2019)	-	-	1.14E-09	ERICA (2019)
Pu-242	2.52E-04	Amiro (1997) - RBE 10	1.01E-08	Amiro (1997)	-	-	6.70E-09	Amiro (1997)
Sn-126	1.20E-05	Amiro (1997)	1.20E-05	Amiro (1997)	-	-	7.98E-06	Amiro (1997)
Th-229	2.48E-04	ICRP (2017)	1.14E-07	ICRP (2017)	-	-	3.59E-07	ICRP (2017)
Th-230	2.37E-04	ERICA (2019)	6.14E-10	ERICA (2019)	-	-	2.10E-09	ERICA (2019)
U-236	2.33E-04	Amiro (1997) - RBE 10	1.10E-08	Amiro (1997)	-	-	7.31E-09	Amiro (1997)
U-238	2.10E-04	ERICA (2019)	4.21E-10	ERICA (2019)	-	-	8.33E-10	ERICA (2019)
Zr-93	9.92E-08	Amiro (1997)	0.00E+00	Amiro (1997)	-	-	0.00E+00	Amiro (1997)
Meadow Vole								
Am-241	2.78E-04	ERICA (2019)	2.19E-08	ERICA (2019)	4.82E-08	ERICA (2019)	-	-
C-14	2.59E-07	ERICA (2019)	0.00E+00	ERICA (2019)	0.00E+00	ERICA (2019)	-	-
Ca-41	1.40E-08	Amiro (1997)	2.81E-09	Amiro (1997)	2.81E-09	Amiro (1997)	-	-
Cd-113m	9.37E-07	Amiro (1997)	4.23E-07	Amiro (1997)	4.23E-07	Amiro (1997)	-	-
Cl-36	1.40E-06	ERICA (2019)	2.63E-10	ERICA (2019)	6.57E-10	ERICA (2019)	-	-
H-3	7.23E-08	ERICA (2019)	0.00E+00	ERICA (2019)	0.00E+00	ERICA (2019)	-	-
Hf-182	1.63E-06	Amiro (1997)	1.56E-06	Amiro (1997)	1.56E-06	Amiro (1997)	-	-
Mo-93	8.22E-08	Amiro (1997)	7.46E-08	Amiro (1997)	7.46E-08	Amiro (1997)	-	-
Nb-93m	1.53E-06	Amiro (1997)	1.34E-08	Amiro (1997)	1.34E-08	Amiro (1997)	-	-
Ni-59	8.13E-08	ERICA (2019)	8.77E-42	ERICA (2019)	7.19E-10	ERICA (2019)	-	-
Ni-63	1.08E-07	ERICA (2019)	0.00E+00	ERICA (2019)	0.00E+00	ERICA (2019)	-	-
Pu-239	2.63E-04	ERICA (2019)	2.81E-10	ERICA (2019)	6.31E-10	ERICA (2019)	-	-
Pu-240	2.63E-04	ERICA (2019)	5.17E-10	ERICA (2019)	1.14E-09	ERICA (2019)	-	-
Pu-242	2.52E-04	Amiro (1997) - RBE 10	1.01E-08	Amiro (1997)	1.01E-08	Amiro (1997)	-	-
Sn-126	1.20E-05	Amiro (1997)	1.20E-05	Amiro (1997)	1.20E-05	Amiro (1997)	-	-
Th-229	2.48E-04	ICRP (2017)	1.14E-07	ICRP (2017)	2.28E-07	ICRP (2017)	-	-
Th-230	2.37E-04	ERICA (2019)	6.05E-10	ERICA (2019)	1.58E-09	ERICA (2019)	-	-

Radionuclide	Internal (Gy/y per Bq/kg)	Reference	External On-soil (Gy/y per Bq/kg)	Reference	External In-soil (Gy/y per Bq/kg)	Reference	Water (Gy/y per Bq/kg)	Reference
U-236	2.33E-04	Amiro (1997) - RBE 10	1.10E-08	Amiro (1997)	1.10E-08	Amiro (1997)	-	-
U-238	2.10E-04	ERICA (2019)	4.12E-10	ERICA (2019)	8.77E-10	ERICA (2019)	-	-
Zr-93	9.92E-08	Amiro (1997)	0.00E+00	Amiro (1997)	0.00E+00	Amiro (1997)	-	-
Moose								
Am-241	2.78E-04	ERICA (2019)	8.06E-09	ERICA (2019)	-	-	-	-
C-14	2.59E-07	ERICA (2019)	0.00E+00	ERICA (2019)	-	-	-	-
Ca-41	1.40E-08	Amiro (1997)	2.81E-09	Amiro (1997)	-	-	-	-
Cd-113m	9.37E-07	Amiro (1997)	4.23E-07	Amiro (1997)	-	-	-	-
Cl-36	1.40E-06	ERICA (2019)	1.31E-10	ERICA (2019)	-	-	-	-
H-3	7.23E-08	ERICA (2019)	0.00E+00	ERICA (2019)	-	-	-	-
Hf-182	1.63E-06	Amiro (1997)	1.56E-06	Amiro (1997)	-	-	-	-
Mo-93	8.22E-08	Amiro (1997)	7.46E-08	Amiro (1997)	-	-	-	-
Nb-93m	1.53E-06	Amiro (1997)	1.34E-08	Amiro (1997)	-	-	-	-
Ni-59	8.06E-08	ERICA (2019)	3.24E-42	ERICA (2019)	-	-	-	-
Ni-63	1.08E-07	ERICA (2019)	0.00E+00	ERICA (2019)	-	-	-	-
Pu-239	2.63E-04	ERICA (2019)	8.33E-11	ERICA (2019)	-	-	-	-
Pu-240	2.63E-04	ERICA (2019)	1.23E-10	ERICA (2019)	-	-	-	-
Pu-242	2.52E-04	Amiro (1997) - RBE 10	1.01E-08	Amiro (1997)	-	-	-	-
Sn-126	1.20E-05	Amiro (1997)	1.20E-05	Amiro (1997)	-	-	-	-
Th-229	2.54E-04	ICRP (2017)	6.14E-08	ICRP (2017)	-	-	-	-
Th-230	2.37E-04	ERICA (2019)	2.19E-10	ERICA (2019)	-	-	-	-
U-236	2.33E-04	Amiro (1997) - RBE 10	1.10E-08	Amiro (1997)	-	-	-	-
U-238	2.10E-04	ERICA (2019)	8.77E-11	ERICA (2019)	-	-	-	-
Zr-93	9.92E-08	Amiro (1997)	0.00E+00	Amiro (1997)	-	-	-	-
Muskrat								
Am-241	2.78E-04	ERICA (2019)	2.19E-08	ERICA (2019)	-	-	7.80E-08	ERICA (2019)
C-14	2.59E-07	ERICA (2019)	0.00E+00	ERICA (2019)	-	-	1.05E-10	ERICA (2019)
Ca-41	1.40E-08	Amiro (1997)	2.81E-09	Amiro (1997)	-	-	1.87E-09	Amiro (1997)
Cd-113m	9.37E-07	Amiro (1997)	4.23E-07	Amiro (1997)	-	-	2.82E-07	Amiro (1997)
Cl-36	1.40E-06	ERICA (2019)	2.63E-10	ERICA (2019)	-	-	8.59E-09	ERICA (2019)
H-3	7.23E-08	ERICA (2019)	0.00E+00	ERICA (2019)	-	-	2.45E-15	ERICA (2019)
Hf-182	1.63E-06	Amiro (1997)	1.56E-06	Amiro (1997)	-	-	1.04E-06	Amiro (1997)
Mo-93	8.22E-08	Amiro (1997)	7.46E-08	Amiro (1997)	-	-	4.97E-08	Amiro (1997)
Nb-93m	1.53E-06	Amiro (1997)	1.34E-08	Amiro (1997)	-	-	8.90E-09	Amiro (1997)

Radionuclide	Internal (Gy/y per Bq/kg)	Reference	External On-soil (Gy/y per Bq/kg)	Reference	External In-soil (Gy/y per Bq/kg)	Reference	Water (Gy/y per Bq/kg)	Reference
Ni-59	8.13E-08	ERICA (2019)	8.77E-42	ERICA (2019)	-	-	1.49E-10	ERICA (2019)
Ni-63	1.08E-07	ERICA (2019)	0.00E+00	ERICA (2019)	-	-	6.49E-12	ERICA (2019)
Pu-239	2.63E-04	ERICA (2019)	2.81E-10	ERICA (2019)	-	-	5.17E-10	ERICA (2019)
Pu-240	2.63E-04	ERICA (2019)	5.17E-10	ERICA (2019)	-	-	8.06E-10	ERICA (2019)
Pu-242	2.52E-04	Amiro (1997) - RBE 10	1.01E-08	Amiro (1997)	-	-	6.70E-09	Amiro (1997)
Sn-126	1.20E-05	Amiro (1997)	1.20E-05	Amiro (1997)	-	-	7.98E-06	Amiro (1997)
Th-229	2.48E-04	ICRP (2017)	1.14E-07	ICRP (2017)	-	-	3.59E-07	ICRP (2017)
Th-230	2.37E-04	ERICA (2019)	6.05E-10	ERICA (2019)	-	-	1.75E-09	ERICA (2019)
U-236	2.33E-04	Amiro (1997) - RBE 10	1.10E-08	Amiro (1997)	-	-	7.31E-09	Amiro (1997)
U-238	2.10E-04	ERICA (2019)	4.12E-10	ERICA (2019)	-	-	5.79E-10	ERICA (2019)
Zr-93	9.92E-08	Amiro (1997)	0.00E+00	Amiro (1997)	-	-	0.00E+00	Amiro (1997)
Pelagic Fish								
Am-241	2.78E-04	ERICA (2019)	-	-	-	-	9.64E-08	ERICA (2019)
C-14	2.59E-07	ERICA (2019)	-	-	-	-	1.58E-10	ERICA (2019)
Ca-41	1.40E-08	Amiro (1997)	-	-	-	-	1.87E-09	Amiro (1997)
Cd-113m	9.37E-07	Amiro (1997)	-	-	-	-	2.82E-07	Amiro (1997)
Cl-36	1.40E-06	ERICA (2019)	-	-	-	-	1.23E-08	ERICA (2019)
H-3	7.23E-08	ERICA (2019)	-	-	-	-	3.16E-15	ERICA (2019)
Hf-182	1.63E-06	Amiro (1997)	-	-	-	-	1.04E-06	Amiro (1997)
Mo-93	8.22E-08	Amiro (1997)	-	-	-	-	4.97E-08	Amiro (1997)
Nb-93m	1.53E-06	Amiro (1997)	-	-	-	-	8.90E-09	Amiro (1997)
Ni-59	8.13E-08	ERICA (2019)	-	-	-	-	2.19E-10	ERICA (2019)
Ni-63	1.08E-07	ERICA (2019)	-	-	-	-	9.64E-12	ERICA (2019)
Pu-239	2.63E-04	ERICA (2019)	-	-	-	-	7.19E-10	ERICA (2019)
Pu-240	2.63E-04	ERICA (2019)	-	-	-	-	1.23E-09	ERICA (2019)
Pu-242	2.52E-04	Amiro (1997) - RBE 10	-	-	-	-	6.70E-09	Amiro (1997)
Sn-126	1.20E-05	Amiro (1997)	-	-	-	-	7.98E-06	Amiro (1997)
Th-229	2.48E-04	ICRP (2017)	-	-	-	-	3.68E-07	ICRP (2017)
Th-230	2.37E-04	ERICA (2019)	-	-	-	-	2.19E-09	ERICA (2019)
U-236	2.33E-04	Amiro (1997) - RBE 10	-	-	-	-	7.31E-09	Amiro (1997)
U-238	2.10E-04	ERICA (2019)	-	-	-	-	8.77E-10	ERICA (2019)
Zr-93	9.92E-08	Amiro (1997)	-	-	-	-	0.00E+00	Amiro (1997)
Ruffed Grouse								
Am-241	2.78E-04	ERICA (2019)	2.19E-08	ERICA (2019)	-	-	-	-

Radionuclide	Internal (Gy/y per Bq/kg)	Reference	External On-soil (Gy/y per Bq/kg)	Reference	External In-soil (Gy/y per Bq/kg)	Reference	Water (Gy/y per Bq/kg)	Reference
C-14	2.59E-07	ERICA (2019)	0.00E+00	ERICA (2019)	-	-	-	-
Ca-41	1.40E-08	Amiro (1997)	2.81E-09	Amiro (1997)	-	-	-	-
Cd-113m	9.37E-07	Amiro (1997)	4.23E-07	Amiro (1997)	-	-	-	-
Cl-36	1.40E-06	ERICA (2019)	2.72E-10	ERICA (2019)	-	-	-	-
H-3	7.23E-08	ERICA (2019)	0.00E+00	ERICA (2019)	-	-	-	-
Hf-182	1.63E-06	Amiro (1997)	1.56E-06	Amiro (1997)	-	-	-	-
Mo-93	8.22E-08	Amiro (1997)	7.46E-08	Amiro (1997)	-	-	-	-
Nb-93m	1.53E-06	Amiro (1997)	1.34E-08	Amiro (1997)	-	-	-	-
Ni-59	8.13E-08	ERICA (2019)	8.77E-42	ERICA (2019)	-	-	-	-
Ni-63	1.08E-07	ERICA (2019)	0.00E+00	ERICA (2019)	-	-	-	-
Pu-239	2.63E-04	ERICA (2019)	2.81E-10	ERICA (2019)	-	-	-	-
Pu-240	2.63E-04	ERICA (2019)	5.26E-10	ERICA (2019)	-	-	-	-
Pu-242	2.52E-04	Amiro (1997) - RBE 10	1.01E-08	Amiro (1997)	-	-	-	-
Sn-126	1.20E-05	Amiro (1997)	1.20E-05	Amiro (1997)	-	-	-	-
Th-229	2.48E-04	ICRP (2017)	1.14E-07	ICRP (2017)	-	-	-	-
Th-230	2.37E-04	ERICA (2019)	6.14E-10	ERICA (2019)	-	-	-	-
U-236	2.33E-04	Amiro (1997) - RBE 10	1.10E-08	Amiro (1997)	-	-	-	-
U-238	2.10E-04	ERICA (2019)	4.21E-10	ERICA (2019)	-	-	-	-
Zr-93	9.92E-08	Amiro (1997)	0.00E+00	Amiro (1997)	-	-	-	-
Short-tailed Shrew								
Am-241	2.78E-04	ERICA (2019)	2.19E-08	ERICA (2019)	4.82E-08	ERICA (2019)	-	-
C-14	2.59E-07	ERICA (2019)	0.00E+00	ERICA (2019)	0.00E+00	ERICA (2019)	-	-
Ca-41	1.40E-08	Amiro (1997)	2.81E-09	Amiro (1997)	2.81E-09	Amiro (1997)	-	-
Cd-113m	9.37E-07	Amiro (1997)	4.23E-07	Amiro (1997)	4.23E-07	Amiro (1997)	-	-
Cl-36	1.40E-06	ERICA (2019)	2.63E-10	ERICA (2019)	6.57E-10	ERICA (2019)	-	-
H-3	7.23E-08	ERICA (2019)	0.00E+00	ERICA (2019)	0.00E+00	ERICA (2019)	-	-
Hf-182	1.63E-06	Amiro (1997)	1.56E-06	Amiro (1997)	1.56E-06	Amiro (1997)	-	-
Mo-93	8.22E-08	Amiro (1997)	7.46E-08	Amiro (1997)	7.46E-08	Amiro (1997)	-	-
Nb-93m	1.53E-06	Amiro (1997)	1.34E-08	Amiro (1997)	1.34E-08	Amiro (1997)	-	-
Ni-59	8.13E-08	ERICA (2019)	8.77E-42	ERICA (2019)	7.19E-10	ERICA (2019)	-	-
Ni-63	1.08E-07	ERICA (2019)	0.00E+00	ERICA (2019)	0.00E+00	ERICA (2019)	-	-
Pu-239	2.63E-04	ERICA (2019)	2.81E-10	ERICA (2019)	6.31E-10	ERICA (2019)	-	-
Pu-240	2.63E-04	ERICA (2019)	5.17E-10	ERICA (2019)	1.14E-09	ERICA (2019)	-	-
Pu-242	2.52E-04	Amiro (1997) - RBE 10	1.01E-08	Amiro (1997)	1.01E-08	Amiro (1997)	-	-

Radionuclide	Internal (Gy/y per Bq/kg)	Reference	External On-soil (Gy/y per Bq/kg)	Reference	External In-soil (Gy/y per Bq/kg)	Reference	Water (Gy/y per Bq/kg)	Reference
Sn-126	1.20E-05	Amiro (1997)	1.20E-05	Amiro (1997)	1.20E-05	Amiro (1997)	-	-
Th-229	2.48E-04	ICRP (2017)	1.14E-07	ICRP (2017)	2.28E-07	ICRP (2017)	-	-
Th-230	2.37E-04	ERICA (2019)	6.05E-10	ERICA (2019)	1.58E-09	ERICA (2019)	-	-
U-236	2.33E-04	Amiro - RBE 10	1.10E-08	Amiro (1997)	1.10E-08	Amiro (1997)	-	-
U-238	2.10E-04	ERICA (2019)	4.12E-10	ERICA (2019)	8.77E-10	ERICA (2019)	-	-
Zr-93	9.92E-08	Amiro (1997)	0.00E+00	Amiro (1997)	0.00E+00	Amiro (1997)	-	-
Blanding's Turtle								
Am-241	2.77E-04	ERICA (2019)	2.10E-08	ERICA (2019)	-	-	9.52E-08	ERICA (2019)
C-14	2.56E-07	ERICA (2019)	0.00E+00	ERICA (2019)	-	-	1.72E-10	ERICA (2019)
Ca-41	1.40E-08	Amiro (1997)	2.81E-09	Amiro (1997)	-	-	1.87E-09	Amiro (1997)
Cd-113m	9.37E-07	Amiro (1997)	4.23E-07	Amiro (1997)	-	-	2.82E-07	Amiro (1997)
Cl-36	1.37E-06	ERICA (2019)	2.63E-10	ERICA (2019)	-	-	1.26E-08	ERICA (2019)
H-3	7.21E-08	ERICA (2019)	0.00E+00	ERICA (2019)	-	-	5.78E-17	ERICA (2019)
Hf-182	1.63E-06	Amiro (1997)	1.56E-06	Amiro (1997)	-	-	1.04E-06	Amiro (1997)
Mo-93	8.22E-08	Amiro (1997)	7.46E-08	Amiro (1997)	-	-	4.97E-08	Amiro (1997)
Nb-93m	1.53E-06	Amiro (1997)	1.34E-08	Amiro (1997)	-	-	8.90E-09	Amiro (1997)
Ni-59	8.10E-08	ERICA (2019)	8.77E-42	ERICA (2019)	-	-	2.33E-10	ERICA (2019)
Ni-63	1.08E-07	ERICA (2019)	0.00E+00	ERICA (2019)	-	-	1.27E-11	ERICA (2019)
Pu-239	2.60E-04	ERICA (2019)	2.72E-10	ERICA (2019)	-	-	7.14E-10	ERICA (2019)
Pu-240	2.61E-04	ERICA (2019)	5.00E-10	ERICA (2019)	-	-	1.25E-09	ERICA (2019)
Pu-242	2.52E-04	Amiro (1997) - RBE 10	1.01E-08	Amiro (1997)	-	-	6.70E-09	Amiro (1997)
Sn-126	1.20E-05	Amiro (1997)	1.20E-05	Amiro (1997)	-	-	7.98E-06	Amiro (1997)
Th-229	2.61E-04	Amiro (1997) - RBE 10	6.52E-07	Amiro (1997)	-	-	4.34E-07	Amiro (1997)
Th-230	2.36E-04	ERICA (2019)	5.87E-10	ERICA (2019)	-	-	2.18E-09	ERICA (2019)
U-236	2.33E-04	Amiro (1997) - RBE 10	1.10E-08	Amiro (1997)	-	-	7.31E-09	Amiro (1997)
U-238	2.12E-04	ERICA (2019)	4.03E-10	ERICA (2019)	-	-	8.92E-10	ERICA (2019)
Zr-93	9.92E-08	Amiro (1997)	0.00E+00	Amiro (1997)	-	-	0.00E+00	Amiro (1997)
Terrestrial Vegetation								
Am-241	2.78E-04	ERICA (2019)	2.89E-08	ERICA (2019)	-	-	-	-
C-14	2.59E-07	ERICA (2019)	0.00E+00	ERICA (2019)	-	-	-	-
Ca-41	1.40E-08	Amiro (1997)	2.81E-09	Amiro (1997)	-	-	-	-
Cd-113m	9.37E-07	Amiro (1997)	4.23E-07	Amiro (1997)	-	-	-	-
Cl-36	1.40E-06	ERICA (2019)	2.75E-10	ERICA (2019)	-	-	-	-
H-3	7.23E-08	ERICA (2019)	0.00E+00	ERICA (2019)	-	-	-	-

Radionuclide	Internal (Gy/y per Bq/kg)	Reference	External On-soil (Gy/y per Bq/kg)	Reference	External In-soil (Gy/y per Bq/kg)	Reference	Water (Gy/y per Bq/kg)	Reference
Hf-182	1.63E-06	Amiro (1997)	1.56E-06	Amiro (1997)	-	-	-	-
Mo-93	8.22E-08	Amiro (1997)	7.46E-08	Amiro (1997)	-	-	-	-
Nb-93m	1.53E-06	Amiro (1997)	1.34E-08	Amiro (1997)	-	-	-	-
Ni-59	8.06E-08	ERICA (2019)	1.14E-09	ERICA (2019)	-	-	-	-
Ni-63	1.08E-07	ERICA (2019)	0.00E+00	ERICA (2019)	-	-	-	-
Pu-239	2.63E-04	ERICA (2019)	5.26E-10	ERICA (2019)	-	-	-	-
Pu-240	2.63E-04	ERICA (2019)	1.14E-09	ERICA (2019)	-	-	-	-
Pu-242	2.52E-04	Amiro (1997) - RBE 10	1.01E-08	Amiro (1997)	-	-	-	-
Sn-126	1.20E-05	Amiro (1997)	1.20E-05	Amiro (1997)	-	-	-	-
Th-229	2.54E-04	ICRP (2017)	9.64E-08	ICRP (2017)	-	-	-	-
Th-230	2.37E-04	ERICA (2019)	1.23E-09	ERICA (2019)	-	-	-	-
U-236	2.33E-04	Amiro (1997) - RBE 10	1.10E-08	Amiro (1997)	-	-	-	-
U-238	2.12E-04	ERICA (2019)	8.77E-10	ERICA (2019)	-	-	-	-
Zr-93	9.92E-08	Amiro (1997)	0.00E+00	Amiro (1997)	-	-	-	-
White-tailed Deer								
Am-241	2.78E-04	ERICA (2019)	8.06E-09	ERICA (2019)	-	-	-	-
C-14	2.59E-07	ERICA (2019)	0.00E+00	ERICA (2019)	-	-	-	-
Ca-41	1.40E-08	Amiro (1997)	2.81E-09	Amiro (1997)	-	-	-	-
Cd-113m	9.37E-07	Amiro (1997)	4.23E-07	Amiro (1997)	-	-	-	-
Cl-36	1.40E-06	ERICA (2019)	1.31E-10	ERICA (2019)	-	-	-	-
H-3	7.23E-08	ERICA (2019)	0.00E+00	ERICA (2019)	-	-	-	-
Hf-182	1.63E-06	Amiro (1997)	1.56E-06	Amiro (1997)	-	-	-	-
Mo-93	8.22E-08	Amiro (1997)	7.46E-08	Amiro (1997)	-	-	-	-
Nb-93m	1.53E-06	Amiro (1997)	1.34E-08	Amiro (1997)	-	-	-	-
Ni-59	8.06E-08	ERICA (2019)	3.24E-42	ERICA (2019)	-	-	-	-
Ni-63	1.08E-07	ERICA (2019)	0.00E+00	ERICA (2019)	-	-	-	-
Pu-239	2.63E-04	ERICA (2019)	8.33E-11	ERICA (2019)	-	-	-	-
Pu-240	2.63E-04	ERICA (2019)	1.23E-10	ERICA (2019)	-	-	-	-
Pu-242	2.52E-04	Amiro (1997) - RBE 10	1.01E-08	Amiro (1997)	-	-	-	-
Sn-126	1.20E-05	Amiro (1997)	1.20E-05	Amiro (1997)	-	-	-	-
Th-229	2.54E-04	ICRP (2017)	6.14E-08	ICRP (2017)	-	-	-	-
Th-230	2.37E-04	ERICA (2019)	2.19E-10	ERICA (2019)	-	-	-	-
U-236	2.33E-04	Amiro (1997) - RBE 10	1.10E-08	Amiro (1997)	-	-	-	-
U-238	2.10E-04	ERICA (2019)	8.77E-11	ERICA (2019)	-	-	-	-

Radionuclide	Internal (Gy/y per Bq/kg)	Reference	External On-soil (Gy/y per Bq/kg)	Reference	External In-soil (Gy/y per Bq/kg)	Reference	Water (Gy/y per Bq/kg)	Reference
Zr-93	9.92E-08	Amiro (1997)	0.00E+00	Amiro (1997)	-	-	-	-
Eastern Wolf								
Am-241	2.78E-04	ERICA (2019)	8.06E-09	ERICA (2019)	-	-	-	-
C-14	2.59E-07	ERICA (2019)	0.00E+00	ERICA (2019)	-	-	-	-
Ca-41	1.40E-08	Amiro (1997)	2.81E-09	Amiro (1997)	-	-	-	-
Cd-113m	9.37E-07	Amiro (1997)	4.23E-07	Amiro (1997)	-	-	-	-
Cl-36	1.40E-06	ERICA (2019)	1.31E-10	ERICA (2019)	-	-	-	-
H-3	7.23E-08	ERICA (2019)	0.00E+00	ERICA (2019)	-	-	-	-
Hf-182	1.63E-06	Amiro (1997)	1.56E-06	Amiro (1997)	-	-	-	-
Mo-93	8.22E-08	Amiro (1997)	7.46E-08	Amiro (1997)	-	-	-	-
Nb-93m	1.53E-06	Amiro (1997)	1.34E-08	Amiro (1997)	-	-	-	-
Ni-59	8.06E-08	ERICA (2019)	3.24E-42	ERICA (2019)	-	-	-	-
Ni-63	1.08E-07	ERICA (2019)	0.00E+00	ERICA (2019)	-	-	-	-
Pu-239	2.63E-04	ERICA (2019)	8.33E-11	ERICA (2019)	-	-	-	-
Pu-240	2.63E-04	ERICA (2019)	1.23E-10	ERICA (2019)	-	-	-	-
Pu-242	2.52E-04	Amiro (1997) - RBE 10	1.01E-08	Amiro (1997)	-	-	-	-
Sn-126	1.20E-05	Amiro (1997)	1.20E-05	Amiro (1997)	-	-	-	-
Th-229	2.54E-04	ICRP (2017)	6.14E-08	ICRP (2017)	-	-	-	-
Th-230	2.37E-04	ERICA (2019)	2.19E-10	ERICA (2019)	-	-	-	-
U-236	2.33E-04	Amiro (1997) - RBE 10	1.10E-08	Amiro (1997)	-	-	-	-
U-238	2.10E-04	ERICA (2019)	8.77E-11	ERICA (2019)	-	-	-	-
Zr-93	9.92E-08	Amiro (1997)	0.00E+00	Amiro (1997)	-	-	-	-
Mushrooms								
Am-241	2.78E-04	ERICA (2019)	2.89E-08	ERICA (2019)	-	-	-	-
C-14	2.59E-07	ERICA (2019)	0.00E+00	ERICA (2019)	-	-	-	-
Ca-41	1.40E-08	Amiro (1997)	2.81E-09	Amiro (1997)	-	-	-	-
Cd-113m	9.37E-07	Amiro (1997)	4.23E-07	Amiro (1997)	-	-	-	-
Cl-36	1.40E-06	ERICA (2019)	2.75E-10	ERICA (2019)	-	-	-	-
H-3	7.23E-08	ERICA (2019)	0.00E+00	ERICA (2019)	-	-	-	-
Hf-182	1.63E-06	Amiro (1997)	1.56E-06	Amiro (1997)	-	-	-	-
Mo-93	8.22E-08	Amiro (1997)	7.46E-08	Amiro (1997)	-	-	-	-
Nb-93m	1.53E-06	Amiro (1997)	1.34E-08	Amiro (1997)	-	-	-	-
Ni-59	8.06E-08	ERICA (2019)	1.14E-09	ERICA (2019)	-	-	-	-
Ni-63	1.08E-07	ERICA (2019)	0.00E+00	ERICA (2019)	-	-	-	-

Radionuclide	Internal (Gy/y per Bq/kg)	Reference	External On-soil (Gy/y per Bq/kg)	Reference	External In-soil (Gy/y per Bq/kg)	Reference	Water (Gy/y per Bq/kg)	Reference
Pu-239	2.63E-04	ERICA (2019)	5.26E-10	ERICA (2019)	-	-	-	-
Pu-240	2.63E-04	ERICA (2019)	1.14E-09	ERICA (2019)	-	-	-	-
Pu-242	2.52E-04	Amiro (1997) - RBE 10	1.01E-08	Amiro (1997)	-	-	-	-
Sn-126	1.20E-05	Amiro (1997)	1.20E-05	Amiro (1997)	-	-	-	-
Th-229	2.54E-04	ICRP (2017)	9.64E-08	ICRP (2017)	-	-	-	-
Th-230	2.37E-04	ERICA (2019)	1.23E-09	ERICA (2019)	-	-	-	-
U-236	2.33E-04	Amiro (1997) - RBE 10	1.10E-08	Amiro (1997)	-	-	-	-
U-238	2.12E-04	ERICA (2019)	8.77E-10	ERICA (2019)	-	-	-	-
Zr-93	9.92E-08	Amiro (1997)	0.00E+00	Amiro (1997)	-	-	-	-
Berries								
Am-241	2.78E-04	ERICA (2019)	2.89E-08	ERICA (2019)	-	-	-	-
C-14	2.59E-07	ERICA (2019)	0.00E+00	ERICA (2019)	-	-	-	-
Ca-41	1.40E-08	Amiro (1997)	2.81E-09	Amiro (1997)	-	-	-	-
Cd-113m	9.37E-07	Amiro (1997)	4.23E-07	Amiro (1997)	-	-	-	-
Cl-36	1.40E-06	ERICA (2019)	2.75E-10	ERICA (2019)	-	-	-	-
H-3	7.23E-08	ERICA (2019)	0.00E+00	ERICA (2019)	-	-	-	-
Hf-182	1.63E-06	Amiro (1997)	1.56E-06	Amiro (1997)	-	-	-	-
Mo-93	8.22E-08	Amiro (1997)	7.46E-08	Amiro (1997)	-	-	-	-
Nb-93m	1.53E-06	Amiro (1997)	1.34E-08	Amiro (1997)	-	-	-	-
Ni-59	8.06E-08	ERICA (2019)	1.14E-09	ERICA (2019)	-	-	-	-
Ni-63	1.08E-07	ERICA (2019)	0.00E+00	ERICA (2019)	-	-	-	-
Pu-239	2.63E-04	ERICA (2019)	5.26E-10	ERICA (2019)	-	-	-	-
Pu-240	2.63E-04	ERICA (2019)	1.14E-09	ERICA (2019)	-	-	-	-
Pu-242	2.52E-04	Amiro (1997) - RBE 10	1.01E-08	Amiro (1997)	-	-	-	-
Sn-126	1.20E-05	Amiro (1997)	1.20E-05	Amiro (1997)	-	-	-	-
Th-229	2.54E-04	ICRP (2017)	9.64E-08	ICRP (2017)	-	-	-	-
Th-230	2.37E-04	ERICA (2019)	1.23E-09	ERICA (2019)	-	-	-	-
U-236	2.33E-04	Amiro - RBE 10	1.10E-08	Amiro - RBE 10	-	-	-	-
U-238	2.12E-04	ERICA (2019)	8.77E-10	ERICA (2019)	-	-	-	-
Zr-93	9.92E-08	Amiro (1997)	0.00E+00	Amiro (1997)	-	-	-	-
American Mink								
Am-241	2.78E-04	ERICA (2019)	2.19E-08	ERICA (2019)	-	-	7.80E-08	ERICA (2019)
C-14	2.59E-07	ERICA (2019)	0.00E+00	ERICA (2019)	-	-	1.05E-10	ERICA (2019)
Ca-41	1.40E-08	Amiro (1997)	2.81E-09	Amiro (1997)	-	-	1.87E-09	Amiro (1997)

Radionuclide	Internal (Gy/y per Bq/kg)	Reference	External On-soil (Gy/y per Bq/kg)	Reference	External In-soil (Gy/y per Bq/kg)	Reference	Water (Gy/y per Bq/kg)	Reference
Cd-113m	9.37E-07	Amiro (1997)	4.23E-07	Amiro (1997)	-	-	2.82E-07	Amiro (1997)
Cl-36	1.40E-06	ERICA (2019)	2.63E-10	ERICA (2019)	-	-	8.59E-09	ERICA (2019)
H-3	7.23E-08	ERICA (2019)	0.00E+00	ERICA (2019)	-	-	2.45E-15	ERICA (2019)
Hf-182	1.63E-06	Amiro (1997)	1.56E-06	Amiro (1997)	-	-	1.04E-06	Amiro (1997)
Mo-93	8.22E-08	Amiro (1997)	7.46E-08	Amiro (1997)	-	-	4.97E-08	Amiro (1997)
Nb-93m	1.53E-06	Amiro (1997)	1.34E-08	Amiro (1997)	-	-	8.90E-09	Amiro (1997)
Ni-59	8.13E-08	ERICA (2019)	8.77E-42	ERICA (2019)	-	-	1.49E-10	ERICA (2019)
Ni-63	1.08E-07	ERICA (2019)	0.00E+00	ERICA (2019)	-	-	6.49E-12	ERICA (2019)
Pu-239	2.63E-04	ERICA (2019)	2.81E-10	ERICA (2019)	-	-	5.17E-10	ERICA (2019)
Pu-240	2.63E-04	ERICA (2019)	5.17E-10	ERICA (2019)	-	-	8.06E-10	ERICA (2019)
Pu-242	2.52E-04	Amiro (1997) - RBE 10	1.01E-08	Amiro (1997)	-	-	6.70E-09	Amiro (1997)
Sn-126	1.20E-05	Amiro (1997)	1.20E-05	Amiro (1997)	-	-	7.98E-06	Amiro (1997)
Th-229	2.48E-04	ICRP (2017)	1.14E-07	ICRP (2017)	-	-	3.59E-07	ICRP (2017)
Th-230	2.37E-04	ERICA (2019)	6.05E-10	ERICA (2019)	-	-	1.75E-09	ERICA (2019)
U-236	2.33E-04	Amiro (1997) - RBE 10	1.10E-08	Amiro (1997)	-	-	7.31E-09	Amiro (1997)
U-238	2.10E-04	ERICA (2019)	4.12E-10	ERICA (2019)	-	-	5.79E-10	ERICA (2019)
Zr-93	9.92E-08	Amiro (1997)	0.00E+00	Amiro (1997)	-	-	0.00E+00	Amiro (1997)
Red Fox								
Am-241	2.78E-04	ERICA (2019)	2.19E-08	ERICA (2019)	-	-	-	-
C-14	2.59E-07	ERICA (2019)	0.00E+00	ERICA (2019)	-	-	-	-
Ca-41	1.40E-08	Amiro (1997)	2.81E-09	Amiro (1997)	-	-	-	-
Cd-113m	9.37E-07	Amiro (1997)	4.23E-07	Amiro (1997)	-	-	-	-
Cl-36	1.40E-06	ERICA (2019)	2.63E-10	ERICA (2019)	-	-	-	-
H-3	7.23E-08	ERICA (2019)	0.00E+00	ERICA (2019)	-	-	-	-
Hf-182	1.63E-06	Amiro (1997)	1.56E-06	Amiro (1997)	-	-	-	-
Mo-93	8.22E-08	Amiro (1997)	7.46E-08	Amiro (1997)	-	-	-	-
Nb-93m	1.53E-07	Amiro (1997)	1.34E-08	Amiro (1997)	-	-	-	-
Ni-59	8.13E-08	ERICA (2019)	8.77E-42	ERICA (2019)	-	-	-	-
Ni-63	1.08E-07	ERICA (2019)	0.00E+00	ERICA (2019)	-	-	-	-
Pu-239	2.63E-04	ERICA (2019)	2.81E-10	ERICA (2019)	-	-	-	-
Pu-240	2.63E-04	ERICA (2019)	5.17E-10	ERICA (2019)	-	-	-	-
Pu-242	2.52E-04	Amiro (1997) - RBE 10	1.01E-08	Amiro (1997)	-	-	-	-
Sn-126	1.20E-05	Amiro (1997)	1.20E-05	Amiro (1997)	-	-	-	-
Th-229	2.48E-04	ICRP (2017)	1.14E-07	ICRP (2017)	-	-	-	-

Radionuclide	Internal (Gy/y per Bq/kg)	Reference	External On-soil (Gy/y per Bq/kg)	Reference	External In-soil (Gy/y per Bq/kg)	Reference	Water (Gy/y per Bq/kg)	Reference
Th-230	2.37E-04	ERICA (2019)	6.05E-10	ERICA (2019)	-	-	-	-
U-236	2.33E-04	Amiro (1997) - RBE 10	1.10E-08	Amiro (1997)	-	-	-	-
U-238	2.10E-04	ERICA (2019)	4.12E-10	ERICA (2019)	-	-	-	-
Zr-93	9.92E-08	Amiro (1997)	0.00E+00	Amiro (1997)	-	-	-	-
Short-tailed Weasel								
Am-241	2.78E-04	ERICA (2019)	2.19E-08	ERICA (2019)	4.82E-08	ERICA (2019)	-	-
C-14	2.59E-07	ERICA (2019)	0.00E+00	ERICA (2019)	0.00E+00	ERICA (2019)	-	-
Ca-41	1.40E-08	Amiro (1997)	2.81E-09	Amiro (1997)	2.81E-09	Amiro (1997)	-	-
Cd-113m	9.37E-07	Amiro (1997)	4.23E-07	Amiro (1997)	4.23E-07	Amiro (1997)	-	-
Cl-36	1.40E-06	ERICA (2019)	2.63E-10	ERICA (2019)	6.57E-10	ERICA (2019)	-	-
H-3	7.23E-08	ERICA (2019)	0.00E+00	ERICA (2019)	0.00E+00	ERICA (2019)	-	-
Hf-182	1.63E-06	Amiro (1997)	1.56E-06	Amiro (1997)	1.56E-06	Amiro (1997)	-	-
Mo-93	8.22E-08	Amiro (1997)	7.46E-08	Amiro (1997)	7.46E-08	Amiro (1997)	-	-
Nb-93m	1.53E-06	Amiro (1997)	1.34E-08	Amiro (1997)	1.34E-08	Amiro (1997)	-	-
Ni-59	8.13E-08	ERICA (2019)	8.77E-42	ERICA (2019)	7.19E-10	ERICA (2019)	-	-
Ni-63	1.08E-07	ERICA (2019)	0.00E+00	ERICA (2019)	0.00E+00	ERICA (2019)	-	-
Pu-239	2.63E-04	ERICA (2019)	2.81E-10	ERICA (2019)	6.31E-10	ERICA (2019)	-	-
Pu-240	2.63E-04	ERICA (2019)	5.17E-10	ERICA (2019)	1.14E-09	ERICA (2019)	-	-
Pu-242	2.52E-04	Amiro (1997) - RBE 10	1.01E-08	Amiro (1997)	1.01E-08	Amiro (1997)	-	-
Sn-126	1.20E-05	Amiro (1997)	1.20E-05	Amiro (1997)	1.20E-05	Amiro (1997)	-	-
Th-229	2.48E-04	ICRP (2017)	1.14E-07	ICRP (2017)	2.28E-07	ICRP (2017)	-	-
Th-230	2.37E-04	ERICA (2019)	6.05E-10	ERICA (2019)	1.58E-09	ERICA (2019)	-	-
U-236	2.33E-04	Amiro - RBE 10	1.10E-08	Amiro (1997)	1.10E-08	Amiro (1997)	-	-
U-238	2.10E-04	ERICA (2019)	4.12E-10	ERICA (2019)	8.77E-10	ERICA (2019)	-	-
Zr-93	9.92E-08	Amiro (1997)	0.00E+00	Amiro (1997)	0.00E+00	Amiro (1997)	-	-

Notes:

(1) The ERICA Tool (2019) provided freshwater and terrestrial internal (alpha; beta/gamma; low beta) and external (low beta; beta/gamma) unweighted DCs for each radionuclide/receptor pair. The internal and external DCs were then compiled for each radionuclide/receptor pair by summing the internal and external radiation components, respectively, while applying the appropriate weighting factor to each component (10 for alpha radiation; 3 for low-energy beta radiation; 1 for high-energy beta and gamma radiation).

(2) Amiro (1997) – RBE 10 indicates that the dose coefficient from Amiro (1997) was multiplied by an RBE factor of 10 for alpha radiation.

3.5.2 Non-Radiological COPCs

For terrestrial vegetation and earthworms, toxicity is based on direct comparison to soil COPC concentrations; an examination of the intakes for these receptors is not necessary. Similarly, assessment of potential effects on aquatic biota via contact with surface water is based on direct comparison to surface water COPC concentrations and exposure modelling is not required.

For mammals and birds, COPC exposure is based on intakes, which are estimated by way of food chain intake calculations. In a broad sense, the total intake of any given COPC for a particular mammal or bird receptor is equal to the sum of intakes from all appropriate pathways, including: incidental ingestion of soil/sediment, incidental ingestion of surface water, and consumption of food (which varies based on the diet of a particular receptor). Equation 3-6 is used to calculate each of the intake routes as follows:

$$I_n = C_n \times IR_n \times f_{loc} \times CF \qquad (3\text{-}6)$$

where

- I_n = intake of COPC via pathway "n" where "n" can represent all exposure routes such as soil, vegetation, etc. [mg/d]
- C_n = COPC concentration in "n" medium [mg/kg]
- IR_n = intake rate of "n" by the receptor [g/d]
- f_{loc} = fraction of time at site [-]
- CF = conversion factor 1.0×10^{-3} [kg/g]

After summing the individual intakes, the total intake was divided by the body weight of the ecological receptor in order to compare the total COPC intake to the TRV (which has the unit of mg/kg-d). This is consistent with CSA (2012, Clause 7.3.4.2.2) methodology for calculating intakes.

3.5.3 Transfer Parameters

To estimate intake up the food chain, concentrations of COPCs in terrestrial vegetation, earthworms and small mammals and birds (as prey) are estimated using concentration ratios (CRs) from literature sources. The associated tissue concentrations in terrestrial vegetation, earthworms and small mammals and birds from all exposure pathways are estimated from soil concentrations as shown in Equation 3-7:

$$\boldsymbol{C_{biota} = C_{soil} \times CR_{soil-to-biota}} \qquad (3\text{-}7)$$

where

- C_{biota} = COPC concentration in biota (vegetation, earthworms, small mammals, birds) [mg/(kg ww)]
- C_{soil} = COPC concentration in soil [mg/(kg dw)]

CR = concentration ratio from soil-to-biota [(mg/(kg ww))/(mg/(kg dw))]

Similarly, the associated tissue concentrations in aquatic vegetation, benthic invertebrates and aquatic mammals and birds from all exposure pathways are estimated from water concentrations as shown in Equation 3-8:

$$\boldsymbol{C_{biota}} = \boldsymbol{C_{water}} \times \boldsymbol{CR_{water-to-biota}} \qquad (3\text{-}8)$$

Concentration ratios from soil- or water-to-small mammals are not always available for all COPCs. As an alternative, mammalian tissue concentrations can be estimated from allometrically scaled feed-to-tissue transfer factors as shown in Equation 3-9:

$$C_{tissue} = I_{total} \times TF_{feed-to-tissue} \qquad (3\text{-}9)$$

where

C_{tissue} = COPC concentration in tissue of ingested animal [mg/(kg ww)]

I_{total} = intake of COPC by ingested animal from all pathways ($\sum I_n$) [mg/d]

$TF_{feed\text{-}to\text{-}tissue}$ = allometrically scaled transfer factor from feed-to-tissue [d/kg]

Transfer factors from literature for feed-to-beef (cow) are available for many COPCs, which can then be allometrically scaled for the ingested animal using the ratio of their body weight to that of the cow using Equation 3-10:

$$\boldsymbol{TF_{mammal}} = \boldsymbol{TF_{fb}} \times \left(\frac{\boldsymbol{BW_{mammal}}}{\boldsymbol{BW_{cow}}}\right)^{\boldsymbol{-0.75}} \quad (3\text{-}10)$$

where

TF_{mammaL} = feed-to-tissue transfer factor for mammal [d/(kg ww)]

TF_{fb} = feed-to-tissue transfer factor for beef [d/(kg ww)]

BW_{mammal} = body weight of mammal [kg]

BW_{cow} = 600, body weight of cow [kg] (N288.1-14 Table G.7; CSA 2018)

Smaller mammals were scaled to a rabbit (1.8 kg body weight) for the radiological assessment and lamb (50 kg body weight) for the lead assessment (body weights from N288.1-14 Table G.7; CSA 2018).

Similarly, transfer factors from literature for feed-to-bird (poultry) can be allometrically scaled for the ingested birds using the ratio of their body weight to that of the poultry using Equation 3-11:

$$TF_{bird} = TF_{poultry} \times \left(\frac{BW_{bird}}{BW_{poultry}} \right)^{-0.75} \quad (3\text{-}11)$$

where

TF_{bird} = feed-to-tissue transfer factor for bird [d/(kg ww)]

$TF_{poultry}$ = feed-to-tissue transfer factor for poultry [d/(kg ww)]

BW_{bird} = body weight of bird [kg]

$BW_{poultry}$ = 2, body weight of poultry [kg] (N288.1-14 Table G.7; CSA 2018)

The concentration ratios and transfer factors for non-radiological and radiological contaminants that were assessed in the EcoRA are summarized Table 3.11 and Table 3.12, respectively. It is noted from Table 3.12 that soil-to-earthworm concentration ratios are not available for Hf-182 and Sn-126 and thus these radionuclides were not included in the dose calculation for the earthworm.

Table 3.11 Transfer Parameters for Lead

Lead (Pb) Transfer Parameter	Unit	Value	Reference
Water-to-Fish (Whole) CR	L/kg FW	250	IAEA (2014), Table 6 (whole organism)
Water-to-Aquatic Vegetation CR	L/kg FW	62	IAEA (2014), Table 6 (avg. algae, vascular plants)
Water-to-Benthos CR	L/kg FW	3020	IAEA (2014), Table 56 (avg. crustaceans, insects, larvae, molluscs)
Soil-to-Earthworm CR	kg DW/kg DW	0.52	IAEA (2014) Table 5 (annelids)
Soil-to-Vegetation CR	g DW/g DW	3.17	IAEA (2014), Table 5 (avg. grasses, shrubs, trees)
Feed-to-Bird TF	d/kg FW	0.4	NCRP (1996)
Feed-to-Mammal TF (large)	d/kg FW	0.0007	IAEA (2010), Table 30 (beef; mean)
Feed-to-Mammal TF (small)	d/kg FW	0.0071	IAEA (2010), Table 31 (mutton; mean)

Note:
Moisture content of earthworms assumed to be 84% (U.S. EPA 1993 Tables 4-1 and 4-2) and 80% for terrestrial vegetation (CSA 2018, Table G.5 for forage).
CR – concentration ratio; TF – transfer factor.

Table 3.12 Transfer Parameters for Radiological COPCs

Radionuclide	Water-to-Aquatic Vegetation CR (L/kg FW) (1)	Water-to-Benthos CR (L/kg FW) (2)	Water-to-Fish (Whole) CR (L/kg FW) (3)	Soil-to-Earthworm CR (g DW/g DW) (4)	Soil-to-Vegetation CR (g DW/g DW) (5)	Feed-to-Bird TF (d/kg FW) (6)	Feed-to-Mammal (Large) TF (d/kg FW) (7)	Feed-to-Mammal (Small) TF d/kg FW) (7)
Am-241	3.10E+03	1.20E+03	2.40E+02 *	1.13E+00	6.30E-04	1.20E-03	5.00E-04	3.30E-03
C-14	5.90E+03	5.20E+03	5.70E+03 *	1.35E+03 (12)	9.75E+02 (12)	Specific Activity Model		
Ca-41	3.75E+02 (4)	4.53E+02 (4)	1.40E+03 (4)	3.07E-01 (9)	2.00E+01 (10)	4.40E-02 (10)	1.30E-02 (10)	1.30E-02 (10)
Cd-113m	6.30E+02 (4)	2.80E+05 (4)	2.30E+02 (4) *	2.88E+01	1.59E+01 (4)	1.70E+00 (10)	5.80E-03 (10)	5.80E-03 (10)
Cl-36	5.00E+01	1.40E+02	9.50E+01 (10)	1.13E+00	8.90E+01	1.75E+00	1.70E-02	1.96E+00
H-3	7.50E-01 (HTO)	7.50E-01 (HTO)	7.50E-01 (HTO) *	9.38E+02 (11)	2.68E+01 (12)	Specific Activity Model		
Hf-182	1.00E+03	9.70E+01	2.10E+03 (10)	N/A	1.60E-02	1.00E-01	6.30E-04	1.10E+02
Mo-93	2.40E+02	3.60E+00	2.70E+01 (10)	1.01E+00 (9)	3.60E-01	1.80E-01	1.00E-03	2.50E-01
Nb-93m	1.20E+03	1.00E+02	3.00E+02 *	3.19E-03)	2.90E-02	3.00E-04	2.60E-07	4.20E-03
Ni-59	5.20E+01	1.00E+02	7.10E+01 (10)	4.5E-01	4.70E-01	3.10E-01	5.00E-03	3.46E-01
Ni-63	5.20E+01	1.00E+02	7.10E+01 (10)	4.63E-01	4.70E-01	3.10E-01	5.00E-03	3.46E-01
Pu-239	4.00E+03	7.20E+02	2.10E+04 *	1..94E-01	1.40E-04	9.20E-04	1.10E-06	3.50E-03
Pu-240	4.00E+03	7.20E+02	2.10E+04 *	1.94E-01	1.40E-04	9.20E-04	1.10E-06	3.50E-03
Pu-242	4.00E+03	7.20E+02	2.10E+04 *	1.94E-01	1.40E-04	9.20E-04	1.10E-06	3.50E-03
Sn-126	1.00E+02	5.90E+02	3.00E+03 *	N/A	4.10E-01	1.20E+00	1.10E-02	2.80E-01
Th-229	1.20E+03	9.00E+02	1.90E+02 (10)	5.73E-02 (8)	3.30E-03	1.00E-02	2.30E-04	2.80E-02
Th-230	1.20E+03	9.00E+02	1.90E+02 (10)	5.73E-02 (8)	3.30E-03	1.00E-02	2.30E-04	2.80E-02
U-236	3.00E+02	9.90E+01	2.40E+00 (10)	5.50E-02	1.00E-02	7.50E-01	3.90E-04	4.10E-02
U-238	3.00E+02	9.90E+01	2.40E+00 (10)	5.50E-02	1.00E-02	7.50E-01	3.90E-04	4.10E-02
Zr-93	3.20E+03	3.00E+03	9.50E+01 (10)	5.97E-02 (8)	3.20E-03	6.00E-05	1.20E-06	7.10E-04

Notes:

(1) N288.1-14 (CSA 2018), Table A.25f (freshwater plants) unless otherwise noted.
(2) N288.1-14 (CSA 2018), Table A.25e (freshwater invertebrates) unless otherwise noted.
(3) N288.1-14 (CSA 2018), Table A.25a (fish muscle for freshwater fish) unless otherwise noted; also applied to green frog (tadpole).
(4) IAEA (2014) Tables 5 and 6.
(5) N288.1-14 (CSA 2018), Table G.3 (concentration ratios); also applied to berries and mushrooms.
(6) N288.1-14 (CSA 2018), Table G.3 (poultry meat).
(7) N288.1-14 (CSA 2018), Table G.3 (beef meat for large mammals; rabbit meat for small mammals).

(8) ERICA (2019).
(9) Sample *et al.* (1998).
(10) IAEA (2010), Tables 17, 30, 34, and 57.
(11) Beresford (2008).
(12) Derived using Specific Activity Model.
CR – Concentration Ratio; TF – transfer factor; N/A – not available.
* water-to-whole fish concentration ratio assumed to be the same as that for water-to-fish muscle.
Moisture content of earthworms assumed to be 84% (U.S. EPA 1993 Tables 4-1 and 4-2) and 80% for terrestrial vegetation (CSA 2018, Table G.5 for forage).

3.5.3.1 Specific Activity Model for Tritium

The plant and animal concentration ratios for tritium were estimated using the specific activity approach, as recommended in Clause 7.3.4.3.6 of N288.6-12 (CSA 2012). Tritium concentration rations for aquatic biota, which have been derived using the specific activity model as described in Clause 7.7.4 of N288.1-14 (CSA 2018), were taken from Tables A.25a, A.25e and A.25f of N288.1-14 (CSA 2018) and summarized below in Table 3.13.

Table 3.13 Tritium Concentration Ratios for Aquatic and Terrestrial Biota

HTO Concentration Ratio (CR)	Unit	Value	Reference
Water-to-Fish (Whole)	L/kg-ww	7.50E-01	CSA 2018, Table A.25a (fish muscle for freshwater fish)
Water-to-Aquatic Vegetation	L/kg-ww	7.50E-01	CSA 2018, Table A.25f (freshwater plants)
Water-to-Benthos	L/kg-ww	7.50E-01	CSA 2018, Table A.25e (freshwater invertebrates)
Soil-to-Earthworm	kg-dw/kg-dw	9.38E+02	Beresford 2008; converted from wet weight assuming a moisture content of 84% (U.S. EPA 1993 Table 4-1 and 4-2)
Soil-to-Vegetation	kg-dw/kg-dw	2.68E+01	Calculated, Equation 3-14; converted from wet weight assuming a moisture content of 80% (CSA 2018, Table G.5 for forage)
Soil-to-Berries	kg-dw/kg-dw	6.02E+01	Calculated, Equation 3-14; converted from wet weight assuming a moisture content of 90% (CSA 2018, Table G.5 for forage)
Soil-to-Mushrooms	kg-dw/kg-dw	6.02E+01	Assumed same as berries due to similar water content (IAEA 2009)

As noted in Clause 7.7.4.1 of N288.1-14 (CSA 2018), tritium in freshwater and seas water undergoes rapid isotopic exchange with water in aquatic organisms. Thus, the model of tritium transfer from surface water to aquatic animals and plants assumes the specific activity in the aqueous compartments has the same specific activity as the surrounding water. Tritium transfer from water to aquatic plants ($P_{HTOwater\_plant}$) and aquatic animals ($P_{HTOwater\_animal}$) was calculated using the following equations (CSA 2018, Clause 7.7.4.1, Equations 7-21a and 7-21b):

$$P_{HTOwater\_plant} = 1 - DW_{aa} \qquad (3\text{-}12)$$

$$P_{HTOwater\_animal} = 1 - Dw_{ap} \qquad (3\text{-}13)$$

where

$P_{HTOwater\_plant}$ = tritium transfer from water to aquatic plants (L/kg-ww)

$P_{HTOwater\_animal}$ = tritium transfer from water to aquatic animals (L/kg-ww)

DW_{ap} = dry weight of aquatic plant per total fresh weight (kg-dw/kg-ww) (value of 0.25 for aquatic plants, Clause 7.7.4.2, CSA 2018)

$(1-DW_{ap})$ = fractional water content of aquatic plants (L kg-ww) (1-0.25)

DW_{aa} = dry weight of aquatic animal food product per total fresh weight (kg-dw/kg-ww) (value of 0.25 for freshwater fish and invertebrates, Clause 7.7.4.2, CSA 2018)

$(1-DW_{aa})$ = fractional water content of aquatic animals (L kg-ww) (1-0.25)

Soil-to-terrestrial biota concentration ratios for tritium were not derived in N288.1-14 (CSA 2018). Instead, the specific activity model was used for the transfer of tritium from air to plants that was based on the air concentration, which also accounted for the contribution from soil (Clause 6.4.6.2 in N288.1-14, CSA 2018). The transfer of tritium from soil to plant ($P_{HTOsoil\text{-}plant}$) was derived based on the ratio of the transfer of tritium from air to plant and the transfer of tritium from air to soil pore water, and was calculated as follows (EcoMetrix and Golder 2017):

$$P_{HTOsoil\_plant} = (P_{air\_plant} \times \rho_b) / (P_{air\_spw} \times 1000 \times \theta) \quad (3\text{-}14)$$

where

P_{air_plant} = transfer from air to plant (m^3/kg-ww)

- 49.5 m^3/kg-ww — CSA 2018, Table A.5c for forage, CRL site
- 55.6 m^3/kg-ww — CSA 2018, Table A.5c for generic fruits and vegetables, CRL site

P_{air_spw} = transfer form air to soil pore water (m^3/L)

- 60.0 m^3/L — CSA 2018, Table A.4g for eastern Ontario

ρ_b = bulk density of soil (kg-dw/m^3)

- 1300 kg/m^3 — CSA 2018, Table A.4f for loam

θ = volumetric moisture content of soil (m^3 water/m^3 soil)

- 0.2 — CSA 2018, Table A.4f for loam

The concentration ratio for the transfer of tritium to terrestrial invertebrates was obtained from Beresford (2008).

The transfer of tritium to animals through water ingestion ($P_{HTOwater\_animal}$) was determined using Equation 6-66 of N288.1-14 (CSA 2018, Clause 6.9.2.1), which assumes that the specific activity of tritium in the portion of the water of the animal food product (meat, milk or eggs) derived from direct water ingestion is the same as in the water itself:

$$P_{HTOwater\_animal} = k_{aw} * f_{w\text{-}w} * (1-DW_a) \quad (3\text{-}15)$$

where

$P_{HTOwater\_animal}$ = transfer of tritium to animal through water ingestion (L/kg-ww)

k_{aw}	=	fraction of water from contaminated sources; assumed to be 1 (unitless) (CSA 2018, Clause 6.9.1.2)
$f_{w\text{-}w}$	=	fraction of the animal water intake derived from direct ingestion of water (unitless)
DW_a	=	dry/fresh weight ratio for animal products (kg-dw/kg-fw)

The transfer of tritium from feed to animals ($P_{HTOfood\_animal}$), is modelled in the same way as the transfer from drinking water to animals where it is assumed that the specific activity of tritium in the portion of water of the animal food product (meat, milk or eggs) derived from feed is the same as that in the water available in the plant feed materials. Animals take in some water with the aqueous portion of their feed and derive another fraction from the metabolic decomposition of the organic matter in the feed. The feed to animal transfer of tritium was modelled as follow (CSA 2018, Clause 6.10.2.1, Equation 6-69):

$$P_{HTOfood\_animal} = k_{af} * ((1-f_{OBT}) * f_{w\text{-}pw} + 0.5 * f_{w\text{-}dw}) * (1-DW_a)/(1-DW_p) \quad (3\text{-}16)$$

where

$P_{HTOfood\_animal}$	=	transfer of tritium to animals through food ingestion (L/kg-ww)
k_{af}	=	fraction of food from contaminated sources; assumed to be 1 (unitless) (CSA 2018, Clause 6.9.1.2)
$f_{w\text{-}pw}$	=	fraction of the animal water intake derived from water in the plant feed
$f_{w\text{-}dw}$	=	fraction of the animal water intake that results from the metabolic decomposition of the organic matter in the feed
f_{OBT}	=	fraction of the total tritium in the animal product as organically bound tritium (OBT) as a result of HTO ingestion
$1-DW_a$	=	water content of the animal product (L water/kg-fw)
$1-DW_p$	=	water content of the plant/food (L water/kg-fw plant)

For each receptor, the water content of the total diet ($1-DW_p$) was determined based on the weighted average of the water content of the individual food items in the receptor's diet (e.g., weighted average of wet weight fraction of terrestrial vegetation (80% water content; 80% of diet) and soil invertebrates (84% water content; 20% of diet)). The water density (1 kg/L) was used to convert to units of L water/kg-fw plant.

A summary of the input parameters used to calculate $P_{HTOwater\_animal}$ and $P_{HTOfood\_animal}$ is presented in Table 3.14.

Table 3.14 Tritium Input Parameters for Specific Activity Calculations and Water and Food to Animal Transfer Parameters

Type	Receptor	f_{w_w} (1) (unitless)	f_{w_pw} (1) (unitless)	f_{w_dw} (1) (unitless)	f_{OBT} (1) (unitless)	$1\text{-}DW_p$ (2) (kg-dw/kg-fw)	$1\text{-}DW_p$ (L/kg-fw)	$P_{HTOwater\_animal}$ (L/kg-fw)	$P_{HTOfood\_animal}$ (unitless)	Qffw (total food intake rate) (g-fw/d)	$P_{HTOfood\_animal}$ (d/kg-fw)
Reptile	Blanding Turtle	0.413	0.509	0.071	0.11	0.757	0.757	0.289	0.19	32.5	5.9
Bird	Bald Eagle	0.220	0.650	0.121	0.10	0.702	0.702	0.154	0.28	564	0.49
Bird	Chimney Swift	0.220	0.650	0.121	0.10	0.840	0.840	0.154	0.23	15.3	49
Bird	Great Blue Heron	0.220	0.650	0.121	0.10	0.713	0.713	0.154	0.27	414	0.65
Bird	Mallard	0.220	0.650	0.121	0.10	0.768	0.768	0.154	0.25	258	0.97
Bird	Ruffed Grouse	0.220	0.650	0.121	0.10	0.806	0.806	0.154	0.24	171	1.40
Mammal	American Mink	0.413	0.510	0.071	0.11	0.730	0.730	0.289	0.20	115	1.75
Mammal	Black Bear	0.413	0.510	0.071	0.11	0.786	0.786	0.289	0.19	9522	0.02
Mammal	Eastern Wolf	0.413	0.510	0.071	0.11	0.680	0.680	0.289	0.22	5500	0.04
Mammal	Little Brown Myotis	0.413	0.509	0.071	0.11	0.813	0.813	0.289	0.18	4.82	22.5
Mammal	Meadow Vole	0.413	0.509	0.071	0.11	0.800	0.800	0.289	0.18	11.5	15.9
Mammal	Moose	0.413	0.510	0.071	0.11	0.790	0.790	0.289	0.19	38095	0.00
Mammal	Muskrat	0.413	0.509	0.071	0.11	0.754	0.754	0.289	0.19	284	0.68
Mammal	Northern River Otter	0.413	0.509	0.071	0.11	0.724	0.724	0.289	0.20	814	0.25
Mammal	Red Fox	0.413	0.509	0.071	0.11	0.739	0.739	0.389	0.20	342	0.58
Mammal	Short-tailed Shrew	0.413	0.509	0.071	0.11	0.840	0.840	0.289	0.17	9.00	19
Mammal	Short-tailed Weasel	0.413	0.509	0.0071	0.11	0.691	0.691	0.289	0.21	31.7	6.69
Mammal	White-tailed Deer	0.330	0.582	0.081	0.11	0.800	0.800	0.231	0.21	11250	0.019

Notes:
(1) f_{w_w}, f_{w_pw}, f_{w_dw} and f_{OBT} taken from Table 16 (beef cow), Table 18 (deer), Table 19 (rabbit) and Table 20 (wild waterfowl), CSA (2018).
(2) $1\text{-}DW_p$ calculated based on the weighted average of the water content of the individual food items in the receptor's diet and converted to L/kg-fw using the density of water (1 kg/L).
fw-w - fraction of the animal water intake derived from direct ingestion of water.
fw-pw - fraction of the animal water intake derived from water in the plant feed.
fw-dw - fraction of the animal water intake that results from the metabolic decomposition of the organic matter in the feed.
f_{OBT} - fraction of the total tritium in the animal product as OBT (organically bound tritium) as a result of HTO (tritiated water vapour) ingestion.
1-DWp - water content of the plant/food.
Qffw - total food intake rate.
$P_{HTOwater\_animal}$ - transfer of tritium to animal through water ingestion.
$P_{HTOfood\_animal}$ - transfer of tritium to animals through food ingestion.

3.5.3.2 Specific Activity Model for Carbon-14

The plant and animal transfer parameters for carbon-14 were estimated using the specific activity approach, as recommended in Clause 7.3.4.3.6 of N288.6-12 (CSA 2012). Carbon-14 concentration ratios for aquatic biota, which have been derived using the specific activity model as described in Clause 7.7.5 of N288.1-14 (CSA 2018), were taken from Tables A.25a, A.25e and A.25f of N288.1-14 (CSA 2018) and summarized below in Table 3.15. The average value of the stable carbon concentration in dissolved inorganic form across the Great Lakes system and rivers is 0.0213 gC/L (CSA 2018 Clause 7.7.5.3). The concentrations of stable carbon in freshwater fish, invertebrates and aquatic plants are 122 gC/kg ww, 111 gC/kg ww and 500 gC/kg dw, respectively (CSA 2018 Clause 7.7.5.6 and Table 23).

Table 3.15 Carbon-14 Concentration Ratios for Aquatic and Terrestrial Biota

C-14 Transfer Factor (TF)	Unit	Value	Reference
Water-to-Fish (Whole)	L/kg FW	5.70E+03	CSA 2018, Table A.25a (fish muscle for freshwater fish)
Water-to-Aquatic Vegetation	L/kg FW	5.90E+03	CSA 2018, Table A.25f (freshwater plants)
Water-to-Benthos	L/kg FW	5.20E+03	CSA 2018, Table A.25e (freshwater invertebrates)
Soil-to-Earthworm	kg DW/kg DW	1.35E+03	Calculated, Equation 3-24
Soil-to-Vegetation	g DW/g DW	9.75E+02	Calculated, Equation 3-24

Water-to-aquatic biota concentration ratios for carbon-14 were calculated as follows (Equation 7-23 in N288.1-14):

$$\boldsymbol{CR_{fw-to-aq\ animals} = M_{aa}/M_w} \qquad (3\text{-}17)$$

where

$CR_{fw\text{-}to\text{-}aq\ biota}$ = transfer factor from water to aquatic biota (L/kg ww)

M_{aa} = mass of stable carbon in aquatic biota (gC/kg ww)

M_w = mass of stable carbon in the dissolved inorganic phase in water (gC/L).

For aquatic plants, a dry/fresh weight ratio of 0.25 was used to convert the mass of stable carbon from 500 gC/kg dw to 125 gC/kg ww.

Soil-to-terrestrial biota concentration ratios for carbon-14 were not derived in N288.1-14 (CSA 2018). Instead, the specific activity model was used for the transfer of carbon-14 from air to plants and animals that was based on the air concentration, which also accounted for the contribution from soil (Clause 6.4.9.1 in N288.1-14, CSA 2018).

As carbon-14 concentrations in air were not modelled for the postclosure phase, an alternative approach given by Yu *et al.* (as cited in IAEA 2009) was used for carbon-14 associated with soil solids. The flux of carbon-14 from the soil to the atmosphere is given by:

$$F = C_{soil} \times E_c \times \rho_b \times d_s \qquad (3\text{-}18)$$

where

- F = flux of C-14 from soil to air ($Bq/m^2/d$)
- C_{soil} = C-14 concentration in soil (Bq/kg dw)
- E_c = C-14 evasion loss rate (per d); 0.033 for loam (IAEA 2009)
- ρb = soil dry bulk density (kg dw/m^3); 1300 for loam (CSA 2018, Clause 6.3.2.2 and IAEA 2009)
- d_s = soil depth (m); assumed 0.2 (CSA 2018, Clause 6.3.1.1).

The specific activity of the carbon evading the soil (SAe, Bq/gC) is given by:

$$SA_e = F/F_c \qquad (3\text{-}19)$$

where

- F = flux of C-14 from soil to air ($Bq/m^2/d$), estimated in above equation
- Fc = average production of stable carbon by decomposition of crop residues ($gC/m^2/d$); suggested value is 0.66 (IAEA 2009).

Assuming that the specific activity of air in the plant canopy is the same as in the soil gas, and modified to account for dilution with uncontaminated air, the specific activity in air is given by:

$$SA_{air} = CD_c \times SA_e \qquad (3\text{-}20)$$

where

- SA_{air} = C-14 specific activity in air (Bq/gC)
- CDc = canopy dilution factor for C-14 (unitless); 0.15 for crops with an open canopy (forage) (IAEA 2009).

By definition,

$$SA_{air} = \frac{C_{air}}{S_{air}} \qquad (3\text{-}21)$$

where:

- S_{air} = concentration of stable carbon in air (gC/m^3); 0.21 (CSA 2018, Clause 6.4.9.3)
- C_{air} = concentration of C-14 in air (Bq/m^3).

Hence, C_{air} (concentration of C-14 in air) can be estimated from C_{soil} (concentration of C-14 in soil) by re-arranging the above equations:

$$C_{air} = C_{soil} \times E_c \times \rho_b \times d_s \times CD_c \times S_{air}/F_c \qquad (3\text{-}22)$$

The estimated C-14 concentration in plants based on the equation given in Clause 6.4.9.2 of N288.1-14 (CSA 2018) without the dry/fresh weight conversion is as follows:

$$C_{plant} = C_{air} \times f_{c\_air} \times S_{plant}/S_{air} \qquad (3\text{-}23)$$

where

- C_{plant} = concentration of C-14 in plants (Bq/kg dw)
- C_{air} = concentration of C-14 in air (Bq/m^3)
- f_{c_air} = fraction of plant stable carbon derived from air (unitless); assumed to be 1.0 (CSA 2018, Clause 6.4.9.3)
- S_{plant} = concentration of stable carbon in plant (gC/kg dw); 500 (CSA 2018, Clause 6.4.9.3)
- S_{air} = concentration of stable carbon in air (gC/m^3); 0.21 (CSA 2018, Clause 6.4.9.3).

Combining equations (3-22) and (3-23),

$$C_{plant} = C_{soil} \times E_c \times \rho_b \times d_s \times CD_c \times S_{air}/F_c \times f_{c\_air} \times S_{plant}/S_{air}$$

$$C_{plant} = C_{soil} \times 0.033 \times 1300 \times 0.2 \times 0.15 \times 0.21/0.66 \times 1.0 \times 500/0.21 \qquad (3\text{-}24)$$

The soil-to-plant concentration ratio for C-14 is estimated to be 975.

Using a similar approach, the specific activity of carbon-14 (Bq/gC) is assumed to be the same in soil invertebrates as in plants. In the absence of data on stable carbon content in terrestrial invertebrates, a value of 111 gC/kg ww (or 694 gC/kg dw assuming a moisture content of 84%) was used, consistent with the value for marine crustaceans (Table 23 in N288.1-14, CSA 2018). By replacing S_{plant} in equation (3-24) with 694 gC/kg dw, the soil-to-earthworm concentration ratio for carbon-14 is estimated to be 1353.

To derive feed-to-flesh transfer factors for carbon-14, it is assumed that food ingestion pathways contribute most of the carbon intake by ecological receptors, compared to the inhalation, water ingestion and soil/sediment ingestion pathways. Using the specific activity approach,

$$C_{animal} = C_{food} \times S_{animal}/S_{food} = Q_{food} \times C_{food} \times TF_{feed-to-flesh} \qquad (3\text{-}25)$$

and hence,

$$TF_{feed-to-flesh} = \frac{S_{animal}}{S_{food}} / Q_{food} \qquad (3\text{-}26)$$

where

C_{animal} = concentration of C-14 in the animal (Bq/kg ww)

C_{feed} = concentration of C-14 in the food (Bq/kg ww)

S_{animal} = concentration of stable carbon in the animal (gC/kg ww); 244 for birds and 201 for mammals (CSA 2018 Table 18 for beef and poultry)

S_{food} = concentration of stable carbon in food in the animal's diet (gC/kg ww); based on weighted average of the stable carbon concentration of the individual food items in the animal's diet

Q_{food} = food intake rate (kg ww/d); based on ecological receptor characteristics

$TF_{feed-to-flesh}$ = feed-to-animal transfer factor (d/kg ww).

The concentrations of stable carbon by food type are given in Table 3.16 and the estimated $TF_{feed-to-flesh}$ for carbon-14 are shown in Table 3.17.

Table 3.16 Stable Carbon Concentration by Food Types

Food Type	Stable Carbon Concentration (gC/kg ww)	Reference
Aquatic Vegetation	50	CSA 2018, Clause 7.7.5.6 converted from 500 gC/kg dw assuming a moisture content of 90%
Birds	244	CSA 2018, Table 18 for poultry
Benthic Invertebrates	111	CSA 2018, Table 23 for marine crustacea
Earthworms	111	CSA 2018, Table 23 for marine crustacea
Fish	122	CSA 2018, Table 23 for fish
Mammals	201	CSA 2018, Table 18 for beef
Terrestrial Vegetation	100	CSA 2018, converted from 500 gC/kg dw assuming a moisture content of 80% (Table G.5 for forage)

Table 3.17 Estimated Feed-to-Flesh Transfer Factors for Carbon-14

Receptor	S_{animal}	Food Intake	Fraction of Food Type in Diet (with stable carbon concentration in gC/kg ww)								S_{food}	Transfer Factor
	(gC/kg ww)	(kg ww/d)	Terrestrial Vegetation	Aquatic Vegetation	Benthic Invertebrates	Fish	Earthworm	Deer	Birds	Small Mammals	(gC/kg ww)	d/kg ww
Bald Eagle	244	0.564				0.65			0.15	0.2	157	2.77E+00
Chimney Swift	244	0.0153					1				111	4.68E+02
Great Blue Heron	244	0.414			0.1	0.65				0.25	141	4.19E+00
Mallard	244	0.258	0.05	0.5	0.4	0.025	0.025				80.2	1.18E+01
Ruffed Grouse	244	0.171	0.85				0.15				102	1.41E+01
Black Bear	201	9.52	0.8			0.05	0.05			0.1	112	1.89E-01
Eastern Wolf	201	5.5						0.2		0.8	201	1.82E-01
Little Brown Myotis (bat)	201	0.005			0.5		0.5				111	2.27E+02
Meadow Vole	201	0.0115	1								100	1.75E+02
Moose	201	38.1	0.8	0.2							90.0	5.86E-02
Muskrat	201	0.284		0.8	0.15	0.05					62.8	1.13E+01
Norther River Otter	201	0.814			0.15	0.8			0.027	0.023	126	1.97E+00
Short-tailed Shrew	201	0.009					1				111	2.01E+02
White-tailed Deer	201	11.3	1								100	1.79E-01
Blanding's Turtle	201	0.032		0.4		0.6					88.8	6.97E+01
American Mink	201	0.115			0.35	0.4			0.125	0.125	143	1.22E+01
Red Fox	201	0.342	0.15				0.25		0.2	0.4	172	3.42E+00
Short-tailed Weasel	201	0.032					0.05		0.25	0.7	207	3.06E+01

4.0 EFFECTS ASSESSMENT

4.1 Radiological Benchmarks

The selection of radiological dose benchmarks was based on a wide review of the literature which included the following main sources:

- IAEA (1992);
- UNSCEAR (1996; 2008);
- U.S. DOE (2019);
- U.K. EA (2002);
- Environment Canada/Health Canada (EC/HC) (2003).

UNSCEAR (2008) conducted a review of the available data on effects to biota, both direct and indirect effects (such as population shifts). Data on the effects of exposure to ionizing radiation were reviewed with a significant amount of information developed from follow-up observations of non-human biota in the zone around the Chernobyl nuclear power plant. The review indicated that there is a considerable range of endpoints and corresponding effects levels presented in the literature. Overall, UNSCEAR (2008) concluded that a chronic dose rate of less than 400 µGy/h (9.6 mGy/d) to any individual in aquatic populations would be unlikely to have any detrimental effect at the population level. With respect to terrestrial wildlife, UNSCEAR (2008) concluded that reproductive changes are a more sensitive indicator of the effects of radiation exposure than mortality and that mammals are the most sensitive animal organisms. Overall, UNSCEAR concluded that a chronic dose rate of less than 100 µGy/h (2.4 mGy/d) to the most highly exposed individuals would be unlikely to have significant effects on most terrestrial communities. CSA N288.6-12 (CSA 2012), which addresses Ecological Risk Assessments at Class I nuclear facilities and uranium mines and mills, recommends adopting the UNSCEAR (2008) recommendations with respect to radiological dose benchmarks.

Table 4.1 presents the radiological dose benchmarks selected for both aquatic and terrestrial biota. Consistent with CSA N288.6-12 (CSA 2012 Clause 7.4.2) guidance, radiological benchmarks for terrestrial biota from UNSCEAR (2008) were adopted for use in the EcoRA. As part of the Ottawa River is located in the Province of Quebec, which has a radiological benchmark for aquatic biota (10 µGy/hr or 0.24 mGy/d) 40 times lower than that recommended by CSA N288.6-12 (CSA 2012), the more restrictive Quebec benchmark of 0.24 mGy/d was applied to aquatic biota (MELCC 2020).

The benchmarks noted above from UNSCEAR (2008) and MELCC (2020) were applied to non-SAR species. As there are no specific radiological benchmarks for SAR species, the UNSCEAR (2008) and MELCC (2020) benchmarks were divided by a factor of 10 when applied to SAR species to provide an extra level of safety.

Table 4.1 Radiological Dose Benchmarks (mGy/d)

Category	Organism	Dose Rate Benchmark	
		Non-SAR Species	SAR Species[3]
Aquatic Biota	Fish (benthic & pelagic)	0.24 mGy/d[1]	N/A
	Aquatic Vegetation	0.24 mGy/d[1]	N/A
	Benthic Invertebrates	0.24 mGy/d[1]	N/A
	Aquatic Birds & Mammals	0.24 mGy/d[1]	0.024 mGy/d
Terrestrial Biota	Terrestrial Invertebrates	2.4 mGy/d[2]	N/A
	Terrestrial Plants	2.4 mGy/d[2]	N/A
	Terrestrial Birds & Mammals	2.4 mGy/d[2]	0.24 mGy/d

Notes: SAR – species at risk; N/A – not applicable.
(1) Ministère de l'Environnement et de la Lutte contre les changements climatiques (MELCC). 2020. *Surface Water Quality Criteria.* Retrieved from the MELCC webpage: http://www.environnement.gouv.qc.ca/eau/criteres_eau/index.asp; protection of aquatic life, chronic effect, for exposure to radionuclides.
(2) Canadian Standards Association (CSA). 2012. *Environmental Risk Assessments at Class I Nuclear Facilities and Uranium Mines and Mills*. N288.6-12. June; United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR). 2008. *Sources and Effects of Ionizing Radiation*, *Annex E: Effects of Ionizing Radiation on Non-Human Biota*.
(3) A safety factor of 10 was applied to the benchmark for species at risk (SAR).

4.2 Toxicological Benchmarks

A hazard assessment identifies the concentration (or dose) of a contaminant that is associated with an adverse effect. It is determined by the use of toxicity reference values (TRVs), which in an ecological risk assessment are often in the form of a benchmark dose or an acceptable daily intake value. Benchmarks are concentrations in an environmental medium that are considered to provide protection to ecological receptors from exposure, where safe doses are the amount per unit body weight that an organism can be exposed to on a daily basis that would be without adverse effects. For ecological receptors, assessment endpoints including negative effects on growth, reproduction and survival were selected to evaluate effects on a population level to animals and plant communities. Consistent with N288.6-12 (CSA 2012) guidance, species at risk were assessed at the individual, rather than the population level and the assessment endpoints involved the adoption of benchmarks or TRVs protective at the individual level.

The no observed adverse effects concentrations/levels (NOAECs or NOAELs) represent values believed to be non-hazardous to wildlife species and are generally used for screening level type assessments, whereas lowest observed adverse effect concentrations/levels (LOAECs or LOAELs) represent threshold levels at which adverse effects are likely to become evident and are used for more detailed risk assessments (Sample *et al.* 1996). It is acknowledged that there is inherent uncertainty associated with the use of LOAEL (or NOAEL) values, as TRVs are not innately related to biologically relevant thresholds and do not provide information about the actual magnitude of effects in the reported studies; however, they have widespread use in the risk assessment community, in part due to policy decisions (Allard *et al.* 2010). It is noted that regulatory agencies in Canada such as the Ontario Ministry of Energy, Conservation and

Parks (MECP), the Canadian Nuclear Safety Commission (CNSC), and branches of Environment Canada in jurisdictions such as Saskatchewan and Ontario support the use of NOAEL and LOAEL TRVs in ecological risk assessments. The FCSAP ecological risk assessment guidance document (Environment Canada 2012c) provides several approaches for deriving TRVs, all of which are based on reviews of the scientific literature and the development of dose response curves for every single COPC and every single receptor, and these TRVs also have inherent uncertainties. In practice, the development of these dose-response relationships for many COPCs and ecological receptors is often constrained by data limitations and is extremely cost prohibitive.

In the current EcoRA, TRVs were aimed to be selected for non-SAR receptors based on Maximum Acceptable Toxicant Concentration (MATC), LOAECs/LOAELs or 20% effect concentration (EC20) values where available. TRVs for non-SAR were selected to be protective of ecological populations based on the assumption that a 20% effect threshold would not significantly impact an ecological population.

The use of NOAELs provides an extra margin of safety where potential risk to individuals may be of concern, although an exceedance of a NOAEL does not indicate that adverse effects will occur. For SAR receptors, TRVs were selected based on NOAECs/NOAELs and 10% effect concentration (EC10s) where available. If a NOAEL or EC10 were not available for a chemical, an uncertainty factor of 10 was applied to TRVs derived based on the LOAEL in order to derive TRVs (NOAEL) protective of species at individual levels (Sample *et al*. 1996).

Overall, ecological toxicity benchmark values for chemicals (i.e., lead) were obtained from credible, recognized references that are used in EcoRAs as common industry practice. The TRV selection process generally incorporated CSA N288.6-12 guidance (CSA 2012) but in cases where N288.6-12 sources were considered outdated, values from more recent credible sources were used preferentially (with supporting rationale). The rationale for the selection of TRVs for lead for terrestrial and aquatic receptors are presented in the following sections.

4.2.1 Terrestrial Invertebrates and Vegetation

In selecting the TRVs for terrestrial vegetation and soil invertebrates (earthworms), the following sources were consulted:

1. MOE (2011) values protective of soil invertebrates and plants, based on residential/parkland land use;
2. CCME supporting documents for Canadian Soil Quality;
3. U.S. EPA Interim Ecological Soil Screening Level (Eco-SSL) Documents (last accessed 2019); and,
4. Efroymson *et al*. (1997a, 1997b).

The MOE (2011) considers ecotoxicity data in the development of soil standards, so that soil standards are protective of ecological health as well as human health. In the MOE update of their soil criteria (MOE 2011), plant and soil invertebrate protection values for agricultural/residential/parkland and industrial/commercial land use were developed following the CCME (1996) protocol using current scientific literature data on toxicity to agricultural crops, native plant species and soil dwelling organisms. It is commonly acknowledged that the level of protection for plants and soil organisms can be less stringent for industrial/commercial land use than for agricultural/residential/parkland land use. Based on the availability of toxicity data several methods including the weight of evidence, lowest observed effect concentration and median effects methods were applied in deriving soil benchmarks protective of terrestrial plants and soil organisms. In the absence of sufficient data to meet the minimum requirements of each method identified above, no benchmark was developed. Toxicity data for both soil invertebrates and terrestrial plants were combined.

MOE (2011) developed a benchmark of 250 mg/kg for the protection of both plants and soil invertebrates. This benchmark was based on nine vegetation and six soil invertebrate studies that were considered for the derivation of direct soil contact. All effects and no effects data were compiled. The 25th percentile rank distribution was estimated at ~250 mg/kg, which was selected as the ecological component value for the protection of plants and soil invertebrates under a residential/parkland/institutional land use scenario. This benchmark does not distinguish between earthworms and terrestrial vegetation.

Following the CCME (1996) protocol was problematic for no observed effect concentration/lowest observed effect concentration (NOEC/LOEC) data (a combined NOEC/LOEC dataset was used for the agricultural/residential/parkland derivation, while an LOEC-only dataset was used for the commercial/industrial derivation, which can throw out useful information and thereby drive the value down). To solve this issue, the MOE used a combined NOEC/LOEC dataset for both land uses and selected the 25th and 50th percentile values as the agricultural/residential/parkland and industrial/commercial protection values, respectively. The MOE also reviewed information from other jurisdictions and found that CCME ecological protection numbers and the numbers developed by the Netherlands would provide a suitable level of protection for Ontario. The Netherlands criteria were derived using the 50th percentile of the NOEC data. Lead TRVs applicable to a residential/parkland land use were considered as candidate TRVs for the current EcoRA. CCME (1999) developed a soil contact guideline of 300 mg/kg for lead. This value is protective of ecological health and is driven by ecotoxicity data for terrestrial plants exposure to lead.

U.S. EPA (2003) developed a standard operation procedure for the assessment of data quality of ecotoxicity data for plants and soil invertebrates and for the selection of appropriate toxicity data to be used for the derivation of Eco-SSL values protective of terrestrial plants and soil invertebrates. Following a literature evaluation scoring system, the relevant studies were selected. The Eco-SSL is calculated as the geometric mean of the toxicity. The Eco-SSL is calculated as the geometric mean of the toxicity values considering the bioavailability score and data availability (U.S. EPA 2003). U.S. EPA (2005) reviewed 439 toxicity studies for the derivation of Eco-SSL values protective of terrestrial plants exposure to lead. Four studies with a bioavailability score greater than 2 were selected. An Eco- SSL value of 120 mg/kg dw was proposed for the protection of terrestrial plants based on a geometric mean of the MATC for 4 test species under 3 different test conditions. For soil invertebrates, U.S. EPA (2005) reviewed 179 papers and selected 4 studies to derive an Eco-SSL of 1700 mg/kg dw based on the geomean of the MATC of one test species under three different test conditions.

Efroymson *et al*. (1997a, 1997b) developed soil benchmarks for plants and soil invertebrates. The plant benchmark for lead was derived based on a study by Dixon (1988) in which the response of red oak seedlings to a lead concentration of 50 ppm in soil was assessed. A 26% reduction in tree weight was observed. This was the lowest exposure concentration among literature studies cited by Efroymson *et al*. (1997b) at which adverse effects were observed. Moderate confidence was reported for the developed benchmark. The benchmark for earthworms was derived based on a study by Bengtsson *et al.* (1986) in which adverse effects on reproduction were observed at an exposure concentration of 500 ppm. This was the lowest exposure concentration at which adverse effects have been observed among the studies considered by Efroymson *et al.* (1997a). The confidence in the selected benchmark was reported to be low.

The final TRVs selected for terrestrial vegetation and soil invertebrates for use in the EcoRA are shown in Table 4.2. The soil benchmarks developed by U.S. EPA (2005) for plants and soil invertebrates were selected for use in the current EcoRA. While the benchmarks reported by Efroymson *et al.* (1997a, 1997b) are lower than the benchmarks reported by U.S. EPA (2005), these values were set equal to the lowest exposure concentration from the literature with low/moderate confidence, and thus were considered to be too conservative. As discussed above, the benchmarks provided by MOE (2011) and CCME (1999) are driven by ecotoxicity data for plants. Therefore, the soil benchmark of 1700 mg/kg protective of earthworms (U.S. EPA 2005) was considered to be appropriate as a lead TRV for earthworms. The TRV for plants was set to the lowest benchmark reported by U.S. EPA (2005), MOE (2011) and CCME (1999).

Table 4.2 Lead Toxicity Reference Values for Terrestrial Vegetation and Soil Invertebrates

Earthworm (mg/kg)	Terrestrial Vegetation (mg/kg)	Source/Comment
1700	120	**Terrestrial Vegetation** U.S. EPA (2005) reviewed 439 studies and found 4 studies with a bioavailability score greater than 2 that could be used for an Eco-SSL derivation. The Eco-SSL value of 120 mg/kg dw was proposed based on an MATC geometric mean for 4 test species under 3 different test conditions. **Soil Invertebrates** U.S. EPA (2005) reviewed 179 papers and selected 4 studies to derive an Eco-SSL of 1700 mg/kg dw. This was based on the MATC geomean of one test species under three different test conditions.

Notes: Eco-SSL – Ecological Soil Screening Level; MATC – Maximum Acceptable Toxicant Concentration.

4.2.2 Aquatic Invertebrates, Vegetation, and Fish

Aquatic biota (aquatic vegetation, benthic invertebrates, benthic and pelagic fish and tadpole) were assessed against both water quality and sediment quality. The surface water and sediment TRVs are discussed in the following sections.

4.2.2.1 Surface Water

In selecting surface water TRVs for aquatic vegetation, invertebrates, fish and amphibians, values were primarily obtained from the following two sources:

1. MOE (2011); and
2. Suter and Tsao (1996).

In addition to MOE (2011), as recommended by CSA N288.6-12 (CSA 2012), benchmarks from Suter and Tsao (1996) were also considered when selecting the final TRVs protective of aquatic biota.

MOE (2011) derived aquatic protection values (APVs) protective of all aquatic organisms. Toxicity data were collected using existing peer reviewed dose-response effects databases, mainly from U.S. EPA ECOTOX, Hazardous Substances Database (HSDB), and the Registry of Toxic Effects of Chemical Substances (RTECS) database. Further, a search of scientific literature was conducted in order to include research papers published after the last update of each of the above noted databases. Standards, guidelines and criteria listed by reputable organizations (e.g., Environment Canada, CCME, U.S. EPA, etc.) were also considered by MOE (2011) in developing the toxicity criteria. In deriving APVs, toxicity data reported on mortality, reproduction and growth were included and the APVs were derived based on the lowest-observed-effect level (LOEL) values. MOE (2011) developed an APV of 2 µg/L for lead, which is based on a water hardness of 70 mg/L.

Suter and Tsao (1996) developed/provided several benchmarks that are widely used in ecological risk assessment. These include:

- Acute/chronic national ambient water quality criteria (NAWQC);
- Secondary acute/chronic values;
- Lowest chronic value for fish, daphnids, non-daphnid invertebrates, aquatic plants and all organisms;
- Lowest test EC20 for fish and daphnids;
- Sensitive species test EC20;
- Population EC20;
- Ecotox Thresholds (ETs) published by EPA's Office of Solid Waste and Emergency Response (OSWER);
- EPA's Region IV acute and chronic ecological screening values for fresh surface water; and
- Background concentrations.

With the exception of benchmarks applicable to sensitive species, the lowest benchmark of all above noted benchmarks from Suter and Tsao (1996) was compared with APVs (i.e., 2 µg/L) from MOE (2011). Table 4.3 summarizes the final aquatic TRVs protective of all aquatic biota that were used in the EcoRA (benthic and pelagic fish, aquatic plants, benthic invertebrates).

Table 4.3 Lead Surface Water Toxicity Reference Values for Aquatic Biota

Test Species	Aquatic Biota (µg/L)	Comments/References
Various/unknown	1.32	The TRV for lead depends on hardness of surface water. The current TRV was developed assuming a hardness of 50 mg/L $CaCO_3$. Criterion reported as Region IV value as presented in Suter and Tsao (1996) (Table 3.1).

Notes: TRV – toxicity reference value

4.2.2.2 Sediment

In selecting sediment TRVs for aquatic vegetation, invertebrates, fish and amphibians, sediment quality criteria were obtained from the following two sources:

1. MOE (1993) provincial sediment quality guidelines for the protection of sediment dwelling (benthic) species; and,
2. CCME (2020; online access) sediment quality guidelines for the protection of freshwater aquatic life.

MOE (1993) derived biologically based sediment guidelines to protect those organisms that are directly impacted by contaminated sediment, namely the sediment dwelling (benthic) species. The guidelines define different levels of ecotoxic effects based on the chronic, long-term effects of contaminants on benthic organisms, which include a Lowest Effect Level (LEL) and a Severe Effect Level (SEL). The LEL indicates a level of sediment contamination that can be tolerated by the majority of benthic organisms. The SEL indicates the level at which pronounced disturbance can be expected, i.e., the sediment concentration of a compound that would be detrimental to the majority of benthic organisms. Both LEL and SEL values have been developed for lead (Table 4.4).

CCME derived sediment quality guidelines for the protection of aquatic life in both freshwater and marine environments that include an Interim Sediment Quality Guideline (ISQG) and Probable Effect Level (PEL). Sediment concentrations for chemicals that are below ISQG values are not expected to be associated with any adverse biological effects. The PEL represents the lower limit of the range of chemical concentrations that is usually or always associated with adverse effects. Both ISQG and PEL values have been developed for lead (Table 4.4).

The most conservative guideline from MOE (1993) and CCME was adopted as the sediment TRV for lead (Table 4.4).

Table 4.4 Lead Sediment Toxicity Reference Values for Aquatic Biota

Contaminant	MOE (1993)		CCME (2020)		Selected TRV
	LEL (µg/g)	SEL (µg/g)	ISQG (µg/g)	PEL (µg/g)	(µg/g)
Lead (Pb)	31	250	35	91.3	31

4.2.3 Mammals and Birds (Terrestrial & Aquatic)

In selecting the TRVs for mammals and birds, the following sources were consulted:

1. MOE (2011) benchmark values;
2. Sample *et al.* (1996); and
3. U.S. EPA Interim Eco-SSL Documents (last accessed 2019).

The mammalian and avian TRVs used in this assessment were taken primarily from MOE (2011) for mammals and birds where available. MOE's objective is to derive TRVs based on LOELs from dose response studies for the selected representative species showing the most sensitive response to a given contaminant. In circumstances where the toxicity data were solely available for lethal effects (LD50), a LOEL was estimated from an LD50 value by applying an uncertainty factor of 10. MOE (2011) found the most reliable sources of TRVs to be CCME and the Risk Assessment Program, Health Sciences Research Division, Oak Ridge, Tennessee. The MOE TRVs for lead in the current assessment are mainly based on toxicity data presented in Sample *et al.* (1996).

Additionally, the data presented in the U.S. EPA risk-based Eco-SSL documents also include data for lead that are of ecological concern at contaminated sites in the United States (U.S. EPA 2005). The Eco-SSL screening process for wildlife toxicity data included a review of primary data sources. It preferentially used data from dietary studies (oral exposure) with exposure durations that encompass multiple generations and/or critical life stages and reported population-relevant endpoints (U.S. EPA 2005). Chronic exposure is generally attributed to an exposure duration encompassing a significant portion of a species lifespan. However, exposure during sensitive life stages, such as reproduction, may produce severe adverse effects in a few days to as little as a few hours during gestation and embryo development (Sample *et al*. 1996). Based on these critical life stages, reproductive studies with exposure durations as short as five days were considered by the EPA to represent chronic exposures. The TRVs for lead developed by U.S. EPA (2005) for the calculation of soil Eco-SSLs protective of wildlife were considered in the current EcoRA.

Table 4.5 present the final TRVs selected for use in the EcoRA for mammals and birds.

Table 4.5 Lead Toxicity Reference Values for Mammals and Birds

Test Species	Endpoint/TRV value (mg/kg/d)	Source/Comments	TRV for non-SAR (mg/kg/d)	TRV SAR (mg/kg/d)
Mammals				
Various species	NOAEL growth and reproduction/ 4.7	U.S. EPA (2005) reviewed 219 journal articles containing data for various mammalian test species and evaluated 343 endpoints to derive a NOAEL geometric mean for growth and reproduction. This value was higher than the lowest bounded LOAEL for reproduction, growth, and mortality. Therefore, the TRV was the highest bounded NOAEL lower than the lowest bounded LOAEL for reproduction, growth or survival was used.	4.7	4.7
Birds				
Various species	NOAEL growth and reproduction/ 1.63	U.S. EPA (2005) reviewed 54 journal articles containing data for various avian test species and evaluated 106 endpoints. A NOAEL geometric mean for growth and reproduction was higher than the lowest bound LOAEL for reproduction, growth, and survival, therefore the highest bounded NOAEL that was lower than the lowest bounded LOAEL for reproduction, growth or survival was used.	1.63	1.63

Notes: NOAEL – no-observed-adverse-effect level; TRV – toxicity reference value; SAR – species at risk.

5.0 RISK CHARACTERIZATION

For exposure to non-radiological COPCs, the ecological risks were assessed by estimating the exposures or intake for each selected receptor and comparing them to the toxicity benchmarks or TRVs. This comparison was undertaken by calculating screening index (SI) values (or hazard quotients, HQs) (CSA 2018, Clause 7.5.2). Screening index values provide an integrated description of the potential hazard, the exposure (or dose) response relationship and the exposure evaluation (U.S. EPA 1992; AIHC 1992). The SI was calculated by dividing the expected exposure or dose concentration by the selected benchmark toxicity value for each ecological receptor, as shown in Equation 5-1.

$$Screening\ Index = \frac{Intake}{Toxicity\ Benchmark} \quad (5\text{-}1)$$

For radionuclides, the total dose rate received by an ecological receptor was divided by the selected dose rate guideline to calculate an SI value, as shown in Equation 5-2.

$$Screening\ Index = \frac{Dose\ Rate}{Dose\ Rate\ Guideline} \quad (5\text{-}2)$$

The SI values reported are not estimates of the probability of ecological impact. Rather, the index values are positively correlated with the potential of an impact, i.e., higher index values imply greater potential for an impact although this relationship is not linear and varies widely among contaminants. Different magnitudes of the SI have been used in other studies to screen for the potential ecological effects. An SI value of 1.0 has been used in some instances (e.g., Suter 1991). In other work, Cadwell *et al.* (1993) suggested an index value of 0.3, based upon a conservative approach designed to account for potential chronic toxicity and chemical synergism. In this study, an index value of 1.0 was used to examine the potential negative effects of radiological and non-radiological COPCs for aquatic and terrestrial receptors.

The next section presents the radiological and non-radiological risk results (SIs) calculated for each ecological receptor-COPC combination during the postclosure phase of the Project. No contaminants were assessed for the decommissioning phase as all radionuclides and chemical contaminants screened-out of the assessment. Sample calculations for radiological doses are provided in Appendix B.

5.1 Risk Results - Postclosure Phase

The main pathway of contaminant release during the postclosure phase is groundwater discharging to the Ottawa River through riverbed sediments or through shoreline sediments in scenario (4b) What-If – River Level Fall only. Contamination of surface soil is also expected through irrigation of crops using impacted river water and through animals drinking water from the impacted river and then excreting it onto the soil. Thus, postclosure scenarios have the potential to impact both the aquatic and terrestrial environments.

The risk results for radiological dose for all postclosure scenarios are summarized in Table 5.1 for terrestrial biota exposed to soil in the garden area and aquatic biota exposed to surface water and sediment (riverbed or shoreline) in the Ottawa River. The table also includes the results for pelagic fish exposed to spring water. Table 5.2 presents the radiological risk results for aquatic based birds and mammals in the Ottawa River, as well as the Moose, Muskrat and Great Blue Heron that ingest spring water as opposed to Ottawa River surface water. Table 5.3 presents the radiological risk results tor terrestrial based receptors in the garden area ingesting either water from the Ottawa River or spring water. The tables include total radiological dose estimates from all radionuclides assessed in the particular scenario along with the corresponding dose benchmark for terrestrial and aquatic receptors as well as SI comparisons. For species at risk, the dose benchmarks were divided by a factor of 10 to provide an extra margin of safety. It should be noted that the Chimney Swift and Eastern Wolf, which are both species at risk, are used as surrogates in the assessment for non-species at risk - the Chimney Swift is a surrogate for the Barn Swallow and the Eastern Wolf for the Algonquin Wolf and Coyote. For this reason, Table 5.3 includes SI values for the Chimney Swift and Eastern Wolf that are based on a benchmark of 2.4 mGy/d for the assessment of the Barn Swallow, Algonquin Wolf and Coyote non-species at risk, as well as a benchmark of 0.24 mGy/d adjusted for the assessment of the Chimney Swift and Eastern Wolf species at risk.

The risk results (SIs) for exposure to lead for scenario (4a) What-If – Mass excavation are summarized in Table 5.4 for terrestrial biota exposed to soil in the garden area and Table 5.5 for aquatic biota exposed to surface water and riverbed sediment in the Ottawa River. Table 5.4 also includes pelagic fish exposed to spring water. Table 5.6 presents the lead risk results for aquatic based birds and mammals in the Ottawa River, as well as the Moose, Muskrat and Great Blue Heron that ingest spring water as opposed to Ottawa River surface water. Table 5.7 presents the lead risk results tor terrestrial based receptors in the garden area ingesting either water from the Ottawa River or spring water. The tables include the total lead intake for each receptor, the TRV, and SI comparison as well as the percent (%) baseline contribution to the dose for reference. Lead was the only chemical contaminant that screened-in for assessment and only for scenario (4a) (see Section 2.4.3). Only NOAEL TRVs for lead were available for mammals and birds and these were applied to species at risk receptors as well non-species at risk receptors.

Table 5.1 Radiological Dose and Screening Index Results for the Postclosure Phase - Terrestrial and Aquatic Biota

Postclosure Scenario	Garden Area				Ottawa River Surface Water - Riverbed or Shoreline (Scenario 4b) Sediments					Spring Water
	Terrestrial Vegetation	Berries	Mushrooms	Earthworm	Aquatic Vegetation	Benthic Fish	Benthic Invertebrates *	Pelagic Fish	Green Frog (Tadpole)	Pelagic Fish
Benchmark (mGy/d)	**2.4**	**2.4**	**2.4**	**2.4**	**0.24**	**0.24**	**0.24**	**0.24**	**0.24**	**0.24**
(1) Normal Evolution Scenario (NES)										
Total Dose (mGy/d)	7.85E-11	1.98E-11	1.98E-11	2.50E-11	5.93E-10	1.03E-06	1.03E-06	2.15E-09	1.03E-06	2.67E-07
SI (unitless)	3.16E-11	8.26E-12	8.26E-12	1.04E-11	2.47E-09	4.28E-06	4.28E-06	8.97E-09	4.28E-06	1.11E-06
(1a) NES Sensitivity Analysis - Radioactive Inventory										
Total Dose (mGy/d)	5.04E-11	1.18E-12	1.18E-12	8.81E-12	5.03E-10	7.12E-07	7.11E-07	1.91E-09	7.12E-07	2.73E-07
SI (unitless)	2.10E-11	4.91E-13	4.91E-13	3.67E-12	2.10E-09	2.97E-06	2.96E-06	7.94E-09	2.97E-06	1.14E-06
(1b) NES Sensitivity Analysis - Sorption										
Total Dose (mGy/d)	3.46E-06	1.73E-06	3.66E-06	4.62E-06	6.89E-06	5.84E-05	4.14E-05	2.09E-05	5.83E-05	2.43E-03
SI (unitless)	1.44E-06	7.20E-07	1.53E-06	1.92E-06	2.87E-05	2.43E-04	1.72E-04	8.73E-05	2.43E-04	1.01E-02
(1c) NES Sensitivity Analysis - Resaturation Rate - Faster										
Total Dose (mGy/d)	7.58E-11	1.99E-11	1.99E-11	2.51E-11	5.93E-10	1.03E-06	1.03E-06	2.15E-09	1.03E-06	2.67E-07
SI (unitless)	3.16E-11	8.28E-12	8.28E-12	1.04E-11	2.47E-09	4.28E-06	4.28E-06	8.97E-09	4.28E-06	1.11E-06
(1d) NES Sensitivity Analysis - Resaturation Rate - Slower										
Total Dose (mGy/d)	7.46E-11	1.87E-11	1.87E-11	2.38E-11	5.92E-10	1.02E-06	1.02E-06	2.15E-09	1.02E-06	2.67E-07
SI (unitless)	3.11E-11	7.80E-12	7.80E-12	9.93E-12	2.47E-09	4.27E-06	4.26E-06	8.97E-09	4.27E-06	1.11E-06
(1e) NES Sensitivity Analysis - Surface Erosion										
Total Dose (mGy/d)	7.60E-06	6.40E-07	6.40E-07	1.08E-06	5.93E-10	1.03E-06	1.03E-06	2.15E-09	1.03E-06	2.67E-07
SI (unitless)	3.17E-06	2.66E-07	2.66E-07	4.48E-07	2.47E-09	4.28E-06	4.28E-06	8.97E-09	4.28E-06	1.11E-06
(1g) NES Sensitivity Analysis - Engineering Degradation										
Total Dose (mGy/d)	7.05E-11	1.83E-11	1.83E-11	2.33E-11	6.13E-10	1.07E-06	1.07E-06	2.23E-09	1.07E-06	7.65E-08
SI (unitless)	2.94E-11	7.62E-12	7.62E-12	9.72E-12	2.55E-09	4.45E-06	4.44E-06	9.27E-09	4.45E-06	3.19E-07
(2a) Disruptive Event - Site Investigation (Human Intrusion)										
Total Dose (mGy/d)	1.33E-09	4.38E-10	4.38E-10	7.11E-10	5.93E-10	1.03E-06	1.03E-06	2.15E-09	1.03E-06	2.67E-07
SI (unitless)	5.52E-10	1.82E-10	1.82E-10	2.96E-10	2.47E-09	4.28E-06	4.28E-06	8.97E-09	4.28E-06	1.11E-06
(2b) Disruptive Event - Extreme Degradation of Engineered Structures										
Total Dose (mGy/d)	2.48E-07	1.24E-07	1.93E-07	9.10E-08	9.35E-05	4.81E-04	1.87E-05	4.81E-04	1.13E-03	2.72E-03
SI (unitless)	1.03E-07	5.16E-08	8.03E-08	3.79E-08	3.90E-04	4.73E-03	2.80E-03	2.00E-03	4.73E-03	1.13E-02
(3a) Defence-in-Depth - Role of Waste Form										
Total Dose (mGy/d)	2.65E-10	1.94E-10	1.94E-10	2.10E-10	7.07E-10	1.65E-06	1.65E-06	2.40E-09	1.65E-06	2.85E-07
SI (unitless)	1.10E-10	8.08E-11	8.08E-11	8.75E-11	2.95E-09	6.89E-06	6.88E-06	1.00E-08	6.89E-06	1.19E-06
(3b) Defence-in-Depth - Role of Existing Facility Structure										
Total Dose (mGy/d)	1.76E-10	4.63E-11	4.63E-11	5.82E-11	8.12E-10	1.15E-06	1.14E-06	2.91E-09	1.15E-06	7.75E-07
SI (unitless)	7.34E-11	1.93E-11	1.93E-11	2.43E-11	3.38E-09	4.77E-06	4.77E-06	1.21E-08	4.77E-06	3.23E-06
(3c) Defence-in-Depth - Role of Grout										
Total Dose (mGy/d)	6.00E-10	1.72E-10	1.72E-10	2.61E-10	1.06E-09	1.37E-06	1.37E-06	3.72E-09	1.37E-06	1.09E-06
SI (unitless)	2.50E-10	7.16E-11	7.16E-11	1.09E-10	4.43E-09	5.70E-06	5.69E-06	1.55E-08	5.70E-06	4.53E-06
(4a) What-If - Mass Excavation										
Total Dose (mGy/d)	1.99E+00	9.93E-01	1.05E+00	2.27E+00	6.08E-07	1.22E-05	1.15E-05	1.15E-06	1.22E-05	1.58E-04
SI (unitless)	8.27E-01	4.14E-01	4.38E-01	9.45E-01	2.53E-06	5.07E-05	4.79E-05	4.79E-06	5.07E-05	6.57E-04
(4b) What-If - River Level Fall										
Total Dose (mGy/d)	7.58E-11	1.98E-11	1.98E-11	2.50E-11	5.98E-10	6.69E-09	5.23E-09	2.16E-09	2.16E-09	2.67E-07
SI (unitless)	3.16E-11	8.26E-12	8.26E-12	1.04E-11	2.49E-09	8.98E-09	2.90E-09	9.01E-09	9.01E-09	1.11E-06

Notes:

Bold – value exceeds the SI benchmark value of 1; SI – screening index.

* As noted in Section 2.2, radiological exposure to zooplankton is bounded by that to benthic invertebrates.

Table 5.2 Radiological Dose and Screening Index Results for the Postclosure Phase – Aquatic Based Birds & Mammals

Postclosure Scenario	Ottawa River - Riverbed or Shoreline (Scenario 4b) Sediments							Spring Water		
	Great Blue Heron	Mallard (Goose, Ducks)	Northern River Otter	Muskrat (Beaver, Raccoon)	American Mink	Moose	Blanding's Turtle *	Moose	Muskrat (Beaver, Raccoon)	Great Blue Heron
Benchmark (mGy/d)	**0.24**	**0.24**	**0.24**	**0.24**	**0.24**	**0.24**	**0.024**	**0.24**	**0.24**	**0.24**
(1) Normal Evolution Scenario (NES)										
Total Dose (mGy/d)	9.59E-07	9.60E-07	9.73E-07	9.79E-07	9.68E-07	1.93E-06	1.03E-06	1.93E-06	9.79E-07	9.59E-07
SI (unitless)	3.99E-06	4.00E-06	4.05E-06	4.08E-06	4.03E-06	8.02E-06	4.30E-05	8.02E-06	4.08E-06	3.99E-06
(1a) NES Sensitivity Analysis - Radioactive Inventory										
Total Dose (mGy/d)	7.11E-07	7.11E-07	7.21E-07	7.26E-07	7.18E-07	1.44E-06	7.14E-07	1.44E-06	7.26E-07	7.11E-07
SI (unitless)	2.96E-06	2.96E-06	3.01E-06	3.02E-06	2.99E-06	6.00E-06	2.98E-05	6.00E-06	3.02E-06	2.96E-06
(1b) NES Sensitivity Analysis - Sorption										
Total Dose (mGy/d)	5.03E-05	6.66E-05	8.90E-05	1.25E-04	7.02E-05	2.76E-05	5.41E-05	2.78E-05	1.26E-04	5.05E-05
SI (unitless)	2.10E-04	2.77E-04	3.71E-04	5.23E-04	2.92E-04	1.15E-04	2.25E-03	1.16E-04	5.24E-04	2.10E-04
(1c) NES Sensitivity Analysis - Resaturation Rate - Faster										
Total Dose (mGy/d)	9.59E-07	9.60E-07	9.73E-07	9.79E-07	9.68E-07	1.93E-06	1.03E-06	1.93E-06	9.79E-07	9.59E-07
SI (unitless)	4.00E-06	4.00E-06	4.05E-06	4.08E-06	4.03E-06	8.02E-06	4.30E-05	8.02E-06	4.08E-06	4.00E-06
(1d) NES Sensitivity Analysis - Resaturation Rate - Slower										
Total Dose (mGy/d)	9.55E-07	9.56E-07	9.69E-07	9.75E-07	9.65E-07	1.92E-06	1.03E-06	1.92E-06	9.75E-07	9.55E-07
SI (unitless)	3.98E-06	3.98E-06	4.04E-06	4.06E-06	4.02E-06	7.99E-06	4.28E-05	7.99E-06	4.06E-06	3.98E-06
(1e) NES Sensitivity Analysis - Surface Erosion										
Total Dose (mGy/d)	9.61E-07	9.65E-07	9.76E-07	9.79E-07	9.83E-07	5.46E-06	1.03E-06	5.46E-06	9.79E-07	9.61E-07
SI (unitless)	4.00E-06	4.02E-06	4.07E-06	4.08E-06	4.09E-06	2.28E-05	4.30E-05	2.28E-05	4.08E-06	4.00E-06
(1g) NES Sensitivity Analysis - Engineering Degradation										
Total Dose (mGy/d)	9.93E-07	9.94E-07	1.01E-06	1.01E-06	1.00E-06	1.99E-06	1.07E-06	1.99E-06	1.01E-06	9.93E-07
SI (unitless)	4.14E-06	4.14E-06	4.20E-06	4.23E-06	4.18E-06	8.31E-06	4.47E-05	8.31E-06	4.23E-06	4.14E-06
(2a) Disruptive Event - Site Investigation (Human Intrusion)										
Total Dose (mGy/d)	9.59E-07	9.60E-07	9.73E-07	9.79E-07	9.68E-07	1.93E-06	1.03E-06	1.93E-06	9.79E-07	9.59E-07
SI (unitless)	3.99E-06	4.00E-06	4.05E-06	4.08E-06	4.03E-06	8.02E-06	4.30E-05	8.02E-06	4.08E-06	3.99E-06
(2b) Disruptive Event - Extreme Degradation of Engineered Structures										
Total Dose (mGy/d)	1.11E-03	1.43E-03	2.59E-03	3.56E-03	1.94E-03	2.72E-04	1.15E-03	2.72E-04	3.56E-03	1.11E-03
SI (unitless)	4.63E-03	5.96E-03	1.08E-02	1.48E-02	8.10E-03	1.13E-03	4.81E-02	1.13E-03	1.48E-02	4.63E-03

Postclosure Scenario	Ottawa River - Riverbed or Shoreline (Scenario 4b) Sediments							Spring Water		
	Great Blue Heron	Mallard (Goose, Ducks)	Northern River Otter	Muskrat (Beaver, Raccoon)	American Mink	Moose	Blanding's Turtle *	Moose	Muskrat (Beaver, Raccoon)	Great Blue Heron
Benchmark (mGy/d)	**0.24**	**0.24**	**0.24**	**0.24**	**0.24**	**0.24**	**0.024**	**0.24**	**0.24**	**0.24**
(3a) Defence-in-Depth - Role of Waste Form										
Total Dose (mGy/d)	1.58E-06	1.58E-06	1.60E-06	1.61E-06	1.59E-06	3.18E-06	1.66E-06	3.18E-06	1.61E-06	1.58E-06
SI (unitless)	6.60E-06	6.60E-06	6.66E-06	6.69E-06	6.64E-06	1.32E-05	6.90E-05	1.32E-05	6.69E-06	6.60E-06
(3b) Defence-in-Depth - Role of Existing Facility Structure										
Total Dose (mGy/d)	1.07E-06	1.07E-06	1.09E-06	1.09E-06	1.08E-06	2.15E-06	1.15E-06	2.15E-06	1.09E-06	1.07E-06
SI (unitless)	4.46E-06	4.46E-06	4.53E-06	4.56E-06	4.50E-06	8.96E-06	4.79E-05	8.96E-06	4.56E-06	4.46E-06
(3c) Defence-in-Depth - Role of Grout										
Total Dose (mGy/d)	1.09E-06	1.09E-06	1.11E-06	1.12E-06	1.10E-06	2.14E-06	1.37E-06	2.14E-06	1.12E-06	1.09E-06
SI (unitless)	4.53E-06	4.54E-06	4.61E-06	4.65E-06	4.58E-06	8.93E-06	5.73E-05	8.94E-06	4.65E-06	4.53E-06
(4a) What-If - Mass Excavation										
Total Dose (mGy/d)	1.14E+00	4.65E-01	1.89E-01	1.04E-05	8.36E-01	3.52E+00	9.44E-06	3.52E+00	1.12E-05	1.14E+00
SI (unitless)	**4.76E+00**	**1.94E+00**	7.89E-01	4.35E-05	**3.48E+00**	**1.47E+01**	3.93E-04	**1.47E+01**	4.65E-05	**4.76E+00**
(4b) What-If - River Level Fall										
Total Dose (mGy/d)	3.93E-09	3.93E-09	4.48E-09	4.30E-09	4.18E-09	7.89E-09	4.60E-09	N/A	N/A	N/A
SI (unitless)	1.64E-08	1.64E-08	1.87E-08	1.79E-08	1.74E-08	3.29E-08	1.92E-07	N/A	N/A	N/A

Notes: * Species at Risk.

Bold – value exceeds the SI benchmark value of 1; SI – screening index; N/A - not assessed; * species at risk.

Table 5.3 Radiological Dose and Screening Index Results for the Postclosure Phase – Terrestrial Based Birds & Mammals

Postclosure Scenario	Garden Area - Ottawa River drinking water												
	Bald Eagle	Chimney Swift (Barn Swallow)	Chimney Swift (SAR)*	Ruffed Grouse (Partridge, Turkey)	Little Brown Myotis (Bat) (SAR)*	Meadow Vole (Rabbit/Hare, Squirrel)	Short-tailed Shrew (Badger)	Short-tailed Weasel (Fisher, Marten)	Black Bear	White-tailed Deer (Elk)	Eastern Wolf (Coyote)	Eastern Wolf (SAR)*	Red Fox
Benchmark (mGy/d)	**2.4**	**2.4**	**0.24**	**2.4**	**0.24**	**2.4**	**2.4**	**2.4**	**2.4**	**2.4**	**2.4**	**0.24**	**2.4**
(1) Normal Evolution Scenario (NES)													
Total Dose (mGy/d)	5.87E-11	2.11E-11	2.11E-11	2.19E-11	1.07E-10	3.28E-11	2.16E-11	1.38E-09	5.00E-10	5.74E-11	2.53E-09	2.53E-09	5.32E-10
SI (unitless)	2.45E-11	8.80E-12	8.80E-11	9.13E-12	4.45E-10	1.37E-11	9.00E-12	5.75E-10	2.08E-10	2.39E-11	1.06E-09	1.06E-08	2.22E-10
(1a) NES Sensitivity Analysis - Radioactive Inventory													
Total Dose (mGy/d)	4.29E-11	3.38E-12	3.38E-12	4.23E-12	7.81E-11	1.42E-11	4.00E-12	1.17E-09	4.19E-10	3.61E-11	2.17E-09	2.17E-09	4.42E-10
SI (unitless)	1.79E-11	1.41E-12	1.41E-11	1.76E-12	3.26E-10	5.90E-12	1.67E-12	4.88E-10	1.75E-10	1.50E-11	9.06E-10	9.06E-09	1.84E-10
(1b) NES Sensitivity Analysis - Sorption													
Total Dose (mGy/d)	9.58E-06	6.23E-06	6.23E-06	6.87E-06	5.59E-06	5.49E-06	5.11E-06	9.95E-06	6.53E-06	5.91E-06	8.99E-06	8.99E-06	8.57E-06
SI (unitless)	3.99E-06	2.60E-06	2.60E-05	2.86E-06	2.33E-05	2.29E-06	2.13E-06	4.15E-06	2.72E-06	2.46E-06	3.74E-06	3.74E-05	3.57E-06
(1c) NES Sensitivity Analysis - Resaturation Rate - Faster													
Total Dose (mGy/d)	5.88E-11	2.12E-11	2.12E-11	2.20E-11	1.07E-10	3.29E-11	2.16E-11	1.38E-09	5.00E-10	5.75E-11	2.53E-09	2.53E-09	5.32E-10
SI (unitless)	2.45E-11	8.82E-12	8.82E-11	9.15E-12	4.45E-10	1.37E-11	9.02E-12	5.75E-10	2.08E-10	2.40E-11	1.06E-09	1.06E-08	2.22E-10
(1d) NES Sensitivity Analysis - Resaturation Rate - Slower													
Total Dose (mGy/d)	5.77E-11	2.01E-11	2.01E-11	2.09E-11	1.06E-10	3.18E-11	2.06E-11	1.38E-09	4.99E-10	5.64E-11	2.53E-09	2.53E-09	5.31E-10
SI (unitless)	2.40E-11	8.38E-12	8.38E-11	8.70E-12	4.40E-10	1.33E-11	8.57E-12	5.74E-10	2.08E-10	2.35E-11	1.06E-09	1.06E-08	2.21E-10
(1e) NES Sensitivity Analysis - Surface Erosion													
Total Dose (mGy/d)	9.23E-07	9.30E-07	9.30E-07	1.04E-06	9.34E-07	2.41E-06	9.68E-07	1.04E-06	4.30E-06	5.51E-06	1.61E-06	1.61E-06	1.17E-06
SI (unitless)	3.85E-07	3.87E-07	3.87E-06	4.33E-07	3.89E-06	1.00E-06	4.03E-07	4.33E-07	1.79E-06	2.30E-06	6.73E-07	6.73E-06	4.86E-07
(1g) NES Sensitivity Analysis - Engineering Degradation													
Total Dose (mGy/d)	5.85E-11	1.95E-11	1.95E-11	2.03E-11	1.08E-10	3.05E-11	2.00E-11	1.43E-09	5.14E-10	5.34E-11	2.63E-09	2.63E-09	5.51E-10
SI (unitless)	2.44E-11	8.13E-12	8.13E-11	8.44E-12	4.50E-10	1.27E-11	8.33E-12	5.97E-10	2.14E-10	2.23E-11	1.10E-09	1.10E-08	2.30E-10
(2a) Disruptive Event - Site Investigation (Human Intrusion)													
Total Dose (mGy/d)	4.72E-10	5.31E-10	5.31E-10	5.16E-10	5.26E-10	6.06E-10	4.66E-10	1.88E-09	1.28E-09	9.64E-10	3.02E-09	3.02E-09	1.00E-09
SI (unitless)	1.97E-10	2.21E-10	2.21E-09	2.15E-10	2.19E-09	2.53E-10	1.94E-10	7.85E-10	5.32E-10	4.02E-10	1.26E-09	1.26E-08	4.18E-10
(2b) Disruptive Event - Extreme Degradation of Engineered Structures													
Total Dose (mGy/d)	9.04E-06	3.06E-08	3.06E-08	1.86E-07	2.02E-06	1.27E-07	2.54E-08	1.17E-05	1.99E-06	2.39E-07	7.74E-06	7.74E-06	8.09E-06
SI (unitless)	3.77E-06	1.27E-08	1.27E-07	7.76E-08	8.42E-06	5.27E-08	1.06E-08	4.88E-06	8.28E-07	9.95E-08	3.22E-06	3.22E-05	3.37E-06
(3a) Defence-in-Depth - Role of Waste Form													
Total Dose (mGy/d)	2.27E-10	1.84E-10	1.84E-10	1.84E-10	2.73E-10	1.95E-10	1.85E-10	1.63E-09	6.87E-10	2.20E-10	2.84E-09	2.84E-09	7.28E-10
SI (unitless)	9.46E-11	7.66E-11	7.66E-10	7.67E-11	1.14E-09	8.11E-11	7.70E-11	6.80E-10	2.86E-10	9.16E-11	1.18E-09	1.18E-08	3.03E-10
(3b) Defence-in-Depth - Role of Existing Facility Structure													
Total Dose (mGy/d)	9.64E-11	4.93E-11	4.93E-11	5.11E-11	1.51E-10	7.62E-11	5.02E-11	1.58E-09	6.24E-10	1.33E-10	2.89E-09	2.89E-09	6.28E-10
SI (unitless)	4.02E-11	2.05E-11	2.05E-10	2.13E-11	6.29E-10	3.18E-11	2.09E-11	6.59E-10	2.60E-10	5.55E-11	1.20E-09	1.20E-08	2.61E-10
(3c) Defence-in-Depth - Role of Grout													
Total Dose (mGy/d)	2.34E-10	1.79E-10	1.79E-10	1.85E-10	3.26E-10	2.68E-10	1.85E-10	1.72E-09	9.26E-10	4.51E-10	3.03E-09	3.03E-09	7.70E-10
SI (unitless)	9.74E-11	7.47E-11	7.47E-10	7.72E-11	1.36E-09	1.12E-10	7.69E-11	7.18E-10	3.86E-10	1.88E-10	1.26E-09	1.26E-08	3.21E-10
(4a) What-If - Mass Excavation													
Total Dose (mGy/d)	1.32E+00	4.80E+00	4.80E+00	4.81E+00	1.98E+00	3.96E+00	3.95E+00	2.41E+00	3.51E+00	3.96E+00	2.90E+00	2.90E+00	2.71E+00
SI (unitless)	5.52E-01	**2.00E+00**	**2.00E+01**	**2.00E+00**	**8.23E+00**	**1.65E+00**	**1.65E+00**	**1.00E+00**	**1.46E+00**	**1.65E+00**	**1.21E+00**	**1.21E+01**	**1.13E+00**
(4b) What-If - River Level Fall													
Total Dose (mGy/d)	3.92E-11	2.11E-11	2.11E-11	2.19E-11	1.07E-10	3.28E-11	2.16E-11	4.41E-11	1.21E-10	5.74E-11	6.76E-11	6.76E-11	3.14E-11
SI (unitless)	1.64E-11	8.80E-12	8.80E-11	9.13E-12	4.45E-10	1.37E-11	9.00E-12	1.84E-11	5.05E-11	2.39E-11	2.82E-11	2.82E-10	1.31E-11

Notes:
Bold – value exceeds the SI benchmark value of 1; SI – screening index; * species at risk.

Table 5.3 Radiological Dose and Screening Index Results for the Postclosure Phase – Terrestrial Based Birds & Mammals (continued)

Postclosure Scenario	Garden Area - Spring drinking water												
	Bald Eagle	Chimney Swift (Barn Swallow)	Chimney Swift (SAR)*	Ruffed Grouse (Partridge, Turkey)	Little Brown Myotis (Bat) (SAR)	Meadow Vole (Rabbit/Hare, Squirrel)	Short-tailed Shrew (Badger)	Short-tailed Weasel (Fisher, Marten)	Black Bear	White-tailed Deer (Elk)	Eastern Wolf (Coyote)	Eastern Wolf (SAR)*	Red Fox
Benchmark (mGy/d)	2.4	2.4	0.24	2.4	0.24	2.4	2.4	2.4	2.4	2.4	2.4	0.24	2.4
(1) Normal Evolution Scenario (NES)													
Total Dose (mGy/d)	5.97E-11	2.23E-11	2.23E-11	2.29E-11	1.21E-10	5.87E-11	3.73E-11	1.40E-09	5.52E-10	1.10E-10	2.60E-09	2.60E-09	5.71E-10
SI (unitless)	2.49E-11	9.29E-12	9.29E-11	9.54E-12	5.06E-10	2.45E-11	1.55E-11	5.85E-10	2.30E-10	4.57E-11	1.08E-09	1.08E-08	2.38E-10
(1a) NES Sensitivity Analysis - Radioactive Inventory													
Total Dose (mGy/d)	4.41E-11	4.79E-12	4.79E-12	5.41E-12	9.25E-11	3.94E-11	1.94E-11	1.19E-09	4.70E-10	8.81E-11	2.24E-09	2.24E-09	4.80E-10
SI (unitless)	1.84E-11	1.99E-12	1.99E-11	2.25E-12	3.85E-10	1.64E-11	8.07E-12	4.97E-10	1.96E-10	3.67E-11	9.31E-10	9.31E-09	2.00E-10
(1b) NES Sensitivity Analysis - Sorption													
Total Dose (mGy/d)	9.74E-06	6.36E-06	6.36E-06	6.99E-06	5.71E-06	5.74E-06	5.21E-06	1.01E-05	6.73E-06	6.09E-06	9.24E-06	9.24E-06	8.88E-06
SI (unitless)	4.06E-06	2.65E-06	2.65E-05	2.91E-06	2.38E-05	2.39E-06	2.17E-06	4.22E-06	2.80E-06	2.54E-06	3.85E-06	3.85E-05	3.70E-06
(1c) NES Sensitivity Analysis - Resaturation Rate - Faster													
Total Dose (mGy/d)	5.98E-11	2.23E-11	2.23E-11	2.29E-11	1.21E-10	5.87E-11	3.74E-11	1.40E-09	5.52E-10	1.10E-10	2.60E-09	2.60E-09	5.71E-10
SI (unitless)	2.49E-11	9.31E-12	9.31E-11	9.56E-12	5.06E-10	2.45E-11	1.56E-11	5.85E-10	2.30E-10	4.57E-11	1.08E-09	1.08E-08	2.38E-10
(1d) NES Sensitivity Analysis - Resaturation Rate - Slower													
Total Dose (mGy/d)	5.86E-11	2.12E-11	2.12E-11	2.18E-11	1.20E-10	5.77E-11	3.63E-11	1.40E-09	5.51E-10	1.09E-10	2.60E-09	2.60E-09	5.69E-10
SI (unitless)	2.44E-11	8.84E-12	8.84E-11	9.09E-12	5.02E-10	2.40E-11	1.51E-11	5.84E-10	2.29E-10	4.53E-11	1.08E-09	1.08E-08	2.37E-10
(1e) NES Sensitivity Analysis - Surface Erosion													
Total Dose (mGy/d)	9.23E-07	9.30E-07	9.30E-07	1.04E-06	9.34E-07	2.41E-06	9.68E-07	1.04E-06	4.30E-06	5.51E-06	1.61E-06	1.61E-06	1.17E-06
SI (unitless)	3.85E-07	3.87E-07	3.87E-06	4.33E-07	3.89E-06	1.00E-06	4.03E-07	4.33E-07	1.79E-06	2.30E-06	6.73E-07	6.73E-06	4.86E-07
(1g) NES Sensitivity Analysis - Engineering Degradation													
Total Dose (mGy/d)	5.88E-11	1.99E-11	1.99E-11	2.06E-11	1.12E-10	3.77E-11	2.44E-11	1.44E-09	5.29E-10	6.80E-11	2.65E-09	2.65E-09	5.62E-10
SI (unitless)	2.45E-11	8.28E-12	8.28E-11	8.56E-12	4.67E-10	1.57E-11	1.02E-11	6.00E-10	2.20E-10	2.83E-11	1.10E-09	1.10E-08	2.34E-10
(2a) Disruptive Event - Site Investigation (Human Intrusion)													
Total Dose (mGy/d)	4.73E-10	5.32E-10	5.32E-10	5.17E-10	5.40E-10	6.32E-10	4.82E-10	1.91E-09	1.33E-09	1.02E-09	3.08E-09	3.08E-09	1.04E-09
SI (unitless)	1.97E-10	2.22E-10	2.22E-09	2.15E-10	2.25E-09	2.63E-10	2.01E-10	7.95E-10	5.54E-10	4.24E-10	1.28E-09	1.28E-08	4.34E-10
(2b) Disruptive Event - Extreme Degradation of Engineered Structures													
Total Dose (mGy/d)	9.13E-06	1.03E-07	1.03E-07	2.54E-07	2.09E-06	2.78E-07	8.25E-08	1.18E-05	2.10E-06	3.41E-07	7.88E-06	7.88E-06	8.27E-06
SI (unitless)	3.80E-06	4.28E-08	4.28E-07	1.06E-07	8.72E-06	1.16E-07	3.44E-08	4.92E-06	8.74E-07	1.42E-07	3.28E-06	3.28E-05	3.45E-06
(3a) Defence-in-Depth - Role of Waste Form													
Total Dose (mGy/d)	2.29E-10	1.86E-10	1.86E-10	1.86E-10	2.89E-10	2.23E-10	2.02E-10	1.66E-09	7.40E-10	2.73E-10	2.90E-09	2.90E-09	7.70E-10
SI (unitless)	9.55E-11	7.77E-11	7.77E-10	7.75E-11	1.20E-09	9.27E-11	8.40E-11	6.90E-10	3.08E-10	1.14E-10	1.21E-09	1.21E-08	3.21E-10
(3b) Defence-in-Depth - Role of Existing Facility Structure													
Total Dose (mGy/d)	9.96E-11	5.32E-11	5.32E-11	5.44E-11	1.92E-10	1.49E-10	9.44E-11	1.65E-09	7.69E-10	2.79E-10	3.06E-09	3.06E-09	7.36E-10
SI (unitless)	4.15E-11	2.22E-11	2.22E-10	2.27E-11	8.01E-10	6.20E-11	3.93E-11	6.87E-10	3.20E-10	1.16E-10	1.28E-09	1.28E-08	3.07E-10
(3c) Defence-in-Depth - Role of Grout													
Total Dose (mGy/d)	2.38E-10	1.84E-10	1.84E-10	1.89E-10	3.86E-10	3.74E-10	2.49E-10	1.82E-09	1.14E-09	6.65E-10	3.29E-09	3.29E-09	9.27E-10
SI (unitless)	9.91E-11	7.67E-11	7.67E-10	7.89E-11	1.61E-09	1.56E-10	1.04E-10	7.59E-10	4.74E-10	2.77E-10	1.37E-09	1.37E-08	3.86E-10
(4a) What-If - Mass Excavation													
Total Dose (mGy/d)	1.32E+00	4.80E+00	4.80E+00	4.81E+00	1.98E+00	3.96E+00	3.95E+00	2.41E+00	3.51E+00	3.96E+00	2.90E+00	2.90E+00	2.71E+00
SI (unitless)	5.52E-01	**2.00E+00**	**2.00E+01**	**2.00E+00**	**8.23E+00**	**1.65E+00**	**1.65E+00**	**1.00E+00**	**1.46E+00**	**1.65E+00**	**1.21E+00**	**1.21E+01**	**1.13E+00**
(4b) What-If - River Level Fall													
Total Dose (mGy/d)	4.02E-11	2.23E-11	2.23E-11	2.29E-11	1.21E-10	5.87E-11	3.73E-11	6.83E-11	1.73E-10	1.10E-10	1.30E-10	1.30E-10	7.00E-11
SI (unitless)	1.68E-11	9.29E-12	9.29E-11	9.54E-12	5.06E-10	2.45E-11	1.55E-11	2.84E-11	7.21E-11	4.57E-11	5.43E-11	5.43E-10	2.92E-11

Table 5.4 Lead Screening Index Results for Postclosure Phase – Terrestrial Biota

Scenario	Garden Area		
	Terrestrial Vegetation	Earthworm	Berries
(4a) What-If - Mass Excavation			
Soil Concentration (mg/kg)	1.76E+03	1.76E+03	1.76E+03
TRV (mg/kg)	120	1700	120
SI (unitless)	**1.47E+01**	**1.04E+00**	**1.47E+01**
% Baseline Contribution	2%	2%	2%

Notes:

Bold – value exceeds the SI benchmark value of 1; TRV – toxicity reference value; SI – screening index.

Table 5.5 Lead Screening Index Results for the Postclosure Phase – Aquatic Biota*

Scenario	Ottawa River Surface Water & Riverbed Sediments					Spring Water
	Aquatic Vegetation	Benthic Fish	Benthic Invertebrates	Pelagic Fish	Green Frog (Tadpole)	Pelagic Fish
(4a) What-If - Mass Excavation						
Surface Water Concentration (mg/L)	9.74E-05	9.74E-05	9.74E-05	9.74E-05	9.74E-05	8.50E-04
TRV (mg/L)	0.00132	0.00132	0.00132	0.00132	0.00132	0.00132
SI (unitless)	7.38E-02	7.38E-02	7.38E-02	7.38E-02	7.38E-02	6.44E-01
% Baseline Contribution	100%	100%	100%	100%	100%	100%
Sediment Concentration (mg/kg)	1.00E+01	1.00E+01	1.00E+01	1.00E+01	1.00E+01	1.00E+01
TRV (mg/kg)	31	31	31	31	31	31
SI (unitless)	3.23E-01	3.23E-01	3.23E-01	3.23E-01	3.23E-01	3.23E-01
% Baseline Contribution	100%	100%	100%	100%	100%	100%

Notes:

Bold – value exceeds the SI benchmark value of 1; TRV – toxicity reference value; SI – screening index.

As noted in Section 2.2, lead exposure to zooplankton would be similar to that of other biota groups included above in Table 5.5.

Table 5.6 Lead Screening Index Results for the Postclosure Phase – Aquatic Based Birds & Mammals

Scenario	Ottawa River - Riverbed Sediments						Spring Water		
	Great Blue Heron	Mallard (Goose, Ducks)	Northern River Otter	Muskrat (Beaver, Raccoon)	American Mink	Moose	Moose	Muskrat (Beaver, Raccoon)	Great Blue Heron
(4a) What-If - Mass Excavation									
Total Intake (mg/kg-d)	4.18E-01	1.29E+01	4.05E-01	2.83E-02	2.39E+00	8.51E+01	8.51E+01	2.83E-02	4.18E-01
NOAEL TRV (mg/kg-d)	1.63	1.63	4.7	4.7	4.7	4.7	4.7	4.7	1.63
SI (unitless)	2.57E-01	**7.89E+00**	8.63E-02	6.01E-03	5.09E-01	**1.81E+01**	**1.81E+01**	6.03E-03	2.57E-01
% Baseline Contribution	6%	2%	5%	100%	3%	2%	2%	100%	6%
Baseline SI (unitless)	1.55E-02	1.60E-01	4.19E-03	6.01E-03	1.37E-02	3.09E-01	3.09E-01	6.03E-03	1.56E-02

Notes:

Bold – value exceeds the SI benchmark value of 1; NOAEL – No-Observed-Adverse-Effect Level; SI – screening index; * species at risk.

Table 5.7 Lead Screening Index Results for the Postclosure Phase – Terrestrial Based Birds & Mammals

Scenario	Garden Area - Ottawa River drinking water										
	Bald Eagle	Chimney Swift (SAR)* (Barn Swallow)	Ruffed Grouse (Partridge, Turkey)	Little Brown Myotis (Bat) (SAR)*	Meadow Vole (Rabbit/Hare, Squirrel)	Short-tailed Shrew (Badger)	Short-tailed Weasel (Fisher, Marten)	Black Bear	White-tailed Deer (Elk)	Eastern Wolf (SAR)* (Coyote)	Red Fox
Total Intake (mg/kg-d)	3.75E+00	1.05E+02	3.11E+02	3.71E+01	3.73E+02	1.10E+02	1.99E+01	1.27E+02	1.69E+02	4.01E+00	2.20E+01
NOAEL TRV (mg/kg-d)	1.63	1.63	1.63	4.7	4.7	4.7	4.7	4.7	4.7	4.7	4.7
SI (unitless)	**2.30E+00**	**6.46E+01**	**1.91E+02**	**7.89E+00**	**7.93E+01**	**2.34E+01**	**4.24E+00**	**2.71E+01**	**3.59E+01**	8.52E-01	**4.67E+00**
% Baseline Contribution	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%
Baseline SI (unitless)	4.07E-02	**1.10E+00**	**3.25E+00**	1.50E-01	**1.35E+00**	3.98E-01	7.29E-02	4.61E-01	6.11E-01	1.45E-02	7.97E-02

Scenario	Garden Area - Spring drinking water										
	Bald Eagle	Chimney Swift (SAR)*	Ruffed Grouse (Partridge, Turkey)	Little Brown Myotis (Bat) (SAR)*	Meadow Vole (Rabbit/Hare, Squirrel)	Short-tailed Shrew (Badger)	Short-tailed Weasel (Fisher, Marten)	Black Bear	White-tailed Deer (Elk)	Eastern Wolf (SAR)*	Red Fox
Total Intake (mg/kg-d)	3.75E+00	1.05E+02	3.11E+02	3.71E+01	3.73E+02	1.10E+02	1.99E+01	1.27E+02	1.69E+02	4.01E+00	2.20E+01
NOAEL TRV (mg/kg-d)	1.63	1.63	1.63	4.7	4.7	4.7	4.7	4.7	4.7	4.7	4.7
SI (unitless)	**2.30E+00**	**6.46E+01**	**1.91E+02**	**7.89E+00**	**7.93E+01**	**2.34E+01**	**4.24E+00**	**2.71E+01**	**3.59E+01**	8.25E-01	**4.67E+00**
% Baseline Contribution	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%
Baseline SI (unitless)	4.07E-02	**1.10E+00**	**3.25E+00**	1.50E-01	**1.35E+00**	3.98E-01	7.29E-02	4.61E-01	6.11E-01	1.46E-02	7.97E-02

Notes:

Bold – value exceeds the SI benchmark value of 1; NOAEL – No-Observed-Adverse-Effect Level; SI – screening index; * species at risk.

5.2 Discussion of Risk Results

5.2.1 Decommissioning Phase

Releases of radiological and non-radiological contaminants under normal operating conditions and potential malfunctions and accidents were very low and below screening criteria protective of non-human biota. As such, none of the decommissioning phase scenarios were carried through the EcoRA for quantitative assessment of risks from exposure to radionuclides or chemical contaminants as no undue effects are expected based on the results of the screening process. However, one decommissioning phase scenario was assessed qualitatively, (13) Malfunctions & Accidents - Major Flood and Release of Radioactivity.

Major Flood and Release of Radioactivity: This scenario was assessed qualitatively in the DecomSA (Garisto *et al.* 2020) based on the results of the Safety Analysis Report (Athauda-Arachchige 2015) and thus had to be assessed qualitatively in the EcoRA as well. The facility Safety Analysis Report acknowledges that external flooding could occur as a result of heavy precipitation, high water levels, or failure of water-controlled structures (dams). However, localized flooding due to surface run-off of meteorological extremes and/or spring thaw conditions is extremely unlikely because of the good drainage provided by site topography, which diverts heavy precipitation from the facility toward the Ottawa River. The facility Safety Analysis Report notes that the anticipated levels of loose contamination released from such an event are minimal. Thus, no undue effects on non-human biota are expected under this scenario.

5.2.2 Postclosure Phase

5.2.2.1 Radiological COPCs

Table 5.1, Table 5.2 and Table 5.3 summarize the radiological dose and SI values for terrestrial and aquatic receptors. As shown in the tables, with the exception of one scenario ((4a) What-If – Mass Excavation), there were no exceedances of the SI benchmark of 1 for any of the receptors, including SAR species. Furthermore, these results have a large safety margin given the very conservative assumptions that were used in the EcoRA. For example, all of the ecological receptors were assumed to spend all of their time on-site, consuming all of their food and water from the site regardless of their migratory patterns or home ranges. More realistically, as an example, the Chimney Swift only spends the summer months in southern Canada and the eastern United States and then migrates south to the upper Amazon basin of Peru, Ecuador, Chile and Brazil for the winter period (Cornell 2019). The area of the NPD property is 375 ha (3.75 km^2) (CNL 2015), representing only a small portion of the home range of many of the ecological receptors. For instance, the home range the Black Bear is about 10 to 40 km^2 for females and 100 km^2 or more for males (CWS 2015). While the Bald Eagle generally nests within 3 km of a waterbody, which is used as the primary food source, its home range varies from 6 to 47 km^2 (Siciliano 2013). Another conservative assumption was the use of maximum radionuclide concentrations predicted in each medium over the entire 10,000-year assessment period for each scenario.

The SI results for Mushrooms, which are included in Table 5.1, were also below the SI benchmark of 1 for all scenarios. However, as was discussed in Section 3.5.3, a limited number of soil-to-mushroom concentration ratios for radiological COPCs were available for inclusion in the EcoRA and these were generally one to a few orders of magnitude higher than their terrestrial vegetation counterparts. Thus, total doses to mushrooms are potentially underestimated as concentration ratios for terrestrial vegetation were applied to the remaining radiological COPCs. However, given the very low SI values and very conservative assumptions of the assessment, there are likely no undue effects to Mushrooms. Similarly, doses to Berries were also estimated using concentration ratios for terrestrial vegetation.

Several exceedances of the SI benchmark of 1 were noted for terrestrial based receptors under scenario (4a) What-If – Mass Excavation. Scenario (4a) is a highly improbable extreme scenario that considers the complete excavation of the entire facility and subsequent dispersal of the excavated material in soil, resulting in very high contaminant levels in soil. Specifically, exceedances of the SI benchmark value of 1 were noted for several terrestrial based birds and mammals including the Chimney Swift (non-SAR also representing Barn Swallow), Chimney Swift (SAR), Ruffed Grouse (also representing Partridge and Turkey), Little Brown Myotis (SAR), Meadow Vole (also representing Rabbit/Hare and Squirrel), Short-tailed Shrew (also representing Badger), Short-tailed Weasel (also representing Fisher and Marten), Black Bear, White-tailed Deer (also representing Elk), Eastern Wolf (non-SAR also representing Algonquin Wolf and Coyote), Eastern Wolf (SAR) and Red Fox, as well as some aquatic based birds and mammals including Mallard (generally representing Waterfowl such as Goose and Ducks) and Moose whose diets include earthworms and terrestrial vegetation and Great Blue Heron and American Mink whose diets include small mammals and birds. These exceedances were noted for both sets of these birds and mammals ingesting water from either the Ottawa River or spring water.

The PostSA (Penfold *et al.* 2020) notes that “in addition to Normal Evolution and Disruptive Event scenarios, illustrative calculations are also made for a range of other cases that are used to explore the performance of the NPD in the light of underlying uncertainties. One category of calculations, “What If” cases, make deliberately extreme assumptions so as to understand the limits of safety performance. These are not compared with any criteria because they are extremely unlikely, and in some cases implausible.” Screening index values for the Mass Excavation and other What-If scenarios included in this assessment were calculated only to provide context to the estimated doses.

5.2.2.2 Non-radiological COPCs

Lead was the only non-radiological contaminant that screened-in for assessment in the EcoRA and for only one scenario, (4a) What-If - Mass Excavation, due to the very high lead levels predicted in soil. As was noted in the previous section, Scenario (4a) is a highly improbable extreme scenario that considers the complete excavation of the entire facility and subsequent dispersal of the excavated material in soil. Specifically, exceedances of the SI benchmark value of 1 were noted for terrestrial based receptors including the soil Earthworm, Terrestrial Vegetation, Berries and several terrestrial birds and mammals including the Bald Eagle, Chimney Swift (SAR also representing Barn Swallow), Ruffed Grouse (also representing Partridge and Turkey), Little Brown Myotis (SAR), Meadow Vole (also representing Rabbit/Hare and Squirrel), Short-tailed Shrew (also representing Badger), Short-tailed Weasel (also representing Fisher and Marten), Black Bear, White-tailed Deer (also representing Elk) and Red Fox, as well as aquatic based Moose whose diet includes a large fraction of terrestrial vegetation (80%) and Mallard (generally representing Waterfowl such as Goose and Ducks) from the consumption of terrestrial vegetation and soil invertebrates. The exceedance was noted for both sets of these birds and mammals ingesting water from either the Ottawa River or spring water. For the Chimney Swift, which is an SAR species, as well as the Ruffed Grouse and Meadow Vole, it is important to note that the SI benchmark value of 1 was also exceeded based on baseline conditions alone. It is important to remember that "What-If" cases represent extreme circumstances that are highly unlikely to occur.

The assessment of Mushrooms was not included in Table 5.4 because a lead TRV is not available for mushrooms. However, if mushrooms are assumed to be similar to terrestrial vegetation or berries then their SI value would also likely exceed the benchmark value of 1 for this extreme scenario.

As was noted previously, What-If cases are not compared with any criteria because they are extremely unlikely, and in some cases implausible. Screening index values for the Mass Excavation and other What-If scenarios included in this assessment were calculated only to provide context to the estimated doses (Penfold *et al.* 2020).

The SI values of aquatic biota assessed against surface water (Ottawa River as well as Spring water for pelagic fish) and sediment (Ottawa River riverbed) quality were all less than 1 with baseline conditions contributing 100% of the exposure (Table 5.5). Other than the Moose and Mallard, the SI values of all other aquatic based receptors included in Table 5.6 were less than 1.

5.3 Species at Risk

Brief discussions of each species at risk included in the EcoRA are provided in the following sections.

5.3.1 Eastern Milksnake

The Eastern Milksnake (*Lampropeltis triangulum*) is a reptile with Special Concern status under *SARA* (Government of Canada 2019a). Milksnakes are found in southern Canada and in Ontario they can be found as far north as Lake Nipissing and Sault St. Marie. The Milksnake is best known for occurring in rural areas, where it is most frequently reported in and around buildings (Government of Canada 2019b).

Milksnakes are diurnal (active at dawn and dusk) in the spring and fall but become largely nocturnal (active at night) in the summer. These snakes are very secretive, spending much of their time hiding beneath logs, rocks, boards, bark and other debris. In Canada, Milksnakes go into hibernation in late October to early November and emerge from their hibernacula in April or May when mating occurs. Suitable hibernation sites will have enough moisture to prevent them from drying out over the winter and include mammal burrows, hollow logs, gravel or dirt banks, old wells, or old building foundations. The two greatest causes of Milksnake population decline are likely road mortality and deliberate killing by humans. They are also affected by habitat loss and modification due to urbanization, as well as predation (Government of Canada 2019b).

Sightings of the Eastern Milksnake have been confirmed at the NPD site with a juvenile Milksnake observed within the NPD building in 2015 (CNL 2015). Milksnakes are also occasionally observed on the NPD site. A lack of appropriate information on snake characteristics precludes a thorough quantitative assessment of the Milksnake. However, the external dose to a snake hibernating in a building on the NPD site can be estimated using the maximum dose rate of 1 mrem/h (0.01 mGy/h or 0.24 mGy/d) reported within RP Zone 2 (CNL 2019b). It can be assumed that the snake will hibernate for about a six-month period from November through April and that no internal dose is received during hibernation. This corresponds to an external dose of 36.24 mGy over 151 days, which is much lower than the corresponding dose limit for terrestrial biota of 362.4 mGy (based on the radiological dose benchmark for terrestrial biota of 2.4 mGy/d discussed in Section 4.1). This assessment indicates that a Milksnake hibernating in a building on the NPD site will not suffer any undue effects.

5.3.2 Chimney Swift

The Chimney Swift (*Chaetura pelagica*) is a small bird with a slender body and very long, narrow, curved wings. It forages over urban and suburban areas, rivers, lakes, forests, and fields, feeding on airborne insects. The Chimney Swift is among the most aerial of birds, flying almost constantly except when roosting overnight or nesting. Its long claws are suited only for clinging to the walls of chimneys or other vertical surfaces such as the inside of hollow trees or caves and thus does not perch as other birds. Chimney Swifts migrate south for the winter to the upper Amazon basin of Peru, Ecuador, Chile and Brazil (Cornell 2019). As the Chimney Swift has experienced a 95% decline in population over the last 40 years due to changes in diet and habitat loss, it is currently listed as a Threatened species under *SARA* (CNL 2015; Government of Canada 2019a).

Historically, Chimney Swifts nested and roosted in natural sites such as caves and hollow trees of old growth forests but now they primarily use chimneys and other artificial sites with vertical surfaces and low light (including air vents, old wells, abandoned cisterns, outhouses, boathouses, garages, silos, barns, lighthouses and firewood sheds) (Cornell 2019). Chimneys used for roosting are generally large masonry chimneys found on churches, schools, or industrial buildings and can house hundreds to thousands of birds during migration (CNL 2015).

There is a Chimney Swift super roost in the vent stack at the NPD site which is in close proximity to site activities (CNL 2015). The EcoRA did not identify any potential undue effects to the Chimney Swift resulting from radiological or chemical exposure during the Decommissioning Phase (normal operations and malfunctions and accidents) of the Project. This includes the accidental collapse of the stack due to a heavy equipment accident. It is noted that an assessment of the Mo-99 Production Facility (MPF) stack at CRL also did not identify any risks to Chimney Swifts that use the stack for roosting during the summer months. In the MPF assessment, the radiation dose to a bird nesting in the stack over a 10-week period while operational was estimated at 200 mGy or 2.9 mGy/d (EcoMetrix and AECL 2013; CNL 2016).

During the Postclosure Phase, the EcoRA identified potential undue effects to the Chimney Swift and several other birds and mammals due to radiological and lead exposure under one scenario only, (4a) What-If – Mass Excavation. This is a highly improbable extreme scenario that considers the complete excavation of the entire facility and subsequent dispersal of the excavated material in soil, resulting in very high contaminant levels in soil. The Chimney Swift is primarily an insectivore feeding on a variety of insect and spider prey. In the model, the Chimney Swift is assumed to feed exclusively on terrestrial insects for which soil invertebrates (earthworms) are used as a surrogate, which are directly exposed to contaminants through soil. Thus, the Chimney Swift's exposure is driven by contaminant concentrations in the soil and the ingestion of earthworms. In the case of lead however, it was noted that undue effects to the Chimney Swift were also predicted based on the baseline soil concentration alone (Table 5.7). Given the extreme nature of this scenario and the fact that undue effects were not predicted for any other postclosure or decommissioning phase scenarios, no residual effects from the Project are expected for the Chimney Swift. Furthermore, the model conservatively assumes that the Chimney Swift spends all of its time on the NPD site consuming food when in reality this bird spends most of its time off-site feeding and returns to the vent stack to roost for the night. In addition, the Chimney Swift migrates to southern destinations for the winter period.

5.3.3 Blanding's Turtle

Blanding's Turtle (*Emydoidea blandingii*) is a medium-sized turtle which lives in shallow water, usually in large wetlands and shallow lakes with lots of water plants. These species hibernate at the bottom of permanent water bodies from October until April. In Ontario, they are found around the Great Lakes basins. Major threats to Blanding's Turtle are known to be loss of habitat, motor vehicles, and raccoons and foxes that consume their eggs (MNRF 2015). Blanding's Turtle (Great Lakes/St. Lawrence population) has been classified as a Threatened species under SARA (Government of Canada 2019a).

This species is an omnivore, usually feeding on insects, leeches, snails, small fish, frogs, and occasionally some plants (Kipp 2000). Therefore, most likely turtles are exposed to COPCs in surface water and sediment. While toxicity data on reptiles are scarce, an assessment of the radiological dose was possible and the results for Blanding's Turtle are shown in Table 5.3 for the postclosure scenarios that were assessed. There were no exceedances of the SI benchmark value of 1 in any of the scenarios for Blanding's Turtle and thus no undue effects from radiation are expected in either the Decommissioning or Postclosure Phases of the Project. While the assessment of lead exposure was not completed for Blanding's Turtle, in considering the aquatic habitat of the turtle and sediment exposure pathway, it may be reasonable to assume that Blanding's Turtle would not be affected by conditions predicted under scenario (4a) What-If – Mass Excavation or any other postclosure scenario, similar to the Muskrat, Northern River Otter, Great Blue Heron and Mallard.

5.3.4 Monarch Butterfly

The Monarch Butterfly is listed as a species of Special Concern under SARA (Government of Canada 2019a). The life cycle of the Monarch Butterfly (*Danaus plexippus*) consists of four stages: egg, larva (caterpillar), pupa (chrysalis), and adult butterfly. The eggs are laid exclusively on milkweed plants and hatch into caterpillars (larvae). The caterpillar consumes the milkweed in order to grow. After about two weeks, the fully grown caterpillar will attach itself to a stem or a leaf and is converted into a chrysalis. Later, during the metamorphosis process, the chrysalis is transformed into a butterfly. The Monarch Butterfly feeds on flowers. The life span of the Monarch Butterfly is only two to six weeks (WWF 2016).

The plant root uptake of COPCs from soil and groundwater is an exposure pathway and COPCs, particularly inorganics (e.g., lead), are likely present in the above ground parts of plants. Maximum exposure for the butterfly likely occurs during the caterpillar stage when it spends considerable time on plants. While the risks to the butterfly could not be quantified in the assessment, the SI values assessing risks of radiological exposure to terrestrial vegetation (Table 5.1) were below the benchmark value of 1 for all postclosure scenarios assessed. The SI value for terrestrial vegetation resulting from exposure to lead was exceeded under the extreme and highly improbable (4a) What-If – Mass Excavation scenario. Given the extreme nature of this scenario and the fact that undue effects were not predicted for terrestrial vegetation under any other postclosure or decommissioning phase scenarios, it may be reasonable to assume no undue effects on the Monarch Butterfly from the Project.

5.3.5 Little Brown Myotis

The Little Brown Myotis (*Myotis lucifugus*) is the most common and widespread of Canada's nineteen species of bat and is protected under *SARA* as it is an Endangered species (Government of Canada 2019a). The Little Brown Myotis is one of the smaller Canadian bats, weighing only seven to fourteen grams and having a wingspan of 22-27 cm (CWF 2016). This and other small-bodied bat species that winter in caves or mines are dying from White-nose Syndrome (WNS), caused by the fungus *Pseudogymnoascus destructans* (*Pd*, formerly known as *Geomyces destructan*) (CNL 2015).

The Little Brown Myotis plays an important role as a predator of night flying insects. It is a very efficient hunter capable of catching over 1000 insects in just one hour. It concentrates on insects that have an aquatic larval stage, such as mosquitoes, midges, and mayflies. Consequently, they prefer roosts in the vicinity of water. Although they prefer to forage over water, they will also hunt in open areas where they catch moths, beetles, and other flying insects (CFW 2016).

Day and night roosts are inhabited during the spring, summer and fall months whereas during the winter, hibernacula (hibernation) sites are used. Day and night roost locations are chosen based upon the presence of stable ambient temperatures. They are used by active bats and include buildings, trees, areas under rocks, and piles of wood. Day roosts have very little or no light and provide good shelter. Nursery roosts are similar to day roosts but are warmer than ambient temperature and are usually only occupied by females and their offspring. Night roosts are selected for their confined spaces where large numbers of bats can cluster together to increase the temperature of the roost and are occupied when the temperature is below 15°C. Hibernation sites usually include abandoned mines or caves where the temperature is continuously above freezing and humidity is high. Northern populations of bats enter hibernation in early September and end in mid-May (Havens 2006).

As discussed in Section 8.6.4.3 of the EIS, surveys in 2019 and 2020 confirmed that a small number of bats are using the NPDWF during the summer months as a roosting area and during the winter months as an overwintering site. Two SAR bats have been identified: Little Brown Myotis and Tri-coloured Bat. Section 9.6.3 of the EIS assesses the habitat impact on bats within the facility, namely the damage and destruction of the residence of an endangered species and for the incidental harm or harassment of individuals that could potentially occur during demolition and grouting activities (for which a Species at Risk permit is required).

For bats external to the facility, the EcoRA did not identify any potential undue effects to the Little Brown Myotis resulting from radiological or chemical exposure during the Decommissioning Phase (normal operations and malfunctions and accidents) of the Project.

During the Postclosure Phase, the EcoRA identified potential undue effects to the Little Brown Myotis and several other mammals and birds due to radiological and lead exposure under one scenario only, (4a) What-If – Mass Excavation. This is a highly improbable extreme scenario that considers the complete excavation of the entire facility and subsequent dispersal of the excavated material in soil, resulting in very high contaminant levels in soil. The Little Brown Myotis is an insectivore and in the model it is assumed to feed on aquatic (50%) and terrestrial (50%) insects for which benthic and soil (earthworms) invertebrates are used as surrogates, respectively. The soil in vertebrates are directly exposed to contaminants through soil. Thus, the bat's exposure is partly driven by contaminant concentrations in the soil and the ingestion of earthworms. Given the extreme nature of this scenario and the fact that undue exposure effects were not predicted for any other Postclosure or Decommissioning Phase scenarios, no residual effects from the Project are expected for the Little Brown Myotis (external to the facility). Furthermore, the model conservatively assumes that the Little Brown Myotis spends all of its time on the NPD site consuming food although this bat hibernates over the winter period.

5.3.6 Eastern Wolf

The Eastern Wolf (*Canis lycaon*) is smaller than other wolves and is found primarily in the forests of the Great Lakes and St. Lawrence regions of Ontario and Quebec where it preys on White-tailed Deer and Moose. Eastern Wolves live in family-based packs composed of a breeding pair and offspring from the current and previous years. Due to loss of habitat, hunting and trapping, it is listed as a species of Special Concern under *SARA* (Government of Canada 2019a).

Eastern Wolf is known to occur in the region (CNL 2015). Wolf sightings have occurred at the NPD site although the species of wolf wasn't confirmed. The EcoRA did not identify any potential undue effects to the Eastern Wolf resulting from radiological or chemical exposure during the Decommissioning Phase (normal operations and malfunctions and accidents) of the Project.

During the Postclosure Phase, the EcoRA identified potential undue effects to the Eastern Wolf and several other mammals and birds due to radiological exposure under one scenario only, (4a) What-If – Mass Excavation. This is a highly improbable extreme scenario that considers the complete excavation of the entire facility and subsequent dispersal of the excavated material in soil, resulting in very high contaminant levels in soil. The Eastern Wolf is a carnivore and in the model it is assumed to feed on small mammals (80%, average of vole, shrew and muskrat) and deer (20%), which predominately feed on soil invertebrates and terrestrial vegetation that are directly exposed to contaminants through soil. Given the extreme nature of this scenario and the fact that undue effects were not predicted for any other Postclosure or Decommissioning Phase scenarios, no residual effects from the Project are expected for the Eastern Wolf. Furthermore, the model conservatively assumes that the Eastern Wolf spends all of its time on the NPD site consuming food although its home range is larger than the site.

6.0 UNCERTAINTIES

This section discusses uncertainties and conservatism in the EcoRA. As noted in the CSA N288.6-12 (Clause 8, CSA 2012) standard, uncertainties exist in the EcoRA that need to be identified and evaluated for each stage of the risk assessment. Uncertainties will likely lead to an overestimation or underestimation of exposure, toxicity or risk and may occur in the following areas of the EcoRA:

(a) Problem formulation, as a result of available ecological and toxicological information;

(b) Exposure assessment, as a result of uncertainty in monitoring data and models;

(c) Toxicity/effects assessment, due to the limited availability of data for some ecological species, life stages, or endpoints of interest, or extrapolation from laboratory to field conditions; and,

(d) Risk characterization, due to uncertainties in exposure or toxicity, or uncertainties about the combined effects of multiple contaminants or physical stressors.

In recognition of these uncertainties, conservative assumptions were used throughout the assessment to ensure that the potential for an undue effect would not be underestimated. The major assumptions are outlined below.

6.1 Problem Formulation

6.1.1 Receptor Occupancy & Home Ranges

All mobile receptors are assumed to be present on site for the entire year, despite any potential migratory behaviour. In addition, the home range of all mobile receptors is assumed to be limited to the location of these maximum exposure concentrations, when in reality, several mobile receptors have large home ranges and the location of a maximum concentration might represent only a small portion of their overall range. Thus, exposures are likely to be conservatively overestimated.

6.1.2 Receptor Characterizations/Exposure Parameters

The characteristics of ecological receptors – mobile receptors in particular - represent another source of uncertainty since receptors will adjust and vary their diet and behaviour according to the food and water sources available and regional conditions in general. The characteristics (e.g., body weight; food, water, and soil consumption rates, etc.) for all receptors were selected based on a review of available information in various credible literature sources. However, for some (though not all) literature sources, these parameters are obtained from studies involving animals in captivity, and therefore may not be fully representative of free-range animals in the wild. An underestimate of exposure might result from this – for example, by assuming a body weight that is greater than for animals in the wild - but there are other conservative assumptions that may compensate (e.g., assuming 100% of COPC intake is absorbed by the body).

6.1.3 Screening Procedure for Radiological COPCs

If a dose coefficient was not available for a radionuclide, then the radionuclide was not assessed in the EcoRA as the radiation dose associated with a radionuclide cannot be estimated without a dose coefficient. The exclusion of a radionuclide from the assessment due to the lack of an available dose coefficient could result in an underestimation of the total dose and any potential effects. A number of radionuclides considered in the radiological COPC screen lacked dose coefficients, namely Ag-108m, Am-242m, Am-243, Ba-133, Cm-245, Cm-246, Ho-166m, Pt-193, Sm-151, and Sn-121m. It is interesting to note that in the previous version of the EcoRA (CNL 2017), Ag-108m was assessed using DCs from the 2016 version of the ERICA Tool, which was available at the time. It was the only radionuclide that screened in for assessment not because it was identified as a high dose contributor but rather because of a lack of environmental screening criteria to screen it out. The assessment of Ag-108m in the previous version of the EcoRA (CNL 2017) did not identify any undue exposure effects on non-human biota. For the current EcoRA, a main source of DCs is the updated version of the ERICA Tool from 2019, which does not include DCs for Ag-108m. Pröhl (2003) and Amiro (1997) also do not have this information. However, it should be noted that no radionuclide exceeding an environmental screening criterion was excluded from the assessment due to the lack of a dose coefficient; all of the radionuclides highlighted in yellow (i.e., screened-in) in the COPC screening tables (Table 2.19 to Table 2.32) were carried through the assessment.

6.2 Exposure Assessment

6.2.1 Exposure Point Concentrations

Contaminant concentrations predicted through model simulations as opposed to measured data were used in the EcoRA for the COPC screen and subsequent assessment. This introduces uncertainty into the assessment as model predictions are likely overestimated due to conservative assumptions used in the modelling approach. The exposure point concentrations used in the EcoRA for radionuclides and lead were the maximum values identified among receptor locations in the DecomSA and over time in the PostSA. The use of these maximum concentrations assumes that receptors are exposed to these higher concentrations while on site, which is assumed to be 100% of their time. As a result, exposures are likely to be conservatively overestimated.

6.2.2 Transfer Parameters

The concentrations/activities in biota had to be estimated using concentration ratios and transfer factors from literature as well as food intake calculations. There is some uncertainty involved in the use of transfer parameters and data that are not site-specific; however, in the absence of measured data, this approach provides the only method for estimating concentrations and for estimating transfer up the food chain, and for prediction of future conditions, e.g., for 10,000 years.

In addition, in some cases, transfer parameters were not available for certain COPCs/receptors. For example:

- Soil-to-earthworm concentration ratios were not available for Hf-182 and Sn-126 and the contributions of these radionuclides had to be omitted from the total dose calculation for the soil earthworm, thus slightly underestimating the exposure.
- Radiological feed-to-reptile transfer factors were not available from CSA (2018) or other sources and feed-to-mammal transfer factors were instead applied to Blanding's Turtle. This could either overestimate or underestimate the exposure to Blanding's Turtle, depending on how transfer factors for reptiles compare to those for mammals. Radiological and chemical concentration ratios for berries and mushrooms were mostly not available and instead wet weight transfer factors for terrestrial vegetation assuming a water content of 90% were applied to both berries and mushrooms. In the case of mushrooms, concentration ratios for a limited number of radionuclides (Am-241m Cs-137, Pu-239, Pu-240, Sr-90, Th-230, Th-232, U-234, and U-238) were obtained for edible mushrooms from IAEA (2009) and applied. These were typically one or more orders of magnitude higher than the analogous terrestrial vegetation concentration ratios, so using terrestrial vegetation concentration ratios for missing values likely underestimates the exposure to mushrooms. The effect with respect to berries is not clear as a similar comparison was not possible.

6.3 Effects Assessment

6.3.1 Toxicity Reference Values

The TRVs used in the assessment were obtained from reputable sources; nonetheless, they are always associated with uncertainty due to the extrapolation of studies from the United States to Canada and of testing on lab species (e.g., rats) to field conditions as well as to the ecological receptors considered in this assessment. Additionally, toxicity information for a COPC was used regardless of its form in the test procedure, even though this may not be the same form used in the assessment. It is difficult to determine the effect of these assumptions.

In addition, lead TRVs specific to berries and mushrooms were not available and the lead TRV for terrestrial vegetation was instead used to roughly assess the effects of lead in soil on berries and mushrooms. It is not clear whether this would overestimate or underestimate the risks.

6.4 Risk Characterization

6.4.1 Combined Effects

Another area of uncertainty in the risk assessment is the effect of multiple COPC. When dealing with toxic chemicals, there is potential interaction with other chemicals that may be found at the same location. It is well established that synergism, potentiation, antagonism or additivity of toxic effects occurs in the environment. In addition, the effects from multiple radionuclides are also additive. A detailed quantitative assessment of these interactions is beyond the scope of the present study, and, for many COPC-receptor combinations there is not an adequate base of toxicological evidence to examine these interactions. This may result in an underestimate of the risk for some COPC combinations. However, it should be noted that in the current assessment only lead was identified as a non-radiological COPC and the additive effect of radionuclides was considered in the dose calculation.

6.5 Summary

Table 6.1 provides a summary of the uncertainties discussed above. It can be seen from the table that, in general, the approaches or assumptions used to overcome uncertainties are likely to lead to an over-estimate of exposures and thus the conclusions of the assessment would remain unchanged.

Table 6.1 EcoRA – Summary of Uncertainties

Uncertainty	Likely Leads to Overestimate	Possibly Leads to Underestimate	Neither Overestimate or Underestimate
Use of model predictions and maximum concentrations to characterize exposures.	X		
Use of transfer parameters to estimate tissue concentrations.	X		
Use of literature characteristics for ecological receptors.			X
Neglecting migratory behaviour, and home range fraction (i.e., assuming *all* ingested food, water, and soil is from within the study area).	X		
Use of laboratory-derived TRVs for chronic exposure and effects.	X		
Use of available DCs as screening criteria.		X	
Synergism, potentiation, antagonism, additivity of toxic effects.		X	

7.0 SUMMARY AND CONCLUSIONS

The results of the EcoRA with respect to the radiological and non-radiological assessments are summarized in Table 7.1. Table 7.1 indicates whether undue effects were potentially predicted for any receptor under any of the scenarios that were assessed for the Decommissioning Phase (under both normal operating conditions and malfunctions and accidents) and Postclosure Phase (under Normal Evolution and Sensitivity Cases, Disruptive Events, Defence-in-Depth, and "What-If" scenarios) of the Project. The table also shows which radiological or chemical contaminants were screened for each scenario and which contaminants were carried through the assessment.

7.1 Decommissioning Phase

Contaminant emissions into the air during the Decommissioning Phase of the Project are limited to tritium, Cs-137, C-14, Co-60, Pb and Hg, depending on the scenario. All radiological and non-radiological contaminants were screened-out of the assessment for the decommissioning phase during the COPC screen. As such, no undue effects on non-human biota are anticipated during the decommissioning phase of the Project from exposure to radiological or chemical contaminants.

7.2 Postclosure Phase

For the Postclosure Phase of the Project, a total of 50 radionuclides were screened for each scenario as well as lead and mercury using maximum concentrations predicted in environmental media (surface water, spring water (groundwater), soil and sediment) over the entire postclosure assessment period (i.e., 10,000 years). For each scenario, lead and a total of 9 to 18 radionuclides screened-in for assessment depending on the scenario, with most radionuclides screened-in due to a lack of environmental screening criteria. Following the COPC screen, a sum of fractions analysis was also completed on aquatic and terrestrial pathways of exposure to ensure that radionuclides accounting for > 97% of the contributing radiation were included in the assessment where the unity rule was exceeded.

With the exception of scenario (4a) What-If – Mass Excavation, the SI values for both lead and radiological dose were below the benchmark value of 1 for all scenarios/receptors, including SAR species. As such, no undue effects on non-human biota are anticipated for these postclosure scenarios from exposure to radiological contaminants or lead.

The PostSA (Penfold *et al.* 2020) notes that "in addition to Normal Evolution and Disruptive Event scenarios, illustrative calculations are also made for a range of other cases that are used to explore the performance of the NPD in the light of underlying uncertainties. One category of calculations, "What-If" cases, make deliberately extreme assumptions so as to understand the limits of safety performance. These are not compared with any criteria because they are extremely unlikely, and in some cases implausible." However, What-If scenarios were assessed in the EcoRA and SI values for the Mass Excavation and other What-If scenarios were calculated for the purpose of providing context to the estimated doses.

Scenario (4a) What-If - Mass Excavation is a highly improbable extreme scenario that considers the complete excavation of the entire facility and subsequent dispersal of the excavated material in soil, resulting in high contaminant levels in soil. For scenario (4a), exceedances of the SI benchmark value of 1 were noted for terrestrial based receptors resulting from exposure to radiation and lead. Specifically, SI values >1 were predicted for the soil Earthworm (lead only), Terrestrial Vegetation (lead only), Berries (lead only) and several terrestrial birds and mammals including the Bald Eagle (radiation only), Chimney Swift (non-SAR, Barn Swallow), Chimney Swift (SAR), Ruffed Grouse (Partridge, Turkey), Little Brown Myotis (SAR), Meadow Vole (Rabbit/Hare, Squirrel), Short-tailed Shrew (Badger), Short-tailed Weasel (Fisher, Marten), Black Bear, White-tailed Deer (Elk), Eastern Wolf (SAR, Algonquin Wolf, Coyote; lead only) and Red Fox, as well as aquatic based Mallard (Goose, Ducks) and Moose whose diets include earthworms and terrestrial vegetation and Great Blue Heron (radiation only) and American Mink (radiation only) whose diets include birds and small mammals. The exceedance was noted for both sets of these birds and mammals ingesting water from either the Ottawa River or spring water. For the Chimney Swift, which is an SAR species, as well as the Ruffed Grouse and Meadow Vole, it is important to note that the SI benchmark value of 1 was also exceeded based on the baseline soil concentration alone.

Given that potential undue exposure effects to non-human biota were only predicted for scenario (4a) What-If – Mass Excavation representing highly unlikely extreme circumstances, the NPD Project is predicted to have negligible residual exposure effects to non-human biota.

Table 7.1 Summary of Undue Effects

Scenario		Type of Contamination	Comments
Decommissioning Phase - Normal Operations			
(2)	Grouting	tritium, Pb	screened-out; no undue exposure effects on biota expected
(3)	Demolition	tritium, Cs-137, C-14, Pb	screened-out; no undue exposure effects on biota expected
Decommissioning Phase - Malfunctions & Accidents			
(6) (7)	Forest Fire and Release of Radioactivity Forest Fire and Release of Chemical Contaminants	tritium, Cs-137, C-14 Pb	screened-out; no undue exposure effects on biota expected
(8) (9)	Tornado (Class EF-2) and Release of Radioactivity Tornado (Class EF-2) and Release of Chemical Contaminants	tritium, Cs-137, C-14 Pb	screened-out; no undue exposure effects on biota expected
(10) (11)	Underground (Indoor) Fire and Release of Radioactivity Underground (Indoor) Fire and Release of Chemical Contaminants	Cs-137, Co-16 Pb, Hg	screened-out; no undue exposure effects on biota expected
(12)	Major Flood and Release of Radioactivity	radiological	Assessed qualitatively; no undue exposure effects on biota expected
(15)	Stack Collapse and Release of Radioactivity	tritium	Screened-out; no undue exposure effects on biota expected
Postclosure Phase - Normal Evolution Case & Sensitivity Analyses			
(1)	Normal Evolution Scenario (NES)	Radiological, Pb, Hg	9 radionuclides screened-in Pb and Hg screened-out no undue exposure effects on biota expected
(1a)	NES SA – Radioactive Inventory	Radiological, Pb, Hg	9 radionuclides screened-in Pb and Hg screened-out no undue exposure effects on biota expected
(1b)	NES SA - Sorption	Radiological, Pb, Hg	15 radionuclides screened-in Pb and Hg screened-out no undue exposure effects on biota expected
(1c)	NES SA – Resaturation Rate - Faster	Radiological, Pb, Hg	9 radionuclides screened-in Pb and Hg screened-out no undue exposure effects on biota expected
(1d)	NES SA – Resaturation Rate - Slower	Radiological, Pb, Hg	9 radionuclides screened-in Pb and Hg screened-out no undue exposure effects on biota expected
(1e)	NES SA – Surface Erosion	Radiological, Pb, Hg	9 radionuclides screened-in Pb and Hg screened-out no undue exposure effects on biota expected

Scenario		Type of Contamination	Comments
(1g)	NES SA – Engineering Degradation	Radiological, Pb, Hg	9 radionuclides screened-in Pb and Hg screened-out no undue exposure effects on biota expected
Postclosure Phase – Disruptive Event Cases			
(2a)	Site Investigation (Human Intrusion)	Radiological, Pb, Hg	9 radionuclides screened-in Pb and Hg screened-out no undue exposure effects on biota expected
(2b)	Extreme Degradation of Engineered Structures	Radiological, Pb, Hg	16 radionuclides screened-in Pb and Hg screened-out no undue exposure effects on biota expected
Postclosure Phase – Defence-in-Depths Cases			
(3a)	Role of Waste Form	Radiological, Pb, Hg	9 radionuclides screened-in Pb and Hg screened-out no undue exposure effects on biota expected
(3b)	Role of Existing Facility	Radiological, Pb, Hg	9 radionuclides screened-in Pb and Hg screened-out no undue exposure effects on biota expected
(3c)	Role of Grout	Radiological, Pb, Hg	9 radionuclides screened-in Pb and Hg screened-out no undue exposure effects on biota expected
Postclosure Phase - "What-If" Cases			
(4a)	Mass Excavation	Radiological, Pb, Hg	18 radionuclides screened-in Hg screened-out Pb screened-in Undue exposure effects predicted for both radiological and lead exposure on terrestrial based biota due to high contaminant levels predicted in soil. However, it is noted that What-If cases make deliberately extreme assumptions so as to understand the limits of safety performance and are not compared with any criteria because they are extremely unlikely, and in some cases implausible. Screening indices were calculated herein to provide context to the calculated doses.
(4b)	River Level Fall	Radiological, Pb, Hg	9 radionuclides screened-in Pb and Hg screened-out no undue exposure effects on biota expected

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APPENDIX A

Ecological Profiles

APPENDIX A: ECOLOGICAL PROFILES

The following tables provide the ecological profiles for the mammals and birds assessed in this EcoRA. Profiles are only provided for those receptors that are assessed quantitatively using pathways analysis as the characteristics are required for the pathways calculations.

A.1 American Black Bear *(Ursus americanus)*

Table A.1 Black Bear Characteristics

Parameter Description	Calculated from		Units	Value	Reference	Notes
Body weight (BW)	-	-	kg	68	Environment Canada (2012) (FCSAP)	-
Water ingestion rate	0.06	L/kg wet BW/day	L/d	4.08	Environment Canada (2012) (FCSAP)	Calculated based on average body weight.
Food ingestion rate	0.03	kg dw/kg wet BW/day	g dw/d g ww/d	2040 9522	Environment Canada (2012) (FCSAP)	Dry weight rate calculated based on average body weight. Wet weight rate calculated assuming a water content of 78.6% for food items.
Fraction of food that is fish	-	-	-	0.05	Environment Canada (2012) (FCSAP)	-
Fraction of food that is terrestrial vegetation	-	-	-	0.8	Environment Canada (2012) (FCSAP)	
Fraction of food that is small mammals	-	-	-	0.1	Environment Canada (2012) (FCSAP)	Carrion in FCSAP, assumed to be small mammals.
Fraction of food that is soil invertebrates	-	-	-	0.05	Environment Canada (2012) (FCSAP)	Other (Insects, small mammals) in FCSAP, assumed to be earthworms.
Water content of diet	-	-	-	0.786	U.S. EPA (1993)	Weighted average calculated assuming water contents of 71.5% for fish, 80.0% for terrestrial vegetation, 68.0% for small mammals, and 84.0% for earthworms based on Tables 4-1 and 4-2 of 1993 U.S. EPA (1993).
Soil ingestion rate	2	%	g dw/d	40.8	Environment Canada (2012) (FCSAP)	The FCSAP profile for the Black Bear does not identify an incidental soil ingestion rate. A soil ingestion rate of 2% of the dry food consumption was assumed as recommended by Environment Canada (2012) (FCSAP) in the absence of any reliable rate.
Inhalation rate	-	-	m^3/d	83.1	Calculated from U.S. EPA (1993)	Calculated using allometric equation (3-20) for all mammals from U.S. EPA (1993) and an applied factor of two to account for free-living metabolic rates, as directed by U.S. EPA (1993).
Fraction of time at site	-	-	-	1	Assumed	-

Notes (Canada Wildlife Service, 2015)**:**

- **Trophic level or ecosystem role (e.g., predator or prey):** Predator and scavenger; high trophic level.
- **Life history:** Generally solitary, aside from mother-offspring bonding. Mating occurs in June to early July, with cubs being born in January to February (~6 month gestation period). Young bears grow rapidly and emerge with the mother in spring. Cubs remain with the mother for approximately 1.5 years, before becoming independent. Reproductive maturity is reached at approximately 3-5 years. Life expectancy ranges from approximately 10 years in the wild, to up to 25-30 years.
- **Importance to humans:** Commonly encountered species. Sometimes considered a nuisance when drawn to areas inhabited by humans. Black bears have important social, economic and cultural significance.
- **Habitat:** Preferred habitat includes heavily wooded areas and dense bushland, especially coniferous forest.
- **Home range size:** Variable, large. Females: 10-40 km^2; Males: 100 km^2 or more.
- **Important population dynamics**: Winter hibernation.

A.2 American Mink *(Neovison vison)*

Table A.2 American Mink Characteristics

Parameter Description	Calculated from		Units	Value	Reference	Notes
Body weight (BW)	-	-	kg	0.820	Environment Canada (2012) (FCSAP)	Average body weight of males and females. Males are smaller than females with an average weight of 0.570 kg compared to 1.060 kg for females.
Water ingestion rate	0.03	L/kg ww BW/day	L/d	0.0246	Environment Canada (2012) (FCSAP)	Calculated based on average body weight.
Food ingestion rate	0.14	kg ww/kg ww BW/day	g dw/d g ww/d	31.0 114.8	Environment Canada (2012) (FCSAP)	Wet weight rate calculated based on average body weight. Dry weight calculated assuming water content of 73% for food items.
Fraction of food that is fish (including tadpole for frog (amphibians))	-	-	-	0.4	Based on Environment Canada (2012) (FCSAP)	The American Mink is a carnivore. FCSAP suggests the following dietary proportions: fish 30%; crustaceans 25%; small mammals/birds 25%; amphibians 10%; and insects 10%. This composition was slightly altered to allow for consistency with the model where amphibians (i.e., frogs) are modelled as tadpoles (fish; i.e., no trophic transfer) representing the most sensitive life stage, and insects are modelled as terrestrial or benthic invertebrates.
Fraction of food that is benthic invertebrates (crustaceans & aquatic insects)	-	-	-	0.35		
Fraction of food that is small mammals	-	-	-	0.125		
Fraction of food this is birds	-	-	-	0.125		
Water content of diet	-	-	-	0.730	U.S. EPA (1993)	Weighted average assuming an average water content of 78.5% for aquatic invertebrates; 71.5% for fish; 68.6% for small mammals; and 67.5% for birds based on Tables 4-1 and 4-2 of 1993 U.S. EPA (1993).
Sediment ingestion rate	2	%	g dw/d	0.62	Environment Canada (2012) (FCSAP)	The FCSAP profile for the American Mink does not identify an incidental sediment ingestion rate. A sediment ingestion rate of 2% of the dry food consumption was assumed as recommended by Environment Canada (2012) (FCSAP) in the absence of any reliable rate.
Inhalation rate	-	-	m^3/d	0.93	Calculated from U.S. EPA (1993)	Calculated using allometric equation (3-20) for all mammals from U.S. EPA (1993) and an applied factor of two to account for free-living metabolic rates, as directed by U.S. EPA (1993).
Fraction of time at site	-	-	-	1	Assumed	

Notes (Schlimme, 2003; Environment Canada, 2012)**:**

- **Trophic level or ecosystem role (e.g., predator or prey):** An important predator of small mammals throughout its range. Carnivore and member of the weasel family. Minks are mostly active at night (nocturnal) and are skilled swimmers and climbers.
- **Life history:** The maximum lifespan for a mink is around 10 years. They are mostly solitary animals and very territorial, and males are generally intolerant of each other. Females become fertile in the winter and both males and females begin mating at ten months. The young are born in the spring (April or May), with litter sizes usually ranging between 1 and 8 individuals. The young remain with the mother through the summer and fall, when they leave to establish their own territories.
- **Importance to humans:** Mink pelts have for years been considered one of the most luxurious furs on the market and mink are thus hunted or reared for their fur.
- **Habitat:** Mink tend to prefer forested areas that are close to water. Streams, ponds, and lakes, with some sort of brushy or rocky cover nearby are considered good mink habitat. Mink dig their burrows in the banks of rivers, lakes and streams, or they may use the old dens of other animals, such as muskrat.
- **Home range size:** They have an average foraging range of 0.06 km^2 (0.006 – 16.3 km^2), with largest ranges determined for adult males).
- **Important population dynamics:** Mostly solitary and very territorial.

A.3 Bald Eagle *(Haliaeetus leucocephalus)*

Table A.3 Bald Eagle Characteristics

Parameter Description	Calculated from		Units	Value	Reference	Notes
Body weight	-	-	kg	4.7	Environment Canada (2012) (FCSAP)	-
Water ingestion rate	0.04	L/kg ww BW/day	L/d	0.188	Environment Canada (2012) (FCSAP)	Calculated based on average body weight.
Food ingestion rate	0.12	kg ww/kg ww BW/day	g dw/d g ww/d	168 564	Environment Canada (2012) (FCSAP)	Wet weight calculated based on average body weight. Dry weight rate calculated assuming a water content of 70.2% for food items.
Fraction of food that is fish	-	-	-	0.65	Environment Canada (2012) (FCSAP)	-
Fraction of food that is bird	-	-	-	0.15	Environment Canada (2012) (FCSAP)	-
Fraction of food that is small mammal	-	-	-	0.20	Environment Canada (2012) (FCSAP)	-
Water content of diet	-	-	-	0.702	U.S. EPA (1993)	Weighted average calculated assuming water contents of 71.5% for fish, 67.5% for birds, and 68.0% for small mammals based on Tables 4-1 and 4-2 of 1993 U.S. EPA (1993).
Soil ingestion rate	2	%	g dw/d	3.36	Environment Canada (2012) (FCSAP)	The FCSAP profile for the Bald Eagle does not identify an incidental soil ingestion rate. A soil ingestion rate of 2% of the dry food consumption was assumed as recommended by Environment Canada (2012) (FCSAP) in the absence of any reliable rate.
Inhalation rate	-	-	m^3/d	2.3	U.S. EPA (1993)	Calculated using allometric equation (3-19) for all passerines from U.S. EPA (1993) and an applied factor of two to account for free-living metabolic rates, as directed by U.S. EPA (1993).
Fraction of time at site	-	-	-	1	Assumed	

Notes (Siciliano Martina, 2013)**:**

- **Trophic level or ecosystem role (e.g., predator or prey):** High trophic level. Predatory species. Eagle eggs are the most vulnerable and are prey for other birds and mammals.
- **Life history:** Generally solitary. Reproductive maturity is reached at 5 years. Mating and egg laying occurs at variable times depending on the population and its geography, with populations in northern locations (e.g., Alaska and northern Canada) having shorter seasons. Eggs hatch after 35 days of incubation. After approximately 8 -14 weeks fledging is complete, and at 18 weeks the young are independent. Estimated life expectancy in the wild is approximately 15 years.
- **Importance to humans:** Local populations in Ontario are listed as 'of special concern' (Ontario Species at Risk: http://www.ontario.ca/page/bald-eagle). The bald eagle has important spiritual and cultural value to many First Nation cultures.
- **Habitat:** Prefer areas near waterbodies including lakes, rivers, and coastlines.
- **Home range size:** Generally nest within 3 km of a waterbody, which is used as the primary food source. Home range can range from 6 to 47 km^2.
- **Important population dynamics:** Migratory behaviour varies; some populations only migrate locally, some not at all, others migrate south to the U.S. or east to the Atlantic Region.

A.4 Blanding's Turtle *(Emydoidea blandingii)*

Table A.4 Blanding's Turtle Characteristics

Parameter Description	Calculated from		Units	Value	Reference	Notes
Body weight			kg	1.3	RCGS (2014)	Average of body weight for Blanding's Turtle.
Water ingestion rate	0.02	g/g wet BW/d	g/d	26	U.S. EPA (1993)	Calculated based on average body weight. In the absence of a water ingestion rate for Blanding's Turtle, the water ingestion rate for the Midland Painted Turtle was assumed for this species.
Food ingestion rate			g dw/d g ww/d	7.89 32.5	U.S. EPA (1993)	Dry weight rate based on the allometric equation provided in U.S. EPA (1993) for reptiles and amphibians (Equation 3-12 for herbivores). Wet weight rate calculated assuming a water content of 75.7% for food items.
Fraction of food that is fish	-	-	-	0.4	Assumed	These species are omnivores and they usually feed on insects, leeches, snails, small fish, frogs, and occasionally some plants (Kipp 2000).
Fraction of food that is benthic invertebrates	-	-	-	0.4	Assumed	
Fraction of food that is aquatic vegetation	-	-	-	0.2	Assumed	
Water content of diet	-	-	-	0.757	U.S. EPA (1993)	Weighted average calculated assuming water contents of 71.5% for fish, 78.5% for benthic invertebrates, and 75.0% for aquatic vegetation based on Tables 4-1 and 4-2 of 1993 U.S. EPA (1993).
Sediment ingestion rate	5.9	%	g dw/d	0.47	Calculated from Beyer *et al.* (1994)	Calculated assuming an incidental sediment ingestion rate of 5.9% of the dry food consumption. The incidental sediment ingestion rate was taken from Beyer *et al.* (1994) based on the Eastern Painted Turtle.
Inhalation rate	-	-	-	-	-	-
Fraction of time at site	-	-	-	1	Assumed	

Notes (Kipp 2000; RCGS 2014; ECCC 2018)**:**

- **Trophic level or ecosystem role (e.g., predator or prey):** Mid trophic level; prey, omnivore.
- **Life history:** Blanding's Turtle is an exceptionally long-lived species known to live over 83 years. In the northern portions of its global range, the Blanding's Turtle can take up to 25 years to reach sexual maturity, which makes it one of the latest maturing turtle species in Canada.
- **Importance to humans:** Unknown.
- **Habitat:** A medium-sized turtle which lives in shallow water, usually in large wetlands and shallow lakes with lots of water plants.
- **Home range size:** NA.
- **Important population dynamics:** It is found in groups on logs, grass clumps, sloping banks, or high perches near the water logs. They usually hibernate from late October until mid-April.

A.5 Chimney Swift *(Chaetura pelagica)*

Table A.5 Chimney Swift Characteristics [1]

Parameter Description	Calculated from		Units	Value	Reference	Notes
Body weight	-	-	kg	0.02133	Chantler and Driessens (2000)	Average weight.
Water ingestion rate	-	-	L/d	0.004	Calculated from U.S. EPA (1993)	Calculated based on average body weight using allometric equation for all birds (Equation 3-15) from U.S. EPA (1993).
Food ingestion rate	-	-	g dw/d g ww/d	4.8 15.3	Calculated from U.S. EPA (1993)	Dry weight rate calculated based on average body weight using allometric equation for all birds (Equation 3-3) from U.S. EPA (1993). Wet weight rate calculated assuming a water content of 69% for food items.
Fraction of food that is terrestrial (flying) insects	-	-	-	1.0	Palmer and Fowler (1975)	Primarily insectivores feeding on a variety of insect and spider prey.
Water content of diet	-	-	-	0.69	U.S. EPA (1993)	69.0% for grasshoppers/crickets based on Table 4-1of U.S. EPA (1993).
Soil ingestion rate	-	-	-	negligible	Assumed	Soil ingestion assumed to be negligible as Chimney Swifts feed exclusively in flight.
Inhalation rate	-	-	m^3/d	0.042	Calculated from U.S. EPA (1993)	Calculated using allometric equation (3-19) for all passerines from U.S. EPA (1993) and an applied factor of two to account for free-living metabolic rates, as directed by U.S. EPA (1993).
Fraction of time at site	-	-	-	1	Assumed	-

Notes (Pappas 2001; Middlebrook 2001)**:**

- **Trophic level or ecosystem role (e.g., predator or prey)**: Low trophic level. Prey species for some birds such as hawks and falcons.
- **Life history:** Estimated average life expectancy is 168 months, in the wild. The breeding season is from May to July. They put their nests in chimneys and occasionally in hollow trees and are usually at least 15.5 m above the ground, but this can vary significantly.
- **Importance to humans:** Control pest insect species.
- **Habitat:** Found mostly in areas settled by humans. They can be found at elevations as high as 2500 m.
- **Home range size:** N/A
- **Important population dynamics:** Generally migratory, migration season is between August and early October. They return usually in April.

A.6 Eastern Wolf *(Canis lycaon)*

Table A.6 Eastern Wolf Characteristics

Parameter Description	Calculated from		Units	Value	Reference	Notes
Body weight	-	-	kg	43	Schmidt and Gilbert (1978)	-
Water ingestion rate	-	-	L/d	2.92	U.S. EPA (1993)	Calculated based on average body weight using allometric equation for all mammals (Equation 3-17) from U.S. EPA (1993).
Food ingestion rate	5.5	kg w food/d	g dw/d g ww/d	1760 5500	Fuller and Keith (1980)	Dry weight rate calculated assuming a water content of 68.0% for food items
Fraction of food that is small mammals	-	-	-	0.8	-	Assumed based on information provided by Smith (2002).
Fraction of food that is deer	-	-	-	0.2	-	Assumed based on information provided by Smith (2002).
Water content of diet	-	-	-	0.680	U.S. EPA (1993)	Water content of 68.0% for mammals based on Tables 4-1 and 4-2 of 1993 U.S. EPA (1993).
Soil ingestion rate	2.8	%	g dw/d	49.3	Calculated from Beyer *et al.* (1994)	An incidental soil ingestion rate of 2.8% of dry food consumption was assumed based on Beyer *et al.* (1994) for the Red Fox.
Inhalation rate	-	-	m^3/d	22.1	U.S. EPA (1993)	Calculated using allometric equation (3-20) for all mammals from U.S. EPA (1993) and an applied factor of two to account for free-living metabolic rates, as directed by U.S. EPA (1993).
Fraction of time at site	-	-	-	1	Assumed	

Notes (Smith 2002; COSEWIC 2015)**:**

- **Trophic level or ecosystem role (e.g., predator or prey):** High trophic level; predator (carnivores, eats terrestrial vertebrates, i.e., white-tailed deer, beaver and moose).
- **Life history:** The average lifespan is 4 or 5 years, with up to 15 years in the wild.
- **Importance to humans:** Identified important in controlling the population of their prey. Their body parts are used as a source of valuable material. They may also boost the ecotourism. The eastern wolf is also a Species at Risk.
- **Habitat:** Found typically in deciduous and in forested areas with low human density. Eastern wolf prefers sandy soil for den sites.
- **Home range size:** Territory size is around 200 km^2.
- **Important population dynamics:** Wolves are pack living animals which live in family-based packs including breeding pair and offspring. Dispersing juveniles stay in pack for 37 weeks. They are active during the night and can travel up to 200 km daily. The breeding season is between late April and early May and female wolf gives birth to an average 5 pups.

A.7 Great Blue Heron *(Ardea herodias)*

Table A.7 Great Blue Heron Characteristics

Parameter Description	Calculated from		Units	Value	Reference	Notes
Body weight			kg	2.3	Environment Canada (2012) (FCSAP)	-
Water ingestion rate	0.04	L/kg wet BW/day	L/d	0.092	Environment Canada (2012) (FCSAP)	Calculated based on average body weight.
Food ingestion rate	0.18	kg wet food/kg wet BW/day	g dw/d g ww/d	119 414	Environment Canada (2012) (FCSAP)	Wet weight rate calculated based on average body weight. Dry weight rate calculated assuming a water content of 71.3% for food items.
Fraction of food that is fish	-	-	-	0.65	Environment Canada (2012) (FCSAP)	-
Fraction of food that is small mammals	-	-	-	0.25	Environment Canada (2012) (FCSAP)	-
Fraction of food that is benthic invertebrates	-	-	-	0.1	Environment Canada (2012) (FCSAP)	-
Water content of diet	-	-	-	0.713	U.S. EPA (1993)	Weighted average calculated assuming water contents of 71.5% for fish, 78.5% for benthic invertebrates, and 68.0% for small mammals based on Tables 4-1 and 4-2 of 1993 U.S. EPA (1993).
Sediment ingestion rate	2	%	g dw/d	2.37	Calculated from Beyer *et al.* (1994)	The FCSAP profile for the Great Blue Heron did not identify an incidental sediment ingestion rate. An incidental sediment ingestion rate of 2% of the dry food consumption was assumed based on Beyer *et al.* (1994) for the Blue-winged Teal and Ring-necked Duck (piscivorous) (<2%).
Inhalation rate	-	-	m^3/d	0.7	Calculated from U.S. EPA (1993)	Calculated using allometric equation (3-19) for all passerines from U.S. EPA (1993) and an applied factor of two to account for free-living metabolic rates, as directed by U.S. EPA (1993).
Fraction of time at site	-	-	-	1	Assumed	

Notes (Naumann, 2011)**:**

- **Trophic level or ecosystem role (e.g., predator or prey):** Mid trophic level; predator carnivores.
- **Life history:** The average lifespan for these species is around 15 years. There is mortality rate of 60% among the young herons before they reach 1 years old.
- **Importance to humans:** No direct importance - biodiversity, aesthetic.
- **Habitat:** Live near sources of water, including rivers, lake edges, marshes, saltwater seacoasts, and swamps.
- **Forage range size:** 16.6 to 2827 km^2.
- **Important population dynamics:** Mostly migratory.

A.8 Green Frog *(Rana clamitans)*

Table A.8 Green Frog Characteristics

Parameter Description	Calculated from		Units	Value	Reference	Notes
Body weight			kg	0.049	U.S. EPA (1993)	
Water ingestion rate			g/d	Not available	U.S. EPA (1993)	U.S. EPA (1993) did not provide an allometric equation for reptiles and amphibians.
Food ingestion rate			g ww/d	Not available	U.S. EPA (1993)	Based on the allometric equation provided in U.S. EPA (1993) assuming 80% moisture content in diet.
Fraction of food that is soil invertebrates				0.8	U.S. EPA (1993)	Reportedly, frogs feed on insects, worms, small fish, crayfish, other crustaceans, newts, spiders, small frogs, and molluscs. Terrestrial beetles often made their most important food item. It was assumed that 80% of their dietary composition is soil invertebrates, while benthic organisms form about 20% of their diet.
Fraction of food that is benthic invertebrates			-	0.2	U.S. EPA (1993)	Assumed. See above.
Sediment ingestion rate			g dw/d	Not available	U.S. EPA (1993)	An incidental sediment ingestion rate was not provided by U.S. EPA (1993).
Inhalation rate			m^3/d	NA	U.S. EPA (1993)	.
Fraction of time at site			-	1	Assumed	

Notes (Siciliano Martina, 2013)**:**

- **Trophic level or ecosystem role (e.g. predator or prey):** low trophic level; prey, carnivore (amphibians, reptiles, insects, terrestrial non-insect arthropods, molluscs, terrestrial worms, aquatic crustaceans, zooplankton) and herbivore (algae).
- **Life history:** green frogs can live up to 10 years in captivity, however the average lifespan in wild is unknown (Gillilland 2000).
- **Importance to humans:** eats insects, barometer of environmental quality.
- **Habitat:** they are found in a wide variety of habitats surrounding the inland waters such as swamps, wooded swamps, ponds, lakes, marshes, slow moving waters, etc.
- **Home range size:** 0.9 to 6.1 m in diameter (Gillilland 2000).
- **Important population dynamics:** green frogs are active during the day and night. During the cold weather, they become less active. Breeding take place in late spring, however, the geographic conditions particularly the temperature can affect the breeding time (Gillilland 2000).

A.9 Little Brown Myotis (Bat) *(Myotis lucifugus)*

Table A.9 Little Brown Myotis Characteristics

Parameter Description	Calculated from		Units	Value	Reference	Notes
Body weight	-	-	kg	0.0095	Havens (2006); CWF (2016)	Average of range reported by Havens (2006); CWF (2016) reported a range of 7 to 14 g; Hinterland (2013) reported a range of 7 to 9 g.
Water ingestion rate	-	-	L/d	0.0015	U.S. EPA (1993)	Calculated based on average body weight using allometric equation for all mammals (Equation 3-17) from U.S. EPA (1993).
Food ingestion rate			g dw/d g ww/d	1.5 4.8	U.S. EPA (1993)	Dry weight rate was calculated using allometric equation for all mammals (Equation 3-7) from U.S. EPA (1993). Wet weight rate was calculated assuming a water content for foods of 69.0%.
Fraction of food that is benthic invertebrates (aquatic insects)	-	-	-	0.5	CWF (2016)	Assumed based on information from CWF (2016). Assumed benthic invertebrates represent insects on surface water.
Fraction of food that is soil invertebrates (earthworm) (terrestrial insects)	-	-	-	0.5	CWF (2016)	Assumed based on information from CWF (2016). Assumed soil invertebrates represent flying insects.
Water content of diet	-	-	-	0.813	U.S. EPA (1993)	Assumed a water content of 69.0% for based on Table 4-1 of U.S. EPA (1993) for grasshoppers/crickets.
Soil ingestion rate	-	-	g dw/d	negligible	Assumed	Consumes flying insects and insects on water surface; assume negligible.
Inhalation rate	-	-	m^3/d	0.0189	MOE (2011)	-
Fraction of time at site	-	-	-	1	Assumed	

Notes (Havens 2006; CWF 2016)**:**

- **Trophic level or ecosystem role (e.g. predator or prey):** mid trophic level; prey, carnivore (insectivore).
- **Life history:** The average lifespan for this species is 6 to 7 years and often they live to more than 10 years. The survival rate in their first year of life is the lowest.
- **Importance to humans:** They control pest population and are widely used in research and education.
- **Habitat:** They have three types of roosts, day, night, and hibernation roosts. Day and night roosts include buildings, trees, under rocks, and in piles of wood and are used during spring, summer and fall. Day roosts have very little or no light, while the night roosts are used as confined spaces where large numbers of bats can live together when the temperature is below 15 ºC. Hibernaculum sites may be shared with SAR *Yuma myotis*. These sites usually include abandoned mines or caves where the temperature is continuously above freezing and humidity is high.
- **Home range size:** Travel several kilometers between day roosts and feeding sites.
- **Important population dynamics:** They are active during the night, about two or three hours after dusk and before dawn. They return to their roosts by 4 or 5 o'clock in the morning. The hibernation time depends on the location of the roosts and it usually starts between September and November and ends in March to May. A large colony of bats (as many as 300,000) has been reported in a single roost.

A.10 Mallard *(Anas platyrhynchos)*

Table A.10 Mallard Characteristics

Parameter Description	Calculated from		Units	Value	Reference	Notes
Body weight	-	-	kg	1.2	Environment Canada (2012) (FCSAP)	-
Water ingestion rate	0.06	L/kg ww BW/day	L/d	0.072	Environment Canada (2012) (FCSAP)	Calculated based on average body weight.
Food ingestion rate	0.05	kg dw/kg ww BW/day	g dw/d g ww/d	60 258	Environment Canada (2012) (FCSAP)	Dry weight rate calculated based on average body weight. Wet weight rate calculated assuming a water content of 76.8.
Fraction of food that is benthic invertebrates	-	-	-	0.4	Environment Canada (2012) (FCSAP)	-
Fraction of food that is aquatic vegetation	-	-	-	0.5	Environment Canada (2012) (FCSAP))	-
Fraction of food that is terrestrial vegetation	-	-	-	0.05	Environment Canada (2012) (FCSAP)	Identified as berries/seeds.
Fraction of food that is fish	-	-	-	0.025	Environment Canada (2012) (FCSAP)	Identified as Other (ground insects, flying insects, fish) in FCSAP, assumed to be 50% fish 50% earthworms.
Fraction of food that is terrestrial invertebrates (earthworms and insects)	-	-	-	0.025	Environment Canada (2012) (FCSAP)	Identified as Other (ground insects, flying insects, fish) in FCSAP, assumed to be 50% fish and 50% earthworms.
Water content of diet	-	-	-	0.768	U.S. EPA (1993)	Weighted average calculated assuming water contents of 78.5% for benthic invertebrates, 75.0% for aquatic vegetation, 80.0% for terrestrial vegetation, 71.5% for fish and 84.0% for earthworms based on Tables 4-1 and 4-2 of 1993 U.S. EPA (1993).
Sediment ingestion rate	3.3	%	g dw/d	1.98	Environment Canada (2012) (FCSAP)	The FCSAP profile for the Mallard presents an incidental sediment ingestion rate of 2.0-3.3% based on U.S. EPA (1993) and Beyer *et al.* (1994). A sediment ingestion rate of 3.3% of dry food consumption was assumed.
Inhalation rate	-	-	m^3/d	0.9	Calculated from U.S. EPA (1993)	Calculated using allometric equation (3-19) for all passerines from U.S. EPA (1993) and an applied factor of two to account for free-living metabolic rates, as directed by U.S. EPA (1993).
Fraction of time at site	-	-	-	1	Assumed	-

Notes (Rogers 2001 and Canada Wildlife Service (online))**:**

- **Trophic level or ecosystem role (e.g., predator or prey):** Low trophic level; prey species.
- **Life history:** Pairing between mates occurs from October to March. Mating occurs in the spring. Females lay a 9-13 egg clutch. Eggs hatch after 26-28 days. Young are led to nearby water, and the nest is abandoned. After 10 weeks the young have matured, and the mother leaves them to be independent. Reproductive maturity is reached at 1 year. Estimated life expectancy can be as high as 25+ years.
- **Importance to humans:** Key species for hunting.
- **Habitat:** Wetlands, particularly where waters produce large amounts of floating, emergent, and submergent vegetation.
- **Home range size:** N/A.
- **Important population dynamics:** Varies by population, but generally migratory. Some overwinter in Southern Ontario, others do not migrate.

A.11 Meadow Vole *(Microtus pennsylvanicus)*

Table A.11 Meadow Vole Characteristics

Parameter Description	Calculated from		Units	Value	Reference	Notes
Body weight	-	-	kg	0.0349	Environment Canada (2012) (FCSAP)	-
Water ingestion rate	0.21	L/kg ww BW/d	L/d	0.007	Environment Canada (2012) (FCSAP)	Calculated based on average body weight.
Food ingestion rate	0.33	kg ww/kg ww BW /d	g dw/d g ww/d	2.3 11.5	Environment Canada (2012) (FCSAP)	Wet weight rate calculated based on average body weight. Dry weight rate calculated assuming a water content for foods of 2.4%.
Fraction of food that is terrestrial vegetation	-	-	-	1	Environment Canada (2012) (FCSAP)	60% berries/seeds; 30% grasses; 10% mushrooms.
Water content of diet	-	-	-	0.8	U.S. EPA (1993)	Assuming 80.0% for terrestrial vegetation based on Tables 4-1 and 4-2 of 1993 U.S. EPA (1993).
Soil ingestion rate	2.4	%	g dw/d	0.055	Environment Canada (2012) (FCSAP)	The FCSAP profile for the Meadow Vole presents an incidental soil ingestion rate of 2.4% based on U.S. EPA (1993). A soil ingestion rate of 2.4% of the dry food consumption was assumed.
Inhalation rate	1.02	m^3/kg/d	m^3/d	0.0356	Environment Canada (2012) (FCSAP)	-
Fraction of time at site	-	-	-	1	Assumed	-

Notes (Neuburger 1999)**:**

- **Trophic level or ecosystem role (e.g., predator or prey):** Low trophic level; prey species.
- **Life history:** Estimated life expectancy in the wild is very short, rarely living for longer than one year.
- **Importance to humans:** Maintains ecosystem balance as an important prey food source for several other mammals and birds. Can be a pest species in large numbers, by consuming crops.
- **Habitat:** Prefers meadows, lowland fields, marshes, river banks and lake shorelines.
- **Home range size:** N/A
- **Important population dynamics:** The meadow vole is active during the day, but tends to be more active during night time in summer and daytime in winter. They dig runways through vegetation where they hide feces and food waste.

A.12 Moose *(Alces alces)*

Table A.12 Moose Characteristics

Parameter Description	Calculated from		Units	Value	Reference	Notes
Body weight	-	-	kg	400	Environment Canada (2012) (FCSAP)	Average: 400 kg Male: 453 kg Female: 350 kg
Water ingestion rate	0.05	L/kg ww BW/day	L/d	20	Environment Canada (2012) (FCSAP)	Calculated based on average body weight.
Food ingestion rate	0.02	kg dw/kg ww BW/day	g dw/d g ww/d	8000 38095	Environment Canada (2012) (FCSAP)	Dry weight rate calculated based on average body weight. Wet weight rate calculated assuming a water content of 79% for dietary items based on Table 4-1 and Table 4-2 of U.S. EPA (1993).
Fraction of food that is terrestrial vegetation	-	-	-	0.8	Environment Canada (2012) (FCSAP)	Woody matter consisting of shrubs and trees (twigs and branches). Willow is most commonly consumed but may also consume in great quantities twigs of trembling aspen, saskatoon, birch and red osier dogwood.
Fraction of food that is aquatic vegetation	-	-	-	0.2	Environment Canada (2012) (FCSAP)	Aquatic vegetation consumed due to high sodium content. In the summer they may feed on aquatic vegetation such as horsetail, bur-reed and pondweed.
Water content of diet	-	-	-	0.790	U.S. EPA (1993)	Weighted average calculated assuming water contents of 75.0% for aquatic vegetation and 80.0% for terrestrial vegetation based on Tables 4-1 and 4-2 of 1993 U.S. EPA (1993).
Sediment ingestion rate	2	%	g dw/d	160	Environment Canada (2012) (FCSAP)	The FCSAP profile for the Moose presents an incidental sediment ingestion rate of <2% based on Beyer *et al.* (1994). A sediment ingestion rate of 2% of dry food consumption was assumed.
Inhalation rate	-	-	m^3/d	132	Calculated from U.S. EPA (1993)	Calculated using allometric equation (3-20) for all mammals from U.S. EPA (1993) and an applied factor of two to account for free-living metabolic rates, as directed by U.S. EPA (1993).
Fraction of time at site	-	-	-	1	Assumed	

Notes (Environment Canada 2012; UW-SP Wildlife Ecology website, online; Wikipedia, online)**:**

- **Trophic level or ecosystem role (e.g., predator or prey):** Low trophic level; herbivorous. Prey species to wolves, grizzly bears, black bears and humans.
- **Life history:** Moose are generally solitary with the strongest bonds between mother and calf. Although moose rarely gather in groups, several may occur in close proximity during the mating season. Mating occurs in September and October. Female moose have an eight-month gestation period, usually bearing one calf, or twins if food is plentiful, in May or June. The young will stay with the mother until just before the next young are born. The calves are helpless at birth and the mother will keep them in seclusion for a couple of days, hidden from their main enemies in a thicket or on an island. The life span of an average moose is about 15-25 years.
- **Importance to humans:** Moose are hunted as a game species in many of the countries where they are found including Canada. Although slow-moving and sedentary, moose can become aggressive and move quickly if angered or startled.
- **Habitat:** Moose are found only in the northern hemisphere. The general habitat type is forest and wetland and more specifically boreal, northern and subalpine forests. Moose are common in recently disturbed habitats where there is a mix of young and old forest stands as well as diverse browse species.
- **Home range size:** Habitat sizes for the moose vary considerably with the geographic location and method of calculation, ranging from 4.6 to 262 km^2.
- **Important population dynamics:** Migration occurs if the benefit of leaving is greater than the benefit of staying within an individual's home range. Often times the purpose of migration is to place an animal into an optimal mating environment. Moose generally spend winters in a communal winter range and summers in a more secluded range. The distance between summer and winter ranges tends to be a function of habitat dispersion and type of terrain. In northwestern Minnesota the migration distances were found to be between 14.0 – 34.1 km and in Alaska 15.9 – 93.0 km. The specific timing of migration varies from year to year and is heavily influenced by climate. Migratory moose will follow the same path for each migration session.

A.13 Muskrat *(Ondatra zibethicus)*

Table A.13 Muskrat Characteristics

Parameter Description	Calculated from		Units	Value	Reference	Notes
Body weight	-	-	kg	1	Environment Canada (2012) (FCSAP)	-
Water ingestion rate	g/d	99	L/d	0.099	Environment Canada (2012) (FCSAP)	-
Food ingestion rate	0.07	kg dry food/kg wet BW/day	g dw/d g ww/d	70 284	Environment Canada (2012) (FCSAP)	Dry weight rate calculated based on average body weight. Wet weight rate calculated assuming a water content of 75.4% for dietary items.
Fraction of food that is aquatic vegetation	-	-	-	0.8	Environment Canada (2012) (FCSAP)	-
Fraction of food that is benthic invertebrates	-	-	-	0.15	Environment Canada (2012) (FCSAP)	-
Fraction of food that is fish	-	-	-	0.05	Environment Canada (2012) (FCSAP)	-
Water content of diet	-	-	-	0.754	U.S. EPA (1993)	Weighted average calculated assuming water contents of 75.0% for aquatic vegetation, 78.5% for benthic invertebrates, and 71.5% for fish based on Tables 4-1 and 4-2 of 1993 U.S. EPA (1993).
Sediment ingestion rate	2	%	g dw/d	1.4	Environment Canada (2012)	The FCSAP profile for the Muskrat does not identify an incidental soil ingestion rate. A soil ingestion rate of 2% of the dry food consumption was assumed as recommended by Environment Canada (2012) (FCSAP) in the absence of any reliable rate.
Inhalation rate	-	-	m^3/d	0.6	U.S. EPA (1993)	-
Fraction of time at site	-	-	-	1	Assumed	

Notes (Newell 2000)**:**

- **Trophic level or ecosystem role (e.g., predator or prey):** Low trophic level; prey, herbivore.
- **Life history:** It is understood that muskrat can live up to 10 years in captivity, while their average life span is 3 years in the wild.
- **Importance to humans:** Their body parts are valuable to humans, for example fur and meats.
- **Habitat:** They are found in in wet environments, particularly locations with four to six feet of water.
- **Home range size:** Small home range.
- **Important population dynamics:** Muskrats live in large groups. They move slowly on land and are active all day long but mostly from mid-afternoon until just after dusk. They are affected by quick changes in temperature.

A.14 Northern River Otter *(Lutra canadensis)*

Table A.14 Northern River Otter Characteristics

Parameter Description	Calculated from		Units	Value	Reference	Notes
Body weight	-	-	kg	7.5	Environment Canada (2012) (FCSAP)	
Water ingestion rate	0.08	g/kg wet BW/d	L/d	0.6	Environment Canada (2012) (FCSAP)	Average of mean water ingestion rate for male and female river otter (U.S. EPA 1993) and the body weight of river otter was used to estimate the water ingestion rate in L/d.
Food ingestion rate	0.03	kg dry food/kg bw/d	g dw/d g ww/d	225 814	Environment Canada (2012) (FCSAP)	As per U.S. EPA (1993), the River Otter in captivity consumes 700-900 g food/day. A food ingestion rate of 0.03 kg dry food/kg bw/d has been reported by Environment Canada (FCSAP) (2012). The food ingestion rate in wet weight/day was calculated assuming the following water contents for food items as per U.S. EPA 1993: Fish: 71.5%; aquatic invertebrates 78.5%, mammals: 68%, birds: 67.5%. The calculated daily food ingestion rate in wet weight is 823 g ww/d. This value is within the consumption rate reported by U.S. EPA for River Otter in captivity.
Fraction of food that is fish	-	-	-	0.8	FCSAP (2012)	The typical diet for River Otter consists primarily of fish but also includes a variety of other food items including insects, crustaceans, amphibians, reptiles, birds and mammals (Davis *et al.* 1992). FCSAP presents a dietary composition of 80% fish, 15% aquatic invertebrates and 5% mammals and birds. The average diet composition (percentage relative frequency of occurrence) of River Otter in different geographical regions including Pannonian, boreal, Atlantic, continental, alpine, and Mediterranean was presented in in a study by Lanszki *et al.* (2016). Lanszki *et al.* (2016) calculated a dietary composition of 2.3% and 2.8% for mammals and birds respectively. This breakdown is consistent with the total dietary composition of 5% reported for mammals and birds in FCSAP (2012). As such a dietary composition of 2.7% for birds and 2.3% for mammals was assumed in the present study.
Fraction of food that is birds	-	-	--	0.027	(Lanszki *et al.* 2016)	
Fraction of food that is mammals	-	-	-	0.023	(Lanszki *et al.* 2016)	
Fraction of food that is aquatic invertebrates (e.g., crayfish)	-	-	-	0.15	Environment Canada (FCSAP) (2012)	

Parameter Description	Calculated from		Units	Value	Reference	Notes
Water content of diet	-	-	-	0.724	U.S. EPA (1993)	Weighted average calculated assuming water contents of 78.5% for benthic invertebrates, 71.5% for fish, 68.0% for small mammals and 67.5% for birds based on Tables 4-1 and 4-2 of 1993 U.S. EPA (1993).
Sediment ingestion rate	2	%	g dw/d	4.5	Environment Canada (FCSAP) (2012)	Sediment ingestion rate was assumed to be 2% of dry food consumption rate. This assumption was based on default rate of 2% soil or sediment in the diet recommended by Environment Canada (FCSAP) (2012) in the absence of any reliable estimates.
Inhalation rate	-	-	m^3/d	2.7	U.S. EPA (1993)	Average of reported estimated inhalation rate for male and female (U.S. EPA 1993).
Fraction of time at site	-	-	-	1	Assumed	

Notes (U.S. EPA 1993; Environment Canada 2012; MENR 2017):

- **Trophic level or ecosystem role (e.g., predator or prey):** mammal, high trophic level; piscivorous diet, carnivore.
- **Life history:** river otter can live between 10-15 years in the wild (MENR 2017).
- **Importance to humans:** river otter is hunted as a furbearer species and their skin is mostly is exported and sold in Canadian fur auction houses (MENR 2017).
- **Habitat:** northern river otter is an aquatic mammal found mainly in freshwater, estuarine, and marine environments from coastal areas to mountain lakes. Food and shelter play important roles on habitat use. They prefer food rich areas such as lower portions of rivers and streams (U.S. EPA 1993).
- **Home range size:** the home range for river otter depends on habitat type. It could be long strips near rivers or coastal areas which measured in km or it could be in polygon shape in areas with many streams and marches which measured in km^2. Males have larger home range than females. The home range of river otter ranges from 3.5 to 30 km along the shorelines, while it can range from 9 to 231 km^2 in a polygon shape around the surface water bodies (Environment Canada 2012).
- **Important population dynamics:** the typical population density for river otter varies between one otter/km and one otter /10 km. River otters become sexually mature at the age of 2 years old. The mortality rates are between 15 to 30% per year (U.S. EPA 1993).

A.15 Northern Short-tailed Shrew *(Blarina brevicauda)*

Table A.15 Northern Short-Tailed Shrew Characteristics

Parameter Description	Calculated from		Units	Value	Reference	Notes
Body weight	-	-	kg	0.015	MOE (2011)	-
Water ingestion rate	-	-	L/d	0.00226	U.S. EPA (1993)	Calculated using allometric equation for all mammals (Equation 3-17) from U.S. EPA.
Food ingestion rate	-	-	kg ww food/d	0.009	MOE (2011)	-
Fraction of food that is invertebrates (earthworms)	-	-	-	1	MOE (2011)	-
Water content of diet	-	-	-	0.840	U.S. EPA (1993)	84.0% for earthworms based on Tables 4-1 and 4-2 of 1993 U.S. EPA (1993).
Soil ingestion rate	-	-	g dw/d	0.187	MOE (2011)	-
Inhalation rate	-	-	m^3/d	0.0189	MOE (2011)	-
Fraction of time at site	-	-	-	1	Assumed	

Notes (Ballenger 2011)**:**

- **Trophic level or ecosystem role (e.g., predator or prey):** Low trophic level; prey.
- **Life history:** The survival rate in their first year of life is high. They can live as long as 3 years.
- **Importance to humans:** They control pest population.
- **Habitat:** Found in all terrestrial habitats, however their population is most dense in damp brushy woodlands, bushy bogs and marshes, and weedy and bushy borders of fields.
- **Home range size:** 2.5 ha.
- **Important population dynamics:** They are active year around while they are more active during the night than the daytime. They are effective in tunnelling through leaves, plants and snow. Most of their time is spent on or under the ground, but they also climb trees to get suet from a bird feeder. In captivity, they live together, however in the wild, they are unsociable and will have their own territory.

A.16 Red Fox *(Vulpes vulpes)*

Table A.16 Red Fox Characteristics

Parameter Description	Calculated from		Units	Value	Reference	Notes
Body weight (BW)	-	-	kg	3.8	Environment Canada (2012) (FCSAP)	Average body weight of males and females. Females are smaller than males with an average weight of 3.4 kg compared to 4.1 kg for males.
Water ingestion rate	0.09	L/kg ww BW/day	L/d	0.342	Environment Canada (2012) (FCSAP)	Calculated based on average body weight.
Food ingestion rate	0.09	kg ww/kg ww BW/day	g dw/d g ww/d	89.3 342	Environment Canada (2012) (FCSAP)	Wet weight rate calculated based on average body weight. Dry weight calculated assuming water content of 73.9% for food items.
Fraction of food that terrestrial vegetation (fruits and plant material)	-	-	-	0.15	Environment Canada (2012) (FCSAP)	The Red Fox is an omnivore. FCSAP suggests the following dietary proportions: small mammals 40%; invertebrates 25%; birds 20%; and fruits and plant material 15%.
Fraction of food that is soil invertebrates (earthworm)	-	-	-	0.25		
Fraction of food that is small mammals				0.40		
Fraction of food that is birds				0.20		
Water content of diet	-	-	-	0.739	CSA (2018) and U.S. EPA (1993)	Weighted average assuming an average water content of 80.0% for terrestrial vegetation (forage) based on Table G.5 of CSA N288.1 (2018); and 84% for soil invertebrates (earthworm); 68.6% for small mammals; and 67.5% for birds based on Tables 4-1 and 4-2 of 1993 U.S. EPA (1993).
Soil ingestion rate	2.4	%	g dw/d	2.14	Environment Canada (2012) (FCSAP)	The FCSAP profile for the Red Fox presents an incidental soil ingestion rate of 2.4% of dry food based on U.S. EPA (1993).
Inhalation rate	-	-	m^3/d	3.18	Calculated from U.S. EPA (1993)	Calculated using allometric equation (3-20) for all mammals from U.S. EPA (1993) and an applied factor of two to account for free-living metabolic rates, as directed by U.S. EPA (1993).
Fraction of time at site	-	-	-	1	Assumed	

Notes (Kelsall, 1993; Canadian Geographic, 2006)**:**

- **Trophic level or ecosystem role (e.g., predator or prey):** Red foxes are omnivores but mostly prey on small mammals such as voles, mice, lemmings, hares and rabbits as they are excellent hunters with exceptional sight, smell and hearing abilities. Red foxes are mostly active at night (nocturnal).
- **Life history:** The average life span of a red fox is 3 to 6 years. Foxes are usually monogamous and breed between late December and mid-March. After breeding the foxes seek a suitable den and pups are born from March through May with a litter ranging from one to ten pups. The young foxes typically leave the den site alone after about three months, once they are able to feed themselves. From autumn until March of the next year, the young foxes bed down in thickets and heavy bush, even during the coldest winter, and if they survive their first winter and find a territory, the young foxes may breed the following spring.
- **Importance to humans:** Although foxes have a bad reputation as chicken thieves, on farmlands they more than compensate for eating the odd chicken by eating vast numbers of crop-destroying small mammals and insects, and now are appreciated by farmers.
- **Habitat:** The red fox generally lives on the edges of wooded areas, prairies and farmlands and typically sleeps in the open and keeps warm by wrapping itself with its long bushy tail. Dens are only used while breeding and are typically dug into soil or sand.
- **Home range size:** They inhabit home ranges of 4 to 8 km^2 around den sites.
- **Important population dynamics:** Young foxes travel widely during autumn seeking new territories. Young males have been traced as far 250 km^2 from their birth sites. Red foxes are usually monogamous having only one mate. Pairs of adult foxes may separate during winter, especially if hunting is poor, but they come together again in late winter or early spring for breeding and denning.

A.17 Ruffed Grouse *(Bonsana umbellus)*

Table A.17 Ruffed Grouse Characteristics

Parameter Description	Calculated from		Units	Value	Reference	Notes
Body weight	-	-	kg	0.552	Environment Canada (2012) (FCSAP)	-
Water ingestion rate	0.07	L/kg wet BW/d	L/d	0.0386	Environment Canada (2012) (FCSAP)	Calculated based on average body weight.
Food ingestion rate	0.06	kg dw food/kg wet BW/d	g dw/d g ww/d	33.1 171	Environment Canada (2012) (FCSAP)	Dry weight rate calculated using average body weight. Wet weight rate calculated assuming a water content for dietary items of 76.8%.
Fraction of food that is terrestrial vegetation	-	-	-	0.85	Environment Canada (2012) (FCSAP)	Leaves and berries.
Fraction of food that is soil invertebrates (earthworms)	-	-	-	0.15	Environment Canada (2012) (FCSAP)	Insects and invertebrates.
Water content of diet	-	-	-	0.768	U.S. EPA (1993)	Weighted average calculated assuming water contents of 80.0% for terrestrial vegetation and 84.0% for earthworms based on Tables 4-1 and 4-2 of 1993 U.S. EPA (1993).
Soil ingestion rate	9.85	%	g dw/d	3.26	Calculated from Beyer *et al.* (1994)	The FCSAP profile for the Ruffed Grouse does not present an incidental soil ingestion rate. A soil ingestion rate of 9.85% of dry food consumption was assumed based on the average value for the American Woodcock and Wild Turkey from Beyer *et al.* (1994).
Inhalation rate	-	-	m^3/d	0.52	U.S. EPA (1993)	Calculated using allometric equation (3-19) for all birds from U.S. EPA (1993) and an applied factor of two to account for free-living metabolic rates, as directed by U.S. EPA (1993).
Fraction of time at site	-	-	-	1	Assumed	-

Notes (Haupt 2001)**:**

- **Trophic level or ecosystem role (e.g. predator or prey):** Low trophic level; prey species, omnivore.
- **Life history:** Estimated life expectancy in the wild is 102 months.
- **Importance to humans:** It is hunted for sport. Decreases insect population during the hatching season.
- **Habitat:** Prefers the forested areas in rough, cold lands. It also favours dim and quiet woods, deep thickets, or sheltered swamps. It doesn't like the open fields.
- **Home range size:** 1 ha.
- **Important population dynamics:** They are solitary birds which prefer living alone except during the mating season. Average hatching time is 24 days and the clutch is about 11 eggs per season.

A.18 Short-tailed Weasel (*Mustela erminea*)

Table A.18 Short-tailed Weasel Characteristics

Parameter Description	Calculated from		Units	Value	Reference	Notes
Body weight (BW)	-	-	kg	0.089	Environment Canada (2012) (FCSAP)	Average body weight of males and females. Females are smaller than males with an average weight of 0.0595 kg compared to 0.1183 kg for males.
Water ingestion rate	0.13	L/kg ww BW/day	L/d	0.01157	Environment Canada (2012) (FCSAP)	Calculated based on average body weight.
Food ingestion rate	0.11	kg dw/kg ww BW/day	g dw/d g ww/d	9.79 31.7	Environment Canada (2012) (FCSAP)	Dry weight rate calculated based on average body weight. Wet weight calculated assuming water content of 69.1% for food items.
Fraction of food that is terrestrial invertebrates (terrestrial insects)	-	-	-	0.05	Based on Environment Canada (2012) (FCSAP)	The Short-tailed Weasel is entirely carnivorous and eats most animals that it can catch. FCSAP suggests the following dietary proportions: small mammals 50%; birds 25%; lagomorphs (rabbits) 20%, and other (amphibians, insects and bird eggs) 5%. This composition was slightly altered to allow for consistency with the model where lagomorphs as prey have been included with small mammals (70%), and insects included in the Other category are modelled as terrestrial invertebrates.
Fraction of food that is small mammals	-	-	-	0.70		
Fraction of food this is birds	-	-	-	0.25		
Water content of diet	-	-	-	0.691	U.S. EPA (1993)	Weighted average assuming an average water content of 68.6% for small mammals; 67.5% for birds and 84% for terrestrial invertebrates (earthworms) based on Tables 4-1 and 4-2 of 1993 U.S. EPA (1993).
Soil ingestion rate	2	%	g dw/d	0.196	Environment Canada (2012) (FCSAP)	The FCSAP profile for the Short-tailed Weasel does not identify an incidental soil ingestion rate. A soil ingestion rate of 2% of the dry food consumption was assumed as recommended by Environment Canada (2012) (FCSAP) in the absence of any reliable rate.
Inhalation rate	-	-	m^3/d	0.158	Calculated from U.S. EPA (1993)	Calculated using allometric equation (3-20) for all mammals from U.S. EPA (1993) and an applied factor of two to account for free-living metabolic rates, as directed by U.S. EPA (1993).
Fraction of time at site	-	-	-	1	Assumed	

Notes (Reid, 2020; Encyclopaedia Britannica Editors, 2020)**:**

- **Trophic level or ecosystem role (e.g., predator or prey):** The Short-tailed Weasel is a carnivore that preys mostly on small mammals such as rabbits, mice, chipmunks, shrews and ground squirrels. When these food items are scarce, they feed on eggs, birds, fish and frogs.
- **Life history:** The average lifespan of the Short-tailed Weasel is up to two years in the wild where they fall prey to foxes, raptors, badgers and fishers. They mate in the late spring or early summer and produce one litter per year consisting of 4 to 9 young. The young mature quickly and by week eight are almost adult size and able to move with their mother. They are mostly nocturnal but are often seen during the day.
- **Importance to humans:** Because Short-tailed Weasels are proficient hunters of small mammals, they are extremely beneficial in maintaining mice populations. The fur of the Short-tailed Weasel, especially the white winter coat, is much valued in the fur trade.
- **Habitat:** The Short-tailed Weasel makes use of a wide range of habitats including riparian woodlands, marshes, meadows and open pastures near forest or bush. They are efficient climbers and swimmers but spend most of their time on land. They make burrows under tree roots, in hollow logs or in unused buildings or re-se the burrows of mice and ground squirrels.
- **Home range size:** The foraging area ranges from of 1.0 to 87.4 ha, with the foraging range of females being slightly smaller than that of males.
- **Important population dynamics:** These animals do not hibernate and are active all year long and are mostly nocturnal. Apart from when they are mating and weaning young, Short-tailed Weasels are solitary animals and fend for themselves in the wild. They are also very territorial.

A.19 White-tailed Deer *(Odocoileus virginianus)*

Table A.19 White-tailed Deer Characteristics

Parameter Description	Calculated from		Units	Value	Reference	Notes
Body weight	-	-	kg	75	Environment Canada (2012) (FCSAP)	-
Water ingestion rate	0.06	L/kg ww BW/day	L/d	4.5	Environment Canada (2012) (FCSAP)	Calculated based on average body weight.
Food ingestion rate	0.03	kg dw/kg ww BW/day	g dw/d g ww/d	2250 11250	Environment Canada (2012) (FCSAP)	Dry weight rate calculated based on average body weight. Wet weight calculated assuming water content of 80% for food items.
Fraction of food that is terrestrial vegetation	-	-	-	1	Environment Canada (2012) (FCSAP)	Broken down into trees, plants, leaves, fruits, mushrooms, grasses and lichens.
Water content of diet	-	-	-	0.800	U.S. EPA (1993)	Assuming 80.0% for terrestrial vegetation based on Tables 4-1 and 4-2 of 1993 U.S. EPA (1993).
Soil ingestion rate	2	%	g dw/d	45	Environment Canada (2012) (FCSAP)	The FCSAP profile for the White-tailed Deer presents an incidental soil ingestion rate of <2.0% based on Beyer *et al*. (1994). A soil ingestion rate of 2.0% of the dry food consumption was assumed.
Inhalation rate	-	-	m^3/d	34.5	Calculated from U.S. EPA (1993)	Calculated using allometric equation (3-20) for all mammals from U.S. EPA (1993) and an applied factor of two to account for free-living metabolic rates, as directed by U.S. EPA (1993).
Fraction of time at site	-	-	-	1	Assumed	

Notes (Dewey 2003)**:**

- **Trophic level or ecosystem role (e.g., predator or prey):** Low trophic level; herbivorous. Prey species.
- **Life history:** Generally solitary, or paired mother and offspring. Mating occurs from October to December, followed by a 6 month gestation period. Young are born able to walk, can eat vegetation within days, follow the mother on foraging trips at 4 weeks, and are fully ruminant at 8 weeks. Weaning is complete after approximately 10 weeks. Young males leave the mother and are independent after 1 year; young females after 2 years. Typical life expectancy is 2-3 years in the wild, with few living past 10 years.
- **Importance to humans:** Commonly encountered species. Key species for hunting. Sometimes considered a nuisance when affecting areas inhabited by humans, typically through crop damage.
- **Habitat:** Highly variable. Prefer forested areas.
- **Home range size:** Generally small, often 1 km^2.
- **Important population dynamics:** Generally, not migratory. Deer in the area of NPD tend to migrate to yards located in the Round Lake area and Eagenville area in winter.

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APPENDIX B

Sample Calculations

APPENDIX B: SAMPLE CALCULATIONS

Sample Calculations for Radiological Dose

			Nb-93m	
WI - River Level Fall				
NB-93M INTAKE BY BALD EAGLE - GARDEN AND OTTAWA RIVER				
Receptor Characteristics				
Body weight	kg	BW	4.7	
Water ingestion rate	L/d	Qwat	0.188	
Fresh weight food ingestion rate	g FW/d	Qffw	564	
Soil ingestion rate	g DW/d	Qsdw	5.91	
Fraction that is fish	-	ffi	0.65	
Fraction that is birds	-	fbd	0.15	
Fraction that is small mammals	-	fsm	0.20	
Fraction of time at site	-	Floc	1.00	
Measured Concentrations				
Surface water concentration	mg/L	Cw	6.79E-09	Ottawa River
Soil concentration	Bq/kg dw	Cs	7.53E-05	Garden
Estimated Concentrations				
TF - Water to fish (Whole)	L/kg (fw)	TFfish	3.00E+02	assumed same as flesh
Whole fish concentration (FW)	Bq/kg fw	Cfishfw	2.04E-06	=Cw*TFfish
Bird concentration (FW)	Bq/kg fw	Cbirdsfw	3.01E-10	average of Ruffed Grouse, Great Blue Heron and Mallard (see calculations below)
Small Mammal concentration (FW)	Bq/kg fw	Csmfw	5.13E-09	average of Meadow Vole, Short-Tailed Shrew and Muskrat (see calculations below)
Calculation of Intakes				
Intake from water	Bq/kg-d	Iw	2.71E-10	=Qwat*Cw*Floc/BW
Intake from soil	Bq/kg-d	Is	5.38E-08	=Qsdw*Cs*1kg/1000g*Floc/BW
Intake from fish	Bq/kg-d	Ifi	1.59E-07	=Qffw*ffi*Cfishfw*1kg/1000g*Floc/BW
Intake from birds	Bq/kg-d	Ibirds	5.42E-12	=Qffw*fbd*Cbirdsfw*1kg/1000g*Floc/BW
Intake from small mammals	Bq/kg-d	Ism	1.23E-10	=Qffw*fsm*Csmfw*1kg/1000g*Floc/BW
Total intake	Bq/kg-d	Itot	2.13E-07	=Iw+Is+Ifi+Ibirds+Ism

Appendix B – Sample Calculations

Estimated Concentration of Bald Eagle				
Feed to Bald Eagle TF	d/kg (FW)	TFeagle	1.58E-04	
Estimated Bald Eagle Conc	Bq/kg (FW)	Ceagle	1.58E-10	=Itot*BW*TFeagle
Estimated Dose				
Internal Dose Coefficient	Gy/y per Bq/kg FW	DC_int	1.53E-07	Amiro
Internal Dose	mGy/d	D_int	6.63E-17	=Ceagle x DC_int x 1000 (mGy/Gy) / 365 (d/y)
External Dose Coefficient - On Soil	Gy/y per Bq/kg DW	DC_ext_onSoil	1.34E-08	Amiro
Occupancy factor on soil/sediment surface	unitless	OFss	1	Assumed
External Dose - On Soil	mGy/d	D_ext_onSoil	2.76E-12	= Cs x DC_ext_onSoil x OFss x 1000 (mGy/Gy) / 365 (d/y)
Total Dose	mGy/d	D_total	2.76E-12	= D_int + D_ext_onSoil

WI - River Level Fall

NB-93M INTAKE BY RUFFED GROUSE - GARDEN AND OTTAWA RIVER

Receptor Characteristics				
Body weight	kg	BW	0.552	
Water ingestion rate	L/d	Qwat	0.0386	
Fresh weight food ingestion rate	g FW/d	Qffw	170.6	
Soil ingestion rate	g DW/d	Qsdw	3.26	
Fraction that is terrestrial vegetation	-	ftv	0.85	
Fraction that is earthworm	-	few	0.15	
Fraction of time at site	-	Floc	1.00	
Measured Concentrations				
Surface water concentration	mg/L	Cw	6.79E-09	Ottawa River
Soil concentration	Bq/kg dw	Cs	7.53E-05	Garden
Estimated Concentrations				
TF - Soil to terrestrial vegetation	kg/kg dw	Tftveg	2.90E-02	CSA (2018) Table G.3
TF - Soil to earthworm	kg/kg dw	Tfearthworm	3.19E-03	IAEA (2014) Table 5
Terrestrial vegetation moisture content	-	Mctveg	80.0%	CSA (2018), Table G.5
Earthworm moisture content	-	Mctveg	84.0%	U.S. EPA (1993)
Terrestrial vegetation concentration (DW)	Bq/kg dw	Ctvegdw	2.18E-06	=Cs*Tftveg
Terrestrial vegetation concentration (FW)	Bq/kg fw	Ctvegfw	4.37E-07	=Ctevgdw*(1-MCtveg)

Earthworm concentration (DW)	Bq/kg dw	Cearthwormdw	2.40E-07	=Cs*Tfearthworm
Earthworm concentration (FW)	Bq/kg fw	Cearthwormfw	3.84E-08	=Cearthwormdw*(1-MCearthworm)
Calculation of Intakes				
Intake from water	Bq/kg-d	Iw	4.75E-10	=Qwat*Cw*Floc/BW
Intake from soil	Bq/kg-d	Is	4.45E-07	=Qsdw*Cs*1kg/1000g*Floc/BW
Intake from terrestrial vegetation	Bq/kg-d	Itveg	1.15E-07	=Qffw*ftveg*Ctvegfw*1kg/1000g*Floc/BW
Intake from earthworm	Bq/kg-d	Iearthworm	1.78E-09	=Qffw*fearthworm*Cearthwormfw*1kg/1000g*Floc/BW
Total intake	Bq/kg-d	Itot	5.62E-07	=Iw+Is+Iseed
Estimated Concentration of Ruffed Grouse				
Feed to Ruffed Grouse TF	d/kg (FW)	Tfgrouse	7.88E-04	
Estimated Ruffed Grouse Conc	Bq/kg (FW)	Cgrouse	2.44E-10	=Itot*BW*TFgrouse
NB-93M INTAKE BY GREAT BLUE HERON - OTTAWA RIVER				
Receptor Characteristics				
Body weight	kg	BW	2.3	
Water ingestion rate	L/d	Qwat	0.092	
Fresh weight food ingestion rate	g FW/d	Qffw	414	
Sediment ingestion rate	g DW/d	Qseddw	2.37	
Fraction that is benthic invertebrates	-	fbi	0.10	
Fraction that is fish	-	ffi	0.65	
Fraction that is small mammals	-	fsm	0.25	
Fraction of time at site	-	Floc	1.00	
Measured Concentrations				
Surface water concentration	mg/L	Cw	6.79E-09	Ottawa River
Sediment concentration	Bq/kg dw	Csed	0.00E+00	Ottawa Riverbed
Estimated Concentrations				
TF - water to benthic	L/kg (ww)	TFbi	1.00E+02	CSA 2018 Table A.25e
TF - water to fish (whole)	L/kg (fw)	TFfi	3.00E+02	assumed same as flesh
Benthic invertebrate concentration (FW)	Bq/kg fw	Cbifw	6.79E-07	=Cw*TFbi
Fish concentration (FW)	Bq/kg fw	Cfifw	2.04E-06	=Cw*TFfi
Small Mammal concentration (FW)	Bq/kg fw	Csmfw	5.13E-09	average of Meadow Vole, Short-Tailed Shrew and Muskrat (see calculations below)

Appendix B – Sample Calculations

Calculation of Intakes				
Intake from water	Bq/kg-d	Iw	2.71E-10	=Qwat*Cw*Floc/BW
Intake from sediment	Bq/kg-d	Ised	0.00E+00	=Qseddw*Csed*1kg/1000g*Floc/BW
Intake from benthic invertebrate	Bq/kg-d	Ibi	1.22E-08	=Qffw*fbi*Cbifw*1kg/1000g*Floc/BW
Intake from fish	Bq/kg-d	Ifi	2.38E-07	=Qffw*ffi*Cfifw*1kg/1000g*Floc/BW
Intake from small mammals	Bq/kg-d	Ism	2.31E-10	=Qffw*fsm*Csmfw*1kg/1000g*Floc/BW
Total intake	Bq/kg-d	Itot	2.51E-07	=Iw+Ised+Ibi+Ifi+Ism
Estimated Concentration of Great Blue Heron				
Feed to Great Blue Heron TF	d/kg (FW)	TFheron	2.70E-04	
Estimated Great Blue Heron Conc	Bq/kg (FW)	Cheron	1.56E-10	=Itot*BW*TFheron
NB-93M INTAKE BY MALLARD - OTTAWA RIVER				
Receptor Characteristics				
Body weight	kg	BW	1.2	
Water ingestion rate	L/d	Qwat	0.072	
Fresh weight food ingestion rate	g FW/d	Qffw	258	
Sediment ingestion rate	g DW/d	Qseddw	1.98	
Fraction that is earthworms	-	few	0.025	
Fraction that is aquatic vegetation	-	fav	0.50	
Fraction that is terrestrial vegetation	-	ftv	0.05	
Fraction that is benthic invertebrate	-	fbi	0.40	
Fraction that is fish	-	ffi	0.025	
Fraction of time at site	-	Floc	1.00	
Measured Concentrations				
Surface water concentration	mg/L	Cw	6.79E-09	Ottawa River
Sediment concentration	Bq/kg dw	Csed	0.00E+00	Ottawa Riverbed
Soil concentration	Bq/kg dw	Cs	7.53E-05	Garden
Estimated Concentrations				
TF - Soil to earthworm	kg/kg dw	Tfew	0.0031875	IAEA (2014) Table 5
TF - water to aq. Veg	L/kg (ww)	Tfav	1200	CSA 2018 Table A.25f
TF - soil to terrestrial vegetation	kg/kg dw	TFtv	0.029	CSA 2018 Table G.3
TF - water to benthic	L/kg (ww)	TFew	100	CSA 2018 Table A.25e

TF - water to fish (whole)	L/kg (fw)	TFew	300	assumed same as flesh
Earthworm moisture content	-	MCew	84.0%	U.S. EPA (1993)
Terrestrial vegetation moisture content	-	MCtv	80.0%	CSA (2018), Table G.5
Earthworm concentration (DW)	Bq/kg dw	Cewdw	2.40E-07	=Cs*TFew
Earthworm concentration (FW)	Bq/kg fw	Cewfw	3.84E-08	=Cewdw*(1-MCew)
Aquatic vegetation concentration (FW)	Bq/kg fw	Cavfw	8.14E-06	=Cw*Tfav
Terrestrial vegetation concentration (DW)	Bq/kg dw	Ctvdw	2.18E-06	=Cs*TFtv
Terrestrial vegetation concentration (FW)	Bq/kg fw	Ctvfw	4.37E-07	=Ctvdw*(1-MCtv)
Benthic invertebrate concentration (FW)	Bq/kg fw	Cbifw	6.79E-07	=Cw*Tfbi
Fish concentration (FW)	Bq/kg fw	Cfifw	2.04E-06	=Cw*Tffi
Calculation of Intakes				
Intake from water	Bq/kg-d	Iw	4.07E-10	=Qwat*Cw*Floc/BW
Intake from sediment	Bq/kg-d	Ised	0.00E+00	=Qsdw*Cs*1kg/1000g*Floc/BW
Intake from earthworm	Bq/kg-d	Iew	2.07E-10	=Qffw*few*Cewfw*1kg/1000g*Floc/BW
Intake from aquatic vegetation	Bq/kg-d	Iav	8.77E-07	=Qffw*fav*Cavfw*1kg/1000g*Floc/BW
Intake from terrestrial vegetation	Bq/kg-d	Itv	4.70E-09	=Qffw*ftv*Ctvfw*1kg/1000g*Floc/BW
Intake from benthic invertebrate	Bq/kg-d	Ibi	5.85E-08	=Qffw*fbi*Cbifw*1kg/1000g*Floc/BW
Intake from fish	Bq/kg-d	Ifi	1.10E-08	=Qffw*ffi*Cfifw*1kg/1000g*Floc/BW
Total intake	Bq/kg-d	Itot	9.52E-07	=Iw+Ised+Iew+Iav+Itv+Ibi+Ifi
Estimated Concentration of Mallard				
Feed to Mallard TF	d/kg (FW)	Tfma	4.40E-04	
Estimated Mallard Conc	Bq/kg (FW)	Cma	5.35E-10	=Itot*BW*Tfma
NB-93M INTAKE BY SHORT-TAILED SHREW - GARDEN AND OTTAWA RIVER				
Receptor Characteristics				
Body weight	kg	BW	0.015	
Water ingestion rate	L/d	Qwat	0.00226	
Fresh weight food ingestion rate	g FW/d	Qffw	9	
Soil ingestion rate	g DW/d	Qsdw	0.19	
Fraction that is earthworms	-	few	1.00	
Fraction of time at site	-	Floc	1.00	
Measured Concentrations				
Surface water concentration	mg/L	Cw	6.79E-09	Ottawa River

Soil concentration	Bq/kg dw	Cs	7.53E-05	Garden
Estimated Concentrations				
TF - Soil to earthworm	kg/kg dw	TFew	3.19E-03	IAEA (2014) Table 5
Earthworm moisture content	-	MCew	84.0%	U.S. EPA (1993)
Earthworm concentration (DW)	Bq/kg dw	Cewdw	2.40E-07	=Cs*TFew
Earthworm concentration (FW)	Bq/kg fw	Cewfw	3.84E-08	=Cewdw*(1-MCew)
Calculation of Intakes				
Intake from water	Bq/kg-d	Iw	1.02E-09	=Qwat*Cw*Floc/BW
Intake from soil	Bq/kg-d	Is	9.38E-07	=Qsdw*Cs*1kg/1000g*Floc/BW
Intake from earthworm	Bq/kg-d	Iew	2.30E-08	=Qffw*few*Cewfw*1kg/1000g*Floc/BW
Total intake	Bq/kg-d	Itot	9.62E-07	=Iw+Is+Iew
Estimated Concentration of Short-tailed Shrew				
Feed to Short-tailed Shrew TF	d/kg (FW)	TFshrew	1.52E-01	
Estimated Short-tailed Shrew Conc	Bq/kg (FW)	Cshrew	2.20E-09	=Itot*BW*TFshrew
NB-93M INTAKE BY MEADOW VOLE - GARDEN AND OTTAWA RIVER				
Receptor Characteristics				
Body weight	kg	BW	0.0349	
Water ingestion rate	L/d	Qwat	0.007	
Fresh weight food ingestion rate	g FW/d	Qffw	11.5	
Soil ingestion rate	g DW/d	Qsdw	0.08	
Fraction that is terr. vegetation	-	ftv	1.00	
Fraction of time at site	-	Floc	1.00	
Measured Concentrations				
Surface water concentration	mg/L	Cw	6.79E-09	Ottawa River
Soil concentration	Bq/kg dw	Cs	7.53E-05	Garden
Estimated Concentrations				
TF - Soil to Terrestrial Vegetation	kg/kg dw	TFtv	0.029	CSA 2018 Table G.3
Terr Veg moisture content	-	MCtv	80.0%	CSA (2018), Table G.5
Terr Veg concentration (DW)	Bq/kg dw	Ctvdw	2.18E-06	=Cs*TFtv
Terr Veg concentration (FW)	Bq/kg fw	Ctvfw	4.37E-07	=Ctvdw*(1-MCtv)
Calculation of Intakes				
Intake from water	Bq/kg-d	Iw	1.36E-09	=Qwat*Cw*Floc/BW
Intake from soil	Bq/kg-d	Is	1.19E-07	=Qsdw*Cs*1kg/1000g*Floc/BW
Intake from terr. Vegetation	Bq/kg-d	Itv	1.44E-07	=Qffw*ftv*Ctvfw*1kg/1000g*Floc/BW

Appendix B – Sample Calculations

Total intake	Bq/kg-d	Itot	2.65E-07	=Iw+Is+Itv
Estimated Concentration of Meadow Vole				
Feed to Meadow Vole TF	d/kg (FW)	TFvole	8.08E-02	
Estimated Meadow Vole Conc	Bq/kg (FW)	Cvole	7.47E-10	=Itot*BW*TFvole
NB-93M INTAKE BY MUSKRAT - OTTAWA RIVER				
Receptor Characteristics				
Body weight	kg	BW	1	
Water ingestion rate	L/d	Qwat	0.099	
Fresh weight food ingestion rate	g FW/d	Qffw	284	
Sediment ingestion rate	g DW/d	Qseddw	1.40	
Fraction that is aq. vegetation	-	fav	0.80	
Fraction that is benthic invertebrate	-	fbi	0.15	
Fraction that is fish	-	ffi	0.05	
Fraction of time at site	-	Floc	1.00	
Measured Concentrations				
Surface water concentration	mg/L	Cw	6.79E-09	Ottawa River
Sediment concentration	Bq/kg dw	Csed	0.00E+00	Ottawa Riverbed
Estimated Concentrations				
TF - water to aq. Veg	L/kg (ww)	TFav	1.20E+03	CSA 2018 Table A.25f
TF - water to benthic	L/kg (ww)	TFbi	1.00E+02	CSA 2018 Table A.25e
TF - water to fish (whole)	L/kg (fw)	TFfi	3.00E+02	assumed same as flesh
Aq Veg concentration (FW)	Bq/kg fw	Cavfw	8.14E-06	=Cw*TFav
Benthic invertebrate concentration (FW)	Bq/kg fw	Cbifw	6.79E-07	=Cw*Tfbi
Fish concentration (FW)	Bq/kg fw	Cfifw	2.04E-06	=Cw*Tffi
Calculation of Intakes				
Intake from water	Bq/kg-d	Iw	6.72E-10	=Qwat*Cw*Floc/BW
Intake from sediment	Bq/kg-d	Ised	0.00E+00	=Qseddw*Csed*1kg/1000g*Floc/BW
Intake from aq. Vegetation	Bq/kg-d	Iav	1.85E-06	=Qffw*fav*Cavfw*1kg/1000g*Floc/BW
Intake from benthic invertebrate	Bq/kg-d	Ibi	2.89E-08	=Qffw*fbi*Cbifw*1kg/1000g*Floc/BW
Intake from fish	Bq/kg-d	Ifi	2.89E-08	=Qffw*ffi*Cfifw*1kg/1000g*Floc/BW
Total intake	Bq/kg-d	Itot	1.91E-06	=Iw+Ised+Iav+Ibi+Ifi
Estimated Concentration of Muskrat				
Feed to Muskrat TF	d/kg (FW)	Tfmuskrat	6.53E-03	
Estimated Muskrat Conc	Bq/kg (FW)	Cmuskrat	1.25E-08	=Itot*BW*Tfmuskrat

Sample Calculations for Non-Radiological Dose

				Lead	GardenOttawaR Scenario
WI - Mass Excavation					
LEAD INTAKE BY BALD EAGLE – GARDEN AND OTTAWA RIVER					
Receptor Characteristics					
	Body weight	kg	BW	4.7	
	Water ingestion rate	L/d	Qwat	0.188	
	Fresh weight food ingestion rate	g FW/d	Qffw	564	
	Soil ingestion rate	g DW/d	Qsdw	5.91	
	Fraction that is fish	-	ffi	0.65	
	Fraction that is birds	-	fbd	0.15	
	Fraction that is small mammals	-	fsm	0.20	
	Fraction of time at site	-	Floc	1.00	
Measured Concentrations				1	
	Surface water concentration	mg/L	Cw	9.74E-05	Ottawa River
	Soil concentration	mq/kg dw	Cs	1.76E+03	Garden
Estimated Concentrations					
	TF - Water to fish (Whole)	L/kg (fw)	TFfish	250	IAEA (2014) Table 6, whole fish
	Whole fish concentration (FW)	mg/kg fw	Cfishfw	2.44E-02	=Cw*TFfish
	Bird concentration (FW)	mg/kg fw	Cbirdsfw	1.26E+02	average of great blue heron, mallard and ruffed grouse (see calculations below)
	Small Mammal concentration (FW)	mg/kg fw	Csmfw	8.88E+00	average of muskrat, short-tailed shrew and meadow vole (see calculations below)
Calculation of Intakes					
	Intake from water	mg/kg-d	Iw	3.90E-06	=Qwat*Cw*Floc/BW
	Intake from soil	mg/kg-d	Is	1.26E+00	=Qsdw*Cs*1kg/1000g*Floc/BW
	Intake from fish	mg/kg-d	Ifi	1.90E-03	=Qffw*ffi*Cfishfw*1kg/1000g*Floc/BW
	Intake from birds	mg/kg-d	Ibirds	2.27E+00	=Qffw*fbd*Cbirdsfw*1kg/1000g*Floc/BW
	Intake from small mammals	mg/kg-d	Ism	2.13E-01	=Qffw*fsm*Csmfw*1kg/1000g*Floc/BW
	Total intake	mg/kg-d	Itot	3.75E+00	=Iw+Is+Ifi+Ibirds+Ism
Estimated Concentration of Bald Eagle					
	Feed to Bald Eagle TF	d/kg (FW)	TFeagle	4.21E-01	
	Estimated Bald Eagle Conc	mg/kg (FW)	Ceagle	7.43E+00	=Itot*BW*TFeagle

Appendix B – Sample Calculations

LEAD INTAKE BY GREAT BLUE HERON – OTTAWA RIVERBED SEDIMENT					
Receptor Characteristics					
	Body weight	kg	BW	2.3	
	Water ingestion rate	L/d	Qwat	0.092	
	Fresh weight food ingestion rate	g FW/d	Qffw	414.0	
	sediment ingestion rate	g DW/d	Qseddw	2.37	
	Fraction that is benthic invertebrates	-	Fbi	0.10	
	Fraction that is fish	-	ffi	0.65	
	Fraction that is small mammals	-	fsm	0.25	
	Fraction of time at site	-	Floc	1.00	
Measured Concentrations					
	Surface water concentration	mg/L	Cw	9.74E-05	Ottawa River
	Sediment concentration	mq/kg dw	Csed	1.00E+01	Ottawa River
Estimated Concentrations					
	TF - water to benthic	L/kg (ww)	Tfwater to benthic	3020	IAEA (2014) Table 6
	benthic concentration (FW)	mg/kg fw	Cbi fw	2.94E-01	=Cw*Tfwater to sediment
	TF - Water to fish (Whole)	L/kg (fw)	Tffi	250	IAEA 2010 Table 57
	Whole fish concentration (FW)	mg/kg fw	Cfi fw	2.44E-02	=Cw*TFfi
	Small Mammal concentration (FW)	mg/kg fw	Csmfw	8.88E+00	average of muskrat, short-tailed shrew and meadow vole (see calculations below)
Calculation of Intakes					
	Intake from water	mg/kg-d	Iw	3.90E-06	=Qwat*Cw*Floc/BW
	Intake from sediment	mg/kg-d	Ised	1.03E-02	=Qseddw*Cs*1kg/1000g*Floc/BW
	Intake from benthic invertebrates	mg/kg-d	Ibi	5.29E-03	=Qffw*fbi*Cbi fw*1kg/1000g*Floc/BW
	Intake from fish	mg/kg-d	Ifi	2.85E-03	=Qffw*ffi**Cfi fw*1kg/1000g*Floc/BW
	Intake from small mammals	mg/kg-d	Ism	4.00E-01	=Qffw*fsm*Csmw*1kg/1000g*Floc/BW
	Total intake	mg/kg-d	Itot	4.18E-01	=Iw+Ised+Ibi+Ifi+Ism
Estimated Concentration of great blue heron					
	Feed to Great Blue Heron TF	d/kg (FW)	TFgh	7.20E-01	
	Estimated Great Blue Heron Conc	mg/kg (FW)	Cgh	6.93E-01	=Itot*BW*TFfinch

LEAD INTAKE BY MALLARD – OTTAWA RIVERBED SEDIMENT					
Receptor Characteristics					
	Body weight	kg	BW	1.2	
	Water ingestion rate	L/d	Qwat	0.072	
	Fresh weight food ingestion rate	g FW/d	Qffw	258	
	Sediment ingestion rate	g DW/d	Qseddw	1.98	
	Fraction that is terrestrial vegetation	-	ftv	0.050	
	Fraction that is aquatic vegetation	-	fav	0.500	
	Fraction that is earthworms	-	few	0.025	
	Fraction that is benthic invertebrates	-	fbi	0.40	
	Fraction that is fish	-	ffi	0.025	
	Fraction of time at site	-	Floc	1.00	
Measured Concentrations					
	Surface water concentration	mg/L	Cw	9.74E-05	Ottawa River
	sediment concentration	mg/kg dw	Csed	1.00E+01	Ottawa Riverbed
	Soil concentration	mg/kg dw	Cs	1.76E+03	Garden
Estimated Concentrations					
	TF - Soil to earthworm	kg/kg dw	TFew	0.52	Sample *et al*. 1998, Table 11, geomean
	Earthworm moisture content	-	MCew	84.0%	U.S. EPA 1993
	Earthworm concentration (DW)	mq/kg dw	Cewdw	9.16E+02	=Cs*TFew
	Earthworm concentration (FW)	mq/kg fw	Cewfw	1.47E+02	=Cewdw*(1-MCew)
	TF - Soil to terrestrial vegetation	kg/kg dw	TFstv	3.17E+00	IAEA (2014) Table 5
	Terrestrial vegetation moisture content	-	MCtv	80% (Forage); 90% (Veg)	CSA 2017, Table G.5
	Terrestrial concentration (DW)	mg/kg dw	Ctv dw	5.58E+03	=Cs*TFstv
	Terrestrial concentration (FW)	mg/kg fw	Ctv fw	1.12E+03	=Ctvdw*(1-MCtv)
	TF- Surface water to aquatic vegetation	L/kg ww	TFav	6.20E+01	IAEA (2014) Table 6
	Aquatic vegetation concentration (FW)	mg/kg fw	Cav fw	6.04E-03	=Cw*Tfav
	TF - water to benthic	L/kg (ww)	TF bi	3.02E+03	IAEA 2010 Table 56
	benthic concentration (FW)	mg/kg fw	Cbi fw	2.94E-01	=Cw*Tfbi
	TF - Water to fish (Whole)	L/kg (fw)	Tffi	2.50E+02	IAEA 2010 Table 57
	Whole fish concentration (FW)	mg/kg fw	Cfi fw	2.44E-02	=Cw*Tffi

Calculation of Intakes					
	Intake from water	mg/kg-d	Iw	5.84E-06	=Qwat*Cw*Floc/BW
	Intake from sediment	mg/kg-d	Is	1.65E-02	=Qsdw*Cs*1kg/1000g*Floc/BW
	Intake from terrestrial vegetation	mg/kg-d	Itv	1.20E+01	=Qffw*ftv*Ctvfw*1kg/1000g*Floc/BW
	Intake from aquatic vegetation	mg/kg-d	Iav	6.50E-04	=Qffw*fav*Cavfw*1kg/1000g*Floc/BW
	Intake from earthworm	mg/kg-d	Iew	7.89E-01	=Qffw*few*Cewfw*1kg/1000g*Floc/BW
	Intake from benthic invertebrates	mg/kg-d	Ibi	2.53E-02	=Qffw*fbi*Cbi fw*1kg/1000g*Floc/BW
	Intake from fish	mg/kg-d	Ifi	1.31E-04	=Qffw*fbi*Cfi fw*1kg/1000g*Floc/BW
	Total intake	mg/kg-d	Itot	1.29E+01	=Iw+Ised+Itv+Iav+Iew+Ibi+Ifi
Estimated Concentration of Mallard					
	Feed to Mallard TF	d/kg (FW)	Tfmu	1.17E+00	
	Estimated Mallard Conc	mg/kg (FW)	Cmu	1.81E+01	=Itot*BW*Tfmu
LEAD INTAKE BY RUFFED GROUSE – GARDEN OTTAWA RIVER					
Receptor Characteristics					
	Body weight	kg	BW	0.552	
	Water ingestion rate	L/d	Qwat	0.0386	
	Fresh weight food ingestion rate	g FW/d	Qffw	1.71E+02	
	Soil ingestion rate	g DW/d	Qsdw	3.26	
	Fraction that is terrestrial vegetation	-	ftv	0.85	
	Fraction that is earthworms	-	few	0.15	
	Fraction of time at site	-	Floc	1.00	
Measured Concentrations					
	Surface water concentration	mg/L	Cw	9.74E-05	Ottawa River
	Soil concentration	Bq/kg dw	Cs	1.76E+03	Garden
Estimated Concentrations					
	TF - Soil to earthworm	kg/kg dw	TFew	0.52	IAEA (2014) Table 5
	Earthworm moisture content	-	MCew	84.0%	U.S. EPA 1993
	Earthworm concentration (DW)	mg/kg dw	Cewdw	9.16E+02	=Cs*TFew
	Earthworm concentration (FW)	mg/kg fw	Cewfw	1.47E+02	=Cewdw*(1-MCew)
	TF - Soil to terrestrial vegetation	kg/kg dw	TFstv	3.17	IAEA (2014) Table 5

	Terrestrial vegetation moisture content	-	MCtv	80% (Forage); 90% (Veg)	CSA 2017, Table G.5
	Terrestrial concentration (DW)	mg/kg dw	Ctv dw	5.58E+03	=Cs*TFstv
	Terrestrial concentration (FW)	mg/kg fw	Ctv fw	1.12E+03	=Ctv dw*(1-MCtv)
Calculation of Intakes					
	Intake from water	mg/kg-d	Iw	6.81E-06	=Qwat*Cw*Floc/BW
	Intake from soil	mg/kg-d	Is	1.04E+01	=Qsdw*Cs*1kg/1000g*Floc/BW
	Intake from terrestrial vegetation	mg/kg-d	Itv	2.93E+02	=Qffw*ftv*Ctvfw*1kg/1000g*Floc/BW
	Intake from earthworm	mg/kg-d	Iew	6.80E+00	=Qffw*few*Cewfw*1kg/1000g*Floc/BW
	Total intake	mg/kg-d	Itot	3.11E+02	=Iw+Is+Itv+Iew
Estimated Concentration of Ruffed Grouse					
	Feed to Ruffed Grouse TF	d/kg (FW)	TFwarbler	2.10E+00	
	Estimated Ruffed Grouse Conc	Bq/kg (FW)	Cwarbler	3.60E+02	=Itot*BW*TFwarbler
LEAD INTAKE BY MUSKRAT – OTTAWA RIVERBED SEDIMENT					
Receptor Characteristics					
	Body weight	kg	BW	1	
	Water ingestion rate	L/d	Qwat	0.099	
	Fresh weight food ingestion rate	g FW/d	Qffw	2.84E+02	
	Soil ingestion rate	g DW/d	Qseddw	3.50	
	Fraction that is aquatic vegetation	-	fav	0.80	
	Fraction that is benthic invertebrates	-	fbi	0.15	
	Fraction that is fish	-	ffi	0.05	
	Fraction of time at site	-	Floc	1.00	
Measured Concentrations					
	Surface water concentration	mg/L	Cw	9.74E-05	Ottawa River
	sediment concentration	mg/kg dw	Csed	1.00E+01	Ottawa River
Estimated Concentrations					
	TF- Surface water to aquatic vegetation	L/kg ww	Tfav	62	IAEA (2014) Table 6
	Aquatic vegetation concentration (FW)	mg/kg fw	Cav fw	6.04E-03	=Cw*Tfav
	TF - water to benthic	L/kg (ww)	Tf bi	3020	IAEA (2014) Table 6
	benthic concentration (FW)	mg/kg fw	Cbi fw	2.94E-01	=Cw*Tfbi

Appendix B – Sample Calculations

	TF - Water to fish (Whole)	L/kg (fw)	Tffi	250	IAEA (2014) Table 6
	Whole fish concentration (FW)	mg/kg fw	Cfi fw	2.4E-02	=Cw*Tffi
Calculation of Intakes					
	Intake from water	mg/kg-d	Iw	9.64E-06	=Qwat*Cw*Floc/BW
	Intake from sediment	mg/kg-d	Ised	1.40E-02	=Qsdw*Cs*1kg/1000g*Floc/BW
	Intake from aquatic vegetation	mg/kg-d	Iav	1.37E-03	=Qffw*fav*Cavfw*1kg/1000g*Floc/BW
	Intake from benthic invertebrates	mg/kg-d	Ibi	1.25E-02	=Qffw*fbi*Cbifw*1kg/1000g*Floc/BW
	Intake from fish	mg/kg-d	Ifi	3.46E-04	=Qffw*ffi*Cfifw*1kg/1000g*Floc/BW
	Total intake	mg/kg-d	Itot	2.83E-02	=Iw+Ised+Iav+Ifi+Ibi
Estimated Concentration of Muskrat					
	Feed to Muskrat TF	d/kg (FW)	Tfmu	1.34E-01	
	Estimated Muskrat Conc	mg/kg (FW)	Cmu	3.77E-03	=Itot*BW*TFewpw
LEAD INTAKE BY SHORT-TAILED SHREW – GARDEN OTTAWA RIVER					
Receptor Characteristics					
	Body weight	kg	BW	0.015	
	Water ingestion rate	L/d	Qwat	2.26E-03	
	Fresh weight food ingestion rate	g FW/d	Qffw	9	
	Soil ingestion rate	g DW/d	Qsdw	0.19	
	Fraction that is earthworms	-	few	1.00	
	Fraction of time at site	-	Floc	1.00	
Measured Concentrations					
	Surface water concentration	mg/L	Cw	9.74E-05	Ottawa River
	Soil concentration	mg/kg dw	Cs	1.76E+03	Garden
Estimated Concentrations					
	TF - Soil to earthworm	kg/kg dw	TFew	0.52	IAEA (2014) Table 5
	Earthworm moisture content	-	MCew	84.0%	U.S. EPA 1993
	Earthworm concentration (DW)	mg/kg dw	Cewdw	916.1	=Cs*TFew
	Earthworm concentration (FW)	mg/kg fw	Cewfw	146.57	=Cewdw*(1-MCew)
Calculation of Intakes					
	Intake from water	mg/kg-d	Iw	1.47E-05	=Qwat*Cw*Floc/BW
	Intake from soil	mg/kg-d	Is	2.20E+01	=Qsdw*Cs*1kg/1000g*Floc/BW

	Intake from earthworm	mg/kg-d	Iew	8.79E+01	=Qffw*few*Cewfw*1kg/1000g*Floc/BW
	Total intake	mg/kg-d	Itot	1.10E+02	=Iw+Is+Iew
Estimated Concentration of Short-tailed Shrew					
	Feed to Short-tailed Shrew TF	d/kg (FW)	TFshrew	3.11E+00	
	Estimated Short-tailed Shrew Conc	mg/kg (FW)	Cshrew	5.13E+00	=Itot*BW*TFshrew
LEAD INTAKE BY MEADOW VOLE – GARDEN OTTAWA RIVER					
Receptor Characteristics					
	Body weight	kg	BW	0.0349	
	Water ingestion rate	L/d	Qwat	0.007	
	Fresh weight food ingestion rate	g FW/d	Qffw	11.517	
	Soil ingestion rate	g DW/d	Qsdw	0.08	
	Fraction that is terr. vegetation	-	ftv	1.00	
	Fraction of time at site	-	Floc	1.00	
Measured Concentrations					
	Surface water concentration	mg/L	Cw	9.74E-05	Ottawa River
	Soil concentration	mg/kg dw	Cs	1.76E+03	Garden
Estimated Concentrations					
	TF - Soil to Terrestrial Vegetation	kg/kg dw	TFtv	3.17	IAEA (2014) Table 5
	Terr Veg moisture content	-	MCtv	80.0%	CSA 2017, Table G.5
	Terr Veg concentration (DW)	mg/kg dw	Ctvdw	5.58E+03	=Cs*TFtv
	Terr Veg concentration (FW)	mg/kg fw	Ctvfw	1.12E+03	=Ctvdw*(1-MCtv)
Calculation of Intakes					
	Intake from water	mg/kg-d	Iw	1.95E-05	=Qwat*Cw*Floc/BW
	Intake from soil	mg/kg-d	Is	4.19E+00	=Qsdw*Cs*1kg/1000g*Floc/BW
	Intake from terr. Vegetation	mg/kg-d	Itv	3.69E+02	=Qffw*ftv*Ctvfw*1kg/1000g*Floc/BW
	Total intake	mg/kg-d	Itot	3.73E+02	=Iw+Is+Itv
Estimated Concentration of Meadow Vole					
	Feed to Meadow Vole TF	d/kg (FW)	TFvole	1.65E+00	
	Estimated Meadow Vole Conc	mg/kg (FW)	Cvole	2.15E+01	=Itot*BW*TFvole

APPENDIX C

Sum of Fractions Analysis for the Postclosure Phase

APPENDIX C: SUM OF FRACTIONS ANALYSIS FOR THE POSTCLOSURE PHASE

Table C.1. Sum of Fractions for Scenario (1) – Normal Evolution Scenario (NES)

Radionuclide	Fractions = Concentration/Criterion			
	Spring Water[1]	Ottawa River	Garden	Riverbed or Rivershore
	Groundwater	Surface Water	Soil	Sediment
Am-241	2.73E-08	5.99E-11	1.70E-11	1.59E-12
C-14	1.69E-04	5.84E-07	3.76E-07	5.89E-03
Cl-36	5.27E-07	1.21E-08	4.02E-03	2.49E-01
Cm-243	3.31E-33	1.31E-32	1.53E-34	5.14E-36
Cm-244	1.02E-31	5.58E-30	6.47E-32	2.17E-33
Co-60	5.43E-12	3.40E-15	2.86E-17	1.39E-20
Cs-135	1.28E-10	1.56E-12	1.55E-11	9.33E-08
Cs-137	2.39E-07	7.01E-10	2.67E-11	2.94E-15
Eu-152	5.05E-20	2.81E-15	1.40E-17	3.02E-21
Eu-154	2.48E-21	1.51E-16	2.97E-19	1.11E-22
H-3	1.03E-05	3.78E-08	1.43E-06	3.47E-04
I-129	6.45E-10	3.18E-12	5.71E-15	4.50E-08
Nb-94	1.78E-07	1.44E-16	3.03E-17	1.29E-11
Ni-59	2.84E-08	8.84E-07	5.68E-09	1.78E-04
Ni-63	1.78E-07	3.23E-13	4.34E-14	3.82E-16
Np-237	6.29E-10	4.73E-08	4.95E-16	8.96E-09
Pu-238	4.45E-08	4.75E-11	1.85E-13	1.00E-15
Pu-239	1.79E-06	6.37E-08	2.74E-08	2.88E-02
Pu-240	2.13E-13	2.79E-14	3.54E-16	1.39E-08
Pu-241	7.38E-17	3.48E-19	4.34E-20	1.89E-14
Sb-125	1.22E-28	3.88E-28	6.64E-32	3.98E-35
Se-79	3.46E-09	2.31E-11	1.21E-11	4.05E-06
Sr-90	3.85E-09	1.30E-11	2.15E-14	1.29E-14
Tc-99	4.07E-08	1.37E-10	6.49E-09	1.95E-05
Th-230	5.63E-06	1.93E-08	2.08E-07	5.20E-04
Th-232	1.60E-09	5.37E-12	1.06E-14	4.00E-10
U-233	4.56E-10	1.77E-10	3.48E-11	2.54E-09
U-234	1.71E-10	1.81E-11	3.50E-11	1.48E-06
U-235	7.04E-08	2.68E-10	2.05E-07	1.58E-05
U-238	1.05E-06	3.91E-09	2.82E-06	2.38E-04
Zr-93	1.73E-11	6.90E-14	1.25E-15	1.75E-13
Sum of Fractions[2]	**1.88E-04**	**1.65E-06**	**4.03E-03**	**2.85E-01**
Terrestrial Pathway Sum of Fractions (Spring Water + Garden Soil)				**4.22E-03**
Terrestrial Pathway Sum of Fractions (Ottawa River Water + Garden Soil)				**4.03E-03**
Aquatic Pathway Sum of Fractions (Ottawa River Water + Riverbed Sediment)				**2.85E-01**
Total Sum of Fractions (Spring Water + Ottawa River Water + Garden Soil + Riverbed Sediment)				**2.89E-01**

Notes:

(1) Spring water (i.e., shallow groundwater) concentrations were compared to surface water criteria.

(2) A sum of fractions value of < 1 indicates no significant ecological impact and a value ≥ 1 requires further assessment.

Appendix C – Sum of Fractions Analysis for the Postclosure Phase

Table C.2. Sum of Fractions for Scenario (1a) – NES Sensitivity Analysis – Radioactive Inventory

Radionuclide	Fractions = Concentration/Criterion			
	Spring Water[1]	Ottawa River	Garden	Riverbed
	Groundwater	Surface Water	Soil	Sediment
Am-241	2.57E-07	5.47E-10	8.74E-10	1.63E-13
C-14	5.18E-08	1.84E-10	1.44E-09	9.20E-06
Cl-36	2.52E-08	3.97E-10	2.25E-06	7.81E-03
Cm-243	7.44E-17	5.98E-16	8.78E-18	2.88E-19
Cm-244	1.49E-16	2.99E-15	3.14E-17	1.05E-18
Co-60	9.96E-11	6.23E-14	5.24E-16	2.55E-19
Cs-135	1.10E-09	3.71E-12	1.94E-11	1.22E-07
Cs-137	1.44E-06	4.24E-09	2.50E-10	1.74E-14
Eu-152	5.11E-20	2.81E-15	1.40E-17	3.02E-21
Eu-154	0.00E+00	0.00E+00	0.00E+00	0.00E+00
H-3	2.00E-05	7.30E-08	2.58E-06	6.70E-04
I-129	1.38E-08	5.06E-11	1.07E-13	6.12E-07
Nb-94	2.77E-16	9.36E-19	1.96E-19	4.85E-14
Ni-59	1.96E-08	5.04E-10	1.19E-10	3.16E-06
Ni-63	5.43E-10	1.83E-12	4.86E-14	3.40E-17
Np-237	1.69E-12	2.91E-14	5.78E-15	8.35E-08
Pu-238	3.07E-09	3.28E-12	2.40E-14	6.92E-17
Pu-239	3.93E-06	1.27E-08	1.07E-06	2.06E-04
Pu-240	5.75E-09	1.90E-11	3.96E-13	3.55E-08
Pu-241	6.82E-12	2.02E-15	2.34E-18	8.56E-21
Sb-125	1.89E-19	6.71E-21	1.06E-24	6.33E-28
Se-79	1.23E-08	4.16E-11	6.22E-11	3.40E-07
Sr-90	2.29E-07	7.71E-10	1.06E-12	1.89E-13
Tc-99	2.17E-08	1.04E-10	6.53E-11	2.91E-05
Th-230	5.14E-10	1.76E-12	1.12E-13	4.01E-08
Th-232	4.28E-15	1.51E-17	6.02E-19	9.28E-13
U-233	9.69E-11	1.03E-12	5.55E-11	1.01E-11
U-234	1.47E-11	6.11E-13	1.52E-12	4.91E-08
U-235	1.37E-12	5.61E-15	1.47E-13	2.69E-10
U-238	3.26E-11	3.14E-13	3.69E-12	2.04E-08
Zr-93	1.84E-10	6.20E-13	8.79E-15	2.12E-14
Sum of Fractions[2]	**2.60E-05**	**9.26E-08**	**5.91E-06**	**8.73E-03**
Terrestrial Pathway Sum of Fractions (Spring Water + Garden Soil)				**3.19E-05**
Terrestrial Pathway Sum of Fractions (Ottawa River Water + Garden Soil)				**6.00E-06**
Aquatic Pathway Sum of Fractions (Ottawa River Water + Riverbed Sediment)				**8.73E-03**
Total Sum of Fractions (Spring Water + Ottawa River Water + Garden Soil + Riverbed Sediment)				**8.76E-03**

Notes:

(1) Spring water (i.e., shallow groundwater) concentrations were compared to surface water criteria.

(2) A sum of fractions value of < 1 indicates no significant ecological impact and a value ≥ 1 requires further assessment.

Table C.3. Sum of Fractions for Scenario (1b) – NES Sensitivity Analysis – Sorption

Radionuclide	Fractions = Concentration/Criterion			
	Spring Water[1]	Ottawa River	Garden	Riverbed
	Groundwater	Surface Water	Soil	Sediment
Am-241	3.70E-07	9.90E-10	1.46E-09	1.66E-10
C-14	1.63E-03	5.49E-06	3.19E-05	7.05E-02
Cl-36	1.40E-05	1.29E-07	1.44E-02	1.98E+00
Cm-243	1.53E-25	9.12E-26	1.11E-27	3.70E-29
Cm-244	5.94E-24	3.89E-23	4.68E-25	1.57E-26
Co-60	5.38E-11	4.67E-14	4.13E-16	1.98E-19
Cs-135	1.48E-09	5.11E-12	6.44E-12	1.02E-07
Cs-137	1.44E-06	4.22E-09	4.92E-10	1.78E-14
Eu-152	5.03E-17	2.79E-13	1.40E-15	3.00E-19
Eu-154	2.48E-19	1.50E-15	2.96E-18	1.11E-21
H-3	1.03E-05	3.78E-08	1.43E-06	3.47E-04
I-129	6.62E-09	6.95E-12	8.65E-14	9.41E-08
Nb-94	9.83E-11	3.34E-13	2.64E-12	1.81E-08
Ni-59	5.28E-06	6.39E-08	1.04E-08	3.05E-04
Ni-63	9.53E-10	3.40E-12	3.75E-12	3.72E-14
Np-237	1.62E-12	3.57E-13	9.99E-14	1.22E-06
Pu-238	4.44E-07	4.75E-10	2.14E-12	1.00E-14
Pu-239	1.30E-04	1.68E-06	9.93E-06	6.65E-01
Pu-240	1.44E-09	5.51E-12	2.50E-11	1.11E-06
Pu-241	8.85E-14	4.59E-17	4.21E-16	3.36E-12
Sb-125	1.21E-25	3.85E-26	6.58E-30	3.94E-33
Se-79	4.50E-09	2.30E-11	5.14E-11	4.02E-06
Sr-90	3.85E-08	1.30E-10	1.29E-12	1.11E-12
Tc-99	1.50E-07	5.08E-10	8.97E-09	5.45E-05
Th-230	1.25E-05	4.30E-08	4.28E-07	1.49E-03
Th-232	1.20E-07	4.04E-10	8.84E-13	6.12E-07
U-233	1.28E-08	1.96E-09	4.29E-09	2.77E-08
U-234	2.25E-09	7.05E-10	1.11E-08	5.91E-05
U-235	6.66E-07	2.25E-09	1.16E-06	3.35E-05
U-238	1.40E-07	3.34E-08	1.60E-05	5.07E-04
Zr-93	5.71E-13	1.02E-09	2.24E-09	6.13E-11
Sum of Fractions[2]	**1.81E-03**	**7.49E-06**	**1.45E-02**	**2.72E+00**
Terrestrial Pathway Sum of Fractions (Spring Water + Garden Soil)				**1.63E-02**
Terrestrial Pathway Sum of Fractions (Ottawa River Water + Garden Soil)				**1.45E-02**
Aquatic Pathway Sum of Fractions (Ottawa River Water + Riverbed Sediment)				**2.72E+00**
Total Sum of Fractions (Spring Water + Ottawa River Water + Garden Soil + Riverbed Sediment)				**2.74E+00**

Notes:

(1) Spring water (i.e., shallow groundwater) concentrations were compared to surface water criteria.

(2) A sum of fractions value of < 1 indicates no significant ecological impact and a value ≥ 1 requires further assessment (shaded in yellow). When the unity rule was exceeded, the data were reviewed to identify the top five (5) radionuclides contributing the majority of the radiation dose (cumulative contribution of >97%) to aquatic and terrestrial pathways to ensure that these radionuclides were included in the assessment of ecological risks for the particular scenario (see Table C.4).

Table C.4. Top 5 Radionuclides in Aquatic Pathway for Scenario (1b) NES Sensitivity Analysis - Sorption

Radionuclide	Fractions = Concentration / Criterion Ottawa River Surface Water	Cumulative Percentage of Fractions	Radionuclide	Fractions = Concentration / Criterion Riverbed Sediment	Cumulative Percentage of Fractions
C-14	5.49E-06	73.36%	**Cl-36**	1.98E+00	72.88%
Pu-239	1.68E-06	95.73%	**Pu-239**	6.65E-01	97.31%
Cl-36	1.29E-07	97.45%	**C-14**	7.05E-02	99.90%
Ni-59	6.39E-08	98.31%	**Th-230**	1.49E-03	99.95%
Th-230	4.30E-08	98.88%	**U-238**	5.07E-04	99.97%
H-3	3.78E-08	99.38%	H-3	3.47E-04	99.98%
U-238	3.34E-08	99.83%	Ni-59	3.05E-04	99.99%
Cs-137	4.22E-09	99.89%	U-234	5.91E-05	100.00%
U-235	2.25E-09	99.92%	Tc-99	5.45E-05	100.00%
U-233	1.96E-09	99.94%	U-235	3.35E-05	100.00%
Zr-93	1.02E-09	99.96%	Se-79	4.02E-06	100.00%
Am-241	9.90E-10	99.97%	Np-237	1.22E-06	100.00%
U-234	7.05E-10	99.98%	Pu-240	1.11E-06	100.00%
Tc-99	5.08E-10	99.99%	Th-232	6.12E-07	100.00%
Pu-238	4.75E-10	99.99%	Cs-135	1.02E-07	100.00%
Th-232	4.04E-10	100.00%	I-129	9.41E-08	100.00%
Sr-90	1.30E-10	100.00%	U-233	2.77E-08	100.00%
Se-79	2.30E-11	100.00%	Nb-94	1.81E-08	100.00%
I-129	6.95E-12	100.00%	Am-241	1.66E-10	100.00%
Pu-240	5.51E-12	100.00%	Zr-93	6.13E-11	100.00%
Cs-135	5.11E-12	100.00%	Pu-241	3.36E-12	100.00%
Ni-63	3.40E-12	100.00%	Sr-90	1.11E-12	100.00%
Np-237	3.57E-13	100.00%	Ni-63	3.72E-14	100.00%
Nb-94	3.34E-13	100.00%	Cs-137	1.78E-14	100.00%
Eu-152	2.79E-13	100.00%	Pu-238	1.00E-14	100.00%
Co-60	4.67E-14	100.00%	Eu-152	3.00E-19	100.00%
Eu-154	1.50E-15	100.00%	Co-60	1.98E-19	100.00%
Pu-241	4.59E-17	100.00%	Eu-154	1.11E-21	100.00%
Cm-244	3.89E-23	100.00%	Cm-244	1.57E-26	100.00%
Cm-243	9.12E-26	100.00%	Cm-243	3.70E-29	100.00%
Sb-125	3.85E-26	100.00%	Sb-125	3.94E-33	100.00%
Top 5 Radionuclides	**C-14, Cl-36, Ni-59, Pu-239, Th-230, U-238**				

Note:

Gray shaded cells are the top 5 radionuclides contributing to the total radiation in each medium.

Table C.5. Sum of Fractions for Scenario (1c) – NES Sensitivity Analysis – Resaturation Rate - Faster

Radionuclide	Fractions = Concentration/Criterion			
	Spring Water[1]	Ottawa River	Garden	Riverbed
	Groundwater	Surface Water	Soil	Sediment
Am-241	2.73E-08	5.99E-11	1.70E-11	1.59E-12
C-14	1.69E-04	5.84E-07	3.76E-07	5.89E-03
Cl-36	5.26E-07	1.22E-08	4.02E-03	2.49E-01
Cm-243	3.31E-33	1.31E-32	1.53E-34	5.14E-36
Cm-244	1.02E-31	5.58E-30	6.48E-32	2.17E-33
Co-60	5.43E-12	4.71E-15	3.89E-17	1.88E-20
Cs-135	1.28E-10	1.56E-12	1.55E-11	9.33E-08
Cs-137	2.80E-07	8.29E-10	2.99E-11	3.39E-15
Eu-152	6.35E-20	3.76E-15	2.16E-17	4.71E-21
Eu-154	3.88E-21	3.83E-16	1.00E-18	3.33E-22
H-3	1.03E-05	3.78E-08	2.57E-06	3.47E-04
I-129	6.47E-10	3.18E-12	5.72E-15	4.51E-08
Nb-94	4.27E-14	1.44E-16	3.03E-17	1.30E-11
Ni-59	8.85E-07	2.84E-08	5.68E-09	1.78E-04
Ni-63	1.07E-10	3.62E-13	4.36E-14	3.86E-16
Np-237	4.99E-16	2.62E-15	4.95E-16	8.96E-09
Pu-238	4.94E-08	5.02E-11	1.95E-13	1.05E-15
Pu-239	1.79E-06	6.37E-08	2.74E-08	2.88E-02
Pu-240	2.14E-13	2.79E-14	3.54E-16	1.39E-08
Pu-241	7.39E-17	7.03E-19	4.34E-20	1.89E-14
Sb-125	1.22E-28	1.25E-26	2.28E-30	1.34E-33
Se-79	3.51E-09	2.31E-11	1.24E-11	4.05E-06
Sr-90	4.11E-09	1.62E-11	2.77E-14	1.39E-14
Tc-99	4.06E-08	1.37E-10	6.48E-09	1.96E-05
Th-230	5.63E-06	1.93E-08	2.08E-07	5.20E-04
Th-232	1.60E-09	5.37E-12	1.06E-14	4.00E-10
U-233	4.56E-10	1.77E-10	3.48E-11	2.54E-09
U-234	1.71E-10	1.81E-11	3.50E-11	1.48E-06
U-235	7.04E-08	2.68E-10	2.05E-07	1.58E-05
U-238	1.05E-06	3.90E-09	2.82E-06	2.38E-04
Zr-93	1.73E-11	6.90E-14	1.26E-15	1.75E-13
Sum of Fractions[2]	**1.89E-04**	**7.50E-07**	**4.03E-03**	**2.85E-01**
Terrestrial Pathway Sum of Fractions (Spring Water + Garden Soil)				**4.22E-03**
Terrestrial Pathway Sum of Fractions (Ottawa River Water + Garden Soil)				**4.03E-03**
Aquatic Pathway Sum of Fractions (Ottawa River Water + Riverbed Sediment)				**2.85E-01**
Total Sum of Fractions (Spring Water + Ottawa River Water + Garden Soil + Riverbed Sediment)				**2.89E-01**

Notes:

(1) Spring water (i.e., shallow groundwater) concentrations were compared to surface water criteria.

(2) A sum of fractions value of < 1 indicates no significant ecological impact and a value ≥ 1 requires further assessment.

Table C.6. Sum of Fractions for Scenario (1d) – NES Sensitivity Analysis – Resaturation Rate - Slower

Radionuclide	Fractions = Concentration/Criterion			
	Spring Water[1]	Ottawa River	Garden	Riverbed
	Groundwater	Surface Water	Soil	Sediment
Am-241	2.73E-08	5.98E-11	1.70E-11	1.58E-12
C-14	1.69E-04	5.84E-07	3.76E-07	5.89E-03
Cl-36	5.28E-07	1.21E-08	4.06E-03	2.48E-01
Cm-243	1.40E-33	5.17E-36	1.15E-37	0.00E+00
Cm-244	2.89E-32	1.61E-34	1.63E-36	0.00E+00
Co-60	5.43E-12	3.40E-15	2.86E-17	1.39E-20
Cs-135	1.30E-10	1.55E-12	1.56E-11	9.31E-08
Cs-137	1.82E-07	5.37E-10	1.47E-11	2.15E-15
Eu-152	1.75E-20	8.69E-23	5.14E-25	9.08E-29
Eu-154	2.04E-21	6.69E-24	2.92E-26	8.73E-30
H-3	1.03E-05	3.78E-08	2.08E-08	3.47E-04
I-129	6.17E-10	3.02E-12	5.42E-15	4.28E-08
Nb-94	4.27E-14	1.44E-16	3.03E-17	1.29E-11
Ni-59	8.82E-07	2.84E-08	5.67E-09	1.78E-04
Ni-63	6.54E-11	2.19E-13	2.17E-14	3.00E-16
Np-237	4.96E-16	2.61E-15	4.93E-16	8.92E-09
Pu-238	2.99E-08	2.83E-11	1.07E-13	5.81E-16
Pu-239	1.79E-06	6.37E-08	2.74E-08	2.88E-02
Pu-240	2.04E-13	2.77E-14	3.51E-16	1.38E-08
Pu-241	7.34E-17	6.27E-20	4.32E-20	1.88E-14
Sb-125	1.22E-28	2.44E-31	5.94E-35	3.60E-38
Se-79	2.37E-09	2.30E-11	7.56E-12	4.06E-06
Sr-90	3.85E-09	1.30E-11	1.71E-14	8.55E-15
Tc-99	4.14E-08	1.40E-10	6.83E-09	1.78E-05
Th-230	5.63E-06	1.93E-08	2.08E-07	5.20E-04
Th-232	1.60E-09	5.37E-12	1.06E-14	3.99E-10
U-233	4.56E-10	1.77E-10	3.48E-11	2.54E-09
U-234	1.71E-10	1.80E-11	3.50E-11	1.47E-06
U-235	7.04E-08	2.68E-10	2.05E-07	1.58E-05
U-238	1.05E-06	3.91E-09	2.82E-06	2.38E-04
Zr-93	1.72E-11	6.84E-14	1.24E-15	1.74E-13
Sum of Fractions[2]	**1.89E-04**	**7.50E-07**	**4.06E-03**	**2.84E-01**
Terrestrial Pathway Sum of Fractions (Spring Water + Garden Soil)				**4.25E-03**
Terrestrial Pathway Sum of Fractions (Ottawa River Water + Garden Soil)				**4.06E-03**
Aquatic Pathway Sum of Fractions (Ottawa River Water + Riverbed Sediment)				**2.84E-01**
Total Sum of Fractions (Spring Water + Ottawa River Water + Garden Soil + Riverbed Sediment)				**2.88E-01**

Notes:

(1) Spring water (i.e., shallow groundwater) concentrations were compared to surface water criteria.

(2) A sum of fractions value of < 1 indicates no significant ecological impact and a value ≥ 1 requires further assessment.

Table C.7. Sum of Fractions for Scenario (1e) – NES Sensitivity Analysis – Surface Erosion

Radionuclide	Fractions = Concentration/Criterion			
	Spring Water[1] Groundwater	Ottawa River Surface Water	Garden Soil	Riverbed Sediment
Am-241	2.73E-08	5.99E-11	3.60E-08	1.59E-12
C-14	1.69E-04	5.84E-07	1.15E-03	5.89E-03
Cl-36	5.27E-07	1.21E-08	5.10E-03	2.49E-01
Cm-243	3.31E-33	1.31E-32	2.27E-29	5.14E-36
Cm-244	1.02E-31	5.58E-30	1.21E-27	2.17E-33
Co-60	5.43E-12	3.40E-15	1.19E-14	1.39E-20
Cs-135	1.28E-10	1.56E-12	1.41E-07	9.33E-08
Cs-137	2.39E-07	7.01E-10	1.78E-07	2.94E-15
Eu-152	5.05E-20	2.81E-15	1.40E-17	3.02E-21
Eu-154	2.48E-21	1.51E-16	7.04E-17	1.11E-22
H-3	1.03E-05	3.78E-08	1.43E-06	3.47E-04
I-129	6.45E-10	3.18E-12	4.55E-14	4.50E-08
Nb-94	4.27E-14	1.44E-16	5.00E-09	1.29E-11
Ni-59	8.84E-07	2.84E-08	3.87E-05	1.78E-04
Ni-63	9.50E-11	3.23E-13	5.32E-11	3.82E-16
Np-237	4.99E-16	2.62E-15	1.14E-10	8.96E-09
Pu-238	4.45E-08	4.75E-11	4.49E-11	1.00E-15
Pu-239	1.79E-06	6.37E-08	9.15E-04	2.88E-02
Pu-240	2.13E-13	2.79E-14	4.08E-10	1.39E-08
Pu-241	7.38E-17	3.48E-19	1.83E-14	1.89E-14
Sb-125	1.22E-28	3.88E-28	6.64E-32	3.98E-35
Se-79	3.46E-09	2.31E-11	4.16E-07	4.05E-06
Sr-90	3.85E-09	1.30E-11	6.26E-12	1.29E-14
Tc-99	4.07E-08	1.37E-10	4.31E-07	1.95E-05
Th-230	5.63E-06	1.93E-08	1.04E-06	5.20E-04
Th-232	1.60E-09	5.37E-12	1.22E-10	4.00E-10
U-233	4.56E-10	1.77E-10	2.67E-07	2.54E-09
U-234	1.71E-10	1.81E-11	2.95E-07	1.48E-06
U-235	7.04E-08	2.68E-10	3.65E-06	1.58E-05
U-238	1.05E-06	3.91E-09	5.60E-05	2.38E-04
Zr-93	1.73E-11	6.90E-14	1.35E-06	1.75E-13
Sum of Fractions[2]	**1.89E-04**	**7.50E-07**	**7.27E-03**	**2.85E-01**
Terrestrial Pathway Sum of Fractions (Spring Water + Garden Soil)				**7.46E-03**
Terrestrial Pathway Sum of Fractions (Ottawa River Water + Garden Soil)				**7.27E-03**
Aquatic Pathway Sum of Fractions (Ottawa River Water + Riverbed Sediment)				**2.85E-01**
Total Sum of Fractions (Spring Water + Ottawa River Water + Garden Soil + Riverbed Sediment)				**3.00E-01**

Notes:

(1) Spring water (i.e., shallow groundwater) concentrations were compared to surface water criteria.

(2) A sum of fractions value of < 1 indicates no significant ecological impact and a value ≥ 1 requires further assessment.

Table C.8. Sum of Fractions for Scenario (1g) – NES Sensitivity Analysis –Engineering Degradation

Radionuclide	Fractions = Concentration/Criterion			
	Spring Water[1]	Ottawa River	Garden	Riverbed
	Groundwater	Surface Water	Soil	Sediment
Am-241	1.15E-07	2.51E-10	3.07E-11	5.00E-12
C-14	1.89E-04	6.53E-07	3.84E-07	6.43E-03
Cl-36	5.11E-07	1.23E-08	4.92E-03	2.54E-01
Cm-243	8.78E-30	2.75E-32	7.67E-34	5.71E-33
Cm-244	2.67E-28	5.58E-30	6.47E-32	8.76E-33
Co-60	5.43E-12	3.40E-15	2.86E-17	1.39E-20
Cs-135	1.20E-10	1.55E-12	1.59E-11	9.31E-08
Cs-137	1.02E-06	3.00E-09	9.28E-11	1.20E-14
Eu-152	6.87E-18	2.81E-15	1.40E-17	3.02E-21
Eu-154	7.63E-21	1.51E-16	2.97E-19	1.11E-22
H-3	1.03E-05	3.78E-08	1.43E-06	3.47E-04
I-129	3.31E-11	2.60E-12	1.90E-15	4.21E-08
Nb-94	4.40E-14	1.48E-16	3.12E-17	1.54E-11
Ni-59	9.44E-07	2.91E-08	5.79E-09	1.84E-04
Ni-63	3.84E-09	1.29E-11	1.98E-12	4.61E-14
Np-237	5.15E-16	2.58E-15	4.89E-16	8.84E-09
Pu-238	1.62E-06	1.55E-09	6.04E-12	3.20E-14
Pu-239	1.90E-06	7.33E-08	2.78E-08	3.34E-02
Pu-240	1.75E-13	2.91E-14	3.60E-16	1.45E-08
Pu-241	7.46E-17	3.48E-19	4.58E-20	2.00E-14
Sb-125	1.22E-28	3.88E-28	6.64E-32	3.98E-35
Se-79	3.47E-10	2.31E-11	7.09E-12	4.05E-06
Sr-90	4.30E-08	1.45E-10	3.66E-13	4.66E-13
Tc-99	6.58E-08	2.23E-10	6.56E-09	1.05E-05
Th-230	5.65E-06	1.94E-08	2.10E-07	5.31E-04
Th-232	1.68E-09	5.65E-12	1.11E-14	4.10E-10
U-233	4.79E-10	1.81E-10	4.09E-11	2.59E-09
U-234	1.72E-10	1.67E-11	3.84E-11	1.36E-06
U-235	7.08E-08	2.66E-10	2.01E-07	1.56E-05
U-238	1.05E-06	3.87E-09	2.79E-06	2.35E-04
Zr-93	1.72E-11	7.06E-14	1.29E-15	2.08E-13
Sum of Fractions[2]	**2.12E-04**	**8.34E-07**	**4.93E-03**	**2.95E-01**
Terrestrial Pathway Sum of Fractions (Spring Water + Garden Soil)				**5.14E-03**
Terrestrial Pathway Sum of Fractions (Ottawa River Water + Garden Soil)				**4.93E-03**
Aquatic Pathway Sum of Fractions (Ottawa River Water + Riverbed Sediment)				**2.95E-01**
Total Sum of Fractions (Spring Water + Ottawa River Water + Garden Soil + Riverbed Sediment)				**3.00E-01**

Notes:

(1) Spring water (i.e., shallow groundwater) concentrations were compared to surface water criteria.

(2) A sum of fractions value of < 1 indicates no significant ecological impact and a value ≥ 1 requires further assessment.

Table C.9. Sum of Fractions for Scenario (2a) Disruptive Event – Site Investigation (Human Intrusion)

Radionuclide	Fractions = Concentration/Criterion			
	Spring Water[1]	Ottawa River	Garden	Riverbed
	Groundwater	Surface Water	Soil	Sediment
Am-241	2.73E-08	5.99E-11	1.84E-06	1.59E-12
C-14	1.69E-04	5.84E-07	1.38E-03	5.89E-03
Cl-36	5.27E-07	1.21E-08	2.00E-02	2.49E-01
Cm-243	3.31E-33	1.31E-32	5.70E-10	5.14E-36
Cm-244	1.02E-31	5.58E-30	2.22E-07	2.17E-33
Co-60	5.43E-12	3.40E-15	1.78E-10	1.39E-20
Cs-135	1.28E-10	1.56E-12	1.70E-11	9.33E-08
Cs-137	2.39E-07	7.01E-10	1.18E-07	2.94E-15
Eu-152	5.05E-20	2.81E-15	2.25E-09	3.02E-21
Eu-154	2.48E-21	1.51E-16	2.97E-19	1.11E-22
H-3	1.03E-05	3.78E-08	1.43E-06	3.47E-04
I-129	6.45E-10	3.18E-12	3.38E-14	4.50E-08
Nb-94	4.27E-14	1.44E-16	6.67E-08	1.29E-11
Ni-59	8.84E-07	2.84E-08	1.46E-08	1.78E-04
Ni-63	9.50E-11	3.23E-13	1.35E-06	3.82E-16
Np-237	4.99E-16	2.62E-15	3.18E-11	8.96E-09
Pu-238	4.45E-08	4.75E-11	6.78E-08	1.00E-15
Pu-239	1.79E-06	6.37E-08	1.28E-07	2.88E-02
Pu-240	2.13E-13	2.79E-14	9.00E-08	1.39E-08
Pu-241	7.38E-17	3.48E-19	4.03E-12	1.89E-14
Sb-125	1.22E-28	3.88E-28	1.25E-18	3.98E-35
Se-79	3.46E-09	2.31E-11	2.84E-11	4.05E-06
Sr-90	3.85E-09	1.30E-11	2.39E-09	1.29E-14
Tc-99	4.07E-08	1.37E-10	1.24E-08	1.95E-05
Th-230	5.63E-06	1.93E-08	2.09E-07	5.20E-04
Th-232	1.60E-09	5.37E-12	2.01E-09	4.00E-10
U-233	4.56E-10	1.77E-10	4.87E-11	2.54E-09
U-234	1.71E-10	1.81E-11	1.69E-08	1.48E-06
U-235	7.04E-08	2.68E-10	2.06E-07	1.58E-05
U-238	1.05E-06	3.91E-09	2.84E-06	2.38E-04
Zr-93	1.73E-11	6.90E-14	6.20E-07	1.75E-13
Sum of Fractions[2]	**1.89E-04**	**7.50E-07**	**2.14E-02**	**2.85E-01**
Terrestrial Pathway Sum of Fractions (Spring Water + Garden Soil)				**2.16E-02**
Terrestrial Pathway Sum of Fractions (Ottawa River Water + Garden Soil)				**2.14E-02**
Aquatic Pathway Sum of Fractions (Ottawa River Water + Riverbed Sediment)				**2.85E-01**
Total Sum of Fractions (Spring Water + Ottawa River Water + Garden Soil + Riverbed Sediment)				**3.06E-01**

Notes:

(1) Spring water (i.e., shallow groundwater) concentrations were compared to surface water criteria.

(2) A sum of fractions value of < 1 indicates no significant ecological impact and a value ≥ 1 requires further assessment.

Table C.10. Sum of Fractions for Scenario (2b) Disruptive Event – Extreme Degradation of Engineered Structures

Radionuclide	Fractions = Concentration/Criterion			
	Spring Water[1] Groundwater	Ottawa River Surface Water	Garden Soil	Riverbed Sediment
Am-241	3.09E-07	8.35E-10	4.29E-11	1.98E-10
C-14	1.04E-03	3.57E-06	1.45E-07	2.25E-01
Cl-36	2.50E-06	2.51E-07	3.82E-03	5.29E+00
Cm-243	5.24E-30	1.65E-32	4.32E-34	4.78E-34
Cm-244	2.54E-29	5.58E-30	6.47E-32	2.17E-33
Co-60	5.43E-12	3.40E-15	2.86E-17	1.39E-20
Cs-135	1.50E-10	1.73E-12	2.29E-13	1.03E-07
Cs-137	2.39E-07	7.01E-10	2.67E-11	2.94E-15
Eu-152	5.05E-20	2.81E-15	1.40E-17	3.02E-21
Eu-154	2.48E-21	1.51E-16	2.97E-19	1.11E-22
H-3	1.03E-05	3.78E-08	1.43E-06	3.47E-04
I-129	1.64E-10	6.20E-12	2.38E-15	1.03E-07
Nb-94	7.70E-08	2.60E-10	5.45E-11	4.11E-05
Ni-59	3.77E-06	9.00E-08	7.90E-10	5.78E-04
Ni-63	9.13E-10	3.08E-12	1.06E-12	1.78E-14
Np-237	3.95E-11	1.10E-11	2.06E-12	3.70E-05
Pu-238	3.34E-07	3.23E-10	1.35E-12	6.80E-15
Pu-239	1.95E-04	4.66E-05	4.27E-07	2.32E+01
Pu-240	1.95E-06	7.28E-09	6.93E-11	3.01E-03
Pu-241	1.53E-12	6.79E-16	3.16E-17	2.24E-11
Sb-125	1.22E-28	3.88E-28	6.63E-32	3.98E-35
Se-79	5.03E-10	2.23E-11	2.33E-12	3.98E-06
Sr-90	3.85E-09	1.30E-11	2.15E-14	1.29E-14
Tc-99	3.60E-08	1.25E-10	1.55E-09	4.47E-05
Th-230	2.95E-06	1.01E-08	2.00E-11	2.61E-03
Th-232	5.42E-07	1.87E-09	3.71E-12	6.58E-05
U-233	3.31E-09	6.19E-10	2.39E-11	8.81E-09
U-234	4.99E-08	2.87E-09	1.72E-09	2.42E-04
U-235	3.37E-07	1.14E-09	9.12E-10	3.30E-05
U-238	5.02E-06	1.69E-08	1.34E-08	5.13E-04
Zr-93	1.95E-05	6.58E-08	7.21E-10	5.14E-08
Sum of Fractions[2]	**1.29E-03**	**5.06E-05**	**3.82E-03**	**2.87E+01**
Terrestrial Pathway Sum of Fractions (Spring Water + Garden Soil)				**5.11E-03**
Terrestrial Pathway Sum of Fractions (Ottawa River Water + Garden Soil)				**3.87E-03**
Aquatic Pathway Sum of Fractions (Ottawa River Water + Riverbed Sediment)				**2.87E+01**
Total Sum of Fractions (Spring Water + Ottawa River Water + Garden Soil + Riverbed Sediment)				**2.88E+01**

Notes:

(1) Spring water (i.e., shallow groundwater) concentrations were compared to surface water criteria.

(2) A sum of fractions value of < 1 indicates no significant ecological impact and a value ≥ 1 requires further assessment (shaded in yellow). When the unity rule was exceeded, the data were reviewed to identify the top five (5) radionuclides contributing the majority of the radiation dose (cumulative contribution of >97%) to aquatic and terrestrial pathways to ensure that these radionuclides were included in the assessment of ecological risks for the particular scenario (see Table C.11).

Table C.11. Top 5 Radionuclides in Aquatic Pathway for Scenario (2b) Disruptive Event – Extreme Degradation of Engineered Structures

Radionuclide	Fractions = Concentration / Criterion Ottawa River Surface Water	Cumulative Percentage of Fractions	Radionuclide	Fractions = Concentration / Criterion Riverbed Sediment	Cumulative Percentage of Fractions
Pu-239	4.66E-05	91.98%	**Pu-239**	2.32E+01	80.78%
C-14	3.57E-06	99.04%	**Cl-36**	5.29E+00	99.19%
Cl-36	2.51E-07	99.53%	**C-14**	2.25E-01	99.97%
Ni-59	9.00E-08	99.71%	**Pu-240**	3.01E-03	99.98%
Zr-93	6.58E-08	99.84%	**Th-230**	2.61E-03	99.99%
H-3	3.78E-08	99.91%	Ni-59	5.78E-04	100.00%
U-238	1.69E-08	99.95%	U-238	5.13E-04	100.00%
Th-230	1.01E-08	99.97%	H-3	3.47E-04	100.00%
Pu-240	7.28E-09	99.98%	U-234	2.42E-04	100.00%
U-234	2.87E-09	99.99%	Th-232	6.58E-05	100.00%
Th-232	1.87E-09	99.99%	Tc-99	4.47E-05	100.00%
U-235	1.14E-09	99.99%	Nb-94	4.11E-05	100.00%
Am-241	8.35E-10	100.00%	Np-237	3.70E-05	100.00%
Cs-137	7.01E-10	100.00%	U-235	3.30E-05	100.00%
U-233	6.19E-10	100.00%	Se-79	3.98E-06	100.00%
Pu-238	3.23E-10	100.00%	Cs-135	1.03E-07	100.00%
Nb-94	2.60E-10	100.00%	I-129	1.03E-07	100.00%
Tc-99	1.25E-10	100.00%	Zr-93	5.14E-08	100.00%
Se-79	2.23E-11	100.00%	U-233	8.81E-09	100.00%
Sr-90	1.30E-11	100.00%	Am-241	1.98E-10	100.00%
Np-237	1.10E-11	100.00%	Pu-241	2.24E-11	100.00%
I-129	6.20E-12	100.00%	Ni-63	1.78E-14	100.00%
Ni-63	3.08E-12	100.00%	Sr-90	1.29E-14	100.00%
Cs-135	1.73E-12	100.00%	Pu-238	6.80E-15	100.00%
Co-60	3.40E-15	100.00%	Cs-137	2.94E-15	100.00%
Eu-152	2.81E-15	100.00%	Co-60	1.39E-20	100.00%
Pu-241	6.79E-16	100.00%	Eu-152	3.02E-21	100.00%
Eu-154	1.51E-16	100.00%	Eu-154	1.11E-22	100.00%
Sb-125	3.88E-28	100.00%	Cm-244	2.17E-33	100.00%
Cm-244	5.58E-30	100.00%	Cm-243	4.78E-34	100.00%
Cm-243	1.65E-32	100.00%	Sb-125	3.98E-35	100.00%
Top 5 Radionuclides	**C-14, Cl-36, Ni-59, Pu-239, Pu-240, Th-230, Zr-93**				

Note:

Gray shaded cells are the top 5 radionuclides contributing to the total radiation in each medium.

Table C.12. Sum of Fractions for Scenario (3a) Defence-in-Depth Cases – Role of Waste Form

Radionuclide	Fractions = Concentration/Criterion			
	Spring Water[1]	Ottawa River	Garden	Riverbed
	Groundwater	Surface Water	Soil	Sediment
Am-241	2.73E-08	5.99E-11	1.70E-11	1.59E-12
C-14	1.69E-04	5.84E-07	3.76E-07	5.89E-03
Cl-36	1.43E-06	2.38E-08	4.02E-03	4.91E-01
Cm-243	3.35E-33	1.31E-32	1.53E-34	5.14E-36
Cm-244	1.02E-31	5.59E-30	6.48E-32	2.17E-33
Co-60	5.43E-12	3.40E-15	2.86E-17	1.39E-20
Cs-135	2.32E-10	2.37E-12	1.44E-11	1.42E-07
Cs-137	2.39E-07	7.01E-10	2.67E-11	2.94E-15
Eu-152	5.05E-20	2.81E-15	1.40E-17	3.02E-21
Eu-154	2.48E-21	1.51E-16	2.97E-19	1.11E-22
H-3	1.03E-05	3.78E-08	1.43E-06	3.47E-04
I-129	1.47E-09	1.21E-11	1.45E-14	1.88E-07
Nb-94	4.35E-14	1.47E-16	3.09E-17	4.13E-11
Ni-59	1.91E-06	5.00E-08	1.17E-08	3.14E-04
Ni-63	9.50E-11	3.23E-13	4.34E-14	3.82E-16
Np-237	1.14E-15	5.43E-15	1.02E-15	1.86E-08
Pu-238	4.45E-08	4.75E-11	1.85E-13	1.00E-15
Pu-239	1.79E-06	6.38E-08	2.74E-08	2.88E-02
Pu-240	1.12E-12	5.48E-14	7.77E-16	2.72E-08
Pu-241	3.28E-16	3.48E-19	2.09E-19	9.24E-14
Sb-125	1.22E-28	3.88E-28	6.63E-32	3.98E-35
Se-79	3.36E-08	1.14E-10	1.16E-10	7.04E-06
Sr-90	3.85E-09	1.30E-11	2.15E-14	1.29E-14
Tc-99	6.54E-08	3.74E-10	6.53E-09	1.29E-04
Th-230	5.63E-06	1.93E-08	2.08E-07	5.21E-04
Th-232	1.60E-09	5.38E-12	1.06E-14	4.12E-10
U-233	4.56E-10	1.78E-10	3.48E-11	2.54E-09
U-234	1.71E-10	2.70E-11	3.73E-11	2.24E-06
U-235	7.04E-08	2.69E-10	2.05E-07	1.58E-05
U-238	1.05E-06	3.91E-09	2.82E-06	2.39E-04
Zr-93	1.52E-10	5.95E-13	1.12E-14	1.37E-12
Sum of Fractions[2]	**1.91E-04**	**7.84E-07**	**4.03E-03**	**5.27E-01**
Terrestrial Pathway Sum of Fractions (Spring Water + Garden Soil)				**4.22E-03**
Terrestrial Pathway Sum of Fractions (Ottawa River Water + Garden Soil)				**4.03E-03**
Aquatic Pathway Sum of Fractions (Ottawa River Water + Riverbed Sediment)				**5.27E-01**
Total Sum of Fractions (Spring Water + Ottawa River Water + Garden Soil + Riverbed Sediment)				**5.31E-01**

Notes:

(1) Spring water (i.e., shallow groundwater) concentrations were compared to surface water criteria.

(2) A sum of fractions value of < 1 indicates no significant ecological impact and a value ≥ 1 requires further assessment.

Table C.13. Sum of Fractions for Scenario (3b) Defence-in-Depth Cases – Role of Existing Facility Structure

Radionuclide	Fractions = Concentration/Criterion			
	Spring Water[1] Groundwater	Ottawa River Surface Water	Garden Soil	Riverbed Sediment
Am-241	3.57E-08	8.26E-11	1.78E-11	1.39E-11
C-14	1.94E-04	6.64E-07	5.00E-07	7.19E-03
Cl-36	2.20E-06	1.75E-08	3.70E-03	2.76E-01
Cm-243	3.56E-25	9.27E-26	1.20E-27	4.01E-29
Cm-244	1.77E-23	3.96E-23	5.08E-25	1.70E-26
Co-60	1.25E-10	7.80E-14	6.57E-16	3.20E-19
Cs-135	6.11E-10	2.03E-12	6.10E-12	8.53E-08
Cs-137	2.19E-06	6.49E-09	1.92E-10	2.68E-14
Eu-152	4.05E-18	5.74E-15	2.87E-17	6.17E-21
Eu-154	2.04E-19	1.51E-16	2.97E-19	1.11E-22
H-3	1.38E-05	5.04E-08	1.20E-06	4.71E-04
I-129	7.53E-10	3.77E-12	1.64E-14	3.97E-08
Nb-94	1.83E-11	6.19E-14	1.31E-14	2.65E-10
Ni-59	5.93E-06	2.51E-08	7.06E-09	1.29E-04
Ni-63	1.51E-09	5.05E-12	1.27E-13	2.09E-13
Np-237	1.45E-12	2.29E-14	4.68E-15	6.37E-08
Pu-238	6.98E-07	6.74E-10	2.55E-12	1.39E-14
Pu-239	3.86E-06	1.57E-07	2.73E-08	7.17E-02
Pu-240	3.54E-09	1.17E-11	3.42E-13	1.28E-07
Pu-241	2.96E-14	1.31E-17	2.15E-18	7.18E-14
Sb-125	7.64E-27	4.40E-28	7.53E-32	4.51E-35
Se-79	7.43E-09	2.52E-11	3.03E-11	3.71E-06
Sr-90	8.93E-08	3.01E-10	4.05E-13	1.82E-12
Tc-99	2.21E-08	7.71E-11	3.06E-09	1.56E-05
Th-230	7.35E-06	2.49E-08	1.81E-07	2.61E-04
Th-232	1.18E-08	3.95E-11	7.77E-14	2.13E-09
U-233	9.94E-10	1.84E-10	3.46E-11	2.60E-09
U-234	3.17E-09	1.21E-10	3.57E-10	9.49E-06
U-235	8.18E-08	2.76E-10	1.92E-07	7.37E-06
U-238	1.21E-06	4.10E-09	2.62E-06	1.14E-04
Zr-93	2.09E-07	7.07E-10	8.80E-12	2.67E-12
Sum of Fractions[2]	**2.31E-04**	**9.52E-07**	**3.71E-03**	**3.56E-01**
Terrestrial Pathway Sum of Fractions (Spring Water + Garden Soil)				**3.94E-03**
Terrestrial Pathway Sum of Fractions (Ottawa River Water + Garden Soil)				**3.71E-03**
Aquatic Pathway Sum of Fractions (Ottawa River Water + Riverbed Sediment)				**3.56E-01**
Total Sum of Fractions (Spring Water + Ottawa River Water + Garden Soil + Riverbed Sediment)				**3.60E-01**

Notes:

(1) Spring water (i.e., shallow groundwater) concentrations were compared to surface water criteria.

(2) A sum of fractions value of < 1 indicates no significant ecological impact and a value ≥ 1 requires further assessment.

Table C.14. Sum of Fractions for Scenario (3c) Defence-in-Depth Cases – Role of Grout

Radionuclide	Fractions = Concentration/Criterion			
	Spring Water[1] Groundwater	Ottawa River Surface Water	Garden Soil	Riverbed Sediment
Am-241	2.85E-08	6.43E-11	8.08E-11	5.15E-12
C-14	1.66E-04	5.75E-07	4.26E-06	5.84E-03
Cl-36	9.65E-07	1.77E-08	9.39E-03	3.37E-01
Cm-243	3.85E-31	6.64E-31	7.80E-33	2.62E-34
Cm-244	1.22E-29	2.84E-28	3.30E-30	1.10E-31
Co-60	5.43E-12	3.84E-15	3.57E-17	1.73E-20
Cs-135	2.01E-10	1.53E-12	2.57E-11	9.13E-08
Cs-137	2.44E-07	7.18E-10	4.03E-11	3.04E-15
Eu-152	1.25E-18	2.73E-14	1.36E-16	2.93E-20
Eu-154	1.30E-20	2.71E-16	5.34E-19	2.00E-22
H-3	1.03E-05	3.77E-08	1.48E-06	3.45E-04
I-129	1.31E-09	4.42E-12	5.32E-14	4.46E-08
Nb-94	1.56E-13	5.27E-16	5.83E-16	2.48E-11
Ni-59	2.40E-06	3.12E-08	9.65E-08	1.79E-04
Ni-63	9.54E-11	3.36E-13	1.49E-13	1.36E-15
Np-237	4.38E-15	4.65E-15	1.11E-15	1.59E-08
Pu-238	4.45E-08	4.75E-11	1.90E-13	1.00E-15
Pu-239	1.96E-05	2.81E-07	3.19E-06	1.07E-01
Pu-240	1.05E-12	5.27E-14	1.76E-14	2.60E-08
Pu-241	6.66E-16	6.26E-19	3.21E-18	2.34E-14
Sb-125	3.53E-27	3.83E-27	6.54E-31	3.92E-34
Se-79	4.15E-09	2.36E-11	5.61E-11	3.73E-06
Sr-90	3.86E-09	1.30E-11	6.94E-14	5.18E-14
Tc-99	4.82E-08	1.63E-10	7.44E-09	2.07E-05
Th-230	3.57E-06	1.25E-08	4.90E-07	6.80E-04
Th-232	8.71E-09	2.93E-11	5.77E-14	4.50E-10
U-233	3.41E-09	6.34E-10	1.50E-09	8.98E-09
U-234	1.43E-10	2.90E-11	5.26E-10	2.44E-06
U-235	7.04E-08	2.63E-10	4.39E-07	1.58E-05
U-238	1.05E-06	3.81E-09	6.09E-06	2.33E-04
Zr-93	2.99E-10	1.03E-12	4.22E-13	3.42E-13
Sum of Fractions[2]	**2.05E-04**	**9.60E-07**	**9.40E-03**	**4.52E-01**
Terrestrial Pathway Sum of Fractions (Spring Water + Garden Soil)				**9.61E-03**
Terrestrial Pathway Sum of Fractions (Ottawa River Water + Garden Soil)				**9.40E-03**
Aquatic Pathway Sum of Fractions (Ottawa River Water + Riverbed Sediment)				**4.52E-01**
Total Sum of Fractions (Spring Water + Ottawa River Water + Garden Soil + Riverbed Sediment)				**4.61E-01**

Notes:

(1) Spring water (i.e., shallow groundwater) concentrations were compared to surface water criteria.

(2) A sum of fractions value of < 1 indicates no significant ecological impact and a value ≥ 1 requires further assessment.

Table C.15. Sum of Fractions for Scenario (4a) What-If Cases – Mass Excavation

Radionuclide	Fractions = Concentration/Criterion			
	Spring Water[1]	Ottawa River	Garden	Riverbed
	Groundwater	Surface Water	Soil	Sediment
Am-241	2.73E-08	5.99E-11	1.09E+00	1.59E-12
C-14	1.69E-04	5.84E-07	2.47E+01	5.89E-03
Cl-36	1.02E-31	1.21E-08	2.55E+02	2.49E-01
Cm-243	1.02E-31	1.31E-32	8.99E-06	5.14E-36
Cm-244	1.02E-31	5.58E-30	3.51E-03	2.17E-33
Co-60	5.43E-12	3.40E-15	2.93E-06	1.39E-20
Cs-135	1.28E-10	1.56E-12	8.40E-08	9.33E-08
Cs-137	2.39E-07	7.01E-10	2.65E-03	2.94E-15
Eu-152	5.05E-20	2.81E-15	3.55E-05	3.02E-21
Eu-154	2.48E-21	1.51E-16	2.26E-07	1.11E-22
H-3	1.03E-05	3.78E-08	8.14E-05	3.47E-04
I-129	6.45E-10	3.18E-12	4.63E-10	4.50E-08
Nb-94	4.27E-14	1.44E-16	1.05E-03	1.29E-11
Ni-59	8.84E-07	2.84E-08	2.31E-04	1.78E-04
Ni-63	9.50E-11	3.23E-13	2.16E-02	3.82E-16
Np-237	4.99E-16	2.62E-15	4.66E-07	8.96E-09
Pu-238	4.45E-08	4.75E-11	7.03E-03	1.00E-15
Pu-239	1.79E-06	6.37E-08	1.28E-01	2.88E-02
Pu-240	2.13E-13	2.79E-14	1.42E-03	1.39E-08
Pu-241	7.38E-17	3.48E-19	2.31E-06	1.89E-14
Sb-125	1.22E-28	3.88E-28	1.98E-14	3.98E-35
Se-79	3.46E-09	2.31E-11	2.68E-07	4.05E-06
Sr-90	3.85E-09	1.30E-11	6.69E-05	1.29E-14
Tc-99	4.07E-08	1.37E-10	9.74E-05	1.95E-05
Th-230	5.63E-06	1.93E-08	5.05E-05	5.20E-04
Th-232	1.60E-09	5.37E-12	2.85E-05	4.00E-10
U-233	4.56E-10	1.77E-10	6.13E-06	2.54E-09
U-234	1.71E-10	1.81E-11	2.67E-04	1.48E-06
U-235	7.04E-08	2.68E-10	8.34E-05	1.58E-05
U-238	1.05E-06	3.91E-09	1.28E-03	2.38E-04
Zr-93	1.73E-11	6.90E-14	9.18E-03	1.75E-13
Sum of Fractions[2]	**1.89E-04**	**7.50E-07**	**2.81E+02**	**2.85E-01**
Terrestrial Pathway Sum of Fractions (Spring Water + Garden Soil)				**2.81E+02**
Terrestrial Pathway Sum of Fractions (Ottawa River Water + Garden Soil)				**2.81E+02**
Aquatic Pathway Sum of Fractions (Ottawa River Water + Riverbed Sediment)				**2.85E-01**
Total Sum of Fractions (Spring Water + Ottawa River Water + Garden Soil + Riverbed Sediment)				**2.81E+02**

Notes:

(1) Spring water (i.e., shallow groundwater) concentrations were compared to surface water criteria.

(2) A sum of fractions value of < 1 indicates no significant ecological impact and a value ≥ 1 requires further assessment (shaded in yellow). When the unity rule was exceeded, the data were reviewed to identify the top five (5) radionuclides contributing the majority of the radiation dose (cumulative contribution of >97%) to aquatic and terrestrial pathways to ensure that these radionuclides were included in the assessment of ecological risks for the particular scenario (see Table C.16).

Table C.16. Top 5 Radionuclides in Terrestrial Pathway for Scenario (4a) What-If Cases – Mass Excavation

Radionuclide	Fractions = Concentration/ Criterion Spring Water Groundwater	Cumulative Percentage of Fractions	Radionuclide	Fractions = Concentration/ Criterion Ottawa River Surface Water	Cumulative Percentage of Fractions	Radionuclide	Fractions = Concentration/ Criterion Graden Soil	Cumulative Percentage of Fractions
C-14	1.69E-04	89.08%	**C-14**	5.84E-07	77.79%	**Cl-36**	2.55E+02	90.75%
H-3	1.03E-05	94.55%	**Pu-239**	6.37E-08	86.28%	**C-14**	2.47E+01	99.55%
Th-230	5.63E-06	97.52%	**H-3**	3.78E-08	91.31%	**Am-241**	1.09E+00	99.94%
Pu-239	1.79E-06	98.47%	**Ni-59**	2.84E-08	95.09%	**Pu-239**	1.28E-01	99.98%
U-238	1.05E-06	99.03%	**Th-230**	1.93E-08	97.67%	**Ni-63**	2.16E-02	99.99%
Ni-59	8.84E-07	99.49%	Cl-36	1.21E-08	99.29%	Zr-93	9.18E-03	99.99%
Cl-36	5.27E-07	99.77%	U-238	3.91E-09	99.81%	Pu-238	7.03E-03	100.00%
Cs-137	2.39E-07	99.90%	Cs-137	7.01E-10	99.90%	Cm-244	3.51E-03	100.00%
U-235	7.04E-08	99.94%	U-235	2.68E-10	99.94%	Cs-137	2.65E-03	100.00%
Pu-238	4.45E-08	99.96%	U-233	1.77E-10	99.96%	Pu-240	1.42E-03	100.00%
Tc-99	4.07E-08	99.98%	Tc-99	1.37E-10	99.98%	U-238	1.28E-03	100.00%
Am-241	2.73E-08	99.99%	Am-241	5.99E-11	99.99%	Nb-94	1.05E-03	100.00%
Sr-90	3.85E-09	100.00%	Pu-238	4.75E-11	99.99%	U-234	2.67E-04	100.00%
Se-79	3.46E-09	100.00%	Se-79	2.31E-11	99.99%	Ni-59	2.31E-04	100.00%
Th-232	1.60E-09	100.00%	U-234	1.81E-11	100.00%	Tc-99	9.74E-05	100.00%
I-129	6.45E-10	100.00%	Sr-90	1.30E-11	100.00%	U-235	8.34E-05	100.00%
U-233	4.56E-10	100.00%	Th-232	5.37E-12	100.00%	H-3	8.14E-05	100.00%
U-234	1.71E-10	100.00%	I-129	3.18E-12	100.00%	Sr-90	6.69E-05	100.00%
Cs-135	1.28E-10	100.00%	Cs-135	1.56E-12	100.00%	Th-230	5.05E-05	100.00%
Ni-63	9.50E-11	100.00%	Ni-63	3.23E-13	100.00%	Eu-152	3.55E-05	100.00%
Zr-93	1.73E-11	100.00%	Zr-93	6.90E-14	100.00%	Th-232	2.85E-05	100.00%
Co-60	5.43E-12	100.00%	Pu-240	2.79E-14	100.00%	Cm-243	8.99E-06	100.00%
Pu-240	2.13E-13	100.00%	Co-60	3.40E-15	100.00%	U-233	6.13E-06	100.00%
Nb-94	4.27E-14	100.00%	Eu-152	2.81E-15	100.00%	Co-60	2.93E-06	100.00%
Np-237	4.99E-16	100.00%	Np-237	2.62E-15	100.00%	Pu-241	2.31E-06	100.00%
Pu-241	7.38E-17	100.00%	Eu-154	1.51E-16	100.00%	Np-237	4.66E-07	100.00%
Eu-152	5.05E-20	100.00%	Nb-94	1.44E-16	100.00%	Se-79	2.68E-07	100.00%
Eu-154	2.48E-21	100.00%	Pu-241	3.48E-19	100.00%	Eu-154	2.26E-07	100.00%

Appendix C – Sum of Fractions Analysis for the Postclosure Phase

Radionuclide	Fractions = Concentration/ Criterion	Cumulative Percentage of Fractions	Radionuclide	Fractions = Concentration/ Criterion	Cumulative Percentage of Fractions	Radionuclide	Fractions = Concentration/ Criterion	Cumulative Percentage of Fractions
	Spring Water			Ottawa River			Graden	
	Groundwater			Surface Water			Soil	
Sb-125	1.22E-28	100.00%	Sb-125	3.88E-28	100.00%	Cs-135	8.40E-08	100.00%
Cm-244	1.02E-31	100.00%	Cm-244	5.58E-30	100.00%	I-129	4.63E-10	100.00%
Cm-243	3.31E-33	100.00%	Cm-243	1.31E-32	100.00%	Sb-125	1.98E-14	100.00%
Top 5 Radionuclides	**Am-241, C-14, Cs-135, Cl-36, H-3, Ni-59, Ni-63, Pu-239, Tc-99, Th-230, U-238**							

Note:

Gray shaded cells are the top 5 radionuclides contributing to the total radiation in each medium.

Table C.17. Sum of Fractions for Scenario (4b) What-If Cases – River Level Fall

Radionuclide	Fractions = Concentration/Criterion			
	Spring Water[1]	Ottawa River	Garden	Rivershore
	Groundwater	Surface Water	Soil	Sediment
Am-241	2.73E-08	5.99E-11	1.70E-11	1.73E-07
C-14	1.69E-04	5.84E-07	3.76E-07	2.70E-04
Cl-36	5.27E-07	1.21E-08	4.02E-03	9.75E-04
Cm-243	3.31E-33	1.31E-32	1.53E-34	7.70E-28
Cm-244	1.02E-31	5.58E-30	6.47E-32	3.31E-25
Co-60	5.43E-12	3.40E-15	2.86E-17	5.68E-12
Cs-135	1.28E-10	1.56E-12	1.55E-11	3.49E-10
Cs-137	2.39E-07	7.02E-10	2.67E-11	2.01E-07
Eu-152	5.05E-20	2.81E-15	1.40E-17	1.19E-12
Eu-154	2.48E-21	1.51E-16	2.97E-19	6.39E-14
H-3	1.03E-05	3.78E-08	1.43E-06	1.47E-05
I-129	6.45E-10	4.21E-12	5.81E-15	2.65E-10
Nb-94	4.27E-14	1.44E-16	3.03E-17	4.59E-12
Ni-59	8.84E-07	2.84E-08	5.68E-09	7.02E-07
Ni-63	9.50E-11	3.23E-13	4.34E-14	3.75E-11
Np-237	4.99E-16	2.62E-15	4.95E-16	3.35E-11
Pu-238	4.45E-08	4.76E-11	1.85E-13	8.86E-08
Pu-239	1.79E-06	1.11E-07	2.78E-08	2.08E-04
Pu-240	2.13E-13	4.03E-14	4.68E-16	7.50E-11
Pu-241	7.38E-17	3.48E-19	4.38E-20	6.53E-16
Sb-125	1.22E-28	3.88E-28	6.64E-32	2.75E-26
Se-79	3.46E-09	2.31E-11	1.21E-11	1.57E-08
Sr-90	3.85E-09	1.30E-11	2.15E-14	1.19E-09
Tc-99	4.07E-08	1.37E-10	6.49E-09	2.11E-07
Th-230	5.63E-06	1.94E-08	2.08E-07	1.01E-04
Th-232	1.60E-09	5.37E-12	1.06E-14	2.82E-08
U-233	4.56E-10	1.77E-10	3.48E-11	9.56E-12
U-234	1.71E-10	1.81E-11	3.50E-11	5.71E-09
U-235	7.04E-08	2.68E-10	2.05E-07	8.38E-08
U-238	1.05E-06	3.91E-09	2.82E-06	1.23E-06
Zr-93	1.73E-11	6.90E-14	1.26E-15	4.26E-15
Sum of Fractions[2]	**1.89E-04**	**7.98E-07**	**4.03E-03**	**1.57E-03**
Terrestrial Pathway Sum of Fractions (Spring Water + Garden Soil)				**4.22E-03**
Terrestrial Pathway Sum of Fractions (Ottawa River Water + Garden Soil)				**4.03E-03**
Aquatic Pathway Sum of Fractions (Ottawa River Water + Rivershore Sediment)				**1.57E-03**
Total Sum of Fractions (Spring Water + Ottawa River Water + Garden Soil + Rivershore Sediment)				**5.79E-03**

Notes:

(1) Spring water (i.e., shallow groundwater) concentrations were compared to surface water criteria.

(2) A sum of fractions value of < 1 indicates no significant ecological impact and a value ≥ 1 requires further assessment.

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