No-Effect Concentrations For Screening Assessment of Radiological Impacts on Non-Human Biota

NWMO TR-2008-02

April 2008

Nava C. Garisto

Farrah Cooper

Stacey L. Fernandes

SENES Consultants Limited

NUCLEAR WASTE MANAGEMENT ORGANIZATION
SOCIÉTÉ DE GESTION DES DÉCHETS NUCLÉAIRES

Nuclear Waste Management Organization
22 St. Clair Avenue East, 6th Floor
Toronto, Ontario
M4T 2S3
Canada

Tel: 416-934-9814
Web: www.nwmo.ca

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ABSTRACT

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Report No.: **NWMO TR-2008-02**
Author(s): Nava C. Garisto
Farrah Cooper
Stacey L. Fernandes
Company: SENES Consultants Limited
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Abstract

This study presents and implements a screening methodology for assessing the potential post-closure radiological impact of a deep geological repository for used nuclear fuel on non-human biota. This screening methodology is designed for hypothetical sites representative of selected Canadian conditions under both present and potential future climate conditions. The screening is carried out by comparing estimated radionuclide concentrations to derived "No Effect Concentrations" (NECs). The NECs are screening or threshold criteria; the conservative nature of the assumptions used to derive the NECs ensures that as long as the NECs are not exceeded, there is confidence that, despite uncertainty in modelled environmental concentrations, there will be no significant ecological effect on non-human biota. In the event NECs are exceeded in screening calculations, a site-specific Ecological Risk Assessment (ERA) would be required to determine whether this is due to conservatism in the assumptions, lack of sufficient data or potential real impact.

NECs are derived in this study for groundwater, soil, surface water and sediment in three ecosystems that represent a range of Canadian conditions: southern Canadian deciduous forest, boreal Canadian Shield forest, and tundra (a potential far-future climate condition during glaciation).

Several indicator species are evaluated for each ecosystem, representing a range of different trophic levels within the ecosystem. The NEC corresponding to the most limiting biota for each radionuclide in a particular environmental medium is used as a concentration screening level. A sum-of-fractions rule has to be used to ensure that the total dose over radionuclides and media does not exceed the estimated no-effect dose-rate values (i.e., radioecological dose benchmarks for population-level effects on biota; these values are compiled from literature).

These NECs were compared to post-closure environmental concentrations estimated in major Canadian post-closure assessments of the geological disposal of used fuel, including the Third Case Study, the Second Case Study and the Environmental Impact Statement study. The results indicate that there would be no significant radioecological impact on non-human biota for these case studies.

ABBREVIATIONS

BF	Boreal Forest Ecosystem
CCME	Canadian Council of Ministers of the Environment
CSA	Canadian Standards Association
CSM	Conceptual Site Model
DC	Dose Coefficient. These are also referred to as Dose Conversion Coefficients (DCCs) in IAEA (2008)
DW	Dry Weight
ENEV	Estimated No Effect Value
ERA	Ecological Risk Assessment
FI	Food Ingestion
FW	Fresh Weight
GM	Geometric Mean
GSD	Geometric Standard Deviation
IR	Inhalation Rate
IT	Inland Tundra Ecosystem
NEC	No Effect Concentration
NOEC	No Observed Effect Concentration
NWMO	Nuclear Waste Management Organization
RBE	Relative Biological Effectiveness
SD	Southern Canadian Deciduous Forest Ecosystem
TF	Transfer Factor. Transfer factors that are concentration ratios are referred to as Concentration Ratios in IAEA (2008).
WC	Water Content (WC_s-sediment; WC_{aqp}-aquatic plant; WC_{bi}-benthos; WC_e-earthworm; WC_f-fish; WC_{fr}-frog)
WI	Water Intake
Wt	Weight
WW	Wet Weight

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Note: An Addendum to this report contains the detailed calculations of doses and no-effect concentrations. It is available as a separate document.

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1. INTRODUCTION

The objective of the present study is to develop a screening methodology for assessing the potential post-closure radiological impact of a deep geological repository for used fuel on non-human biota. Chemical toxicity impacts are not addressed in this study. The screening methodology is designed for hypothetical sites representative of selected Canadian conditions under both present and potential future climate conditions.

The "core" of the methodology involves the estimation of reference "No Effect Concentrations", or NECs for radionuclides in environmental media to which non-human biota are exposed (Garisto *et al*. 2005). The screening would be carried out by comparing estimated radionuclide concentrations to these NECs. The NECs are screening or threshold criteria; the conservative nature of the assumptions used to derive the NECs ensures that as long as the NECs are not exceeded, there is confidence that, despite uncertainty in modelled environmental concentrations, there will be no significant ecological effect on non-human biota. In the event NECs are exceeded, a site-specific Ecological Risk Assessment (ERA) would be required to determine whether this is due to conservatism in the assumptions, lack of sufficient data or potential real impact.

NECs for radionuclides are derived in this study for groundwater, soil, surface water and sediment, in a set of ecosystems of interest in the Nuclear Waste Management Organization (NWMO) program. The NEC corresponding to the most limiting biota for each radionuclide in a particular environmental medium is used as a concentration screening level for a particular ecosystem. A sum-of-fractions rule has to be used to ensure that total dose over radionuclides and/or over pathways in a given ecosystem does not exceed the estimated no-effect dose-rate values (i.e., radioecological dose benchmarks for population-level effects on biota; these values are compiled from literature).

NECs are developed in this study for three ecosystems, southern Canadian deciduous forest, boreal (Canadian Shield) forest, and inland tundra. Several indicator species are evaluated for each ecosystem, representing a range of different trophic levels within the ecosystem. For example:

> Southern Canadian deciduous forest – Representative specific indicator species such as benthic lake fish (e.g. white sucker), pelagic lake fish (e.g. round whitefish), muskrat, deer and wild turkey.
>
> Boreal (Canadian Shield) forest – Representative specific indicator species such as beaver, ruffed grouse, moose, wolf and common loon [Sheppard 2002].
>
> Inland tundra – Representative specific indicator species such as lichen, arctic char, caribou, arctic hare, arctic fox and willow ptarmigan.

The selection of radionuclides for this study was based primarily on the results of previous conceptual case studies: the Third Case Study – Defective Container Scenario and the Horizontal Borehole – Defective Container Scenario (Garisto *et al.* 2004 and Garisto *et al.* 2005, respectively). These scenarios assume that some containers are emplaced in the repository with small undetected defects. This allows groundwater to enter the container and contact the fuel, thereby providing a pathway for release of radionuclides into the groundwater surrounding the repository. The safety assessment of this scenario indicates that even though defective containers are presumed to release radionuclides shortly after repository closure, most radionuclides decay within the repository and adjacent geosphere and only a few radionuclides reach the surface.

NECs were developed for a set of 12 reference radionuclides: C-14, Cl-36, Zr-93, Nb-94, Tc-99, I-129, Cs-135, Ra-226, Np-237, U-238, Pb-210 and Po-210.

This list of radionuclides includes the main contributors to human dose from the Third Case Study and its extension to a Horizontal Borehole Emplacement concept. In addition, representative activation radionuclides are included. This list of radionuclides is also similar to that identified in other assessments, such as Nagra (2002), ANDRA (2005) and SKB (1999, 2006). An additional radionuclide, Se-79, was also identified as a lesser contributor in these studies. An assessment of Se-79 is beyond the scope of this study.

The report is structured as follows:

Section 2 provides general details on the overall methodology for deriving NECs

Section 3 describes the conceptual models representing the three ecosystems. This includes:

- Definition of indicator species for the three ecosystems
- Definition of ecological profiles
- Definition of environmental pathways and food webs

Section 4 presents the parameter values for the models.

Section 5 summarizes dose calculations for unit concentrations of each radionuclide.

Section 6 summarizes the derivation of the NEC values.

Section 7 provides an example application of the derived NEC values for a screening assessment of the post-closure radiological impact of a deep geological repository for used nuclear fuel.

Section 8 provides a discussion.

Detailed ecological profiles, dose calculations, etc. are provided in Appendices.

2. METHODOLOGY

The overall approach taken for calculating NEC values for each radionuclide in a given environmental medium in each ecosystem is described below and shown in Figure 1. The following steps are involved:

- *Select the ecological receptor categories and individual indicator species to be included in the derivation of NECs (see Section 3)*.
- *Define the ecological profile for each indicator species*. The profile includes the amount of water, food and soil/sediment consumed, as well as a determination of the food types that comprise the diet (see Section 3 and Appendix A).
- *Collect information needed to model environmental behaviour and transfer for each radionuclide*. NECs are calculated for water, sediment, soil and groundwater concentrations. To determine the concentration in different biota (e.g. fish, terrestrial plants), it is necessary to be able to estimate the concentration in all environmental media through the use of transfer factors. Transfer factors estimate radionuclide concentrations in the whole body of the specified biota with uniform distribution. For more complex biota, radionuclide concentrations in the body were calculated via multiple intake pathways. Transfer factors were, in general, selected from readily available information (see Section 4 and Appendix B).
- *Compile Dose Coefficients (DCs) for each radionuclide for both internal and external exposure, from readily-available information/compilations* (see Section 4 and Appendix C).
- *Select appropriate dose rate criteria (ENEVs) for the various indicator species, from readily-available information/compilations* (see Section 4)*.*
- *Calculate the dose for unit concentrations of radionuclides in water.* For each radionuclide, calculate the dose that biota would receive from a concentration of 1 Bq/L in water, assuming sediment, soil and groundwater concentrations are zero. This procedure is carried out for each radionuclide for each biota that is exposed to water. This unit dose calculation step is then repeated for all other media: soil (i.e., by setting concentrations of each radionuclide in soil equal to one and all other concentrations equal to zero), sediment and groundwater (see Sections 5).
- *For each of the radionuclides in each of the base environmental media (i.e. water, sediment, soil, groundwater),back-calculate the concentration of radionuclide that corresponds to the selected ENEV.* For example, calculate the concentration of C-14 in water that would generate a dose to common loon of 1 mGy/day (the selected ENEV for loon). Repeat for each medium and each relevant biota.
- *Group the biota by ecosystem: Southern Canadian Deciduous Forest, Boreal Forest or Inland Tundra* (see Section 6).
- *Select the lowest back-calculated concentration value for each radionuclide.* These concentrations, termed No Effect Concentrations (NECs), are generic and can be applied at a variety of sites within each ecosystem (see Section 6).

The overall approach for application of NECs is described below and shown in Figure 2.

In the application of the NECs, concentration data for each of the selected radionuclides are compared to the corresponding NEC for each appropriate medium. The sum of the ratios is then compared to a sum of one.

For example, for soil:

Comparison of individual soil radionuclide concentrations to soil NECs:

$\frac{L_1}{NEC_1} < 1; \quad \frac{L_2}{NEC_2} < 1 \ldots \frac{L_n}{NEC_n} < 1$; and

Sum of ratios for soil:

$$\sum^{n} soil = \frac{L_1}{NEC_1} + \frac{L_2}{NEC_2} + \frac{L_3}{NEC_3} + \ldots \frac{L_n}{NEC_n} < 1$$

where:

n	Represents the radionuclide number (e.g. 1, 2, 3…n)
$L_{1,2,3,..n}$	Measured level of radionuclide 1, 2, 3…n in soil (Bq/kg);
$NEC_{1,2,3,..n}$	Estimated No-Effect Concentration (NEC) for radionuclide 1, 2, 3…n in soil (Bq/kg).

In the application of the NECs, the sum of ratios over all media is calculated (i.e. water, sediment, soil and groundwater). This is done under the conservative assumption that all biota are exposed to all media. This can be shown as follows:

$$\sum overall = \sum^{n} water + \sum^{n} soil + \sum^{n} sed\,iment + \sum^{n} groundwater < 1$$

These NECs are used for screening purposes. The use of conservative assumptions in the derivation of the values ensures that if the sum of ratios is less than one, environmental harm is not likely. However, if the sum of ratios is estimated to be greater than one, follow-up work (such as an Ecological Risk Assessment) is required. The sum of ratios approach can be used to focus the assessment on the media needing consideration.

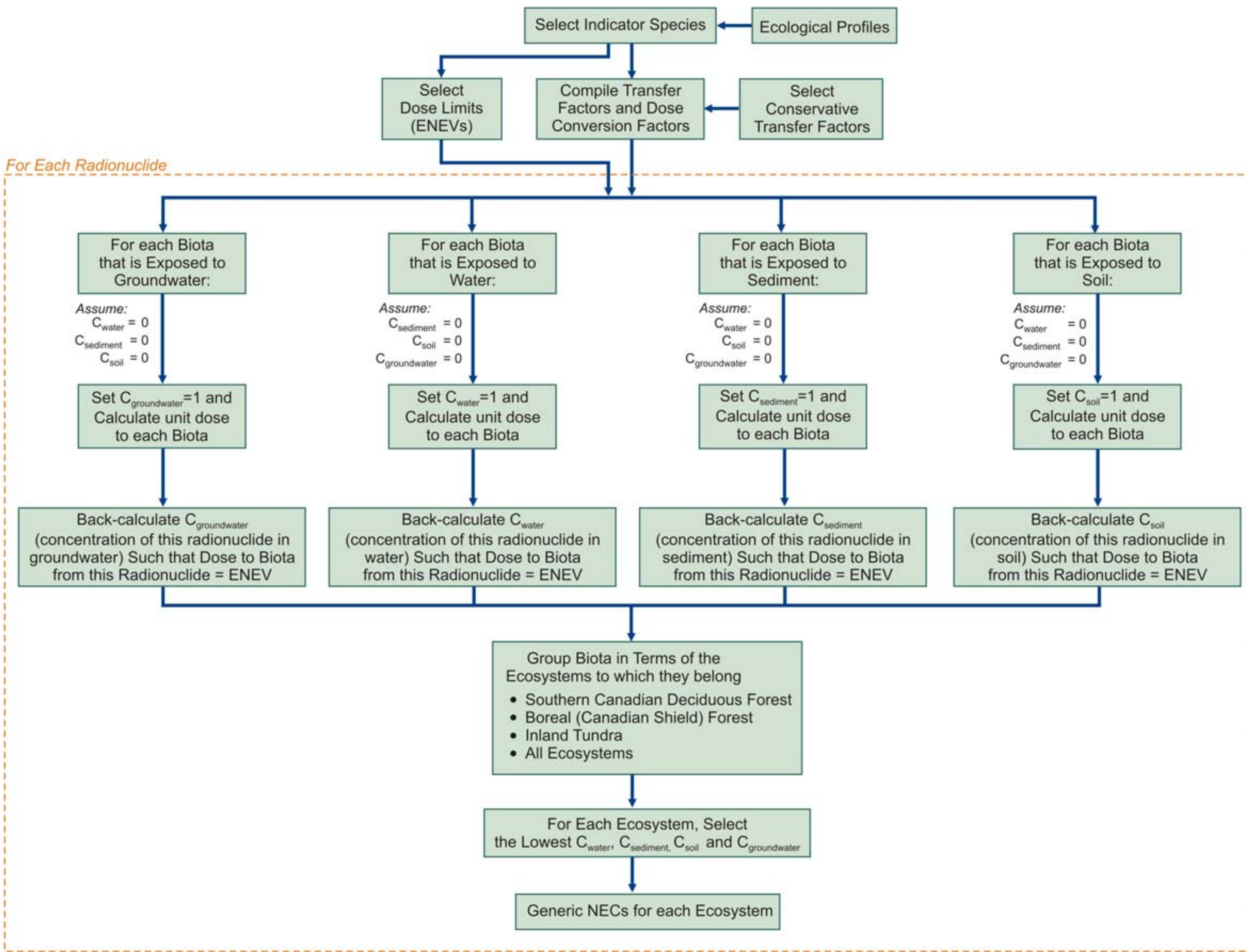


Figure 1: Schematic Flow Chart of the NEC Derivation Process

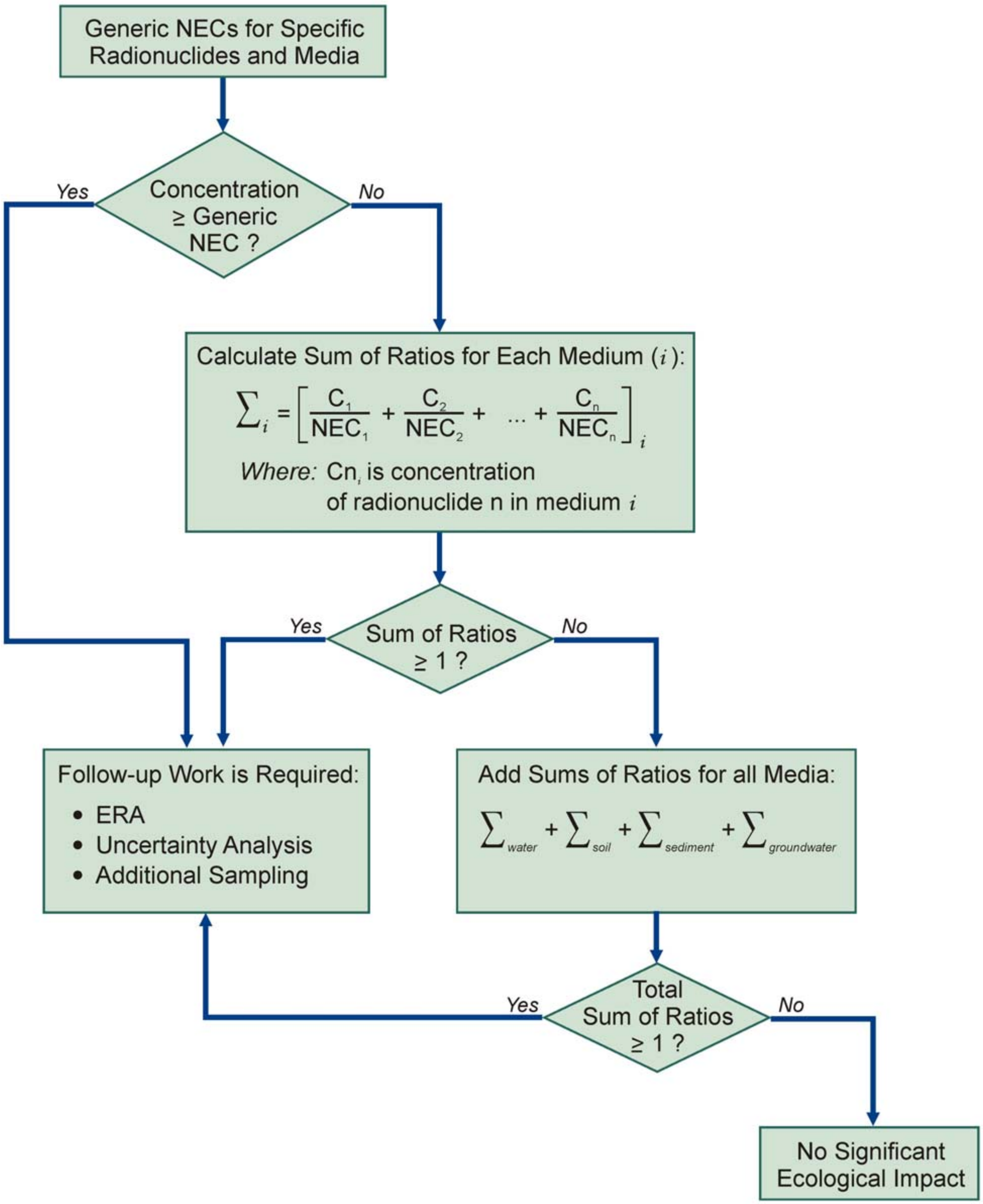


Figure 2: Schematic Flowchart of NEC Application

3. ECOLOGICAL PROFILES AND CONCEPTUAL MODELS

This section describes the ecosystems considered (Southern Canadian Deciduous Forest, Boreal Forest and Inland Tundra) and lists the indicator species selected within each ecosystem. Ecological profiles describing the diet and behaviour of the selected indicator species are summarized. A conceptual site model showing the potential interactions between the indicator species is presented.

3.1 Ecosystems

An ecosystem is a natural unit consisting of biota communities and their non-living (abiotic) environment, interacting as a functional unit. The following is a description of the three selected ecosystems as defined by the National Ecological Framework for Canada, Terrestrial Ecozones and Ecoregions (Environment Canada 2005, www.ec.gc.ca/soer-ree/English/Framework/NarDesc/canada_e.cfm).

(i) Southern Canadian Deciduous Forest

This ecosystem covers the lower Great Lakes-St. Lawrence River region. Its geography, waterways and combination of gentle topography, fertile soils and warm seasons have made the region the most populated in Canada. The climate is marked by warm summers and cool winters. The mean summer temperature ranges from 16°C to 18°C. The mean winter temperature ranges from -2.5°C to -7°C.

Today, the forest covers less than 10% of this area. It varies from the mixed coniferous-deciduous stands of White, Red and **Jack Pines**, Eastern Hemlock, Oaks, Maples, and Birches in the northern portions to the rich diversity of the deciduous Carolinian forest in the south. The rarest trees in Canada, such as Sassafras, Tulip Tree, Sycamore, and Cucumber-tree, are encountered in the south area. Shrubs carrying berries can also be found in this ecozone. This ecozone is underlain by carbonate-rich Palaeozoic bedrock. The topography ranges from plains and hills consisting of moraine deposits. The typical mammal is the **White-tailed Deer**, whose populations have increased in recent decades. Smaller mammals such as Raccoon, Voles, Black (Grey) Squirrel, Eastern Cottontail, **Groundhog** and **Muskrat** are common. Rare bird species such as the Carolina Wren, Bobwhite, and Green Heron are unique to the area. Other representative birds include **American Crow**, Canada Goose, Ruffed Grouse, **Wild Turkey**, Great Blue Heron, Red-shouldered Hawk, Whip-poor-will, Northern Cardinal, Blue Jay, Red-headed Woodpecker and Baltimore Oriole.

In the aquatic environment, there are numerous aquatic plants, including **Cattails** and **Pondweeds.** Amphibians include **Northern Leopard Frog**. Important fish species include **Brook Trout, Brown Trout, Rainbow Trout, Round Whitefish, Chinook Salmon,** Smallmouth bass and **Largemouth Bass,** as well as **White Sucker**.

The species shown in bold above, as well as **Benthic Invertebrates** and **Earthworms**, were selected as indicator species for this study.

(ii) Boreal (Canadian Shield) Forest

Canada's largest ecozone is the Boreal (Canadian Shield) Forest, also referred to as Boreal Shield. This ecosystem extends from Saskatchewan to Newfoundland, passing over Lake Winnipeg, the Great Lakes, and the St. Lawrence River. The Boreal Forest is a vast stretch of trees, waterbodies, and bedrock. This ecozone has a strong continental climate with long cold winters and short warm summers, modified by maritime conditions in Atlantic Canada. Mean summer temperatures range between 11°C and 15°C. Mean winter temperatures range between -20.5°C in the west and -1°C in the east. The Great Lakes have a moderating effect on the climate of the Boreal Forest of Ontario, warming in the winter and cooling in the summer.

This ecozone is represented by closed stands of conifers, largely white and black spruce, balsam fir, and tamarack. In the south, there are broadleaf trees, such as white birch, trembling aspen, and balsam poplar, and needle-leaf trees, such as white, red, and jack pine. In the contrasting areas of exposed bedrock, the mosaic of soils and rock is often covered with communities of shrubs. The ecozone has broadly rolling mosaic of uplands and associated wetlands, and Precambrian granitic bedrock outcrops. The landscape is dotted with numerous small to medium-sized lakes. Peatlands with organic soils are common in wetland areas. Characteristic wildlife includes White-tailed Deer, **Moose**, **Beaver**, **Muskrat**, Black Bear, **Gray Wolf**, Red Fox, Raccoon, Marten, Groundhog and Eastern Chipmunk. Representative birds include American Crow, Boreal and Great Horned Owls, Canada Goose, **Common Loon**, **Ruffed Grouse**, Wild Turkey, Yellow Rumped Warbler, Blue Jay and Evening Grosbeak.

Representative specific indicator species of vegetation include lichens (numerous taxa), shrubs carrying berries and **Black Spruce**. In the aquatic environment, aquatic plants are numerous, including **Pondweeds** and **Cattails**, and amphibians include **Northern Leopard Frog**. Inhabiting the sediment are **Benthic Invertebrates**. In lakes, important fish are Brook Trout, Rainbow Trout and **Smallmouth Bass** and various pelagic fish.

The species shown in bold above, as well as **Earthworms**, were selected as indicator species for this study.

(iii) Inland Tundra

The Inland Tundra ecosystem is also referred to as Northern Lowlands. Canada's Inland Tundra ecozone includes the Southern Arctic Region (Northern parts of Northwest Territories, Nunavut and Quebec) and the Hudson Plains Region (North of Central Ontario). The area is the largest extensive area of wetlands in the world. The Inland Tundra is strongly influenced by the cold and moisture of the Hudson Bay-low and Polar-high air masses. The summers are short and cool, and the winters are very cold and reflect a cold continental climate. Mean summer temperatures range from 10.5°C to 11.5°C. Mean winter temperatures range between -19°C and -16°C in the Hudson Plains Region and -28°C and -17.5°C in the Southern Arctic Region.

The poorly-drained areas of the Hudson Plains Region support dense sedge-moss-lichen covers, and dwarfed shrubs. The better-drained areas are sites of open scattered woodlands of black spruce and tamarack. Tree growth is hindered by low temperatures and short growing seasons. The Inland Tundra contains plains that are underlain by flat Palaeozoic and Proterozoic sedimentary rocks that slope gently towards the Arctic Ocean, Hudson Bay and James Bay. The wetlands include extensive peatlands (largely bogs and fens), and shallow open waters less than 2 m deep. Permafrost ranges from isolated patches in the south to continuous in the north.

The Southern Arctic Region represents a major area of vegetative transition between the taiga forest to the south and the treeless arctic tundra to the north. It is characterized by dwarf shrubs that decrease in size to the north. The terrain consists largely of broadly rolling uplands and lowlands. Throughout the region, there are exposures of bedrock. The landscape is studded with lakes, ponds and wetlands. Cryosols are the dominant soils, and are underlain by continuous permafrost with active (thaw) layers that are usually moist or wet throughout the summer.

Characteristic wildlife for the Inland Tundra includes **Barren-Ground Caribou**, Polar Bears, **Arctic Fox**, **Arctic Hare** and **Willow Ptarmigan**. The Inland Tundra is an important habitat for breeding waterfowl, particularly **Canada Goose**.

Representative specific indicator species of vegetation include **Dwarf (Arctic) Willow**, **Lichens** and shrubs carrying **Berries**. In the aquatic environment and inhabiting the sediment are **Benthic Invertebrates**. In shallow lakes, a most important fish is the **Arctic Char**.

This is a hypothetical location in the context of the present study, and is designed to represent periglacial climate conditions in the very distant future.

3.2 Indicator Species and Ecological Profiles

Ecological receptors were identified for the three ecosystems considered, as follows:

- Southern Canadian Deciduous Forest: based on previous Environmental Assessments such as for the Western Waste Management Facility, supplemented by Environment Canada (2005);
- Boreal Forest: based on Sheppard (2002); and
- Inland Tundra: based on relevant experience, supplemented by Environment Canada (2005).

Specific indicator species were then selected to represent the biota in each category of ecological receptor; these are presented in Table 1. Ecological profiles were prepared for each of the identified indicator species and these detailed profiles have been included in Appendix A. The profiles outline the general habitat requirements of the indicator species as well as their diet and other exposure parameters.

For a number of receptor types, the internal concentration of radionuclides is estimated through the use of a transfer factor. For example, the concentration in aquatic plants is estimated using the environmental water concentration and a water-to-plant transfer factor. The receptor types included in this approach include plants, fish, amphibians and invertebrates. This approach is discussed in more detail in Section 4. For other receptor types (birds and mammals), an estimate of the intake is required to determine the internal concentration. A summary of the ecological profiles for the indicator species for these receptor types has been included in Table 2.

In this report, two types of earthworms are defined: those exposed to soil and those exposed to groundwater. There are indicator species other than earthworms that are exposed to more than one medium; however for these biota it is not considered necessary to create separate indicator species (such as Wolf-Soil and Wolf-Water). Biota exposures to various media are represented adequately within the model, using various exposure pathways (e.g., drinking water, eating soil, etc.). Biota that consume earthworms will likely ingest them from the soil (e.g., surface) layer, not from groundwater. Biota other than earthworms are not expected to have exposure to groundwater, as it is typically too far below the surface.

For fish, the external exposure is dependent on the environment in which they reside. The environment that each type of fish prefers is included in the ecological profiles (Appendix A). Fish in the demersal environment live at or near the bottom of a water body and are treated as benthic fish. Fish in the pelagic environment live within the water column and do not have significant exposure to sediments. Benthopelagic fish live in both bottom and middle of the water column. As a cautious approach, these fish are treated as benthic and receive external radiation from sediment and water.

Table 1: Summary of Selected Indicator Species

Species	Habitat	Receptor	Southern Cdn Deciduous Forest	Boreal (Cdn Shield) Forest	Inland Tundra
American Crow	Terrestrial	Bird	✓		
Arctic Char	Aquatic	Fish- benthic			✓
Arctic Fox	Terrestrial	Mammal			✓
Arctic Hare	Terrestrial	Mammal			✓
Barren-Ground Caribou	Terrestrial	Mammal			✓
Beaver	Aquatic / Terrestrial	Mammal		✓	
Benthic Invertebrates	Aquatic	Invertebrate	✓	✓	✓
Berries	Terrestrial	Plant			✓
Black Spruce	Terrestrial	Plant		✓	
Brook Trout	Aquatic	Fish- benthic	✓		
Brown Trout	Aquatic	Fish- pelagic	✓		
Canada Goose	Aquatic / Terrestrial	Bird			✓
Cattails	Aquatic	Plant	✓	✓	
Chinook Salmon	Aquatic	Fish- benthic	✓		
Common Loon	Aquatic	Bird		✓	
Dwarf (Arctic) Willow	Terrestrial	Plant			✓
Earthworms	Terrestrial	Invertebrate	✓	✓	
Gray Wolf	Terrestrial	Mammal		✓	
Groundhog	Terrestrial	Mammal	✓		
Jack Pine*	Terrestrial	Plant	✓		
Largemouth Bass	Aquatic	Fish- benthic	✓		
Lichens	Terrestrial	Plant			✓
Moose	Aquatic / Terrestrial	Mammal		✓	
Muskrat	Aquatic	Mammal	✓	✓	
Northern Leopard Frog	Aquatic	Amphibian	✓	✓	
Pondweeds	Aquatic	Plant	✓	✓	
Rainbow Trout	Aquatic	Fish- benthic	✓		
Round Whitefish	Aquatic	Fish- benthic	✓		
Ruffed Grouse	Terrestrial	Bird		✓	
Smallmouth Bass	Aquatic	Fish- benthic		✓	
White Sucker	Aquatic	Fish- benthic	✓		
White-tailed Deer	Terrestrial	Mammal	✓		
Wild Turkey	Terrestrial	Bird	✓		
Willow Ptarmigan	Terrestrial	Bird			✓

Notes:
* - Jack Pine is selected as the representative indicator species for both coniferous and deciduous trees. According to Environment Canada and Health Canada (2003), "angiosperms (conifers) are more sensitive, by almost an order of magnitude, than deciduous trees and are among the most sensitive of all plants."
** - Aquatic plants (cattails and pondweeds) are assumed to be floating plants, i.e., exposed to water and not sediment. Both are represented by the cattails ecological profile in Appendix A.
American robin is included in this study as part of the American crow food chain; it is noted listed in this table because it is not an indicator species.

Table 2: Overview of Indicator Species Characteristics

Species	Body Weight (kg)	Intake Rate (g ww/d)	Drink Water (L/d)	Fraction of Time	Fraction from Each Food Type											Intake Rate (g/d)	
					Berries [b]	Terrestrial Veg.	Lichen	Aquatic Veg.	Benthic Invert.	Fish	Worms	Hare	Bird	Moose	Deer	Soil	Sediment
American Crow	0.45	115	0.03	0.5		0.5					0.4		0.1			3.4	
American Robin[a]	0.077	93	0.01	0.5	0.6						0.4					1.9	
Arctic Fox	4	276	0.3	1								0.75	0.25			2.3	
Arctic Hare	4	716	0.3	1	0.1	0.9										14	
Barren-Ground Caribou	135	6460	8.2	0.5		0.25	0.75									194	
Beaver	24	3750	1.7	1		0.7		0.3									47
Canada Goose	4	120	0.15	0.5		1										3.1	
Common Loon	4	730	0.15	0.5						1							2.9
Gray Wolf	43	5500	2.9	0.25										0.5	0.5	46	
Groundhog	4	716	0.3	1		1										11	
Moose	600	23000	31	1		0.8		0.2									140
Muskrat	1.2	360	1.2	1				0.98	0.02								2.4
Ruffed Grouse	0.62	140	0.04	1	0.1	0.8					0.1					4.2	
White-Tailed Deer	110	10900	6.8	1		1										66	
Wild Turkey	7.4	710	0.23	1		0.9					0.1					20	
Willow Ptarmigan	0.62	140	0.04	1	0.1	0.8					0.1					4.2	

Note:
Only those indicator species where an intake needs to be estimated have been included here (i.e. mammals and birds). Internal concentrations of other indicator species (e.g. plants, earthworms, fish, amphibians) addressed through the application of a transfer factor.
Table provides a summary of the detailed ecological profiles, which have been provided in Appendix A (including all references).
Fraction of Time refers to the estimated fraction of the year that this biota is expected to spend on-site, based on habitat range and/or migration.
a Not an indicator species but included as part of the food chain of the American Crow.
b If berries were not identified as an indicator species in the ecosystem, berries are assumed to be represented by terrestrial plants.

3.3 Conceptual Site Model

A Conceptual Site Model (CSM) is a description of a site with respect to the exposure of indicator species. CSMs can consolidate data from a range of sources in order to convey exposure information. A description of the linkage between the selected receptor types and the environmental compartments or media is included in Table 3. Pictorial representations have been prepared of the different ecosystems (shown in Figure 3, Figure 4 and Figure 5) as well as schematic CSMs. Schematic CSMs for the three ecosystems use food chain block diagrams to describe exposures in each ecosystem. One block diagram is used to show the food chains and external exposure pathways of the aquatic biota in the three ecosystems. Individual block diagrams are used to depict the food chains for terrestrial biota in each ecosystem.

The detailed ecological profiles on which the CSMs are based, are provided in Appendix A along with full references.

Table 3: Overview of Conceptual Site Model [1,2]

Receptors	Species	Abiotic Environmental Components	Modes of Exposure	Exposure Model
– Fish	• Rainbow Trout • Brook Trout • Brown Trout • Chinook Salmon • Arctic Char • Round Whitefish • Largemouth Bass • Smallmouth Bass • White Sucker	• surface water • sediment	• ingestion • immersion in water • external exposure to sediment	– Estimate internal concentration from water concentration through TF. Pelagic fish have external exposure from water while benthic fish are exposed to water and sediment.
– Benthic Invertebrates	– Various	• surface water • sediment	• ingestion • external exposure to sediment	– Estimate internal concentration from water concentration through TF. External exposure from sediment.
– Aquatic Plants	– Various including cattails and pond weed	• surface water • sediment	• uptake • immersion in water • external exposure to sediment	– Estimate internal concentration from water concentration through TF. External exposure from water, roots exposed to sediment.

Receptors	Species	Abiotic Environmental Components	Modes of Exposure	Exposure Model
– Amphibians	– Northern Leopard Frog[9]	• surface water • sediment	• ingestion • immersion in water • external exposure to sediment	– Estimate internal concentration from water concentration through TF. External exposure from water and sediment.
– Terrestrial Invertebrates	– Earthworm	• soil • groundwater	• ingestion • immersion in soil and/or groundwater	– Estimate internal concentration from soil or groundwater through TF. External exposure from soil or groundwater.
– Terrestrial Plants	• Berries • Black spruce • Dwarf willow • Jack Pine • Lichen	• soil [3] • air [7]	• uptake from soil • transfer from air [4] • external exposure to soil	– Estimate internal concentration from soil through TF. External exposure from soil. For lichen, the concentration due to deposition from air will be considered.
– Terrestrial Birds	• American Crow • Canada Goose[5] • Ruffed Grouse • Wild Turkey • Willow Ptarmigan	• soil • surface water	• ingestion of food/prey • ingestion of soil • ingestion of water	– Estimate concentration in food through TF from soil. Estimated concentration in prey from intake rates of prey and TF. Internal concentration estimated from intake of food, soil and water and application of a TF.
– Aquatic Birds	– Common Loon	• surface water • sediment	• ingestion (fish, water, sediment) • external exposure to water	– Estimate concentration in food through TF from water. Internal concentration estimated from intake of food, sediment and water and application of a TF. External exposure from water.
– Terrestrial Mammals	• Arctic Fox • Arctic Hare • Barren-Ground Caribou • Beaver [6] • Gray Wolf • Groundhog • Moose [6] • White-Tailed Deer	• soil • surface water • sediment [8]	• ingestion of food/prey • ingestion of soil • ingestion of water • external exposure to soil or sediment	– Estimate concentration in food through TF from soil or water. Estimated concentration in prey from intake rates of prey and TF. Internal concentration estimated from intake of food, soil, sediment and/or water and application of a TF. External exposure from soil or sediments.

Receptors	Species	Abiotic Environmental Components	Modes of Exposure	Exposure Model
– Aquatic Mammals	• Muskrat	• soil • surface water • sediment	• ingestion of food/prey • ingestion of sediment • ingestion of water • external exposure to water/ sediment	– Estimate concentration in food through TF from water. Internal concentration estimated from intake of food, sediment and water and application of a TF. External exposure from water and sediment as appropriate.

Notes:

1 Conceptual model developed as per CCME (1996, p. 9). Mechanism of transport addressed by using concentrations at species locations.
2 Effects of interest for all species are at the population level.
3 Terrestrial plant uptake is modeled using transfer factors from soil. Groundwater was not considered for terrestrial plants because of lack of groundwater-specific transfer factors. In addition, because of the shallow root zone of most plants, the soil-plant pathway is typically considered more relevant than the groundwater-plant pathway. Groundwater was assessed for terrestrial invertebrates. Irrigation is neglected for wild plants.
4 Air concentration estimated based on re-suspended soil. Only considered for lichen, due to its long life and ability to integrate over a long time.
5 Canada goose does reside near water but consumes terrestrial plants and is thus classified as a terrestrial bird.
6 Significant source of exposure from both terrestrial and aquatic environments.
7 Lichen only.
8 For Beaver and Moose only (and wolf, through ingestion of moose).
9 In its early life stages, frog is exposed more to water. The calculations carried out for frogs reflect early life stage (e.g., use of fish transfer factors when frog data are absent), which is sensitive.

Exposure pathways and food chains for aquatic biota in the Southern Canadian Deciduous Forest and/or the Boreal Forest ecosystem are shown schematically in Figure 6.

The food chains for terrestrial biota in the Southern Canadian Deciduous Forest ecosystem are depicted in Figure 7. The food chains for terrestrial biota in the Boreal Forest ecosystem are depicted in Figure 8. The food chains for terrestrial biota in the Inland Tundra ecosystem are depicted in Figure 9.

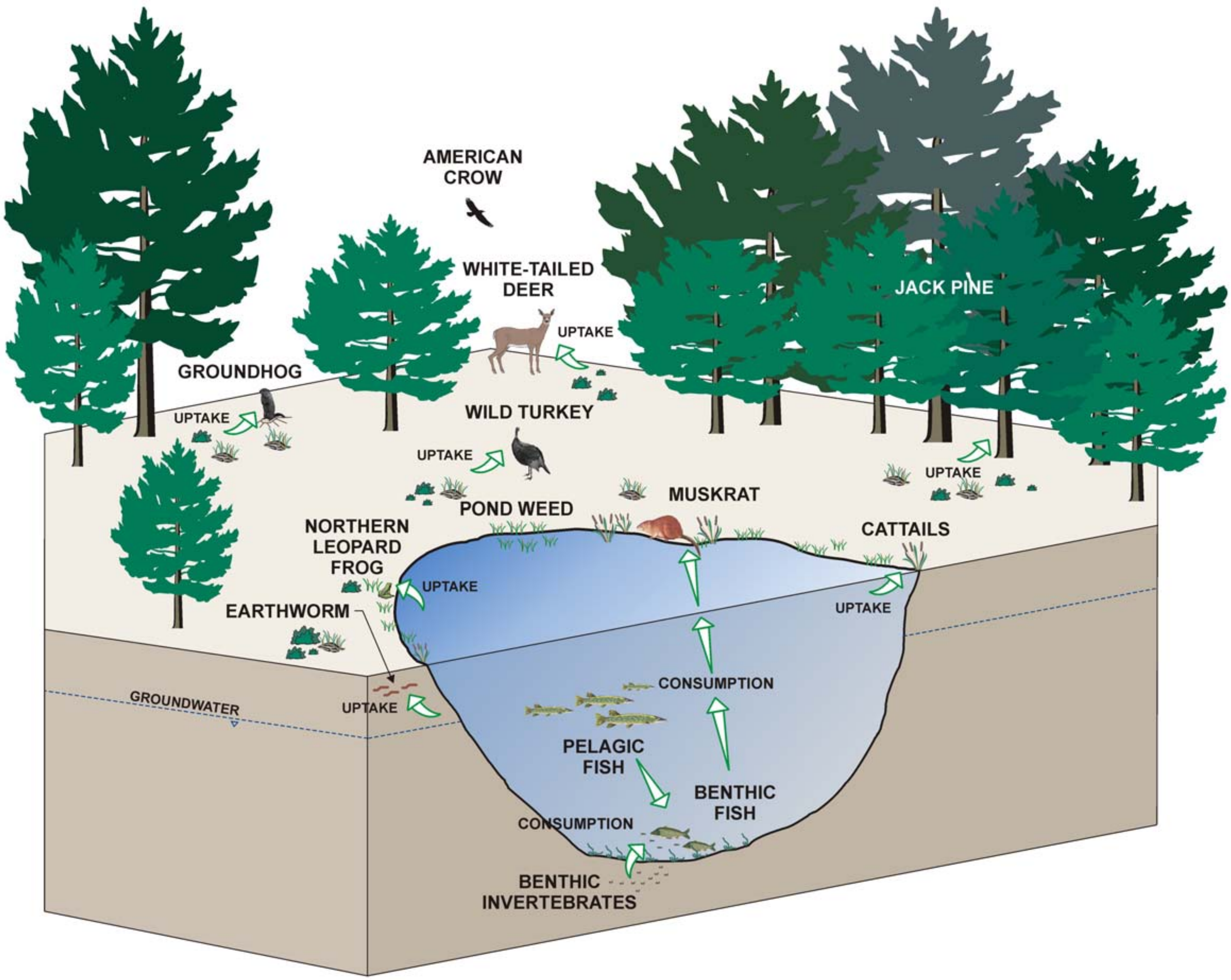


Figure 3: Representation of Conceptual Site Model for Southern Canadian Deciduous Forest Ecosystem

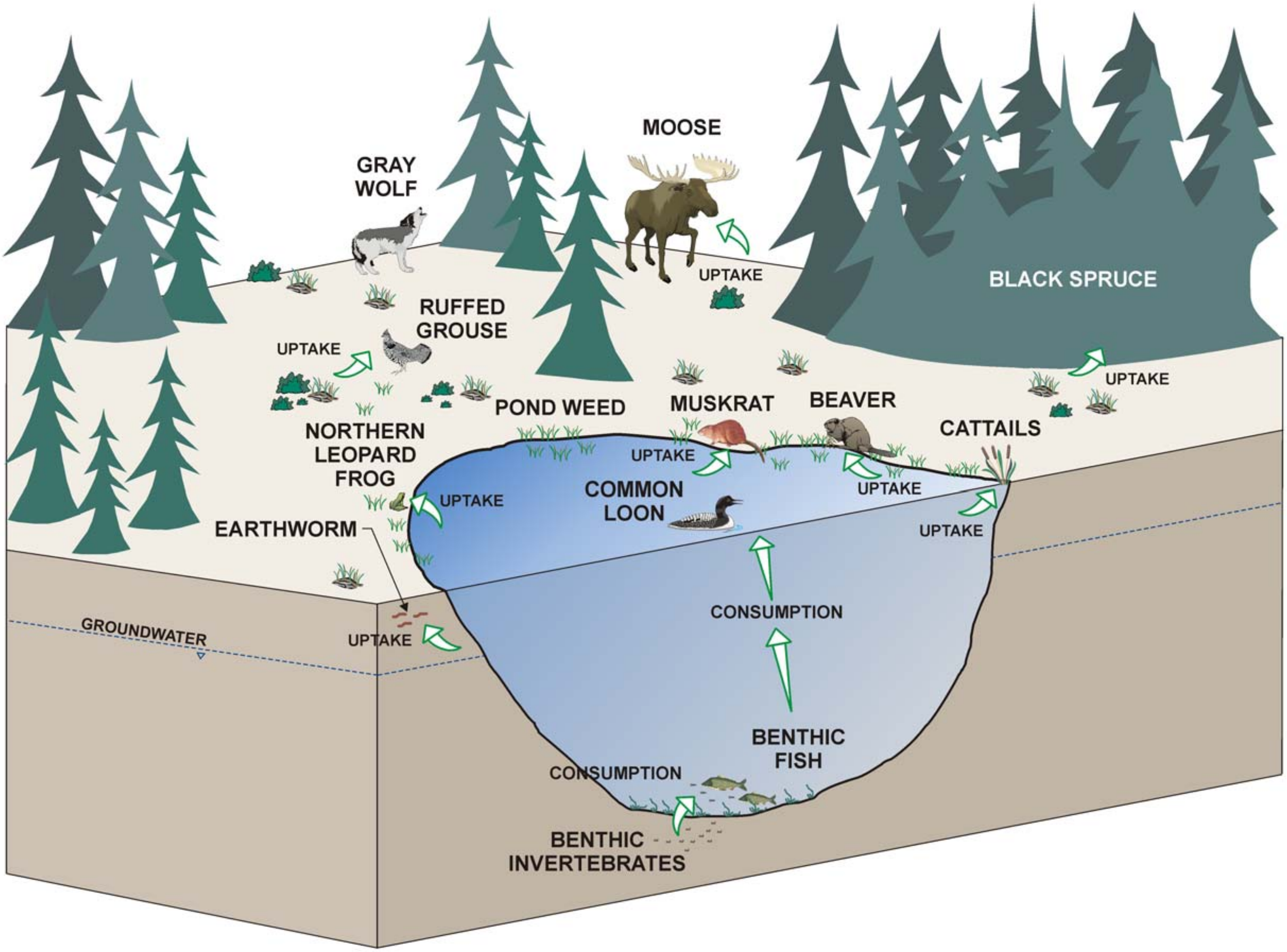


Figure 4: Representation of Conceptual Site Model for Boreal Forest Ecosystem

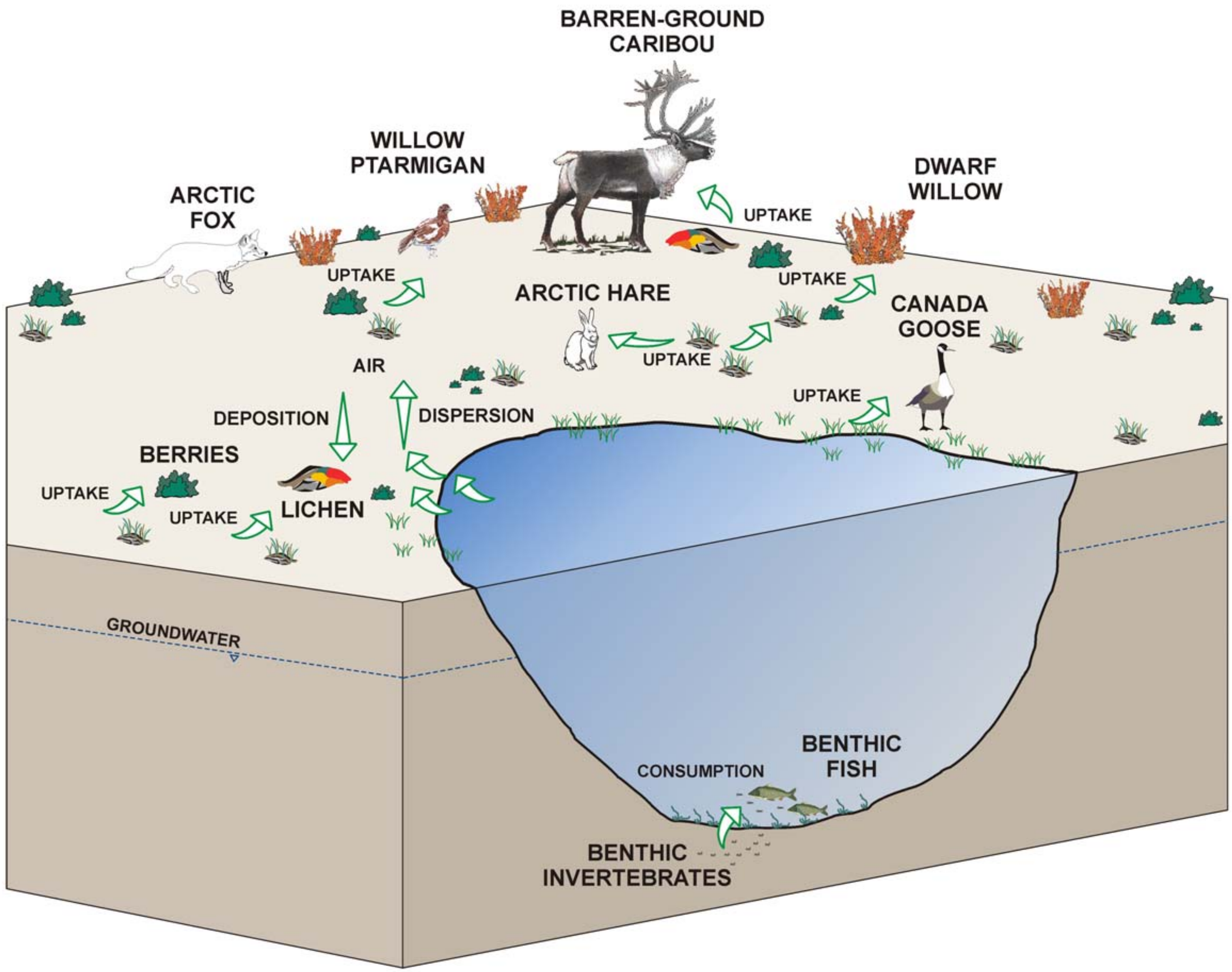


Figure 5: Representation of Conceptual Site Model for Inland Tundra Ecosystem

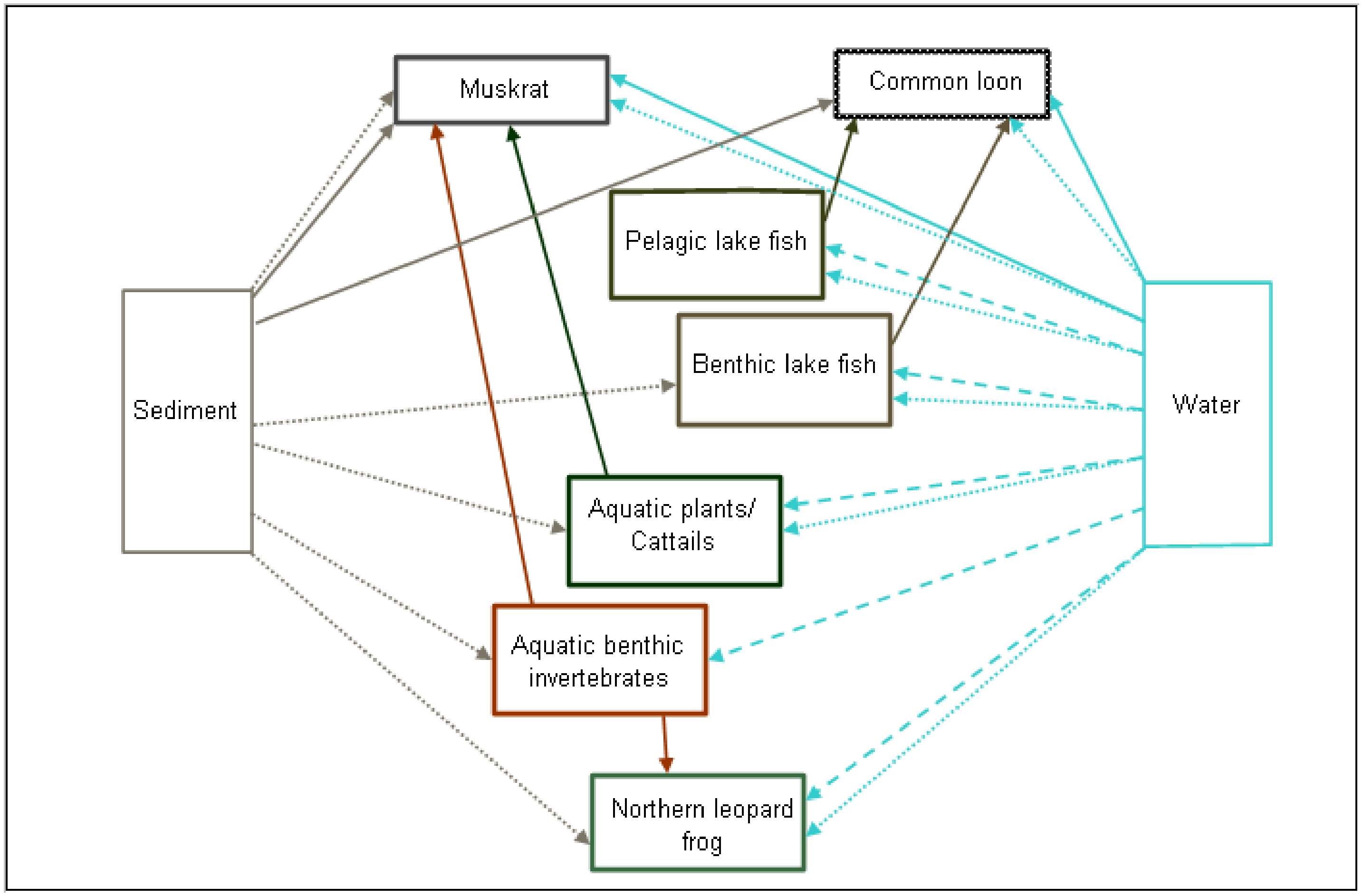


Figure 6: Exposure Pathways and Food Chain for Aquatic Biota

Indicator species are shown in Bold boxes.

Exposure pathways originating from a medium are shown in a single color (e.g. all pathways from water are shown in light blue). Generic transfer pathways shown for food (e.g. not specified for different vegetation types).

- Line types: Dashed line indicates that exposure and concentration are modeled through the use of a transfer factor (TF). The TF is assumed to account for direct and indirect pathways. Solid line indicates that exposure is modeled by estimating the intake. Dotted line indicates an external exposure pathway.

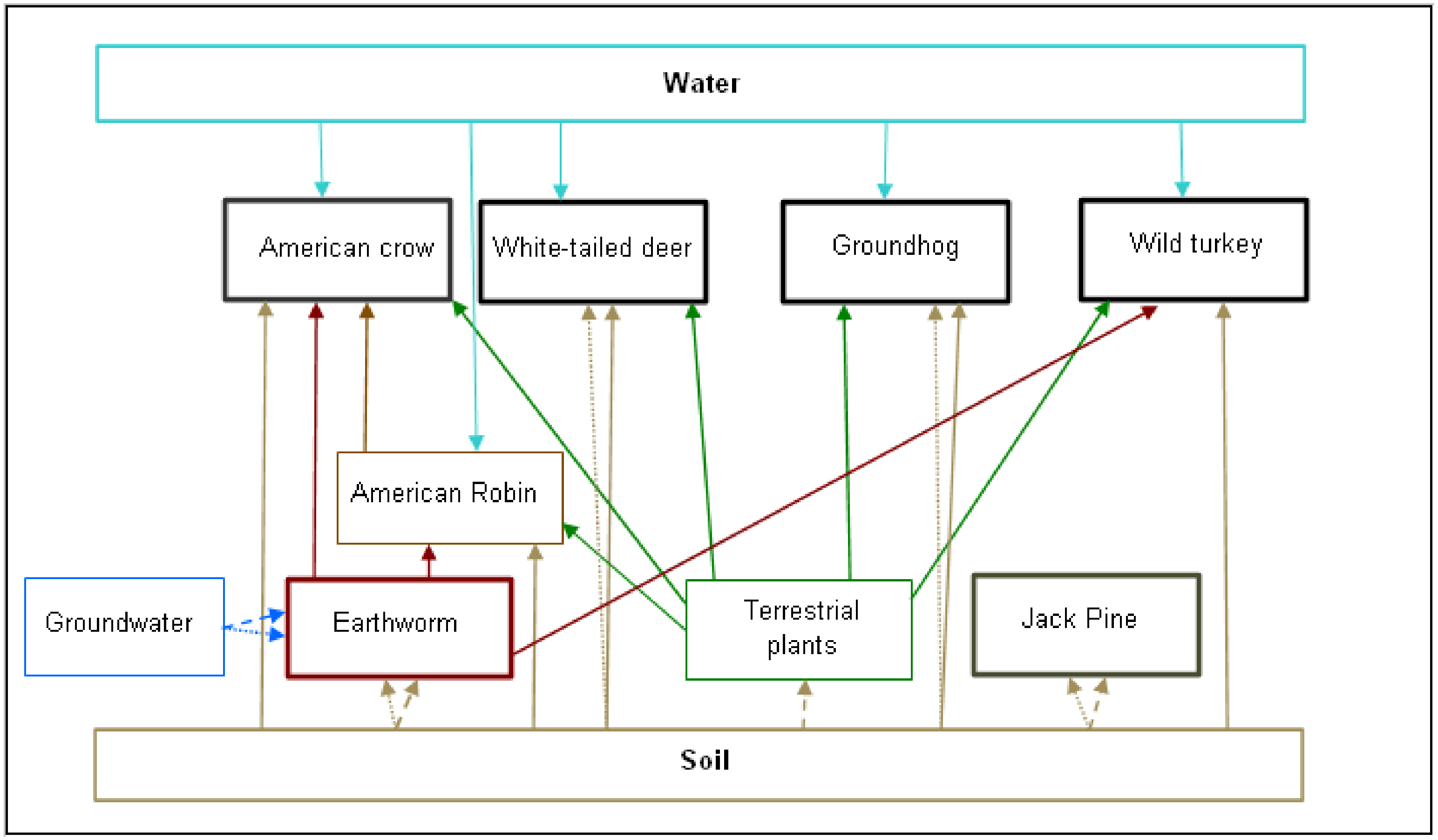


Figure 7: Exposure Pathways and Food Chain for the Terrestrial Biota in the Southern Canadian Deciduous Forest Ecosystem

Indicator species are shown in Bold boxes.

Exposure pathways originating from a medium are shown in a single color (e.g. all pathways from water are shown in light blue). Generic transfer pathways shown for food (e.g. not specified for different vegetation types). American robin is taken to represent all birds in the American crow diet.

- Line types: Dashed line indicates that exposure and concentration are modeled through the use of a transfer factor (TF). The TF is assumed to account for direct and indirect pathways. Solid line indicates that exposure is modeled by estimating the intake. Dotted line indicates an external exposure pathway.

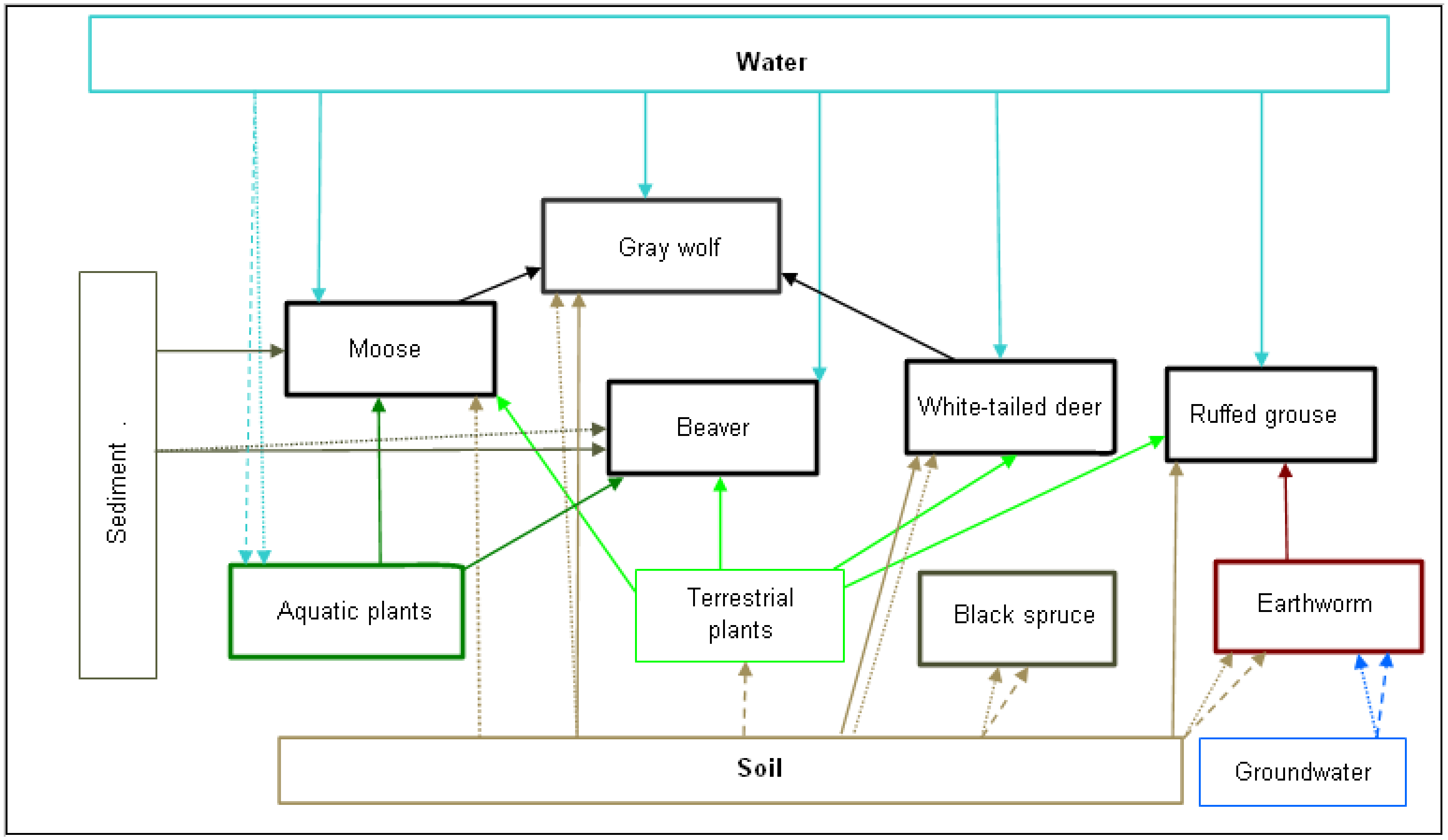
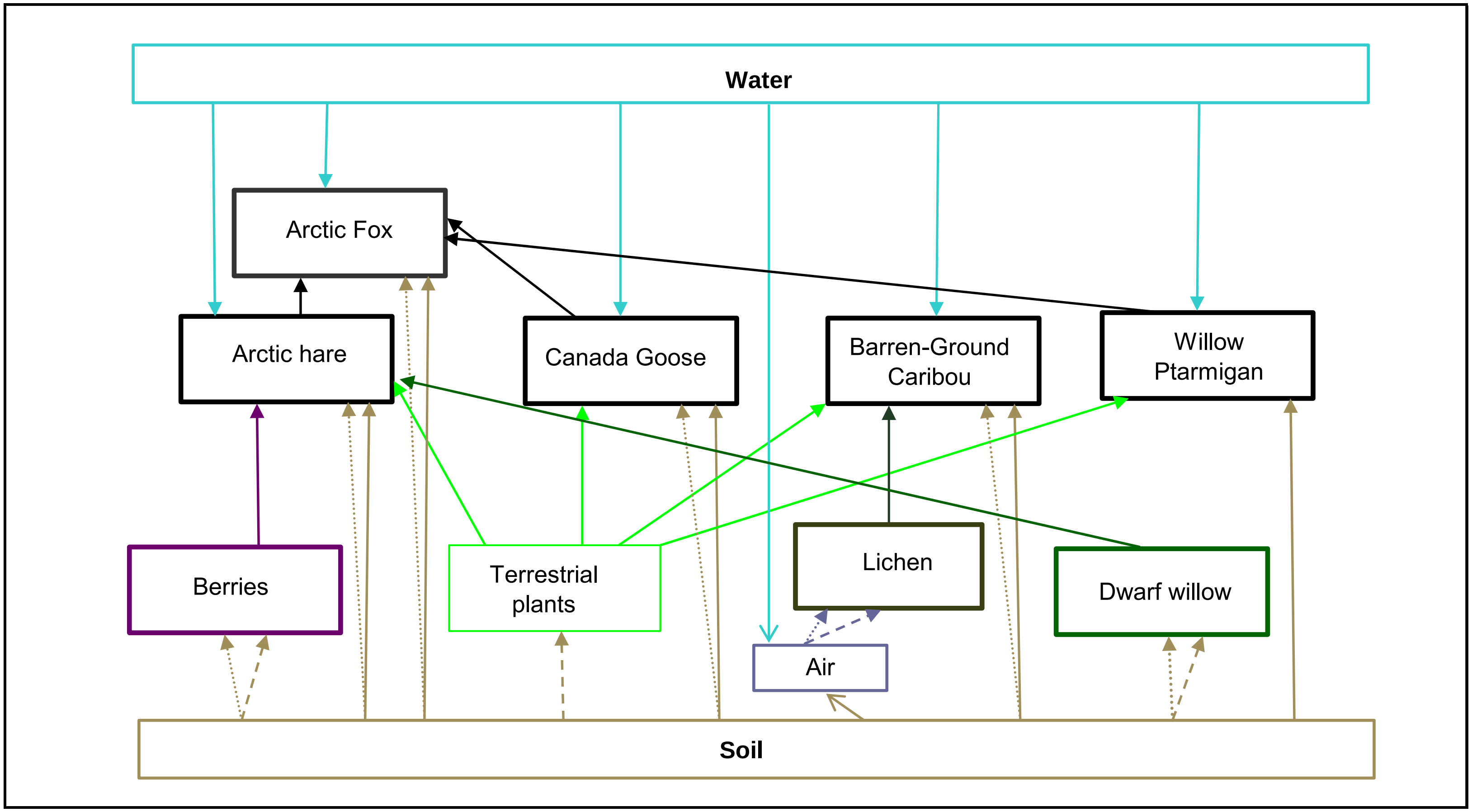


Figure 8: Exposure Pathways and Food Chain for the Terrestrial Biota in the Boreal Forest Ecosystem

Indicator species are shown in Bold boxes.

Exposure pathways originating from a medium are shown in a single color (e.g. all pathways from water are shown in light blue). Generic transfer pathways shown for food (e.g. not specified for different vegetation types).

– Line types: Dashed line indicates that exposure and concentration are modeled through the use of a transfer factor (TF). The TF is assumed to account for direct and indirect pathways. Solid line indicates that exposure is modeled by estimating the intake. Dotted line indicates an external exposure pathway.



Note: Indicator species are shown in Bold boxes. Other biota in the food web are shown in regular boxes.

Figure 9: Exposure Pathways and Food Chain for the Terrestrial Biota in the Inland Tundra Ecosystem Indicator Species are shown in Bold Boxes.

Exposure pathways originating from a medium are shown in a single color (e.g. all pathways from water are shown in light blue). Generic transfer pathways shown for food (e.g. not specified for different vegetation types).
Line types: Dashed line indicates that exposure and concentration are modeled through the use of a transfer factor (TF). The TF is assumed to account for direct and indirect pathways. Solid line indicates that exposure is modeled by estimating the intake. Dotted line indicates an external exposure pathway. Open arrow (→) indicates re-suspension of soil or water into the air compartment. Note for lichen a different calculation procedure is employed which is discussed within the ecological profile (Appendix A).

4. PARAMETER VALUES FOR THE MODELS

This section summarizes parameter values used in the dose assessment and NEC derivation. These are as follows:

- Transfer Factors (Section 4.1);
- Dose Coefficients (Section 4.2);
- Relative Biological Effectiveness (RBE, radioecological weighting factors, Section 4.3); and
- Estimated No Effect Values (ENEVs, Section 4.4).

Two sets of parameter values were used in the calculations. These correspond to an Upper Estimate case and a Central Estimate case. The Upper Estimate values are more conservative than the Central Estimate values. The degree of conservatism in each of these sets of parameters is discussed below. The same dietary intake rate and exposure data were applied to the Central and Upper Estimate calculations.

4.1 Transfer Factors

Transfer Factors (TFs) were used to estimate the concentrations in biota. TFs are generally empirically derived values that provide a measure of the partitioning behaviour of a radionuclide between two environmental media. For example, TFs can be used to describe the relationship between water-fish, soil-earthworm, food-to-animal flesh, as well as others. TFs encompass all routes of exposure. For example, for fish, the water-to-fish TF implicitly includes ingestion pathway as well as absorption. TFs were obtained from the literature for general classes of species (fish, bird and mammal). Differences between different species, such as a hare and a wolf, will arise because of differences in the type and quantity of food consumed, as well as the amount of time spent in one area.

Table 4 and Table 5 show the selected Transfer Factors for the Upper Estimate and Central Estimate cases, respectively. Details of this selection and references are shown in Appendix B. The Central Estimates are geometric means (GM) of literature data. The Upper Estimates are calculated as either:

- the maximum value of a range (if a range is specified); or
- the product of the GM and the square of the geometric standard deviation (GSD), i.e., $GM*GSD^2$ (Where GSD = geometric standard deviation up to a maximum value of 5). If there was only one data point, the Upper Estimate was calculated as $Value*5^2$.

To assess the radiation exposure to birds and mammals, an internal concentration needs to be determined. The TFs summarized in the tables, provided in units of d/kg, are used in this approach to estimate the concentration from the intake. The TFs provided in the tables (from literature) are generally derived from information on domestic livestock species such as cattle and chicken. However, the use of these values will result in an underestimate of the transfer to wildlife tissues, particularly for smaller wildlife species (with lower food intake). Therefore, allometric scaling of the TFs provided in Table 4 and Table 5 has been used for the specific wildlife species. Appendix B.2 provides a discussion on this approach. A species-specific approach could not be applied to all TFs, as explained in the following paragraphs. However, conservatism was emphasized in the TF selection process.

Consideration was given to selection of different TF values for other species within a class. This was implemented for berries, which is a subset of terrestrial plants. However, in general there is little data available in the standard TF compilations to be able to account for this differentiation. In addition, on a generic basis, the variation between biota is often greater than that which can be distinguished from different species. For example, Sheppard and Evenden (1988) identified significant variations in concentration ratios among some soil and plant types. Sheppard et al. (2008, in press) found a high variability in concentration ratios for all vegetation types over all regions.

A conservative approach has been implemented in the selection of TFs for use in deriving NECs which would further mask any differences between species. TFs for different species could be considered for any site-specific ERA. This is demonstrated in Table 6 where site-specific example TFs for two different types of fish are shown along with the selected values for use in the NECs. This table shows that for U, the pelagic TF is slightly higher than the benthic TF, whereas for Ra, it is the other way around. The values selected for the present study are conservative.

Sediment-water equilibrium distribution coefficients, or Kd_s, are also included among the transfer factors. The Kd values are used in the exposure/dose calculations to estimate the concentrations of radionuclides in porewater based on sediment concentrations. The porewater concentrations are used to estimate benthic invertebrate concentrations as well as external doses to benthic fish, benthic invertebrates, muskrats and beavers from sediment (see detailed dose calculations in Garisto et al. (2008, Addendum).

Table 4: Selected Transfer Factors for the Upper Estimate Case

Element	Sediment-Water, K_d (L/kg)		Aquatic Plant TF (L/kg dw)		Benthic Invertebrate TF (L/kg fw)		Fish TF (L/kg fw)		Soil-Vegetation TF (kg/kg dw)		Soil-Berries TF (kg/kg dw)		Feed/Water-Bird TF* (d/kg fw)		Feed/Water-Mammal TF* (d/kg fw)	
	Value	*Ref*	***Value***	*Ref*	***Value***	*Ref*	***Value***	*Ref*	***Value***	*Ref*	***Value***	*Ref*	***Value***	*Ref*	***Value***	*Ref*
C	5.00E+04	*1*	7.50E+05	*6 & 7*	2.25E+05	*7*	1.25E+06	*9 / 3*	2.50E+01	*12*	1.75E+01	*13*	1.60E+02	*15*	1.60E+00	*3*
Cl	2.75E+02	*2*	8.33E+03	*7*	1.25E+03	*7*	2.50E+04	*9*	2.50E+03	*9*	1.75E+03	*14*	9.68E+00	*2*	2.00E+00	*14*
Zr	2.50E+05	*3*	8.33E+05	*7*	1.25E+03	*7*	7.50E+03	*9*	2.50E+00	*9*	2.50E-02	*13 **	1.50E-03	*1*	5.00E-01	*3*
Nb	2.50E+05	*3*	8.33E+04	*7*	1.25E+03	*7*	3.00E+04	*1*	5.00E+00	*3*	6.25E-01	*13*	5.00E-02	*3*	6.25E+00	*14 / 3*
Tc	5.00E+03	*3*	8.33E+05	*7*	2.50E+03	*7*	7.50E+02	*3*	5.25E+03	*13 **	3.75E+01	*14*	2.00E-01	*1*	2.13E-01	*14*
I	5.00E+03	*3*	5.00E+04	*7*	2.50E+03	*7*	3.13E+03	*10*	4.00E+00	*3*	1.25E+00	*14*	7.68E+01	*16*	1.00E+00	*9*
Cs	7.50E+05	*3*	6.67E+05	*8*	1.50E+04	*8*	6.61E+05	*11*	2.50E+01	*9 & 1*	5.50E+00	*13 **	2.80E+03	*8*	1.25E+00	*3*
Ra	1.25E+04	*4*	5.00E+06	*7 & 6*	2.50E+04	*7*	1.25E+03	*9*	5.00E+00	*9*	3.75E-01	*14*	8.33E+00	*17*	2.50E-02	*1 & 9*
Np	4.36E+02	*5*	5.00E+04	*7*	7.50E+02	*7*	3.75E+03	*1 & 5*	2.75E+01	*3*	2.50E-01	*14*	2.05E-01	*5*	2.50E-02	*1 & 9*
U	7.50E+05	*3*	1.50E+05	*7*	2.50E+03	*7*	5.00E+02	*3*	2.50E+00	*9*	1.00E-01	*14*	3.00E+01	*3*	2.00E-02	*9*
Pb	3.75E+03	*4*	3.33E+05	*7*	5.00E+05	*7*	2.50E+03	*9*	8.33E+00	*9*	3.40E-01	*18*	5.75E+01	*7*	2.00E-02	*9*
Po	1.00E+06	*1*	7.50E+04	*7*	2.50E+03	*7*	1.00E+04	*1*	8.33E+00	*9*	8.33E-02	*9*	1.50E-01	*7*	1.25E-01	*9*

Notes:
- The TF for the Upper Estimate case was selected as the maximums of the Upper Estimate from each of the data sets for each radionuclide (see Appendix B). In each dataset, the representative value for the Upper Estimate was the upper range of the available data or the GM* GSD^2. In each dataset, if the GSD was larger than 5 (interpreted as an outlier), or was not provided, it was set equal to 5.
- Values expressed in exponential format. 2.00E+03 is equivalent to 2.00×10^3
* Values are for domestic animals (beef cattle and chickens) and will be scaled for wildlife, as described in Appendix B.2.

References:

1	IAEA (1994)	10	Chant (1999)	a – adopted value from IAEA (1994)
2	Zach *et al*. (1996) as cited in Sheppard *et al*., (2004a)	11	Environment Canada (2000)	
		12	Sheppard *et al.* (1994)	
3	CSA (1987)	13	PNNL (2003)	
4	Bechtel Jacobs (1998)	14	Baes *et al.* (1984)	
5	Sheppard *et al.* (2004b)	15	Zach and Sheppard (1992)	
6	Bird and Schwartz (1996)	16	Sheppard *et al.* (2002)	
7	US DOE (2003)	17	Clulow *et al.* (1992)	
8	Polikarpov (1966)	18	U.S. EPA (1998), R6	
9	NCRP (1996)			

Table 5: Selected Transfer Factors for the Central Estimate Case

Element	Sediment-Water, K_d (L/kg)		Aquatic Plant TF (L/kg dw)		Benthic Invertebrate TF (L/kg fw)		Fish TF (L/kg fw)		Soil-Vegetation TF (kg/kg dw)		Soil-Berries TF (kg/kg dw)		Feed/Water-Bird TF* (d/kg fw)		Feed/Water-Mammal TF* (d/kg fw)	
	Value	*Ref*	***Value***	*Ref*	***Value***	*Ref*	***Value***	*Ref*	***Value***	*Ref*	**Value**	*Ref*	***Value***	*Ref*	***Value***	*Ref*
C	2.00E+03	*1*	1.01E+05	*6 & 7*	9.00E+03	*7*	5.00E+04	*9 / 3*	1.00E+00	*12*	7.00E-01	*13*	3.00E-02	*15*	6.40E-02	*3*
Cl	1.10E+01	*2*	3.33E+02	*7*	5.00E+01	*7*	1.00E+03	*9*	1.00E+02	*9*	7.00E+01	*14*	2.00E+00	*2*	8.00E-02	*14*
Zr	1.00E+04	*3*	3.33E+04	*7*	5.00E+01	*7*	3.00E+02	*9*	1.00E-01	*9*	1.00E-03	*13 **	6.00E-05	*1*	2.00E-02	*3*
Nb	1.00E+04	*3*	3.33E+03	*7*	5.00E+01	*7*	1.73E+03	*1*	2.00E-01	*3*	2.50E-02	*13*	2.00E-03	*3*	2.50E-01	*14 / 3*
Tc	2.00E+02	*3*	3.33E+04	*7*	1.00E+02	*7*	3.00E+01	*3*	2.10E+02	*13 **	1.50E+00	*14*	7.75E-02	*1*	8.50E-03	*14*
I	4.25E+02	*3*	2.00E+03	*7*	1.00E+02	*7*	1.25E+02	*10*	1.60E-01	*3*	5.00E-02	*14*	7.50E+00	*16*	4.00E-02	*9*
Cs	3.00E+04	*3*	2.67E+04	*8*	8.77E+02	*8*	2.64E+04	*11*	1.00E+00	*9 & 1*	2.20E-01	*13 **	1.40E+03	*8*	5.00E-02	*9*
Ra	5.00E+02	*4*	2.00E+05	*7 & 6*	1.00E+03	*7*	5.00E+01	*9*	2.00E-01	*9*	1.50E-02	*14*	3.33E-01	*17*	1.58E-03	*1 & 9*
Np	2.58E+02	*5*	2.00E+03	*7*	3.00E+01	*7*	1.73E+02	*1 & 5*	1.10E+00	*3*	1.00E-02	*14*	2.00E-02	*5*	1.00E-03	*1 & 9*
U	3.00E+04	*3*	6.00E+03	*7*	1.00E+02	*7*	2.00E+01	*3*	1.00E-01	*9*	4.00E-03	*14*	1.20E+00	*3*	8.00E-04	*9*
Pb	2.70E+02	*4*	1.33E+04	*7*	5.00E+02	*7*	3.00E+02	*9*	3.33E-01	*9*	1.36E-02	*18*	8.00E-01	*7*	8.00E-04	*9*
Po	1.50E+02	*4*	1.33E+04	*7*	2.00E+04	*7*	1.00E+02	*9*	3.33E-01	*9*	3.33E-03	*9*	2.30E+00	*7*	5.00E-03	*1 & 7 & 9*

Notes:
- The TF's for the Central Estimate case were selected as the maximums of the Central Estimate from each of the data sets for each radionuclide (see Appendix B). In each dataset, the representative value for the Central Estimate was the geometric mean (GM) or the only available data point. In each dataset, if there was a range, the GM was calculated using the two available data points.
- Values expressed in exponential format. 2.00E+03 is equivalent to 2.00×10^3.

* Values are for domestic animals (beef cattle and chickens) and will be scaled for wildlife, as described in Appendix B.2.

References:

1 IAEA (1994)
2 Sheppard *et al*. (2004a)
3 CSA (1987)
4 Bechtel Jacobs (1998)
5 Sheppard *et al.* (2004b)
6 Bird and Schwartz (1996)
7 US DOE (2003)
8 Polikarpov (1966)
9 NCRP (1996)
10 Chant (1999)
11 Environment Canada (2000)
12 Sheppard *et al*. (1994)
13 PNNL (2003)
14 Baes *et al.* (1984)
15 Zach and Sheppard (1992)
16 Sheppard *et al.* (2002)
17 Clulow *et al*. (1992)
18 U.S. EPA (1998), R6
a Adopted value from IAEA (1994)

Table 6: Comparison of Site-Specific Transfer Factors for Different Fish to the Values Selected for NECs. The GSDs are provided in parenthesis

Element	Site-Specific TF		TF used in NEC Calculations
	Default TF Benthic*	Default TF Pelagic**	Central/Upper Estimate***
U	0.67 (2.1)	1.1 (3.5)	20/500
Ra	47 (2.1)	7.6 (2.5)	50/1250

Note:
Site-specific TFs derived from data collected in an area of northern Saskatchewan for use in an assessment of uranium mining (COGEMA 2004)
* transfer factors were calculated for benthic fish in northern Saskatchewan: lake whitefish and white sucker.
** transfer factors were calculated for predator fish in northern Saskatchewan: lake trout, northern pike and game fish.
*** see Tables 4 and 5.

4.2 Dose Coefficients

Table 7 and Table 8 show the selected Dose Coefficients (DCs) for the Upper Estimate and Central Estimate cases, respectively. The same generic DCs are used for all biota. Details of this selection and references are shown in Appendix C.

The Upper Estimates are the maximum values out of Amiro (1997), FASSET (2003) and U.S. DOE (2002) over all biota.

The Central Estimates are based on Amiro (1997). These internal DCs conservatively assume that all energies emitted by radionuclides from within the biota are absorbed by the biota regardless of size. This is a conservative assumption especially for gamma radiation. The external DCs from water, soil and sediment assume that the organism is submerged 0.1 m below the surface of a semi-infinite uniformly contaminated body of water or soil or sediment. The DCs in Tables 7 and 8 include a radioecological weighting factor (RBE) for alpha-emitting radionuclides (see Section 4.3).

Table 7: Selected DC's for the Upper Estimate Case

Radionuclide	Weighted Internal DC (Gy/y per Bq/kg) [1]	External-water DC (Gy/y per Bq/m^3) [2]	External-soil DC (Gy/y per Bq/kg) [2]
C-14	2.50E-07	1.20E-10	2.50E-07
Cl-36	1.39E-06	4.00E-10	2.24E-10
Zr-93	9.92E-08	0.00E+00	0.00E+00
Nb-94	8.80E-06	7.52E-09	8.60E-06
Tc-99	5.11E-07	2.10E-10	4.30E-07
I-129	4.46E-07	2.00E-10	4.00E-07
Cs-135	3.41E-07	1.40E-10	2.80E-07
Ra-226	9.84E-04	1.02E-08	1.40E-05
Np-237	1.00E-03	1.30E-09	2.50E-06
U-238	1.05E-03	2.30E-09	4.60E-06
Pb-210	2.19E-06	1.10E-09	2.20E-06
Po-210	1.09E-03	3.99E-14	1.28E-11

[1] Amiro (1997); Weighted Internal DC= Internal DC × Weighting Factor (a Weighting Factor of 40 for Alpha); for U-238 and Pb-210, the progenies are also included; for details please see Appendix C.

[2] The higher of FASSET (2003) values over all biota (in-soil and on-soil), US DOE (2002) value and Amiro (1997). In Amiro (1997), for immersion in water and soil/sediment, the receptor is assumed to be submerged 0.1m below the surface of a semi-infinite uniformly-contaminated body of water or soil/sediment. The soil DC is also applied to sediment. Progenies are included; please see Appendix C for details.

N/A- Not Applicable

Table 8: Selected DC's for the Central Estimate Case

Radionuclide	Weighted Internal DC (Gy/y per Bq/kg) [1]	External-water DC (Gy/y per Bq/m^3)	External-soil DC (Gy/y per Bq/kg)
C-14	2.50E-07	6.51E-12	9.77E-09
Cl-36	1.39E-06	5.80E-10	8.69E-07
Zr-93	9.92E-08	0.00E+00	0.00E+00
Nb-94	8.80E-06	6.56E-09	9.84E-06
Tc-99	5.11E-07	8.62E-11	1.29E-07
I-129	4.46E-07	1.19E-10	1.79E-07
Cs-135	3.41E-07	2.66E-07	3.99E-08
Ra-226	4.92E-04	3.20E-11	4.80E-08
Np-237	5.00E-04	1.56E-10	2.34E-07
U-238	5.23E-04	2.05E-09	3.07E-06
Pb-210	2.19E-06	6.08E-10	9.12E-07
Po-210	5.46E-04	3.44E-14	5.16E-11

Reference: Amiro (1997)

1 Weighted Internal DC= Internal DC × Weighting Factor (a Weighting Factor of 20 for Alpha); for U-238 and Pb-210, the progenies are also included; for details please see Appendix C.

N/A- Not Applicable

4.3 Relative Biological Effectiveness for Alpha-emitting Radionuclides

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

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

The Upper Estimate case assumed a radioecological weighting factor of 40 for alpha (EC/HC 2001). This value is conservative.

The Central Estimate case assumed a radioecological weighting factor of 20 for alpha. This value is also conservative (Kocher and Trabalka, 2000; Trivedi and Gentner, 2002).

The RBE is applied to un-weighted doses from alpha-emitting radionuclides; the weighted doses retain their units (i.e., mGy/day).

4.4 Estimated No Effect (Dose) Values

Estimated No Effect dose-rate Values (ENEVs) are used in ecological risk assessments as a benchmark for population-level impacts on non-human biota. The ENEVs used in this study are based on several compilations, as shown in Table 9. These compilations are from the following sources:

- Environment Canada and Health Canada (2003) Priority Substances List (PSL2) Assessment Report on Releases of Radionuclides from Nuclear Facilities (Impact on Non-human Biota);
- United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR 1996). Effects of Radiation on the Natural Environment;
- Garisto (2005) Nominal Radioecological Benchmarks for the Ecological Risk Assessment of Radioactive Waste Management Facilities; and
- Other references such as Bird *et al.* (2002) and Mihok (2003).

Table 10 shows the ENEVs used in this report to derive NECs. The values in Table 10 were selected as follows:

- For the upper estimate, the lowest of all available values was selected.
- For the central estimate, values from the PSL2 assessment (EC/HC 2003) were selected for all biota except fish, birds and frogs. The fish ENEV in the PSL2 assessment is based on Chernobyl cooling pond data. Factors other than radiation (e.g., thermal and chemical pollution) may have contributed to the effects observed in the Chernobyl study. Acute exposure of the parents around the time of the accident could also be a confounding factor in this study. Therefore, fish ENEVs from Garnier-Laplace *et al*. (2006) were used. ENEVs for birds and frogs are not available in the PSL2 assessment; for these biota, the lowest available literature values (from Table 9) were used.

Table 9: Summary of Available Estimated No Effect Values (mGy/d)

Species	PSL2 [1]	UNSCEAR [2]	Garisto [3]	Other [4]
American Crow	NA	1	5	1.6
Arctic Char	0.6	10	5	8.4
Arctic Fox	3	1	1	1.6
Arctic Hare	3	1	10 [5]	100 [5,6]
Aquatic Plants	2.4	10	2.4	
Barren-Ground Caribou	3	1	1	1.6
Beaver	3	1	1	1.6
Benthic Invertebrates	5.5	10	5	8.4
Berries	2.4	10	2.4	1.6
Black Spruce	2.4	10	2.4	1.6
Brook Trout	0.6	10	5	8.4
Brown Trout	0.6	10	5	8.4
Canada Goose	NA	1	5	1.6
Cattails	2.4	10	2.4	
Chinook Salmon	0.6	10	5	8.4
Common Loon	NA	1	5	1.6
Dwarf Willow	2.4	10	2.4	1.6
Earthworm	5.5[7]	1	5	5.3 [8] 1.6
Gray Wolf	3	1	1	1.6
Groundhog	3	1	1	1.6
Jack Pine	2.4	10	2.4	1.6
Largemouth Bass	0.6	10	5	8.4
Lichens	2.4	10	2.4	1.6
Moose	3	1	1	1.6
Muskrat	3	1	1	1.6
Northern Leopard Frog	NA	10	5	
Pond Weeds	2.4	10	2.4	
Rainbow Trout	0.6	10	5	8.4
Round Whitefish	0.6	10	5	8.4
Ruffed Grouse	NA	1	5	1.6
Smallmouth Bass	0.6	10	5	8.4
White Sucker	0.6	10	5	8.4
White-Tailed Deer	3	1	1	1.6

Species	PSL2 [1]	UNSCEAR [2]	Garisto [3]	Other [4]
Wild Turkey	NA	1	5	1.6

Notes:
NA: Not Available
The effects evaluated in each reference may not be identical; e.g., the UNSCEAR/IAEA values are applicable to the most exposed individuals within a population, whereas the Garnier-Laplace values are EDR_{10} (dose rate giving 10% change in observed effect) and HDR_5 (hazardous dose rate giving 10% effect to 5% of species) values.
[1] Environment Canada and Health Canada (EC/HC 2003)
[2] UNSCEAR (1996). Aquatic organisms and terrestrial plants 10 mGy/d, other terrestrial organisms 1 mGy/d
[3] Garisto (2005)
[4] From Garnier-Laplace *et al*. (2006), unless otherwise noted. Value where no trophic weight was applied; terrestrial value includes consideration of plants, invertebrates, birds and mammals and was thus applied to all these categories; freshwater chronic value includes consideration of crustaceans, molluscs and fish and was thus applied to all these categories.
[5] Hare taken to be a rapidly-reproducing mammal in this reference (ENEV not selected for the present study).
[6] Mihok (2003)
[7] Taken to be same as benthic invertebrates.
[8] Bird *et al.* (2002)

Table 10: Recommended ENEVs for use in Deriving NECs (mGy/d)

Species	Upper Estimate		Central Estimate	
	Value	Reference	Value	Reference
American Crow	1	2, 4	1	2
Arctic Char	0.6	1	8.4	4
Arctic Fox	1	2, 4	3	1
Arctic Hare	1	2, 3	3	1
Aquatic Plants	2.4	1, 3	2.4	1
Barren-Ground Caribou	1	2, 3	3	1
Beaver	1	2, 4	3	1
Benthic Invertebrates	5	3	5.5	
Berries	1.6	4	2.4	1
Black Spruce	1.6	4	2.4	1
Brook Trout	0.6	1	8.4	4
Brown Trout	0.6	1	8.4	4
Canada Goose	1	2	1	2
Cattails	2.4	1, 3	2.4	1
Chinook Salmon	0.6	1	8.4	4
Common Loon	1	2	1	2
Dwarf Willow	1.6	4	2.4	1
Earthworm	1.6	4	5.5	1
Gray Wolf	1	2	3	1
Groundhog	1	2	3	1
Jack Pine	1.6	4	2.4	1
Largemouth Bass	0.6	1	8.4	4
Lichen	1.6	4	2.4	1
Moose	1	2	3	1
Muskrat	1	2	3	1
Northern Leopard Frog	5	3	5	3
Pond Weed	2.4	1, 3	2.4	1
Rainbow Trout	0.6	1	8.4	4
Round Whitefish	0.6	1	8.4	4
Ruffed Grouse	1	2	1	2
Smallmouth Bass	0.6	1	8.4	4
White Sucker	0.6	1	8.4	4

Species	Upper Estimate		Central Estimate	
	Value	Reference	Value	Reference
White-Tailed Deer	1	[2]	3	[1]
Wild Turkey	1	[2]	1	[2]

Notes:
[1] Environment Canada and Health Canada (EC/HC 2003)
[2] UNSCEAR (1996)
[3] Garisto (2005)
[4] Garnier-Laplace *et al.* (2006)
Additional notes on selection of ENEVs from references provided in Table 9.

5. DOSE CALCULATIONS

As described in Section 2, dose calculations were carried out based on the exposure characteristics and conceptual model defined in Section 3 and the model parameters defined in Section 4. Garisto et al. (2008, Addendum) shows the dose calculation model, which documents all parameter values, references and equations used.

Using the dose calculation model, unit doses were calculated for each indicator species and each radionuclide. For example, the concentration of each radionuclide in water was set equal to 1 Bq/L, while the radionuclide concentrations in all other media were set equal to zero. The model calculated the dose received by each indicator species from a concentration of 1 Bq/L of each radionuclide. Similar unit dose calculations were carried out for groundwater, sediment and soil. These unit dose calculations were used to calculate the NEC values, as shown in Section 6.

Section 5.1 summarizes the dose calculations for the Upper Estimate case, for all biota and ecosystems. Section 5.2 summarizes the dose calculations for the Central Estimate case, for all biota and ecosystems.

5.1 Upper Estimate Dose Calculations

The tables below summarize the unit dose calculations for the Upper Estimate case, for all indicator species, as follows:

- Table 11 shows the doses calculated with water concentrations set to 1 Bq/L and concentrations in all other media set to zero;
- Table 12 shows doses calculated with soil concentrations set to 1 Bq/kg and concentrations in all other media set to zero;
- Table 13 shows doses calculated with sediment concentrations set to 1 Bq/kg and concentrations in all other media set to zero; and
- Table 14 shows doses calculated with groundwater concentrations set to 1 Bq/L and concentrations in all other media set to zero.

Table 11: Unit Doses (in mGy/day) Calculated with Water Concentration set to 1 Bq/L (All other Concentrations set to Zero) – Upper Estimate

Receptor Category:	Fish		Benthos	Aq. Plants	Amphibians	Terr. Invertebrates		Terrestrial Plants			Terrestrial Birds				Aq. Birds
Indicator Species:	**Fish (pelagic)**	**Fish (benthic)**	**Benthos**	**Aq. Plants**	**Frog**	**Worm (soil)**	**Worm (gw)**	**Berries**	**Plants**	**Lichen**	**Crow**	**Goose**	**Grouse or Ptarmigan**	**Turkey**	**Loon**
C-14	8.56E-01	8.56E-01	0.00E+00	7.71E-02	3.42E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.37E-05	3.41E-05	6.12E-06	1.35E-05	1.18E-05	3.72E+01
Cl-36	9.52E-02	9.52E-02	0.00E+00	4.76E-03	3.81E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.32E-04	2.69E-06	2.06E-06	4.56E-06	3.98E-06	2.51E-01
Zr-93	2.04E-03	2.04E-03	0.00E+00	3.40E-02	8.15E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	9.39E-06	2.97E-11	2.28E-11	5.04E-11	4.40E-11	8.31E-07
Nb-94	7.23E-01	7.23E-01	0.00E+00	3.01E-01	4.18E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	8.33E-04	6.94E-08	6.73E-08	1.49E-07	1.30E-07	9.84E-03
Tc-99	1.05E-03	1.05E-03	0.00E+00	1.75E-01	4.23E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.84E-05	1.62E-08	1.56E-08	3.46E-08	3.02E-08	5.74E-05
I-129	3.83E-03	3.82E-03	0.00E+00	9.16E-03	1.53E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.22E-05	1.68E-05	5.24E-06	1.16E-05	1.01E-05	7.98E-02
Cs-135	6.18E-01	6.18E-01	0.00E+00	9.42E-02	8.13E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.23E-05	1.18E-02	1.46E-04	3.23E-04	2.82E-04	4.70E+02
Ra-226	3.37E+00	3.37E+00	0.00E+00	2.02E+03	1.35E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	9.31E-02	4.49E-04	4.06E-04	8.98E-04	7.85E-04	2.47E+00
Np-237	1.03E+01	1.03E+01	0.00E+00	2.05E+01	4.75E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	9.46E-02	3.25E-05	3.14E-05	6.94E-05	6.06E-05	5.73E-01
U-238	1.43E+00	1.43E+00	0.00E+00	6.45E+01	5.73E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	9.90E-02	9.04E-03	4.80E-03	1.06E-02	9.29E-03	1.17E+01
Pb-210	1.50E-02	1.50E-02	0.00E+00	3.00E-01	1.50E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.07E-04	5.13E-05	1.92E-05	4.26E-05	3.72E-05	2.34E-01
Po-210	2.99E+01	2.99E+01	0.00E+00	3.37E+01	2.99E+01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.03E-01	2.59E-05	2.51E-05	1.39E-06	4.85E-05	1.22E+00
Total Dose (mGy/d)	4.73E+01	4.73E+01	0.00E+00	2.14E+03	3.07E+01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.91E-01	2.14E-02	5.44E-03	1.20E-02	1.05E-02	5.24E+02
Relevant Ecosystem(s)	SD	SD,BF,IT	SD,BF,IT	SD,BF	SD,BF	SD, BF	SD, BF	IT	SD,BF,IT	IT	SD	IT	BF,IT	SD	BF

Receptor Category:	Terrestrial Mammals								Aq. Mammals
Indicator Species:	**Fox**	**Hare**	**Caribou**	**Beaver**	**Wolf**	**Groundhog**	**Moose**	**Deer**	**Muskrat**
C-14	2.34E-04	1.27E-05	2.66E-04	1.40E+00	3.69E+00	1.27E-05	5.13E-01	2.41E-05	4.16E+00
Cl-36	1.54E-03	8.86E-05	1.85E-03	1.08E-01	3.59E-01	8.86E-05	3.98E-02	1.67E-04	3.21E-01
Zr-93	7.93E-06	1.58E-06	3.30E-05	1.93E-01	1.59E-01	1.58E-06	7.07E-02	2.98E-06	5.73E-01
Nb-94	8.97E-02	1.75E-03	3.66E-02	2.14E+01	2.20E+02	1.75E-03	7.84E+00	3.31E-03	6.35E+01
Tc-99	9.42E-06	3.47E-06	7.25E-05	4.24E-01	1.48E-01	3.47E-06	1.55E-01	6.55E-06	1.26E+00
I-129	1.59E-04	1.42E-05	2.97E-04	1.04E-01	1.72E-01	1.42E-05	3.82E-02	2.68E-05	3.09E-01
Cs-135	1.23E-03	1.36E-05	2.84E-04	1.33E+00	2.73E+00	1.36E-05	4.86E-01	2.56E-05	3.94E+00
Ra-226	1.00E-03	7.84E-04	1.64E-02	5.75E+02	2.36E+01	7.84E-04	2.10E+02	1.48E-03	1.71E+03
Np-237	9.61E-04	7.97E-04	1.67E-02	5.85E+00	2.41E-01	7.97E-04	2.14E+00	1.50E-03	1.73E+01
U-238	1.34E-03	6.67E-04	1.39E-02	1.47E+01	4.83E-01	6.67E-04	5.37E+00	1.26E-03	4.35E+01
Pb-210	3.90E-06	1.39E-06	2.91E-05	6.82E-02	1.73E-04	1.39E-06	1.92E-03	2.63E-06	2.02E-01
Po-210	8.73E-03	4.35E-03	9.09E-02	4.79E+01	7.66E-01	4.35E-03	1.35E+00	8.21E-03	1.42E+02
Total Dose (mGy/d)	1.05E-01	8.49E-03	1.77E-01	6.69E+02	2.52E+02	8.49E-03	2.28E+02	1.60E-02	1.98E+03
Relevant Ecosystem(s)	IT	IT	IT	BF	BF	SD	BF	SD	SD,BF

Notes:
SD: Southern Canadian Deciduous Forest Ecosystem
BF: Boreal Forest Ecosystem
IT: Inland Tundra Ecosystem
Zero dose values indicate species for which this medium is not an exposure pathway

Table 12: Unit Doses (in mGy/day) Calculated with Soil Concentration set to 1 Bq/kg (All other Concentrations set to Zero) – Upper Estimate

Receptor Category:	Fish		Benthos	Aq. Plants	Amphibians	Terr. Invertebrates		Terrestrial Plants			Terrestrial Birds				Aq. Birds
Indicator Species:	**Fish (pelagic)**	**Fish (benthic)**	**Benthos**	**Aq. Plants**	**Frog**	**Worm (soil)**	**Worm (gw)**	**Berries**	**Plants**	**Lichen**	**Crow**	**Goose**	**Grouse or Ptarmigan**	**Turkey**	**Loon**
C-14	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	7.88E-07	0.00E+00	4.28E-06	5.82E-06	2.01E-07	2.83E-03	3.72E-05	3.12E-04	2.49E-04	0.00E+00
Cl-36	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.95E-06	0.00E+00	2.00E-03	2.86E-03	1.12E-06	4.71E-03	1.24E-03	9.36E-04	8.30E-03	0.00E+00
Zr-93	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.08E-08	0.00E+00	2.04E-09	2.04E-07	7.98E-08	1.84E-08	1.41E-11	1.14E-10	9.76E-11	0.00E+00
Nb-94	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.06E-05	0.00E+00	3.15E-05	6.31E-05	7.08E-06	1.37E-05	1.36E-05	2.76E-05	2.75E-05	0.00E+00
Tc-99	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.39E-06	0.00E+00	1.69E-05	2.21E-03	4.11E-07	4.92E-05	2.03E-05	1.54E-04	1.33E-04	0.00E+00
I-129	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.28E-06	0.00E+00	1.55E-06	2.56E-06	3.59E-07	4.73E-05	5.69E-06	4.34E-05	3.95E-05	0.00E+00
Cs-135	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	9.07E-07	0.00E+00	2.31E-06	7.77E-06	2.74E-07	1.18E-01	8.80E-04	7.03E-03	5.92E-03	0.00E+00
Ra-226	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.43E-04	0.00E+00	3.42E-04	4.08E-03	7.92E-04	1.31E-03	5.15E-04	3.99E-03	3.41E-03	0.00E+00
Np-237	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.18E-04	0.00E+00	2.12E-04	2.26E-02	8.04E-04	5.18E-04	2.11E-04	1.62E-03	1.40E-03	0.00E+00
U-238	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.43E-04	0.00E+00	9.86E-05	2.16E-03	8.42E-04	1.14E-02	2.99E-03	2.41E-02	2.06E-02	0.00E+00
Pb-210	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	6.93E-06	0.00E+00	6.64E-06	2.10E-05	1.76E-06	1.46E-04	4.19E-05	1.66E-04	2.69E-04	0.00E+00
Po-210	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.49E-04	0.00E+00	7.48E-05	7.48E-03	8.78E-04	1.33E-04	5.06E-05	5.29E-06	3.43E-04	0.00E+00
Total Dose (mGy/d)	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.80E-03	0.00E+00	2.79E-03	4.15E-02	3.33E-03	1.39E-01	6.00E-03	3.84E-02	4.07E-02	0.00E+00
Relevant Ecosystem(s)	SD	SD,BF,IT	SD,BF,IT	SD,BF	SD,BF	SD, BF	SD, BF	IT	SD,BF,IT	IT	SD	IT	BF,IT	SD	BF

Receptor Category:	Terrestrial Mammals								Aq. Mammals
Indicator Species:	**Fox**	**Hare**	**Caribou**	**Beaver**	**Wolf**	**Groundhog**	**Moose**	**Deer**	**Muskrat**
C-14	4.18E-03	2.23E-04	2.12E-05	2.18E-04	3.06E-03	2.29E-04	1.38E-04	2.90E-04	0.00E+00
Cl-36	2.47E+00	1.54E-01	1.28E-02	1.52E-01	2.66E+00	1.59E-01	9.51E-02	2.01E-01	0.00E+00
Zr-93	1.05E-05	2.62E-06	5.32E-07	2.71E-06	1.19E-05	2.89E-06	1.70E-06	3.62E-06	0.00E+00
Nb-94	2.91E-01	5.84E-03	8.56E-04	6.00E-03	3.30E-01	6.37E-03	3.79E-03	8.01E-03	0.00E+00
Tc-99	2.02E-02	1.17E-02	1.05E-03	1.25E-02	2.33E-02	1.30E-02	7.82E-03	1.65E-02	0.00E+00
I-129	4.24E-04	3.97E-05	6.56E-06	3.89E-05	3.43E-04	4.23E-05	2.55E-05	5.30E-05	0.00E+00
Cs-135	2.58E-02	2.26E-04	2.26E-05	2.33E-04	2.55E-03	2.44E-04	1.47E-04	3.09E-04	0.00E+00
Ra-226	8.27E-04	2.62E-03	3.96E-04	2.68E-03	6.05E-04	2.87E-03	1.72E-03	3.61E-03	0.00E+00
Np-237	2.96E-03	1.42E-02	1.42E-03	1.50E-02	3.30E-03	1.57E-02	9.41E-03	1.99E-02	0.00E+00
U-238	1.49E-03	1.12E-03	2.31E-04	1.14E-03	2.09E-04	1.23E-03	7.28E-04	1.54E-03	0.00E+00
Pb-210	1.60E-05	1.36E-05	3.95E-06	2.30E-05	2.47E-06	1.44E-05	6.11E-06	1.66E-05	0.00E+00
Po-210	2.38E-02	2.36E-02	2.93E-03	2.48E-02	1.87E-02	2.61E-02	2.44E-04	3.30E-02	0.00E+00
Total Dose (mGy/d)	2.85E+00	2.13E-01	1.97E-02	2.14E-01	3.04E+00	2.24E-01	1.19E-01	2.84E-01	0.00E+00
Relevant Ecosystem(s)	IT	IT	IT	BF	BF	SD	BF	SD	SD,BF

Notes:
SD: Southern Canadian Deciduous Forest Ecosystem
BF: Boreal Forest Ecosystem
IT: Inland Tundra Ecosystem
Zero dose values indicate species for which this medium is not an exposure pathway

Table 13: Unit Doses (in mGy/day) Calculated with Sediment Concentration set to 1 Bq/kg (All other Concentrations set to Zero) – Upper Estimate

Receptor Category:	Fish		Benthos	Aq. Plants	Amphibians	Terr. Invertebrates		Terrestrial Plants			Terrestrial Birds				Aq. Birds
Indicator Species:	**Fish (pelagic)**	**Fish (benthic)**	**Benthos**	**Aq. Plants**	**Frog**	**Worm (soil)**	**Worm (gw)**	**Berries**	**Plants**	**Lichen**	**Crow**	**Goose**	**Grouse or Ptarmigan**	**Turkey**	**Loon**
C-14	0.00E+00	3.43E-08	3.15E-06	0.00E+00	3.43E-08	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	1.18E-07
Cl-36	0.00E+00	1.23E-07	1.76E-05	0.00E+00	1.23E-07	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	3.98E-08
Zr-93	0.00E+00	1.19E-07	1.36E-09	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	4.40E-13
Nb-94	0.00E+00	1.35E-06	2.82E-06	0.00E+00	1.35E-06	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	1.30E-09
Tc-99	0.00E+00	5.90E-08	8.18E-07	0.00E+00	5.90E-08	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	3.02E-10
I-129	0.00E+00	5.49E-08	7.21E-07	0.00E+00	5.49E-08	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	1.01E-07
Cs-135	0.00E+00	3.84E-08	9.54E-08	0.00E+00	3.84E-08	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	2.82E-06
Ra-226	0.00E+00	1.92E-06	5.40E-03	0.00E+00	1.92E-06	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	7.85E-06
Np-237	0.00E+00	3.50E-07	4.71E-03	0.00E+00	3.50E-07	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	6.06E-07
U-238	0.00E+00	6.30E-07	9.56E-06	0.00E+00	6.30E-07	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	9.29E-05
Pb-210	0.00E+00	3.02E-07	8.00E-04	0.00E+00	3.02E-07	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	3.72E-07
Po-210	0.00E+00	7.07E-12	7.48E-06	0.00E+00	7.07E-12	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	4.85E-07
Total Dose (mGy/d)	0.00E+00	4.98E-06	1.10E-02	0.00E+00	4.86E-06	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	1.05E-04
Relevant Ecosystem(s)	SD	SD,BF,IT	SD,BF,IT	SD,BF	SD,BF	SD, BF	SD, BF	IT	SD,BF,IT	IT	SD	IT	BF,IT	SD	BF

Receptor Category:	Terrestrial Mammals								Aq. Mammals
Indicator Species:	**Fox**	**Hare**	**Caribou**	**Beaver**	**Wolf**	**Groundhog**	**Moose**	**Deer**	**Muskrat**
C-14	0.00E+00	0.00E+00	0.00E+00	5.89E-07	9.97E-07	0.00E+00	1.39E-07	0.00E+00	3.52E-06
Cl-36	0.00E+00	0.00E+00	0.00E+00	3.87E-06	8.66E-06	0.00E+00	9.65E-07	0.00E+00	2.44E-05
Zr-93	0.00E+00	0.00E+00	0.00E+00	6.46E-08	3.86E-08	0.00E+00	1.72E-08	0.00E+00	3.59E-09
Nb-94	0.00E+00	0.00E+00	0.00E+00	7.43E-05	5.36E-04	0.00E+00	1.91E-05	0.00E+00	3.89E-05
Tc-99	0.00E+00	0.00E+00	0.00E+00	2.60E-07	3.61E-08	0.00E+00	3.78E-08	0.00E+00	3.36E-07
I-129	0.00E+00	0.00E+00	0.00E+00	6.91E-07	6.95E-07	0.00E+00	1.55E-07	0.00E+00	8.55E-07
Cs-135	0.00E+00	0.00E+00	0.00E+00	6.32E-07	8.30E-07	0.00E+00	1.48E-07	0.00E+00	3.92E-07
Ra-226	0.00E+00	0.00E+00	0.00E+00	3.59E-05	9.58E-07	0.00E+00	8.54E-06	0.00E+00	9.98E-05
Np-237	0.00E+00	0.00E+00	0.00E+00	3.33E-05	9.74E-07	0.00E+00	8.68E-06	0.00E+00	9.79E-05
U-238	0.00E+00	0.00E+00	0.00E+00	2.85E-05	6.52E-07	0.00E+00	7.26E-06	0.00E+00	1.51E-05
Pb-210	0.00E+00	0.00E+00	0.00E+00	6.61E-07	1.36E-09	0.00E+00	1.52E-08	0.00E+00	1.19E-05
Po-210	0.00E+00	0.00E+00	0.00E+00	1.78E-04	2.66E-05	0.00E+00	4.74E-05	0.00E+00	9.23E-06
Total Dose (mGy/d)	0.00E+00	0.00E+00	0.00E+00	3.57E-04	5.76E-04	0.00E+00	9.24E-05	0.00E+00	3.02E-04
Relevant Ecosystem(s)	IT	IT	IT	BF	BF	SD	BF	SD	SD,BF

Notes:
SD: Southern Canadian Deciduous Forest Ecosystem
BF: Boreal Forest Ecosystem
IT: Inland Tundra Ecosystem
Zero dose values indicate species for which this medium is not an exposure pathway

Table 14: Unit Doses (in mGy/day) Calculated with Groundwater Concentration set to 1 Bq/L (All other Concentrations set to Zero) – Upper Estimate

Receptor Category:	Fish		Benthos	Aq. Plants	Amphibians	Terr. Invertebrates		Terrestrial Plants			Terrestrial Birds				Aq. Birds
Indicator Species:	**Fish (pelagic)**	**Fish (benthic)**	**Benthos**	**Aq. Plants**	**Frog**	**Worm (soil)**	**Worm (gw)**	**Berries**	**Plants**	**Lichen**	**Crow**	**Goose**	**Grouse or Ptarmigan**	**Turkey**	**Loon**
C-14	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.01E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Cl-36	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.40E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Zr-93	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.72E-07	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-94	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.47E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Tc-99	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.98E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
I-129	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.77E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Cs-135	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	7.30E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ra-226	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.72E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Np-237	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.74E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
U-238	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.87E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Pb-210	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	9.01E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Po-210	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.99E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Total Dose (mGy/d)	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.21E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Relevant Ecosystem(s)	SD	SD,BF,IT	SD,BF,IT	SD,BF	SD,BF	SD, BF	SD, BF	IT	SD,BF,IT	IT	SD	IT	BF,IT	SD	BF

Receptor Category:	Terrestrial Mammals								Aq. Mammals
Indicator Species:	**Fox**	**Hare**	**Caribou**	**Beaver**	**Wolf**	**Groundhog**	**Moose**	**Deer**	**Muskrat**
C-14	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
Cl-36	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
Zr-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
Nb-94	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
Tc-99	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
I-129	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
Cs-135	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
Ra-226	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
Np-237	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
U-238	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
Pb-210	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
Po-210	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
Total Dose (mGy/d)	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
Relevant Ecosystem(s)	IT	IT	IT	BF	BF	SD	BF	SD	SD,BF

Notes:
SD: Southern Canadian Deciduous Forest Ecosystem
BF: Boreal Forest Ecosystem
IT: Inland Tundra Ecosystem
Zero dose values indicate species for which this medium is not an exposure pathway

5.2 Central Estimate Dose Calculations

The tables below summarize the unit dose calculations for the Central Estimate case, for all indicator species, as follows:

- Table 15 shows the doses calculated with water concentrations set to 1 Bq/L and concentrations in all other media set to zero;
- Table 16 shows doses calculated with soil concentrations set to 1 Bq/kg and concentrations in all other media set to zero;
- Table 17 shows doses calculated with sediment concentrations set to 1 Bq/kg and concentrations in all other media set to zero; and
- Table 18 shows doses calculated with groundwater concentrations set to 1 Bq/L and concentrations in all other media set to zero.

Table 15: Unit Doses (in mGy/day) Calculated with Water Concentration set to 1 Bq/L (All other Concentrations set to Zero) – Central Estimate

Receptor Category:	Fish		Benthos	Aq. Plants	Amphibians	Terr. Invertebrates		Terrestrial Plants			Terrestrial Birds				Aq. Birds
Indicator Species:	**Fish (pelagic)**	**Fish (benthic)**	**Benthos**	**Aq. Plants**	**Frog**	**Worm (soil)**	**Worm (gw)**	**Berries**	**Plants**	**Lichen**	**Crow**	**Goose**	**Grouse/ Ptarmigan**	**Turkey**	**Loon**
C-14	3.42E-02	3.42E-02	0.00E+00	1.04E-02	3.42E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.37E-05	1.18E-09	1.15E-09	2.54E-09	2.22E-09	2.79E-04
Cl-36	3.81E-03	3.81E-03	0.00E+00	1.92E-04	3.81E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.32E-04	4.62E-07	4.25E-07	9.41E-07	8.22E-07	2.07E-03
Zr-93	8.15E-05	8.15E-05	0.00E+00	1.36E-03	8.15E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	9.39E-06	9.90E-13	9.11E-13	2.02E-12	1.76E-12	1.33E-09
Nb-94	4.18E-02	4.18E-02	0.00E+00	1.21E-02	4.18E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	8.33E-04	2.77E-09	2.69E-09	5.96E-09	5.21E-09	3.17E-05
Tc-99	4.22E-05	4.21E-05	0.00E+00	7.00E-03	4.21E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.84E-05	6.25E-09	6.06E-09	1.34E-08	1.17E-08	1.01E-06
I-129	1.53E-04	1.53E-04	0.00E+00	3.67E-04	1.53E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.22E-05	6.36E-07	5.12E-07	1.13E-06	9.90E-07	3.12E-04
Cs-135	2.54E-02	2.51E-02	0.00E+00	4.47E-03	8.13E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.23E-05	2.98E-03	7.31E-05	1.62E-04	1.41E-04	9.40E+00
Ra-226	6.74E-02	6.74E-02	0.00E+00	4.04E+01	6.74E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.66E-02	8.39E-06	8.12E-06	1.80E-05	1.57E-05	1.98E-03
Np-237	2.37E-01	2.37E-01	0.00E+00	4.11E-01	2.37E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.73E-02	1.58E-06	1.53E-06	3.39E-06	2.96E-06	1.29E-03
U-238	2.87E-02	2.87E-02	0.00E+00	1.29E+00	2.87E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.95E-02	1.02E-04	9.61E-05	2.13E-04	1.86E-04	9.45E-03
Pb-210	1.80E-03	1.80E-03	0.00E+00	1.20E-02	1.80E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.07E-04	2.82E-07	2.68E-07	5.92E-07	5.18E-07	3.92E-04
Po-210	1.50E-01	1.50E-01	0.00E+00	2.99E+00	1.50E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.17E-02	2.10E-04	1.92E-04	2.13E-05	3.71E-04	9.37E-02
Total Dose (mGy/d)	5.90E-01	5.90E-01	0.00E+00	4.52E+01	5.66E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.96E-01	3.31E-03	3.72E-04	4.20E-04	7.19E-04	9.51E+00
Relevant Ecosystem(s)	SD	SD,BF,IT	SD,BF,IT	SD,BF	SD,BF	SD, BF	SD, BF	IT	SD,BF,IT	IT	SD	IT	BF,IT	SD	BF

Receptor Category:	Terrestrial Mammals								Aq. Mammals
Indicator Species:	**Fox**	**Hare**	**Caribou**	**Beaver**	**Wolf**	**Groundhog**	**Moose**	**Deer**	**Muskrat**
C-14	7.72E-07	5.10E-07	1.07E-05	7.56E-03	7.95E-04	5.10E-07	2.77E-03	9.63E-07	2.24E-02
Cl-36	6.02E-06	3.54E-06	7.41E-05	1.79E-04	2.97E-05	3.54E-06	7.19E-05	6.69E-06	5.18E-04
Zr-93	7.34E-08	6.32E-08	1.32E-06	3.09E-04	1.02E-05	6.32E-08	1.13E-04	1.19E-07	9.17E-04
Nb-94	2.11E-04	7.01E-05	1.47E-03	3.44E-02	1.44E-02	7.01E-05	1.27E-02	1.32E-04	1.02E-01
Tc-99	1.48E-07	1.38E-07	2.89E-06	6.77E-04	9.53E-06	1.38E-07	2.48E-04	2.61E-07	2.01E-03
I-129	8.72E-07	5.69E-07	1.19E-05	1.68E-04	1.16E-05	5.69E-07	6.24E-05	1.07E-06	4.96E-04
Cs-135	2.24E-05	5.43E-07	1.14E-05	2.13E-03	1.75E-04	5.43E-07	7.79E-04	1.03E-06	6.53E-03
Ra-226	2.52E-05	2.48E-05	5.18E-04	7.28E-01	1.90E-03	2.48E-05	2.66E-01	4.68E-05	2.16E+00
Np-237	1.61E-05	1.59E-05	3.33E-04	4.70E-03	1.45E-05	1.59E-05	1.75E-03	3.01E-05	1.39E-02
U-238	1.39E-05	1.33E-05	2.79E-04	1.18E-02	2.11E-05	1.33E-05	4.33E-03	2.52E-05	3.48E-02
Pb-210	5.74E-08	5.58E-08	1.17E-06	1.09E-04	3.46E-08	5.58E-08	3.19E-06	1.05E-07	3.24E-04
Po-210	9.62E-05	8.70E-05	1.82E-03	1.70E-01	1.51E-04	8.70E-05	4.98E-03	1.64E-04	5.05E-01
Total Dose (mGy/d)	3.92E-04	2.17E-04	4.53E-03	9.60E-01	1.76E-02	2.17E-04	2.94E-01	4.09E-04	2.85E+00
Relevant Ecosystem(s)	IT	IT	IT	BF	BF	SD	BF	SD	SD,BF

Notes:
SD: Southern Canadian Deciduous Forest Ecosystem
BF: Boreal Forest Ecosystem
IT: Inland Tundra Ecosystem
Zero dose values indicate species for which this medium is not an exposure pathway

Table 16: Unit Doses (in mGy/day) Calculated with Soil Concentration set to 1 Bq/kg (All other Concentrations set to Zero) – Central Estimate

Receptor Category:	Fish		Benthos	Aq. Plants	Amphibians	Terr. Invertebrates		Terrestrial Plants			Terrestrial Birds				Aq. Birds
Indicator Species:	**Fish (pelagic)**	**Fish (benthic)**	**Benthos**	**Aq. Plants**	**Frog**	**Worm (soil)**	**Worm (gw)**	**Berries**	**Plants**	**Lichen**	**Crow**	**Goose**	**Grouse/ Ptarmigan**	**Turkey**	**Loon**
C-14	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.30E-07	0.00E+00	1.71E-07	2.32E-07	2.01E-07	1.42E-08	1.37E-08	2.95E-08	2.89E-08	0.00E+00
Cl-36	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.95E-06	0.00E+00	8.24E-05	1.17E-04	1.12E-06	2.93E-05	1.14E-05	1.02E-05	7.10E-05	0.00E+00
Zr-93	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.08E-08	0.00E+00	8.15E-11	8.15E-09	7.98E-08	6.21E-12	4.07E-14	4.87E-13	3.81E-13	0.00E+00
Nb-94	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.06E-05	0.00E+00	2.71E-05	2.84E-05	7.08E-06	1.35E-05	1.35E-05	2.70E-05	2.70E-05	0.00E+00
Tc-99	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.63E-07	0.00E+00	9.83E-07	8.86E-05	4.11E-07	9.32E-07	4.82E-07	2.72E-06	2.40E-06	0.00E+00
I-129	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	6.74E-07	0.00E+00	5.09E-07	5.49E-07	3.59E-07	5.65E-07	2.75E-07	8.27E-07	7.23E-07	0.00E+00
Cs-135	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.49E-07	0.00E+00	1.71E-07	3.90E-07	2.74E-07	3.30E-03	1.91E-05	1.65E-04	1.37E-04	0.00E+00
Ra-226	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.02E-04	0.00E+00	6.20E-06	8.10E-05	3.96E-04	2.00E-06	6.23E-07	6.01E-06	4.84E-06	0.00E+00
Np-237	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.06E-04	0.00E+00	4.75E-06	4.53E-04	4.02E-04	1.50E-06	7.56E-07	4.31E-06	3.75E-06	0.00E+00
U-238	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.23E-04	0.00E+00	1.01E-05	5.14E-05	4.21E-04	2.36E-05	8.50E-06	5.98E-05	4.86E-05	0.00E+00
Pb-210	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.40E-06	0.00E+00	2.52E-06	3.10E-06	1.76E-06	1.40E-06	1.28E-06	1.38E-06	2.71E-06	0.00E+00
Po-210	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.24E-04	0.00E+00	1.50E-06	1.50E-04	4.39E-04	1.15E-04	1.93E-05	4.49E-06	1.53E-04	0.00E+00
Total Dose (mGy/d)	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	8.95E-04	0.00E+00	1.36E-04	9.73E-04	1.67E-03	3.49E-03	7.53E-05	2.82E-04	4.50E-04	0.00E+00
Relevant Ecosystem(s)	SD	SD,BF,IT	SD,BF,IT	SD,BF	SD,BF	SD, BF	SD, BF	IT	SD,BF,IT	IT	SD	IT	BF,IT	SD	BF

Receptor Category:	Terrestrial Mammals								Aq. Mammals
Indicator Species:	**Fox**	**Hare**	**Caribou**	**Beaver**	**Wolf**	**Groundhog**	**Moose**	**Deer**	**Muskrat**
C-14	2.25E-07	4.05E-07	1.41E-07	3.49E-07	2.09E-07	4.11E-07	2.46E-07	4.99E-07	0.00E+00
Cl-36	1.62E-04	2.49E-04	2.23E-05	2.43E-04	1.71E-04	2.56E-04	1.55E-04	3.24E-04	0.00E+00
Zr-93	1.61E-09	7.03E-09	1.25E-08	4.33E-09	1.27E-09	6.85E-09	2.71E-09	6.90E-09	0.00E+00
Nb-94	5.24E-05	3.94E-05	2.78E-05	9.60E-06	2.97E-05	3.96E-05	3.30E-05	4.10E-05	0.00E+00
Tc-99	1.69E-06	1.91E-05	1.88E-06	1.99E-05	1.57E-06	2.12E-05	1.28E-05	2.67E-05	0.00E+00
I-129	5.59E-07	5.78E-07	3.60E-07	6.23E-08	1.50E-07	5.76E-07	5.29E-07	5.83E-07	0.00E+00
Cs-135	2.23E-05	4.93E-07	1.91E-07	3.72E-07	1.96E-07	5.18E-07	3.43E-07	6.13E-07	0.00E+00
Ra-226	4.02E-07	4.51E-06	5.12E-06	3.40E-06	2.43E-07	4.59E-06	2.26E-06	5.09E-06	0.00E+00
Np-237	8.70E-07	1.27E-05	4.40E-06	1.20E-05	3.70E-07	1.38E-05	8.17E-06	1.68E-05	0.00E+00
U-238	8.63E-06	9.90E-06	6.85E-06	9.13E-07	2.20E-06	9.85E-06	8.98E-06	9.86E-06	0.00E+00
Pb-210	2.50E-06	2.51E-06	1.26E-06	2.63E-07	6.25E-07	2.51E-06	2.50E-06	2.52E-06	0.00E+00
Po-210	2.78E-06	2.28E-05	1.84E-05	1.99E-05	1.19E-06	2.40E-05	1.95E-07	2.79E-05	0.00E+00
Total Dose (mGy/d)	2.55E-04	3.61E-04	8.87E-05	3.09E-04	2.07E-04	3.73E-04	2.24E-04	4.56E-04	0.00E+00
Relevant Ecosystem(s)	IT	IT	IT	BF	BF	SD	BF	SD	SD,BF

Notes:
SD: Southern Canadian Deciduous Forest Ecosystem
BF: Boreal Forest Ecosystem
IT: Inland Tundra Ecosystem
Zero dose values indicate species for which this medium is not an exposure pathway

Table 17: Unit Doses (in mGy/day) Calculated with Sediment Concentration set to 1 Bq/kg (All other Concentrations set to Zero) – Central Estimate

Receptor Category:	Fish		Benthos	Aq. Plants	Amphibians	Terr. Invertebrates		Terrestrial Plants			Terrestrial Birds				Aq. Birds
Indicator Species:	**Fish (pelagic)**	**Fish (benthic)**	**Benthos**	**Aq. Plants**	**Frog**	**Worm (soil)**	**Worm (gw)**	**Berries**	**Plants**	**Lichen**	**Crow**	**Goose**	**Grouse/ Ptarmigan**	**Turkey**	**Loon**
C-14	0.00E+00	1.34E-09	3.08E-06	0.00E+00	1.34E-09	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	2.22E-11
Cl-36	0.00E+00	2.16E-07	1.77E-05	0.00E+00	2.16E-07	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	8.22E-09
Zr-93	0.00E+00	1.19E-07	1.36E-09	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	1.76E-14
Nb-94	0.00E+00	1.35E-06	2.82E-06	0.00E+00	1.35E-06	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	5.21E-11
Tc-99	0.00E+00	1.85E-08	7.37E-07	0.00E+00	1.85E-08	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	1.17E-10
I-129	0.00E+00	2.50E-08	3.38E-07	0.00E+00	2.50E-08	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	9.90E-09
Cs-135	0.00E+00	5.47E-09	3.83E-08	0.00E+00	5.47E-09	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	1.41E-06
Ra-226	0.00E+00	6.69E-09	2.70E-03	0.00E+00	6.69E-09	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	1.57E-07
Np-237	0.00E+00	3.32E-08	1.59E-04	0.00E+00	3.32E-08	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	2.96E-08
U-238	0.00E+00	4.21E-07	4.78E-06	0.00E+00	4.21E-07	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	1.86E-06
Pb-210	0.00E+00	1.29E-07	1.14E-05	0.00E+00	1.29E-07	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	5.18E-09
Po-210	0.00E+00	7.49E-12	1.99E-01	0.00E+00	7.49E-12	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	3.72E-06
Total Dose (mGy/d)	0.00E+00	2.32E-06	2.02E-01	0.00E+00	2.21E-06	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	7.19E-06
Relevant Ecosystem(s)	SD	SD,BF,IT	SD,BF,IT	SD,BF	SD,BF	SD, BF	SD, BF	IT	SD,BF,IT	IT	SD	IT	BF,IT	SD	BF

Receptor Category:	Terrestrial Mammals								Aq. Mammals
Indicator Species:	**Fox**	**Hare**	**Caribou**	**Beaver**	**Wolf**	**Groundhog**	**Moose**	**Deer**	**Muskrat**
C-14	0.00E+00	0.00E+00	0.00E+00	2.35E-08	1.60E-09	0.00E+00	5.55E-09	0.00E+00	1.41E-07
Cl-36	0.00E+00	0.00E+00	0.00E+00	5.78E-07	1.39E-08	0.00E+00	3.86E-08	0.00E+00	1.57E-06
Zr-93	0.00E+00	0.00E+00	0.00E+00	2.58E-09	6.18E-11	0.00E+00	6.88E-10	0.00E+00	1.44E-10
Nb-94	0.00E+00	0.00E+00	0.00E+00	5.56E-06	8.57E-07	0.00E+00	7.63E-07	0.00E+00	5.18E-06
Tc-99	0.00E+00	0.00E+00	0.00E+00	4.26E-08	5.75E-11	0.00E+00	1.51E-09	0.00E+00	5.85E-08
I-129	0.00E+00	0.00E+00	0.00E+00	7.33E-08	1.11E-09	0.00E+00	6.19E-09	0.00E+00	8.93E-08
Cs-135	0.00E+00	0.00E+00	0.00E+00	3.31E-08	1.33E-09	0.00E+00	5.92E-09	0.00E+00	2.70E-08
Ra-226	0.00E+00	0.00E+00	0.00E+00	1.03E-06	1.92E-09	0.00E+00	2.70E-07	0.00E+00	3.00E-06
Np-237	0.00E+00	0.00E+00	0.00E+00	7.18E-07	7.79E-10	0.00E+00	1.74E-07	0.00E+00	5.17E-07
U-238	0.00E+00	0.00E+00	0.00E+00	1.39E-06	5.22E-10	0.00E+00	1.45E-07	0.00E+00	1.44E-06
Pb-210	0.00E+00	0.00E+00	0.00E+00	2.61E-07	2.18E-12	0.00E+00	6.07E-10	0.00E+00	3.69E-07
Po-210	0.00E+00	0.00E+00	0.00E+00	3.56E-06	2.13E-08	0.00E+00	9.47E-07	0.00E+00	6.87E-04
Total Dose (mGy/d)	0.00E+00	0.00E+00	0.00E+00	1.33E-05	9.00E-07	0.00E+00	2.36E-06	0.00E+00	6.99E-04
Relevant Ecosystem(s)	IT	IT	IT	BF	BF	SD	BF	SD	SD,BF

Notes:
SD: Southern Canadian Deciduous Forest Ecosystem
BF: Boreal Forest Ecosystem
IT: Inland Tundra Ecosystem
Zero dose values indicate species for which this medium is not an exposure pathway

Table 18: Unit Doses (in mGy/day) Calculated with Groundwater Concentration set to 1 Bq/L (All other Concentrations set to Zero) – Central Estimate

Receptor Category:	Fish		Benthos	Aq. Plants	Amphibians	Terr. Invertebrates		Terrestrial Plants			Terrestrial Birds				Aq. Birds
Indicator Species:	**Fish (pelagic)**	**Fish (benthic)**	**Benthos**	**Aq. Plants**	**Frog**	**Worm (soil)**	**Worm (gw)**	**Berries**	**Plants**	**Lichen**	**Crow**	**Goose**	**Grouse or Ptarmigan**	**Turkey**	**Loon**
C-14	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	7.03E-07	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Cl-36	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.40E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Zr-93	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.72E-07	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-94	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.21E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Tc-99	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.64E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
I-129	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.55E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Cs-135	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	7.30E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ra-226	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.35E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Np-237	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.37E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
U-238	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.44E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Pb-210	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	7.66E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Po-210	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.50E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Total Dose (mGy/d)	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	6.44E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Relevant Ecosystem(s)	SD	SD,BF,IT	SD,BF,IT	SD,BF	SD,BF	SD, BF	SD, BF	IT	SD,BF,IT	IT	SD	IT	BF,IT	SD	BF

Receptor Category:	Terrestrial Mammals								Aq. Mammals
Indicator Species:	**Fox**	**Hare**	**Caribou**	**Beaver**	**Wolf**	**Groundhog**	**Moose**	**Deer**	**Muskrat**
C-14	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
Cl-36	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
Zr-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
Nb-94	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
Tc-99	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
I-129	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
Cs-135	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
Ra-226	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
Np-237	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
U-238	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
Pb-210	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
Po-210	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
Total Dose (mGy/d)	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
Relevant Ecosystem(s)	IT	IT	IT	BF	BF	SD	BF	SD	SD,BF

Notes:
SD: Southern Canadian Deciduous Forest Ecosystem
BF: Boreal Forest Ecosystem
IT: Inland Tundra Ecosystem
Zero dose values indicate species for which this medium is not an exposure pathway

6. NECs

This section presents the NECs that were derived based on the unit dose calculations shown above.

6.1 NEC Approach and Results

NECs were derived for each radionuclide in each medium, using the methodology presented in Section 2 of this report.

For example, as seen in Table 18, the Central Estimate dose to an earthworm from a unit concentration of 1 Bq/L C-14 in groundwater is 7.03x10^{-7} mGy/day. As seen in Table 10, the selected Central Estimate ENEV for earthworms is 5.5 mGy/day. These values can be used to calculate the concentration at which the dose to the earthworm would correspond to the ENEV, as follows:

$$Concentration\ (worm, gw, C-14) = \frac{Unit\ Concentration \times ENEV}{Unit\ Dose}$$

$$Concentration\ (worm, gw, C-14) = \frac{1\frac{Bq}{L} \times 5.5\frac{mGy}{day}}{7.03 \times 10^{-7}\frac{mGy}{day}} = 7.8 \times 10^{6}\frac{Bq}{L}$$

Similar calculations were carried out for all biota and all radionuclides in all relevant media. For each ecosystem, only the relevant biota were selected. There may be cases in which combining the three ecosystems would be useful, such as for simplifying the results and recognizing uncertainties (e.g., variability in transfer factors). Therefore, NEC results for all biota are also presented, under an “All Ecosystems” category.

In each medium, the lowest concentration of each radionuclide was selected. This concentration is the NEC for that radionuclide and medium. The results are shown in Garisto et al. (2008, Addendum) and are summarized in the following tables.

Table 19 summarizes the Upper Estimate NECs calculated for each of the ecosystems, in each of the following media:

a) radionuclides in water;
b) radionuclides in soil;
c) radionuclides in sediment; and
d) radionuclides in groundwater.

Table 20 summarizes the Central Estimate NECs calculated for each of the ecosystems, in each of the following media:

a) radionuclides in water;
b) radionuclides in soil;
c) radionuclides in sediment; and
d) radionuclides in groundwater.

Table 19 (a) Upper Estimate NECs Calculated for Radionuclides in Water (Bq/L)

Ecosystem	C-14	Cl-36	Zr-93	Nb-94	Tc-99	I-129	Cs-135	Ra-226	Np-237	U-238	Pb-210	Po-210
S.Can. Dec. Forest	2.40E-01	3.11E+00	1.75E+00	1.57E-02	7.95E-01	3.23E+00	2.54E-01	5.86E-04	5.77E-02	2.30E-02	4.95E+00	7.04E-03
Boreal Forest	2.69E-02	2.78E+00	1.75E+00	4.54E-03	7.95E-01	3.23E+00	2.13E-03	5.86E-04	5.77E-02	2.30E-02	4.27E+00	7.04E-03
Inland Tundra	7.01E-01	6.30E+00	2.94E+02	8.30E-01	5.71E+02	1.57E+02	9.71E-01	1.78E-01	5.84E-02	4.19E-01	4.01E+01	2.01E-02
All Ecosystems	2.69E-02	2.78E+00	1.75E+00	4.54E-03	7.95E-01	3.23E+00	2.13E-03	5.86E-04	5.77E-02	2.30E-02	4.27E+00	7.04E-03

Table 19 (b) Upper Estimate NECs Calculated for Radionuclides in Soil (Bq/kg)

Ecosystem	C-14	Cl-36	Zr-93	Nb-94	Tc-99	I-129	Cs-135	Ra-226	Np-237	U-238	Pb-210	Po-210
S.Can. Dec. Forest	3.53E+02	4.97E+00	2.77E+05	1.25E+02	6.05E+01	1.89E+04	8.48E+00	2.77E+02	5.02E+01	4.85E+01	3.71E+03	3.03E+01
Boreal Forest	3.26E+02	3.76E-01	8.38E+04	3.03E+00	4.29E+01	2.92E+03	1.42E+02	2.51E+02	6.67E+01	4.15E+01	6.03E+03	4.03E+01
Inland Tundra	2.39E+02	4.04E-01	9.49E+04	3.43E+00	4.96E+01	2.36E+03	3.88E+01	2.51E+02	7.05E+01	4.15E+01	6.03E+03	4.21E+01
All Ecosystems	2.39E+02	3.76E-01	8.38E+04	3.03E+00	4.29E+01	2.36E+03	8.48E+00	2.51E+02	5.02E+01	4.15E+01	3.71E+03	3.03E+01

Table 19 (c) Upper Estimate NECs Calculated for Radionuclides in Sediment (Bq/kg)

Ecosystem	C-14	Cl-36	Zr-93	Nb-94	Tc-99	I-129	Cs-135	Ra-226	Np-237	U-238	Pb-210	Po-210
S.Can. Dec. Forest	2.84E+05	4.10E+04	5.04E+06	2.57E+04	2.97E+06	1.17E+06	2.55E+06	9.27E+02	1.06E+03	6.64E+04	6.25E+03	1.08E+05
Boreal Forest	2.84E+05	4.10E+04	5.04E+06	1.87E+03	2.97E+06	1.17E+06	3.54E+05	9.27E+02	1.06E+03	1.08E+04	6.25E+03	5.62E+03
Inland Tundra	1.59E+06	2.85E+05	5.04E+06	4.45E+05	6.11E+06	6.94E+06	1.56E+07	9.27E+02	1.06E+03	5.23E+05	6.25E+03	6.68E+05
All Ecosystems	2.84E+05	4.10E+04	5.04E+06	1.87E+03	2.97E+06	1.17E+06	3.54E+05	9.27E+02	1.06E+03	1.08E+04	6.25E+03	5.62E+03

Table 19(d) Upper Estimate NECs Calculated for Radionuclides in Groundwater (Bq/L)

Ecosystem	C-14	Cl-36	Zr-93	Nb-94	Tc-99	I-129	Cs-135	Ra-226	Np-237	U-238	Pb-210	Po-210
S.Can. Dec. Forest	1.58E+06	2.96E+05	5.89E+06	3.58E+04	8.10E+05	9.04E+05	2.19E+03	5.87E+02	5.83E+02	5.57E+02	1.78E+05	5.35E+02
Boreal Forest	1.58E+06	2.96E+05	5.89E+06	3.58E+04	8.10E+05	9.04E+05	2.19E+03	5.87E+02	5.83E+02	5.57E+02	1.78E+05	5.35E+02
All Ecosystems	1.58E+06	2.96E+05	5.89E+06	3.58E+04	8.10E+05	9.04E+05	2.19E+03	5.87E+02	5.83E+02	5.57E+02	1.78E+05	5.35E+02

Note: Groundwater exposure to biota is not considered in the Inland Tundra ecosystem.

Table 20 (a) Central Estimate NECs Calculated for Radionuclides in Water (Bq/L)

Ecosystem	C-14	Cl-36	Zr-93	Nb-94	Tc-99	I-129	Cs-135	Ra-226	Np-237	U-238	Pb-210	Po-210
S.Can. Dec. Forest	1.34E+02	1.31E+03	1.77E+03	2.95E+01	3.43E+02	6.05E+03	3.30E+02	5.93E-02	5.84E+00	1.86E+00	2.00E+02	8.02E-01
Boreal Forest	1.34E+02	4.83E+02	1.77E+03	2.95E+01	3.43E+02	3.20E+03	1.06E-01	5.93E-02	5.84E+00	1.86E+00	2.00E+02	8.02E-01
Inland Tundra	2.45E+02	2.21E+03	1.03E+05	2.01E+02	4.96E+04	5.49E+04	3.35E+02	5.15E+01	3.54E+01	4.85E+01	4.67E+03	4.64E+01
All Ecosystems	1.34E+02	4.83E+02	1.77E+03	2.95E+01	3.43E+02	3.20E+03	1.06E-01	5.93E-02	5.84E+00	1.86E+00	2.00E+02	8.02E-01

Table 20 (b) Central Estimate NECs Calculated for Radionuclides in Soil (Bq/kg)

Ecosystem	C-14	Cl-36	Zr-93	Nb-94	Tc-99	I-129	Cs-135	Ra-226	Np-237	U-238	Pb-210	Po-210
S.Can. Dec. Forest	6.01E+06	9.26E+03	1.35E+08	3.71E+04	2.71E+04	1.38E+06	3.03E+02	2.72E+04	5.30E+03	2.06E+04	3.69E+05	6.55E+03
Boreal Forest	8.59E+06	1.24E+04	1.35E+08	3.71E+04	2.71E+04	1.21E+06	6.06E+03	2.72E+04	5.30E+03	1.67E+04	7.27E+05	1.60E+04
Inland Tundra	5.86E+06	1.21E+04	3.01E+07	3.68E+04	2.71E+04	1.21E+06	6.06E+03	6.06E+03	5.30E+03	5.70E+03	3.96E+05	5.46E+03
All Ecosystems	5.86E+06	9.26E+03	3.01E+07	3.68E+04	2.71E+04	1.21E+06	3.03E+02	6.06E+03	5.30E+03	5.70E+03	3.69E+05	5.46E+03

Table 20 (c) Central Estimate NECs Calculated for Radionuclides in Sediment (Bq/kg)

Ecosystem	C-14	Cl-36	Zr-93	Nb-94	Tc-99	I-129	Cs-135	Ra-226	Np-237	U-238	Pb-210	Po-210
S.Can. Dec. Forest	1.78E+06	3.10E+05	7.05E+07	5.79E+05	7.46E+06	1.63E+07	1.11E+08	2.04E+03	3.45E+04	1.15E+06	4.84E+05	2.76E+01
Boreal Forest	1.78E+06	3.10E+05	7.05E+07	5.39E+05	7.46E+06	1.63E+07	7.08E+05	2.04E+03	3.45E+04	5.38E+05	4.84E+05	2.76E+01
Inland Tundra	1.78E+06	3.10E+05	7.05E+07	1.95E+06	7.46E+06	1.63E+07	1.44E+08	2.04E+03	3.45E+04	1.15E+06	4.84E+05	2.76E+01
All Ecosystems	1.78E+06	3.10E+05	7.05E+07	5.39E+05	7.46E+06	1.63E+07	7.08E+05	2.04E+03	3.45E+04	5.38E+05	4.84E+05	2.76E+01

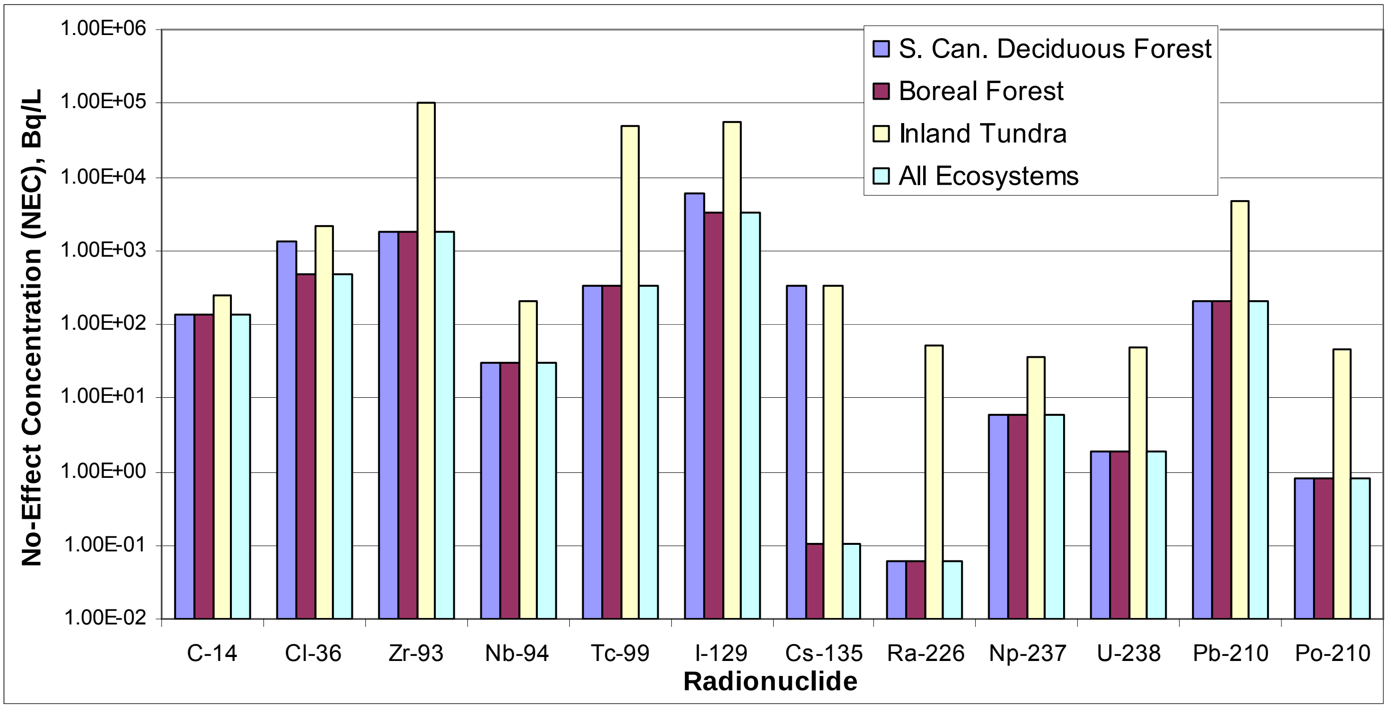
Table 20 (d) Central Estimate NECs Calculated for Radionuclides in Groundwater (Bq/L)

Ecosystem	C-14	Cl-36	Zr-93	Nb-94	Tc-99	I-129	Cs-135	Ra-226	Np-237	U-238	Pb-210	Po-210
S.Can. Dec. Forest	7.83E+06	1.02E+06	2.02E+07	1.31E+05	3.36E+06	3.55E+06	7.54E+03	4.08E+03	4.01E+03	3.82E+03	7.18E+05	**3.68E+03**
Boreal Forest	7.83E+06	1.02E+06	2.02E+07	1.31E+05	3.36E+06	3.55E+06	7.54E+03	4.08E+03	4.01E+03	3.82E+03	7.18E+05	**3.68E+03**
All Ecosystems	7.83E+06	1.02E+06	2.02E+07	1.31E+05	3.36E+06	3.55E+06	7.54E+03	4.08E+03	4.01E+03	3.82E+03	7.18E+05	3.68E+03

Note: Groundwater exposure to biota is not considered in the Inland Tundra ecosystem.

As seen in Tables 19 and 20, many of the calculated NECs are similar between ecosystems, mostly due to the presence of the same biota in multiple ecosystems.

The following figure illustrates an example of the differences between the NECs calculated for different ecosystems.



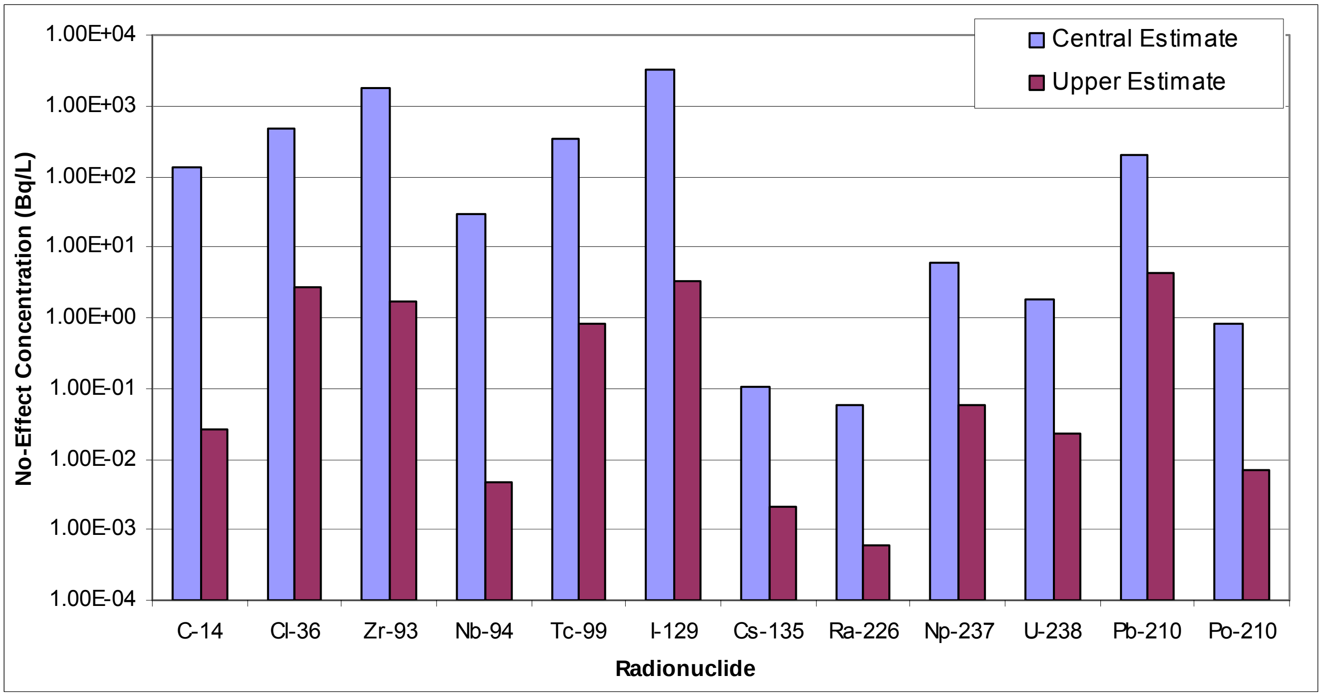
Notes:
Due to the wide range of values presented, the vertical axis in the above chart is shown on a logarithmic scale. The values shown above are Central Estimate NECs.

Figure 10: Comparison of Calculated NECs for Radionuclides in Water (Central Estimate) for Different Ecosystems

The figure shows that there are some differences in NECs between the different ecosystems. For example, the NEC calculated for Cs-135 is significantly lower (i.e., more restrictive) for the Boreal Forest ecosystem than for the other two ecosystems. This low NEC value can be attributed to the inclusion of the common loon in the Boreal Forest ecosystem. The loon, which is the most restrictive biota (for Cs-135 in water) in the Boreal Forest ecosystem is not included in the other two ecosystems. It also appears that the Inland Tundra provides higher (i.e., less restrictive) NECs than the other two ecosystems. This is likely due to the difference in and smaller number of indicator species in the Inland Tundra ecosystem.

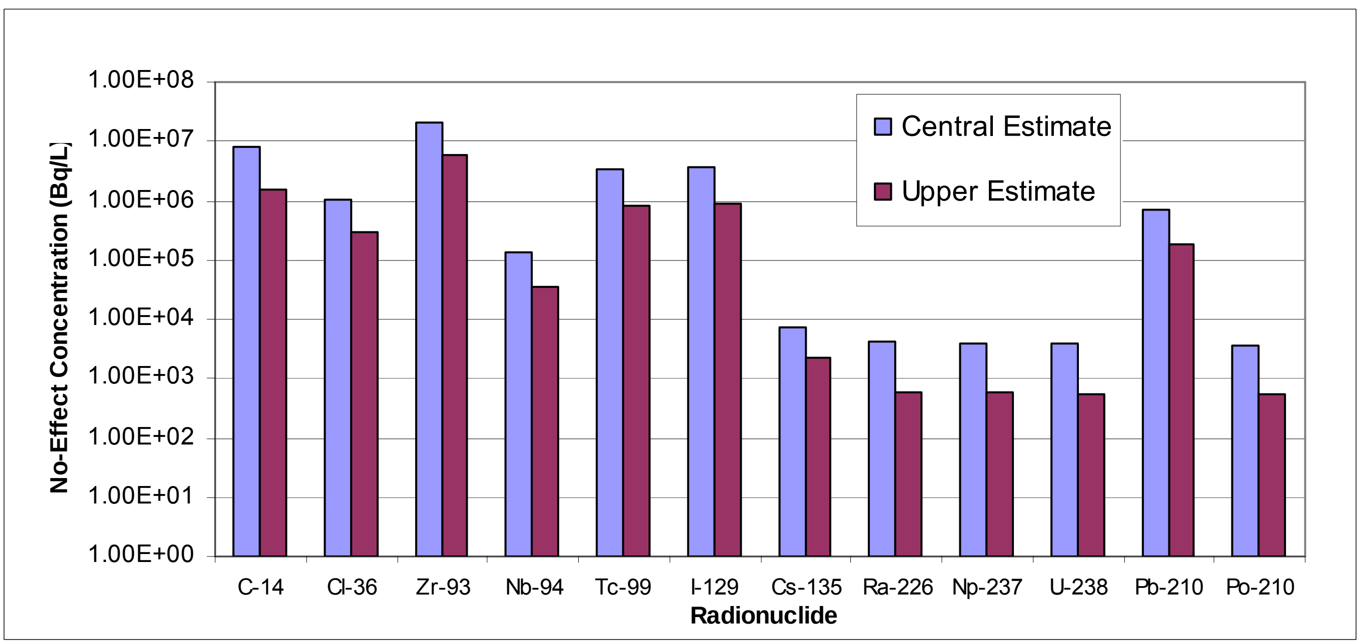
The differences in NEC results between ecosystems are likely less than the uncertainty present in the calculations. While it has not been calculated explicitly, uncertainty could be present due to variability in transfer factors, selection of ENEVs, assumptions made in ecological profiles, etc. This is why the "All Ecosystems" case, with limiting NEC values, has also been presented.

The Central Estimate NECs and the Upper Estimate NECs can also be compared, as shown in the following figures.



Note: Due to the wide range of values presented, the vertical axis in the above chart is shown on a logarithmic scale.

Figure 11: Comparison of Central Estimate and Upper Estimate NECs Calculated for Radionuclides in Water (All Ecosystems)



Note: Due to the wide range of values presented, the vertical axis in the above chart is shown on a logarithmic scale.

Figure 12: Comparison of Central Estimate and Upper Estimate NECs Calculated for Radionuclides in Groundwater (All Ecosystems)

As expected, the Central Estimate NECs are substantially higher (i.e., less restrictive) than the Upper Estimate NECs.

Garisto et al. (2008, Addendum) presents all of the calculated NECs. An application of the NECs is shown in the Section 7. Appendix D provides a comparison of these NECs to concentration limits derived in other international studies.

6.2 NEC Discussion

The following section provides a brief discussion/analysis of the NEC calculation results shown in Garisto et al. (2008, Addendum).

Table 21 shows the radionuclide with the lowest NEC in each medium and each ecosystem, for both the Central and Upper Estimates.

Table 21: Radionuclide with Lowest NEC in Each Medium and Each Ecosystem

(a) Upper Estimate

Medium	Ecosystem			
	S. Cdn. Deciduous	Boreal Forest	Inland Tundra	All Ecosystems
Water	Ra-226	Ra-226	Po-210	Ra-226
Soil	Cl-36	Cl-36	Cl-36	Cl-36
Sediment	Ra-226	Ra-226	Ra-226	Ra-226
Groundwater	Po-210	Po-210	not calculated	Po-210

(b) Central Estimate

Medium	Ecosystem			
	S. Cdn. Deciduous	Boreal Forest	Inland Tundra	All Ecosystems
Water	Ra-226	Ra-226	Np-237	Ra-226
Soil	Cs-135	Np-237	Np-237	Cs-135
Sediment	Po-210	Po-210	Po-210	Po-210
Groundwater	Po-210	Po-210	not calculated	Po-210

As seen in Table 21, Ra-226 and Po-210 are often the radionuclides with the lowest NECs. These radionuclides are limiting due to a combination of factors, including high transfer factors and high dose coefficients.

Table 22 shows the biota with the lowest NEC in each radionuclide, each medium and each ecosystem, for the Upper Estimate case. Table 23 shows the same information for the Central Estimate case. In both tables, this species is considered the limiting (i.e., most restrictive) biota.

A comparison of the biota listed in Table 22 (Upper Estimate) and Table 23 (Central Estimate) identifies the following points of note:

- There is a slightly larger diversity of biota in Table 23 (Central Estimate);
- Table 23 (Central Estimate) appears to contain more biota from lower trophic levels than Table 22 (Upper Estimate). This could be due to conservatisms in the selection of transfer factors; and
- For any single radionuclide, the limiting biota are often different between the Upper and Central estimates.

Table 22: Limiting Biota for Each Radionuclide, Medium and Ecosystem – Upper Estimate

(a) Southern Canadian Deciduous Forest

Medium	Radionuclide											
	C-14	Cl-36	Zr-93	Nb-94	Tc-99	I-129	Cs-135	Ra-226	Np-237	U-238	Pb-210	Po-210
Water	Muskrat	Muskrat	Muskrat	Muskrat	Muskrat	Muskrat	Muskrat	Muskrat	Muskrat	Muskrat	Muskrat	Muskrat
Soil	Crow	Deer	Deer	Deer	Deer	Deer	Crow	Deer	Deer	Turkey	Turkey	Deer
Sediment	Muskrat	Muskrat	Benthic Fish	Muskrat	Muskrat	Muskrat	Muskrat	Benthos	Benthos	Muskrat	Benthos	Muskrat
Groundwater	Worm	Worm	Worm	Worm	Worm	Worm	Worm	Worm	Worm	Worm	Worm	Worm

(b) Boreal Forest

Medium	Radionuclide											
	C-14	Cl-36	Zr-93	Nb-94	Tc-99	I-129	Cs-135	Ra-226	Np-237	U-238	Pb-210	Po-210
Water	Loon	Wolf	Muskrat	Wolf	Muskrat	Muskrat	Loon	Muskrat	Muskrat	Muskrat	Loon	Muskrat
Soil	Wolf	Wolf	Wolf	Wolf	Wolf	Wolf	Grouse	Grouse	Beaver	Grouse	Grouse	Beaver
Sediment	Muskrat	Muskrat	Benthic Fish	Wolf	Muskrat	Muskrat	Loon	Benthos	Benthos	Loon	Benthos	Beaver
Groundwater	Worm	Worm	Worm	Worm	Worm	Worm	Worm	Worm	Worm	Worm	Worm	Worm

(c) Inland Tundra

Medium	Radionuclide											
	C-14	Cl-36	Zr-93	Nb-94	Tc-99	I-129	Cs-135	Ra-226	Np-237	U-238	Pb-210	Po-210
Water	Char	Char	Char	Char	Char	Char	Char	Char	Char	Char	Char	Char
Soil	Fox	Fox	Fox	Fox	Fox	Fox	Fox	Ptarmigan	Hare	Ptarmigan	Ptarmigan	Fox
Sediment	Benthos	Benthos	Char	Char	Benthos	Benthos	Char	Benthos	Benthos	Benthos	Benthos	Benthos

Note: Exposure to groundwater not considered in Inland Tundra ecosystem.

(d) All Ecosystems

Medium	Radionuclide											
	C-14	Cl-36	Zr-93	Nb-94	Tc-99	I-129	Cs-135	Ra-226	Np-237	U-238	Pb-210	Po-210
Water	Loon	Wolf	Muskrat	Wolf	Muskrat	Muskrat	Loon	Muskrat	Muskrat	Muskrat	Loon	Muskrat
Soil	Fox	Wolf	Wolf	Wolf	Wolf	Fox	Crow	Grouse	Deer	Grouse	Turkey	Deer
Sediment	Muskrat	Muskrat	Benthic Fish	Wolf	Muskrat	Muskrat	Loon	Benthos	Benthos	Loon	Benthos	Beaver
Groundwater	Worm	Worm	Worm	Worm	Worm	Worm	Worm	Worm	Worm	Worm	Worm	Worm

Table 23: Limiting Biota for Each Radionuclide, Medium and Ecosystem – Central Estimate

(a) Southern Canadian Deciduous Forest

Medium	Radionuclide											
	C-14	Cl-36	Zr-93	Nb-94	Tc-99	I-129	Cs-135	Ra-226	Np-237	U-238	Pb-210	Po-210
Water	Muskrat	Frog	Aq.Plants	Muskrat	Aq.Plants	Muskrat	Pelagic Fish	Aq.Plants	Aq.Plants	Aq.Plants	Aq.Plants	Aq.Plants
Soil	Deer	Deer	Worm	Turkey	Pine	Turkey	Crow	Worm	Pine	Turkey	Turkey	Turkey
Sediment	Benthos	Benthos	Benthic Fish	Muskrat	Benthos	Benthos	Muskrat	Benthos	Benthos	Benthos	Benthos	Benthos
Groundwater	Worm	Worm	Worm	Worm	Worm	Worm	Worm	Worm	Worm	Worm	Worm	Worm

(b) Boreal Forest

Medium	Radionuclide											
	C-14	Cl-36	Zr-93	Nb-94	Tc-99	I-129	Cs-135	Ra-226	Np-237	U-238	Pb-210	Po-210
Water	Muskrat	Loon	Aq.Plants	Muskrat	Aq.Plants	Loon	Loon	Aq.Plants	Aq.Plants	Aq.Plants	Aq.Plants	Aq.Plants
Soil	Beaver	Beaver	Worm	Grouse	Spruce	Grouse	Grouse	Worm	Spruce	Grouse	Grouse	Spruce
Sediment	Benthos	Benthos	Benthic Fish	Beaver	Benthos	Benthos	Loon	Benthos	Benthos	Loon	Benthos	Benthos
Groundwater	Worm	Worm	Worm	Worm	Worm	Worm	Worm	Worm	Worm	Worm	Worm	Worm

(c) Inland Tundra

Medium	Radionuclide											
	C-14	Cl-36	Zr-93	Nb-94	Tc-99	I-129	Cs-135	Ra-226	Np-237	U-238	Pb-210	Po-210
Water	Char	Char	Char	Char	Lichen	Char	Char	Lichen	Char	Lichen	Char	Lichen
Soil	Berries	Hare	Lichen	Berries	Willow	Ptarmigan	Ptarmigan	Lichen	Willow	Lichen	Berries	Lichen
Sediment	Benthos	Benthos	Char	Benthos	Benthos	Benthos	Benthos	Benthos	Benthos	Benthos	Benthos	Benthos

Note: Exposure to groundwater not considered in Inland Tundra ecosystem.

(d) All Ecosystems

Medium	Radionuclide											
	C-14	Cl-36	Zr-93	Nb-94	Tc-99	I-129	Cs-135	Ra-226	Np-237	U-238	Pb-210	Po-210
Water	Muskrat	Loon	Aq.Plants	Muskrat	Aq.Plants	Loon	Loon	Aq.Plants	Aq.Plants	Aq.Plants	Aq.Plants	Aq.Plants
Soil	Berries	Deer	Lichen	Berries	Plants	Grouse	Crow	Lichen	Plants	Lichen	Turkey	Lichen
Sediment	Benthos	Benthos	Benthic Fish	Beaver	Benthos	Benthos	Loon	Benthos	Benthos	Loon	Benthos	Benthos
Groundwater	Worm	Worm	Worm	Worm	Worm	Worm	Worm	Worm	Worm	Worm	Worm	Worm

7. EXAMPLE APPLICATION OF NECs

In this section, the calculated NECs are compared to environmental concentrations estimated in Postclosure Safety Assessment studies. The ratios of environmental concentrations to NECs are calculated and added, using the approach described in Section 2.

The NECs used in these comparisons are the lowest (i.e., most restrictive) Upper Estimate concentrations across all ecosystems.

7.1 NEC Application to Water, Soil, Sediment and Groundwater Concentrations

The following table compares the calculated NECs for radionuclides in each medium with the estimated environmental concentrations from various Postclosure Safety Assessment studies.

Table 24: Comparison of NECs to Environmental Concentrations from Postclosure Safety Assessment Studies

(a) Water

Radionuclide	Water Upper Estimate NEC* (Bq/L)	Estimated Environmental Concentration in Water in Various Studies (Bq/L)			
		EIS	SCS	TCS	HBC
C-14	2.69E-02	N/A	N/A	5.77E-14	5.37E-12
Cl-36	2.78E+00	N/A	N/A	1.06E-04	1.18E-04
Zr-93	1.75E+00	N/A	N/A	N/A	N/A
Nb-94	4.54E-03	N/A	N/A	N/A	N/A
Tc-99	7.95E-01	N/A	N/A	0.00E+00	0.00E+00
I-129	3.23E+00	N/A	N/A	2.10E-04	1.80E-04
Cs-135	2.13E-03	N/A	N/A	N/A	0.00E+00
Ra-226	5.86E-04	N/A	N/A	1.02E-11	8.66E-11
Np-237	5.77E-02	N/A	N/A	3.02E-09	1.93E-08
U-238	2.30E-02	N/A	N/A	3.17E-10	1.10E-09
Pb-210	4.27E+00	N/A	N/A	2.61E-11	2.19E-10
Po-210	7.04E-03	N/A	N/A	4.19E-10	3.45E-09

(b) Soil

Radionuclide	Soil Upper Estimate NEC* (Bq/kg)	Estimated Environmental Concentration in Soil in Various Studies (Bq/kg)			
		EIS	SCS	TCS	HBC
C-14	2.39E+02	1.19E-05	N/A	3.25E-15	3.40E-13
Cl-36	3.76E-01	N/A	N/A	5.86E-05	1.32E-05
Zr-93	8.38E+04	N/A	N/A	N/A	N/A
Nb-94	3.03E+00	N/A	N/A	N/A	N/A
Tc-99	4.29E+01	3.24E-22	N/A	0.00E+00	0.00E+00
I-129	2.36E+03	1.39E-01	N/A	1.86E-03	1.83E-03
Cs-135	8.48E+00	0.00E+00	N/A	N/A	0.00E+00
Ra-226	2.51E+02	N/A	1.10E-09	1.71E-08	1.56E-07
Np-237	5.02E+01	N/A	1.62E-04	1.11E-08	3.22E-08
U-238	4.15E+01	0.00E+00	1.09E-08	8.07E-09	2.94E-08
Pb-210	3.71E+03	N/A	1.86E-09	1.47E-08	1.34E-07
Po-210	3.03E+01	N/A	1.06E-08	1.48E-08	1.35E-07

(c) Sediment

Radionuclide	Sediment Upper Estimate NEC* (Bq/kg)	Estimated Environmental Concentration in Sediment in Various Studies (Bq/kg)			
		EIS	SCS	TCS	HBC
C-14	2.84E+05	5.46E-04	N/A	3.62E-12	3.39E-10
Cl-36	4.10E+04	N/A	N/A	1.53E-05	1.68E-05
Zr-93	5.04E+06	N/A	N/A	N/A	N/A
Nb-94	1.87E+03	N/A	N/A	N/A	N/A
Tc-99	2.97E+06	2.15E-23	N/A	0.00E+00	0.00E+00
I-129	1.17E+06	8.45E-02	N/A	2.44E-02	2.07E-02
Cs-135	3.54E+05	0.00E+00	N/A	N/A	0.00E+00
Ra-226	9.27E+02	N/A	8.21E-09	4.11E-10	3.44E-09
Np-237	1.06E+03	N/A	2.87E-04	4.39E-08	1.11E-08
U-238	1.08E+04	0.00E+00	8.33E-09	4.61E-09	1.58E-08
Pb-210	6.25E+03	N/A	8.25E-09	1.10E-09	9.14E-09
Po-210	5.62E+03	N/A	8.23E-09	1.27E-09	1.05E-08

(d) Groundwater

Radionuclide	Groundwater Upper Estimate NEC* (Bq/L)	Estimated Environmental Concentration in Groundwater in Various Studies (Bq/L)			
		EIS	SCS	TCS	HBC
C-14	1.58E+06	2.50E-02	N/A	2.86E-10	2.89E-08
Cl-36	2.96E+05	N/A	N/A	2.69E-01	2.97E-01
Zr-93	5.89E+06	N/A	N/A	N/A	N/A
Nb-94	3.58E+04	N/A	N/A	N/A	N/A
Tc-99	8.10E+05	8.97E-22	N/A	5.73E-31	6.57E-25
I-129	9.04E+05	2.05E+00	N/A	1.17E+00	1.12E+00
Cs-135	2.19E+03	0.00E+00	N/A	N/A	0.00E+00
Ra-226	5.87E+02	N/A	1.25E-09	3.57E-08	3.19E-07
Np-237	5.83E+02	N/A	2.36E-04	8.75E-06	4.83E-05
U-238	5.57E+02	0.00E+00	1.82E-08	9.19E-07	3.24E-06
Pb-210	1.78E+05	N/A	1.05E-09	3.02E-08	2.69E-07
Po-210	5.35E+02	N/A	5.72E-06	5.50E-07	4.91E-06

Notes:
N/A – Data not available
* - Most restrictive Upper Estimate NEC selected (i.e., smallest concentration of all ecosystems)
References for Postclosure Studies:

EIS: AECL (1994)
SCS: Goodwin *et al*. (1996)
TCS: Garisto *et al*. (2004)
HBC: Garisto *et al*. (2005)
Note that the concentrations above are not referenced in these actual reports. The data are from the system model runs associated with particular scenarios.

In Table 25, the ratios of the environmental concentrations to the NECs are calculated for each medium, and the sum of ratios over all radionuclides is calculated.

Table 25: Ratios of Study Concentrations to Upper Estimate NECs

(a) Water

Radionuclide	Water Upper Estimate NEC* (Bq/L)	Ratio of Study Concentration to NEC			
		EIS	SCS	TCS	HBC
C-14	2.69E-02	N/A	N/A	2.15E-12	2.00E-10
Cl-36	2.78E+00	N/A	N/A	3.81E-05	4.24E-05
Zr-93	1.75E+00	N/A	N/A	N/A	N/A
Nb-94	4.54E-03	N/A	N/A	N/A	N/A
Tc-99	7.95E-01	N/A	N/A	0.00E+00	0.00E+00
I-129	3.23E+00	N/A	N/A	6.50E-05	5.57E-05
Cs-135	2.13E-03	N/A	N/A	N/A	0.00E+00
Ra-226	5.86E-04	N/A	N/A	1.74E-08	1.48E-07
Np-237	5.77E-02	N/A	N/A	5.24E-08	3.35E-07
U-238	2.30E-02	N/A	N/A	1.38E-08	4.79E-08
Pb-210	4.27E+00	N/A	N/A	6.11E-12	5.13E-11
Po-210	7.04E-03	N/A	N/A	5.95E-08	4.90E-07
	Sum of Ratios	**N/A**	**N/A**	**1.03E-04**	**9.91E-05**

(b) Soil

Radionuclide	Soil Upper Estimate NEC* (Bq/kg)	Ratio of Study Concentration to NEC			
		EIS	SCS	TCS	HBC
C-14	2.39E+02	4.98E-08	N/A	1.36E-17	1.42E-15
Cl-36	3.76E-01	N/A	N/A	1.56E-04	3.51E-05
Zr-93	8.38E+04	N/A	N/A	N/A	N/A
Nb-94	3.03E+00	N/A	N/A	N/A	N/A
Tc-99	4.29E+01	7.55E-24	N/A	0.00E+00	0.00E+00
I-129	2.36E+03	5.89E-05	N/A	7.89E-07	7.76E-07
Cs-135	8.48E+00	0.00E+00	N/A	N/A	0.00E+00
Ra-226	2.51E+02	N/A	4.39E-12	6.82E-11	6.22E-10
Np-237	5.02E+01	N/A	3.23E-06	2.21E-10	6.41E-10
U-238	4.15E+01	0.00E+00	2.63E-10	1.95E-10	7.09E-10
Pb-210	3.71E+03	N/A	5.01E-13	3.96E-12	3.61E-11
Po-210	3.03E+01	N/A	3.50E-10	4.88E-10	4.45E-09
	Sum of Ratios	**5.90E-05**	**3.23E-06**	**1.57E-04**	**3.59E-05**

(c) Sediment

Radionuclide	Sediment Upper Estimate NEC* (Bq/kg)	Ratio of Study Concentration to NEC			
		EIS	SCS	TCS	HBC
C-14	2.84E+05	1.92E-09	N/A	1.27E-17	1.19E-15
Cl-36	4.10E+04	N/A	N/A	3.73E-10	4.09E-10
Zr-93	5.04E+06	N/A	N/A	N/A	N/A
Nb-94	1.87E+03	N/A	N/A	N/A	N/A
Tc-99	2.97E+06	7.23E-30	N/A	0.00E+00	0.00E+00
I-129	1.17E+06	7.23E-08	N/A	2.09E-08	1.77E-08
Cs-135	3.54E+05	0.00E+00	N/A	N/A	0.00E+00
Ra-226	9.27E+02	N/A	8.86E-12	4.44E-13	3.71E-12
Np-237	1.06E+03	N/A	2.71E-07	4.14E-11	1.05E-11
U-238	1.08E+04	0.00E+00	7.74E-13	4.28E-13	1.47E-12
Pb-210	6.25E+03	N/A	1.32E-12	1.76E-13	1.46E-12
Po-210	5.62E+03	N/A	1.46E-12	2.26E-13	1.87E-12
	Sum of Ratios	**7.42E-08**	**2.71E-07**	**2.13E-08**	**1.81E-08**

(d) Groundwater

Radionuclide	Groundwater Upper Estimate NEC* (Bq/L)	Ratio of Study Concentration to NEC			
		EIS	SCS	TCS	HBC
C-14	1.58E+06	1.58E-08	N/A	1.81E-16	1.83E-14
Cl-36	2.96E+05	N/A	N/A	9.07E-07	1.00E-06
Zr-93	5.89E+06	N/A	N/A	N/A	N/A
Nb-94	3.58E+04	N/A	N/A	N/A	N/A
Tc-99	8.10E+05	1.11E-27	N/A	7.07E-37	8.11E-31
I-129	9.04E+05	2.27E-06	N/A	1.29E-06	1.24E-06
Cs-135	2.19E+03	0.00E+00	N/A	N/A	0.00E+00
Ra-226	5.87E+02	N/A	2.13E-12	6.08E-11	5.43E-10
Np-237	5.83E+02	N/A	4.05E-07	1.50E-08	8.28E-08
U-238	5.57E+02	0.00E+00	3.27E-11	1.65E-09	5.82E-09
Pb-210	1.78E+05	N/A	5.91E-15	1.70E-13	1.51E-12
Po-210	5.35E+02	N/A	1.07E-08	1.03E-09	9.18E-09
	Sum of Ratios	**2.28E-06**	**4.15E-07**	**2.22E-06**	**2.34E-06**

Notes:
N/A – Data not available
* - Most restrictive Upper Estimate NEC selected (i.e., smallest concentration of all ecosystems)
EIS: AECL (1994)
SCS: Goodwin *et al*. (1996)
TCS: Garisto *et al*. (2004)
HBC: Garisto *et al*. (2005)

As seen in Table 25, all of the sums-of-ratios are below one (where data are available).

7.2 Overall Sum of Ratios

The methodology discussed in the Section 2 suggests that once the sum of ratios has been calculated for each medium, the total sum of ratios in all media be calculated. This is a conservative approach, as it assumes that all biota are exposed to all media, whereas the only indicator species that are exposed to water, soil and sediment are wolf and moose.

Table 26 shows the sums-of-ratios calculated for each medium as well as the overall sum. The ratios were calculated by comparing the environmental concentrations to the Upper Estimate NECs.

Table 26: Overall Sum of Ratios from Postclosure Safety Assessment Studies based on Comparison to Upper Estimate NECs

	Postclosure Safety Assessment Study			
Medium	**EIS**	**SCS**	**TCS**	**HBC**
Water	n/a	n/a	1.03E-04	9.91E-05
Soil	5.90E-05	3.23E-06	1.57E-04	3.59E-05
Sediment	7.42E-08	2.71E-07	2.13E-08	1.81E-08
Groundwater	2.28E-06	4.15E-07	2.22E-06	2.34E-06
Total	**6.14E-05**	**3.91E-06**	**2.62E-04**	**1.37E-04**

As seen in the table above, all of the overall sums-of-ratios are below one.

The sums-of-ratios shown above were calculated based on the Upper Estimate NECs, which are more conservative (i.e., more restrictive). If ratios and sums-of-ratios are calculated using Central Estimate NECs, the results would be similar to the Upper Estimate NEC results. This is demonstrated in the following table.

Table 27: Overall Sum of Ratios from Postclosure Safety Assessment Studies based on Comparison to Central Estimate NECs

	Postclosure Safety Assessment Study			
Medium	**EIS**	**SCS**	**TCS**	**HBC**
Water	n/a	n/a	2.86E-07	3.10E-07
Soil	1.15E-07	3.06E-08	7.88E-09	3.00E-09
Sediment	5.50E-09	8.62E-09	1.60E-09	1.71E-09
Groundwater	5.80E-07	6.04E-08	5.96E-07	6.21E-07
Total	**7.01E-07**	**9.95E-08**	**8.92E-07**	**9.36E-07**

As expected, all sums-of-ratios are less than one and are less than those in the Upper Estimate case.

8. DISCUSSION

NECs were derived in this study for groundwater, soil, surface water and sediment in three ecosystems that represent a range of Canadian conditions: southern Canadian deciduous forest, boreal Canadian Shield forest, and tundra (a potential far-future climate condition during glaciation).

These NECs were compared to post-closure environmental concentrations estimated in major Canadian post-closure assessments of the geological disposal of used fuel, including the Third Case Study, the Second Case Study and the Environmental Impact Statement study. The results indicate that there would be no significant radioecological impact on non-human biota for these case studies.

The following list identifies gaps and recommends future improvements.

- The list of indicator species spans many trophic levels. Nevertheless, it may be useful to consider adding aquatic birds in the Southern Deciduous Forest (this was not included because the identification of indicator species was based on the WWMF EAs, which did not include aquatic birds).
  In practice, the NECs can be modified to fit site-specific applications by considering the indicator species corresponding to Valued Ecological Components (VECs, defined below) identified in site-specific Environmental Assessments. This can be done readily, because a large range of indicator species is included in the derivation of the NECs.
  VECs are features of the environment selected to be the focus of an Environmental Assessment because of their ecological, social or economic value and their potential vulnerability to the project. VECs are usually individual valued species or represent important groups of species within food webs.
- The NEC derived for U-238 based on its potential radioecological impact is expected to be much higher than the value which could be derived based on its chemical toxicity. We recommend that this is addressed in a future update.
- Consider adding Se-79 to the list of radionuclides, because it appears as a potentially important radionuclide (for dose contribution to humans in some scenarios) in international assessments of used fuel disposal.
- Consider how to assess groundwater in the Inland Tundra (perhaps use 10*NEC for the protection of surface water, following the philosophy described in the MOEE (1996) guidance document. This would likely lead to a conservative estimate of groundwater NEC, compared to the other ecosystems.
- The ICRP is developing reference animals and plants for which they estimated dose conversion factors, taking geometrical factors into account (ICRP 2007 draft). We recommend to review the NECs in light of this development. It is expected that the derivation of NECs in the “Upper Estimate” case is conservative because it reflects geometry corrections (i.e., all the energy from internal radionuclides is deposited within the organism). Nevertheless, it would be useful to verify this assumption once the ICRP report is published.
- To address uncertainty in amphibian ENEVs, consider changing the frog Upper Estimate ENEV to 1 mGy/d. This would be considered even more conservative and would match the approach used for birds and mammals.

- Data sources are often reviews or compilations, implying that the same base data could potentially be considered more than once. This could reduce variability, compared to if original data sources had been considered. A critical review of the data would address this.

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APPENDIX A: ECOLOGICAL PROFILES

Ecological Profile: American Crow

General Description
American crows (*Corvus brachyrhynchos*) are completely black birds. American crows prefer open areas with nearby trees. Agricultural and grassland areas are ideal habitat for crows to forage for their food. American crows also use nearby woodlots and forest edges for breeding and roosting. Nests are usually placed high in trees. Breeding populations north of southern Canada move south for winter (Parr 2005, NatureServe 2007, Cornell 2003).

Size
Adult American crows weigh on average 450 g (Parr 2005).
Weight 458 grams (NatureServe 2007).
Weight: 316 to 620 g (Cornell 2003).

Based on the above information a typical crow is expected to weigh approximately 450 g (0.45 kg) (Parr 2005).

Home Range:
Spring-summer home range averages approximately 2.6 sq km (NatureServe 2007).

Feeding Habits:
American crows are omnivores and opportunistic; will eat almost anything. During the breeding season, American crows consume insects, worms, fruits, grains, and nuts. They can prey on small animals such as frogs, mice, and young rabbits, though they more likely to scavenge carrion such as roadkill. However, the American Crow is not specialized to be a scavenger, and carrion is only a very small part of its diet. They also are significant nest predators, preying on the eggs and nestlings of smaller birds. In the fall and winter they eat more nuts, such as walnuts and acorns. They forage mostly on the ground; pecking at the ground surface and digging through litter (Parr 2005, Cornell 2003).

Based on the available information the crow is assumed to consume terrestrial vegetation, worms and birds. Worms are used as a surrogate for insects. Terrestrial vegetation is assumed to represent 50%, worms 40% and birds 10% of the diet.

Food Consumption Rate:
Allometric equation for birds (U.S. EPA 1993): FI (g (dw)/day) = 0.648 $Wt^{0.651}$ (g)

Based on a body weight of 450 g the FI is 35 g (dw)/d or 115 g (ww)/d (moisture content of 70%).

Based on the above information the food consumption rate was taken to be 115 g (ww)/d.

Soil Ingestion:
Beyer *et al.* (1994) provides a value of 10.4% for a woodcock and 9.3% for wild turkey, the average of these values (9.9%) was used in lieu of species specific data. Based on a dry weight consumption rate of 35 g/d this corresponds to approximately 3.4 g/d.

Water Intake Rate:
Allometric equation for birds (U.S. EPA 1993): WI (L/day) = 0.059 $Wt^{0.67}$ (kg)

Based on a body weight of 0.45 kg the WI is 0.03 L/d

Inhalation Rate:
Allometric equation for birds (U.S. EPA 1993): IR (m^3/day) = 0.4089 $Wt^{0.77}$ (kg)

Based on a body weight of 0.45 kg the IR is 0.2 m^3/d

Ecological Profile: American Crow

Summary Table:

Exposure Characteristics		
Body Weight (kg)	0.45	Parr 2005
Food Intake Rate (g (ww)/d)	115	U.S. EPA 1993 (allometric scaling)
Soil Ingestion Rate: (g (dw)/d) Fraction of ww diet:	 3.4 0.03	Beyer *et al.* 1994
Water Intake Rate (L/d)	0.03	U.S. EPA 1993 (allometric scaling)
Inhalation Rate (m^3/d)	0.2	U.S. EPA 1993 (allometric scaling)
Fraction of Time in Area	0.5	Assumed (migratory)
Fractional Composition of Diet		
Terrestrial Plants	0.5	Based on information from Parr (2005) and Cornell (2003)
Worms	0.4	
Birds	0.1	

References:

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Ecological Profile: American Robin

General Description

American Robin (*Turdus migratorius*) is one of the best-known birds in North America. The American Robin is a thrush, not a robin; the largest thrush in North America. The American Robin was originally a forest species, but it has adapted well to other areas. There is scarcely any type of habitat, except marshes, where the American Robin will not nest. Access to fresh water, protected nesting sites, and productive foraging areas are important requirements for breeding robins. The American Robin is located throughout most of the continental United States and Canada during the breeding season. Northern populations migrate and winter in the southern half of the United States and in Mexico and Central America (CWS 2005, U.S. EPA 1993, Dewey and Middlebrook 2001, Cornell 2003).

Size

Weighs about 77 g (CWS 2005).
Average weight: 77 g (Dewey and Middlebrook 2001).
Weight: 77 g (NatureServe 2007).
Weight: 77 g (Cornell 2003).
U.S. EPA (1993) provides values from 3 studies; range for adults is 77.3 g to 86.2 g. The average of males and females from the studies is 80 g.

Based on the above information a typical robin is expected to weigh approximately 77 g (CWS 2005, Dewey and Middlebrook 2001, Cornell 2003).

Home Range:

The territory size ranges from 0.11 to 0.42 ha with a foraging range of 0.15 to 0.81 during the summer (U.S. EPA 1993).

Feeding Habits:

Earthworms provide only a part of the robin's diet; invertebrates (such as earthworms, beetles, and caterpillars) provide about 40 percent of its diet with the remainder of the diet comprising fruit. Chokecherries, barberries, and rowan berries are preferred species along with cherries, wine grapes, and tomatoes. In the months preceding and during the breeding season, robins feed mainly (greater than 90 percent volume) on invertebrates and on some fruits; during the remainder of the year, their diet consists primarily (over 80 to 99 percent by volume) of fruits. Young birds in the nest eat mostly earthworms and beetle grubs (CWS 2005, U.S. EPA 1993, Dewey and Middlebrook. 2001, Cornell 2003).

Based on the available information the robin is assumed to consume berries and worms. Berries is assumed to represent 60% of the diet and worms 40%.

Food Consumption Rate:

The U.S. EPA (1993) provides a food intake rate range of 0.89 to 1.52 g (ww)/d per g body weight (average is 1.2 g (ww)/(g d)). Based on a body weight of 77 g the FI is 93 g (ww)/d or 19 g (dw)/d (moisture content of 80% for earthworms and berries).
Allometric equation for birds (U.S. EPA 1993): FI (g (dw)/day) = 0.648 $Wt^{0.651}$ (g)

Based on a body weight of 77 g the FI is 11 g (dw)/d or 55 g (ww)/d (moisture content of 80%)

Based on the above information the food consumption rate was taken to be 93 g (ww)/d (U.S. EPA 1993).

Soil Ingestion:

Beyer *et al.* (1994) provides a value of 10.4% for a woodcock and 9.3% for wild turkey, the average of these values (9.9%) was used in lieu of species specific data. Based on a dry weight consumption rate of 19 g/d this corresponds to approximately 1.9 g (dw)/d.

Water Intake Rate:
The U.S. EPA (1993) provides a water intake rate range of 0.14 g/d per g body. Based on a body weight of 77 g the WI is 11 g/d or 0.01 L/d.
Allometric equation for birds (U.S. EPA 1993): WI (L/day) = 0.059 $Wt^{0.67}$ (kg)
Based on a body weight of 0.077 kg the WI is 0.01 L/d

Inhalation Rate:
Allometric equation for birds (U.S. EPA 1993): IR (m^3/day) = 0.4089 $Wt^{0.77}$ (kg)
Based on a body weight of 0.077 kg the IR is 0.06 m^3/d

Summary Table:

Exposure Characteristics		
Body Weight (kg)	0.077	CWS 2005, Dewey and Middlebrook 2001, Cornell 2003
Food Intake Rate (g (ww)/d)	93	U.S. EPA 1993
Soil Ingestion Rate: (g (dw)/d) Fraction of ww diet:	 1.9 0.02	Beyer *et al.* 1994
Water Intake Rate (L/d)	0.01	U.S. EPA 1993
Inhalation Rate (m^3/d)	0.06	U.S. EPA 1993 (allometric scaling)
Fraction of Time in Area	0.5	Assumed (migratory)
Fractional Composition of Diet		
Berries	0.6	Based on information from CWS 2005, U.S. EPA 1993, Dewey and Middlebrook. 2001, Cornell 2003
Worms	0.4	

References:

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Ecological Profile: Aquatic Plants / Pond Weed

General Description

Pond weed (*Elodea canadensis*) is an underwater perennial plant, which sometimes occurs as tangled masses in lakes, ponds, and ditches. Individual plants within each species vary in appearance depending on growing conditions. Some are bushy and robust, others have few leaves and weak stems (Aquatic Weed Control LLC. 2007).

This species is found in lakes, rivers, ponds and ditches. The pond weed lives entirely underwater with the exception of small white flowers which bloom at the surface and are attached to the plant by delicate stalks. Silty sediments and water rich in nutrients favor the growth of pond weed in nutrient-rich lakes. However, the plant will grow in a wide range of conditions, from very shallow to deep water, and in many sediment types. It can even continue to grow unrooted, as floating fragments. It is found throughout temperate North America, where it is one of the most common aquatic plants (Wikipedia 2007).

Faunal Associations

Pond weed provides food and habitat for fish, waterfowl and other wildlife (e.g. beaver and muskrat). It is also used in cool water aquariums (Aquatic Weed Control LLC. 2007).

References:

Aquatic Weed Control LLC. 2007. Online Aquatic Plant Identification Utility. Retrieved from http://awc-america.com/plant_id_utility/plants/elocan.html. Accessed 20/9/2007

Wikipedia. 2007. http://en.wikipedia.org/wiki/Pond_Weed. Accessed 20/9/2007

Ecological Profile: Arctic Char

General Description:

Arctic char or Arctic charr (*Salvelinus alpinus(L.)*) is both a freshwater and saltwater fish in the Salmonidae family. Arctic char may be exceedingly colorful, as when spawning, or may exhibit the relatively drab silvery color of nonspawning. It is native to Arctic, sub-Arctic and alpine lakes and coastal waters. In Canada, arctic char occur in insular Newfoundland, Labrador, and extreme east of Quebec, coastwise and north along the Atlantic coast to Hudson Strait, Hudson Bay, and the Arctic Archipelago. It maybe either anadromous, moving downstream to the sea in spring, returning in the autumn, or they may remain permanently in fresh water (Scott and Crossman 1998).

Arctic char spend most of the year in deep water (>10 metres) but come into shallow rocky and gravelly areas in November and December to spawn (Ulster Museum Sciences Division 2007).

Size:
The average length is about 38-46 cm. The average weight of a sea-run char us about 1-5 kg (Scott and Crossman 1998).

Feeding Habits:
Arctic char are carnivorous but have an exceedingly varied diet. They eat different species of vertebrate and invertebrate animals such as amphipods and mysids, lumpfishes and seasnails (Scott and Crossman 1998).

Environment:
They are found in the benthopelagic environment (Froese and Pauly 2007).

Reference:

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Ecological Profile: Arctic Fox

General Description
The arctic fox (*Alopex lagopus*) is also known as the white fox. It is found in the treeless tundra extending through the arctic regions of Eurasia, North America, Greenland, and Iceland. The foxes live a communal and nomadic life Foxes construct homes called dens; these dens have 4 to 8 entrances and a system of tunnels covering about 30 square meters. They do not hibernate during the winter months (CWS 1990, Middlebrook 1999).

Size
Weighs from 2.5 to 9 kg (CWS 1990)
Weight 4000 grams (4 kg) (NatureServe 2007)
Fully grown arctic foxes weigh from 6 to 10 pounds (2.7 to 4.5 kg) (ADF&G 1994).

Based on the above information a typical arctic fox is expected to weigh 4 kg (NatureServe 2007).

Home Range:
When food is abundant the foxes hunt over an area of 2.5 to 5.0 km^2. However, when food is scarcer, the adults probably range much further (CWS 1990). Their home range is much larger in winter than in summer. Based on a few radiotelemetry studies, adult home range is around 10 to 20 km^2 but depends on food resources
.

Feeding Habits:
The arctic fox is a carnivore and an opportunistic feeder, eating practically any animal. Their diet varies greatly from one part of its range to another. In the vast expanses of the continental tundra region, the arctic fox is almost entirely dependent on lemmings throughout the year. In other areas, other rodents, such as ground squirrels and voles, are an important source of food, and during summer, adult birds, eggs, and flightless young also make up a large part of the diet (CWS 1993, NatureServe 2007, Middlebrook 1999).

Based on the available information the fox is assumed to consume small mammals (75%) and birds (25%).

Food Consumption Rate:
Specific information for arctic fox not available in U.S. EPA (1993), however a food consumption rate of 0.069 g/d per g body weight is provided for red fox (weight of 4.5 kg). With a body weight of 4000 g for an arctic fox this corresponds to an intake of 276 g (ww)/d which is 83 g (dw)/d with a 70% moisture content.

Allometric equation for mammals (U.S. EPA 1993): FI (g (dw)/day) = $0.235\ Wt^{0.822}$ (g)

Based on a body weight of 4000 g the FI is 215 g (dw)/d or 710 g (ww)/d (moisture content of 70%)

Due to the similarity to the red fox, the food ingestion rate was taken to be 276 g (ww)/d (U.S. EPA 1993). It is noted that this estimate is lower than the one provided from the allometric equation.

Soil Ingestion:
Beyer *et al.* (1994) provides values of 2.8% for red fox which was used for the arctic fox. Based on a dry weight consumption rate of 83 g/d this corresponds to approximately 2.3 g/d.

Water Intake Rate:
Allometric equation for mammals (U.S. EPA 1993): WI (L/day) = $0.099\ Wt^{0.9}$ (kg)

Based on a body weight of 4 kg the WI is 0.3 L/d.

Inhalation Rate:
Allometric equation for mammals (U.S. EPA 1993): IR (m^3/day) = $0.5458\ Wt^{0.8}$ (kg)

Based on a body weight of 4 kg the IR is 1.7 m^3/d.

Ecological Profile: Arctic Fox

Summary Table:

Exposure Characteristics		
Body Weight (kg)	4	NatureServe 2007
Food Intake Rate (g (ww)/d)	276	U.S. EPA 1993 (using intake rate for red fox)
Soil Ingestion Rate: (g (dw)/d) Fraction of ww diet:	 2.3 0.008	Beyer *et al.* 1994
Water Intake Rate (L/d)	0.3	U.S. EPA 1993 (allometric scaling)
Inhalation Rate (m^3/d)	1.7	U.S. EPA 1993 (allometric scaling)
Fraction of Time in Area	1	Assumed
Fractional Composition of Diet		
Small Mammals	0.75	Based on information from CWS 1993, NatureServe 2007, Middlebrook 1999
Birds	0.25	

References:

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Canadian Wildlife Service (CWS) 1990. *Hinterland Who's Who. Mammal Fact Sheet: Arctic Fox.* Available at: http://www.hww.ca/hww2.asp?id=81

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NatureServe. 2007. NatureServe Explorer: An online encyclopedia of life. Version 6.2. NatureServe, Arlington, Virginia. Available http://www.natureserve.org/explorer. 8 June (Accessed: September 19, 2007).

United States Environmental Protection Agency (U.S. EPA) 1993. *Wildlife Exposure Factors Handbook.* EPA/600/R-93/187.

Ecological Profile: Arctic Hare

General Description
Arctic hare (*Lepus arcticus*), also called the tundra hare, are distributed through the tundra of Canada from Newfoundland and Labrador to the Mackenzie delta of the Northwest Territories. Present in tundra and rocky slopes, hills and lower mountain slopes, arctic hare generally avoid low, flat country lacking sheltered situations. The arctic hare is most common where vegetation is not deeply and extensively snow-covered. This hare species is active throughout the year and are nocturnal. In many areas, populations fluctuate widely over periods of several years (Gorog 2003, NatureServe 2007).

Size
3 to 5 kg (Gorog 2003).
Weight 6800 grams (6.8 kg) (NatureServe 2007).
The Alaskan hare is 2.7 to 5.4 kg in weight (ADF&G 1994).

Based on the above information a typical arctic hare is expected to weigh 4 kg (Gorog 2003).

Home Range:
Arctic hares have small home ranges and tend to follow familiar paths as they forage (Gorog 2003).
Summer range of females was half that of males (116 \to 155 ha) in Newfoundland. Mean home range size was reported as 290 ha in Newfoundland (NatureServe 2007).

Feeding Habits:
Arctic hare are herbivores. The staple food for Arctic hare consists of woody plants. They are reported to eat twigs and roots of willows and birch buds, berries, foliage, mosses and lichens. In the winter, they dig through the snow crust to reach food (Gorog 2003, NatureServe 2007).

Based on the available information, the arctic hare is assumed to consume terrestrial vegetation and berries. This is likely to comprise primarily browse in the winter and browse and forage in the summer. In the model this is expressed as 90% general terrestrial vegetation and 10% berries.

Food Consumption Rate:
Allometric equation for mammals (U.S. EPA 1993): FI (g (dw)/day) = 0.235 $Wt^{0.822}$ (g)

Based on a body weight of 4000 g the FI is 215 g dw/d or 716 g (ww)/d (moisture content of 70%).

Soil Ingestion:
The estimated % soil in diet (dry weight) for a jackrabbit is 6.3% (U.S. EPA 1993, Table 4-5). Based on a dry weight consumption rate of 215 g/d this corresponds to approximately 14 g/d.

Water Intake Rate:
Allometric equation for mammals (U.S. EPA 1993): WI (L/day) = 0.099 $Wt^{0.9}$ (kg)

Based on a body weight of 4 kg the WI is 0.3 L/d.

Inhalation Rate:
Allometric equation for mammals (U.S. EPA 1993): IR (m^3/day) = 0.5458 $Wt^{0.8}$ (kg)

Based on a body weight of 4 kg the IR is 1.7 m^3/d.

Ecological Profile: Arctic Hare

Summary Table:

Exposure Characteristics		
Body Weight (kg)	4	Gorog 2003
Food Intake Rate (g (ww)/d)	716	U.S. EPA 1993 (allometric scaling)
Soil Ingestion Rate: (g (dw)/d) Fraction of ww diet:	 14 0.019	U.S. EPA 1993
Water Intake Rate (L/d)	0.3	U.S. EPA 1993 (allometric scaling)
Inhalation rate (m^3/d)	1.7	U.S. EPA 1993 (allometric scaling)
Fraction of time in area	1	Assumed
Fractional Composition of Diet		
Terrestrial Plants	0.9	Based on Gorog 2003, NatureServe 2007
Berries	0.1	

References:

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Canadian Wildlife Service (CWS) 1990. *Hinterland Who's Who. Mammal Fact Sheet: White-tailed Deer.* Available at: http://www.ffdp.ca/hww2.asp?id=106

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United States Environmental Protection Agency (U.S. EPA) 1993. *Wildlife Exposure Factors Handbook.* EPA/600/R-93/187.

Ecological Profile: Barren-Ground Caribou

General Description
The caribou (*Rangifer tarandus*) is a medium-sized member of the deer family. In Europe, caribou are called reindeer, but in Alaska and Canada only the domestic forms are called reindeer. Both female and male caribou carry antlers. Four subspecies of caribou occur in Canada: woodland, Peary, barren-ground west of the Mackenzie River (also known as Grant's caribou), and barren-ground east of the Mackenzie River. About half of the 2.4 million caribou in Canada are barren-ground caribou. They spend much or all of the year on the tundra from Alaska to Baffin Island (CWS 2005, Shefferly and Joly 2000).

Size
Barren-ground caribou are somewhat smaller than woodland caribou (CWS 2005).
Their mass varies from 55 to 318 kg, subspecies inhabiting the more southerly latitudes are larger than their northern cousins (Shefferly and Joly 2000).
Weight 270000 grams (270 kg) (NatureServe 2007).
Weights of adult bulls average 159 to 182 kg; mature females average 80 to 120 kg (ADF&G 1999).

Based on the above information a typical barren-ground caribou is expected to weigh 135 kg (ADF&G 1999).

Home Range:
Caribou are known to travel distances greater than any other terrestrial mammal. The can traverse more than 5,000 kilometers in a year, with extensive migrations in spring and fall (Shefferly and Joly 2000).
Tundra caribou may travel extensively in summer while attempting to avoid bothersome insects (NatureServe 2007).

Feeding Habits:
Ground and tree lichens are the primary winter food of caribou, providing a highly digestible and energy-rich food source. Although lichens are a good source of energy, they are not a good source of protein (nitrogen). As soon as spring snow melts, caribou are eager to switch to fresh green vegetation (e.g. leaves of willows and birches, mushrooms, cotton grass, sedges), which is rich in nitrogen (CWS 2005, NatureServe 2007, Shefferly and Joly 2000).

Based on the available information caribou is assumed to consume terrestrial vegetation. This is likely to comprise primarily lichen in the winter and primarily forage in the summer (75% lichen, 25% terrestrial vegetation).

Food Consumption Rate:
Allometric equation for mammals (U.S. EPA 1993): FI (g (dw)/day) = 0.235 $Wt^{0.822}$ (g)

Based on a body weight of 1.35E5 g the FI is 3870 g (dw)/d or 6460 g (ww)/d (moisture content of lichen = 40%)

Soil Ingestion:
No specific information is available, therefore the general value for all mammals of 5% based on the information provided Beyer *et al.* (1994) was used. Based on a dry weight consumption rate of 3870 g/d this corresponds to approximately 194 g/d.

Water Intake Rate:
Allometric equation for mammals (U.S. EPA 1993): WI (L/day) = 0.099 $Wt^{0.9}$ (kg)

Based on a body weight of 135 kg the WI is 8.2 L/d.

Inhalation Rate:
Allometric equation for mammals (U.S. EPA 1993): IR (m^3/day) = 0.5458 $Wt^{0.8}$ (kg)

Based on a body weight of 135 kg the IR is 27 m^3/d.

Ecological Profile: Barren-Ground Caribou

Summary Table:

Exposure Characteristics		
Body Weight (kg)	135	ADF&G 1999
Food Intake Rate (g (ww)/d)	6460	U.S. EPA 1993 (allometric scaling)
Soil Ingestion Rate: (g (dw)/d) Fraction of ww diet:	 194 0.03	Beyer *et al.* 1994
Water Intake Rate (L/d)	8.2	U.S. EPA 1993 (allometric scaling)
Inhalation Rate (m^3/d)	27	U.S. EPA 1993 (allometric scaling)
Fraction of Time in Area	0.5	Assumed (move large distances)
Fractional Composition of Diet		
Terrestrial Plants	0.25	Based on CWS 2005, NatureServe 2007, Shefferly and Joly 2000
Lichen	0.75	

References:

Alaska Department of Fish & Game (ADF&G) 1999. Wildlife Notebook Series: Caribou. Accessed September 19, 2007 at: http://www.adfg.state.ak.us/pubs/notebook/biggame/caribou.php

Beyer, W. N., E. Connor, and S. Gerould. 1994. *Survey of Soil Ingestion by Wildlife.* Journal of Wildlife Management 58:375-382.

Canadian Wildlife Service (CWS) 2005. *Hinterland Who's Who. Mammal Fact Sheet: Caribou.* Available at: http://www.hww.ca/hww2.asp?id=85

NatureServe. 2007. NatureServe Explorer: An online encyclopedia of life. Version 6.2. NatureServe, Arlington, Virginia. Available http://www.natureserve.org/explorer. 8 June (Accessed: September 19, 2007).

Shefferly, N. and K. Joly. 2000. "Rangifer tarandus" (On-line), Animal Diversity Web. Accessed September 19, 2007 at http://animaldiversity.ummz.umich.edu/site/accounts/information/Rangifer_tarandus.html.

United States Environmental Protection Agency (U.S. EPA) 1993. *Wildlife Exposure Factors Handbook.* EPA/600/R-93/187.

Ecological Profile: Beaver

General Description

The beaver (*Castor canadensis*) is the largest rodent in North America. Most common in forested areas, beavers also expand into unforested habitats, where there are water-courses bordered by deciduous trees or shrubs. Beavers are most active from dusk to dawn. Beavers live in lodges and are primarily aquatic animals (CWS 2005, Anderson 2002).

Size

An adult beaver weighs from 16 to 32 kg (CWS 2005).
Usually 20 to 27 kg (eNature 2005).
Beavers weigh between 13 and 32 kg (Anderson 2002).
Weight: 27000 grams (NatureServe 2007).

Based on the above information a typical beaver is expected to weigh 24 kg (CWS 2005).

Home Range:

Summer home range areas average 10.34 ha, fall average 3.07 ha, winter home ranges are restricted to less than 0.25 ha around the lodge (Wheatley 1994).

Feeding Habits:

In the winter beavers rely on their underwater cache for food. They prefer trembling aspen, poplar, willow, and birch. They also swim out under the ice and retrieve the thick roots and stems of aquatic plants, such as pond lilies and cattails. Beavers shift from a woody diet to a herbaceous diet as new growth appears in the spring. During summer, beavers eat grasses, herbs, leaves of woody plants, fruits, and aquatic plants (CWS 2005, NatureServe 2007).

Based on the available information the beaver is assumed to consume terrestrial vegetation and aquatic vegetation. This is likely to comprise primarily browse in the winter with some aquatic vegetation and primarily forage and aquatic plants in the summer. In general, this corresponds to 70% terrestrial vegetation (browse) and 30% aquatic plants on an annual basis.

Food Consumption Rate:

Allometric equation for mammals (U.S. EPA 1993): FI (g (dw)/day) = 0.235 $Wt^{0.822}$ (g)

> Based on a body weight of 24000 g the FI is 937 g (dw)/d or 3750 g (ww)/d (moisture content of 75%)

Based on the above information the food consumption rate was taken to be 3750 g (ww)/d.

Sediment Ingestion:

The estimated % soil in diet (dry weight) for mammals is 5% (Beyer *et al.* 1994). Based on a dry weight consumption rate of 937 g/d this corresponds to approximately 47 g/d. Due to the aquatic habitat of this animal it is assumed that this ingestion is primarily sediment.

Water Intake Rate:

Allometric equation for mammals (U.S. EPA 1993): WI (L/day) = 0.099 $Wt^{0.9}$ (kg)

> Based on a body weight of 24 kg the WI is 1.7 L/d

Inhalation Rate:

Allometric equation for mammals (U.S. EPA 1993): IR (m^3/day) = 0.5458 $Wt^{0.8}$ (kg)

> Based on a body weight of 24 kg the IR is 7 m^3/d

Ecological Profile: Beaver

Summary Table:

Exposure Characteristics		
Body Weight (kg)	24	CWS 2005
Food Intake Rate (g (ww)/d)	3750	U.S. EPA 1993 (allometric scaling)
Sediment Ingestion Rate: (g (dw)/d) Fraction of ww diet:	 47 0.013	Beyer *et al.* 1994
Water Intake Rate (L/d)	1.7	U.S. EPA 1993 (allometric scaling)
Inhalation rate (m^3/d)	7	U.S. EPA 1993 (allometric scaling)
Fraction of time in area	1	Assumed
Fractional Composition of Diet		
Terrestrial Plants	0.7	Based on CWS 2005, NatureServe 2007
Aquatic Plants	0.3	

References:

Anderson, R. 2002. "Castor canadensis" (On-line), Animal Diversity Web. Accessed September 11, 2007 at http://animaldiversity.ummz.umich.edu/site/accounts/information/Castor_canadensis.html.

Canadian Wildlife Service (CWS) 2005. *Hinterland Who's Who. Mammal Fact Sheet: Beaver*. Available at: http://www.ffdp.ca/hww2.asp?id=825

eNature 2005. *Field Guide: American Beaver*. Available at: http://www.enature.com/fieldguides/detail.asp?shapeID=1038&curGroupID=5&lgfromWhere=&curPageNum=6. (Accessed: September 24, 2007).

NatureServe. 2007. NatureServe Explorer: An online encyclopedia of life. Version 6.2. NatureServe, Arlington, Virginia. Available http://www.natureserve.org/explorer. 8 June (Accessed: September 17, 2007).

United States Environmental Protection Agency (U.S. EPA) 1993. *Wildlife Exposure Factors Handbook.* EPA/600/R-93/187.

Wheatley, M. 1994. Boreal Beavers (*Castor canadensis*): Home Range, Territoriality, Food Habits and Genetics of a Mid-continent Population. Unpubl. PhD. Thesis, University of Manitoba: 350 pp. Available at: http://www.wilds.mb.ca/taiga/tbspub40.html

Ecological Profile: Benthic Invertebrates

Description:
Freshwater benthic invertebrates, or "benthos", are animal without a spinal column. The benthos include crustaceans such as crayfish, mollusks such as clams and snails, aquatic worms and the immature forms of aquatic insects such as stonefly and mayfly nymphs. These animals live on rocks, logs, sediment, debris and aquatic plants during some period in their life.

Many species of benthos are able to move around and expand their distribution by drifting with currents to a new location during the aquatic phase of their life or by flying to a new stream during their terrestrial phase. Most benthic species can be found throughout the year, but the largest numbers occur in the spring just before the reproductive period. In colder months, many species burrow deep within the mud or remain inactive on rock surfaces.

Feeding Habits:
Many invertebrates feed on algae and bacteria. Some shred and eat leaves and other organic matter that enters the water. Benthos are an important part of the food chain, especially for fish.

Reference:

Maryland Department of Natural Resources. 2004. Freshwater Benthic Macroinvertebrates. Retrieved from http://www.dnr.state.md.us/streams/pubs/freshwater.html. Accessed 19/9/2007.

Ecological Profile: Berries

General Description

In botany, the berry is the most common type of simple fleshy fruit; a fruit in which the entire ovary wall ripens into an edible pericarp. The flowers of these plants have a superior ovary and they have one or more carpels within a thin covering and very fleshy interiors. The seeds are embedded in the common flesh of the ovary (Wikipedia 2007).

In the Arctic region, through years of adaptation, a wide range of berry species have developed unique means for surviving the extreme climate by storing the energy of the long and intense summer in the form of multiple nutrients such as antioxidants and vitamins (Yang 2005).

Faunal Associations

Berries are eaten by a variety of mammals and birds, such as bears, coyote, raccoon, fox, skunk, rabbit, deer and turkey (North Wood Field Guide 2007).

References:

North Wood Field Guide. 2007. North Wood Animals. Retrieved from http://www.northwoodsguides.com/animal_notes.htm. Accessed on 21/9/2007.

Wikipedia. 2007. Retrieved from http://en.wikipedia.org/wiki/Berries . Accessed on 21/9/2007.

Yang, B. 2005. Technical note on Oils from Arctic Berries as Unique Active Ingredients for Skincare. Retrieved from http://www.nyscc.org/news/archive/tech1005.htm. Accessed on 21/9/2007.

Ecological Profile: Black Spruce

General Description

The Black Spruce (Picea mariana) is a common coniferous tree in North America, ranging from Newfoundland west to Alaska, and south to northern New York, Minnesota and central British Columbia. It is a slow-growing, small upright tree or shrub, having a straight trunk with little taper, a scruffy habit, and a narrow, pointed crown of short, compact, drooping branches with upturned tips. It grows in both lowland and upland sites. In the southern portion of range it is found primarily on wet organic soils, but farther north its abundance on uplands increases (Conifer Specialist Group (1998).

Size

It averages 10 to 15 m tall with 15 to 25 cm diameter trunks at maturity, though occasional specimens can reach 30 m tall and 60 cm diameter.

Faunal Associations

Moose occasionally browse saplings, but white-tailed deer eat it only under starvation conditions. It is a major food of snowshoe hares, especially in winter. Red squirrels consume seed from harvested cones. Mice, voles, shrews, and chipmunks eat seeds off the ground. Spruce grouse feed entirely on spruce needles in winter. Chickadees, nuthatches, crossbills, grosbeaks, and pine siskin extract seeds from open spruce cones and eat seeds off the ground (BWCAW 2006).

References:

Conifer Specialist Group (1998). Pinus banksiana. 2006 IUCN Red List of Threatened Species.

The Boundary Waters Canoe Area Wilderness (BWCAW) 2006. Flora, Fauna, Earth, and Sky The Natural History of the Northwoods: Picea mariana Black Spruce. Retrieved from http://www.rook.org/earl/bwca/nature/trees/piceamar.html . Accessed on 24 September 2007.

Ecological Profile: Brook Trout

General Description:

The brook trout (*Salvelinus fontinalis*) is of dark green to brown basic colouration with a distinctive marbled pattern of lighter shades across the flanks and back and extending at least to the dorsal fin, and often to the tail. It is native to a wide area of eastern North America. In Canada, the brook trout is widely distributed throughout the Maritime Provinces (Scott and Crossman 1998).

Individuals normally spend their entire life in fresh water, but some may spend up to three months at sea in the spring, not straying more than a few kilometers from the river mouth. The fish return upstream to spawn in the late summer or autumn. It inhabits shallow areas of lakes and clear streams, rarely entering brackish water (Froese and Pauly 2007).

Size:
The body is typically troutlike, elongate with an average length of 25-30 cm. It reaches a maximum weight of 6.06 kg (Scott and Crossman 1998).

Feeding Habits:
Brook trout are carnivorous, and feed upon a wide range of organisms, such as aquatic insect larvae and terrestrial insects (Scott and Crossman 1998).

Environment:
They are found in the demersal environment (Froese and Pauly 2007).

Reference:

Froese, R. and D. Pauly. Editors. 2007. FishBase. World Wide Web electronic publication. Retrieved from http://www.fishbase.org/Summary/SpeciesSummary.php?id=2682 . Accessed on 19/9/2007.

Scott, W.B. and E.J. Crossman. 1998. Freshwater Fishes of Canada. Galt House Publication Ltd. Oakville, ON. Canada.

Ecological Profile: Brown Trout

General Description:

The brown trout (*Salmo trutta* Linnause) is light brown or tawny overall, brown on the back and silvery on the sides with pronounced black spots in back, sides of the body and head. It is native to Europe and western Asia. It was introduced to Canada first in 1884. It has been introduced mainly into stream or river habitats, although a number of lake or sea-run populations now exist. It inhabits shallow areas of lakes and clear streams, rarely entering brackish water (Scott and Crossman 1998).

The brown trout is most usually potamodromous, migrating from lakes into rivers or streams to spawn. There is evidence that anadromous and non-anadromous morphs coexisting in the same river can be genetically identical (Clover 2004).

Size:

The brown trout is a medium sized fish, with an average length of 41 cm, growing to 20 kg or more in some localities although in many smaller rivers a mature weight of 1 kg or less is common (Froese and Pauly 2007).

Feeding Habits:

Brown trout are carnivorous and eat a variety of organisms, particularly aquatic and terrestrial insects and their larvae, crustaceans, especially crayfish, mollusks, salamanders, frogs, and rodent and fishes (Scott and Crossman 1998).

Environment:

They are found in the pelagic environment (Froese and Pauly 2007).

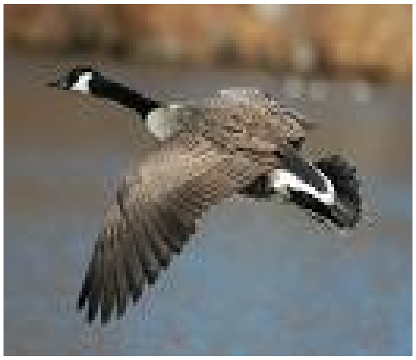
References:

Clover, C. 2004. The End of the Line: How overfishing is changing the world and what we eat. Ebury Press, London. ISBN 0-09-189780-7

Froese, R. and D. Pauly. Editors. 2007. FishBase. World Wide Web electronic publication. Retrieved from http://www.fishbase.org/Summary/SpeciesSummary.php?id=2682 . Accessed on 19/9/2007.

Scott, W.B. and E.J. Crossman. 1998. Freshwater Fishes of Canada. Galt House Publication Ltd. Oakville, ON. Canada.

Ecological Profile: Canada Goose



General Description

Canada Geese (*Branta Canadensis)* are the most familiar and widespread geese in North America and are found on almost any type of wetland, from small ponds to large lakes and rivers. However, Canada Geese spend as much or more time on land as they do in water. They prefer low-lying areas with great expanses of wet grassy meadows and an abundance of ponds and lakes. The percentage of the population wintering in the north is now higher than in the past, due at least in part to increased availability of food (CWS 2003, NatureServe 2007, Cornell 2003, U.S. EPA 1993).

Size

Canada goose weighs between 1.10 to 8 kg (Dewey and Lutz 2002).
Weight 4741 grams (4.74 kg) (NatureServe 2007).
Weight: 3000 to 9000 g (3 to 9 kg) (Cornell 2003).
U.S. EPA (1993) provides values from 4 studies; range for adults is 2.5 kg (female) to 4.9 kg (male). The average of males and females from the studies is 3.7 kg.

Based on the above information a typical grouse is expected to weigh approximately 4 kg (NatureServe 2007, Cornell 2003, U.S. EPA 1993).

Home Range:

The foraging home range of Canada geese varies with season, latitude, and breeding condition (U.S. EPA 1993).

Feeding Habits:

Canada Geese are herbivorous and feed mostly on land. In spring and summer, they mostly graze on the leaves of grassy plants, but they also eat a wide variety of leaves, flowers, stems, roots, seeds, and berries. During the winter, Canada Geese often feed in fields where they find an abundance of spilled corn, oats, soybeans, and other crops (CWS 2003, Cornell 2003, U.S. EPA 1993).

Based on the available information the goose is assumed to consume terrestrial vegetation.

Food Consumption Rate:

The U.S. EPA (1993) provides 2 studies with food intake rates ranging from 0.03 to 0.033 g (ww)/d per g body weight (average of studies is 0.031 g/(g d)). Based on a body weight of 4000 g the FI is 124 g (ww)/d or 37 g (dw)/d (moisture content of 70%).
Allometric equation for birds (U.S. EPA 1993): FI (g (dw)/day) = $0.648\ Wt^{0.651}$ (g)

> Based on a body weight of 4000 g the FI is 140 g (dw)/d or 480 g (ww)/d (moisture content of 70%).

Based on the above information the food consumption rate was taken to be 120 g (ww)/d (U.S. EPA 1993); however it is noted that the information generated from specific studies is much lower than the allometric estimate.

Soil Ingestion:

Canada Geese must consume grit at some point to assure proper digestion (U.S. EPA 1993). Beyer *et al.* (1994) provides a value of 8.2% for a Canada Goose. Based on a dry weight consumption rate of 37 g/d, the corresponding grit intake equals approximately 3.1 g/d.

Water Intake Rate:

The U.S. EPA (1993) provides 2 studies with a water intake rate range of 0.035 to 0.053 g (ww)/d per g body weight (average of studies is 0.044 g/(g d)). Based on a body weight of 4000 g the WI is 180 g/d or 0.18 L/d.

Allometric equation for birds (U.S. EPA 1993): WI (L/day) = 0.059 $Wt^{0.67}$ (kg)

Based on a body weight of 4 kg the WI is 0.15 L/d.

Based on the above information the water consumption rate was taken to be 0.15 L/d (U.S. EPA 1993), which agrees well with the allometric estimate.

Inhalation Rate:

The U.S. EPA (1993) studies provided with an inhalation rate range of 0.52 to 1.4 m^3/d, average 0.9 m^3/d.
Allometric equation for birds (U.S. EPA 1993): IR (m^3/day) = 0.4089 $Wt^{0.77}$ (kg)

Based on a body weight of 4 kg the IR is 1.2 m^3/d.

Based on the above information the inhalation rate was taken to be 0.9 m^3/d (U.S. EPA 1993), which agrees well with the allometric estimate.

Summary Table:

Exposure Characteristics		
Body Weight (kg)	4	NatureServe 2007, Cornell 2003, U.S. EPA 1993
Food Intake Rate (g (ww)/d)	120	U.S. EPA 1993
Soil Ingestion Rate: (g (dw)/d) Fraction of ww diet:	 3.1 0.026	Beyer *et al.* 1994
Water Intake Rate (L/d)	0.15	U.S. EPA 1993
Inhalation Rate (m^3/d)	0.9	U.S. EPA 1993
Fraction of Time in Area	0.5	Assumed (migratory)
Fractional Composition of Diet		
Terrestrial Plants	1	Based on information from CWS 2003, Cornell 2003, U.S. EPA 1993

References:

Beyer, W. N., E. Connor, and S. Gerould. 1994. *Survey of Soil Ingestion by Wildlife.* Journal of Wildlife Management 58:375-382.

Canadian Wildlife Service (CWS) 2003. *Hinterland Who's Who. Bird Fact Sheet: Canada Goose.* Available at: http://www.hww.ca/hww2.asp?id=35

Cornell 2003. *All About Birds. Bird Guide.* Cornell Lab of Ornithology. Accessed September 18, 2007 http://www.birds.cornell.edu/AllAboutBirds/BirdGuide/

Dewey, T. and H. Lutz. 2002. "Branta canadensis" (On-line), Animal Diversity Web. Accessed September 17, 2007 at http://animaldiversity.ummz.umich.edu/site/accounts/information/Branta_canadensis.html.

NatureServe. 2007. NatureServe Explorer: An online encyclopedia of life. Version 6.2. NatureServe, Arlington, Virginia. Available http://www.natureserve.org/explorer. 8 June (Accessed: September 17, 2007).

United States Environmental Protection Agency (U.S. EPA) 1993. *Wildlife Exposure Factors Handbook.* EPA/600/R-93/187.

Ecological Profile: Cattails

General Description
Cattails (*Typha* spp.) are common emergent aquatic plants. They are native perennials that grow in moist soil and are adapted to water depths up to 2.5 feet (Porter 2000). The genus has a largely Northern Hemisphere distribution, but is essentially cosmopolitan. Typha plants grow along lake margins and in marshes, often in dense colonies, and are sometimes considered a weed in managed wetlands. (Wikipedia 2007).

Size
This native perennial plant is about 1.2 to 2.7 m tall and unbranched, consisting of 6 or more leaves and a flowering stalk. This stalk is light green to green, glabrous, stiff, and round in cross-section. The leaves are up to 2.3 m long and 2.5 cm across. They are linear, green to bluish grey (often the latter), hairless, and rather flattened. Relative to the flowering stalk, the leaves are erect to slightly spreading; they originate from the base of the plant (Hilty 2007).

Faunal Associations
The caterpillars of various moths feed on cattails (the leaves, stalk, flowers, or developing seeds). The starchy rootstocks of Cattails are an important source of food to Muskrats. The Canada Goose and other geese eat the rootstocks to a more limited extent (Hilty 2007).

References:

Hilty, J. 2007. Illinois Wildflowers. Common Cattail. Retrieved from http://www.illinoiswildflowers.info/wetland/plants/cattail.htm

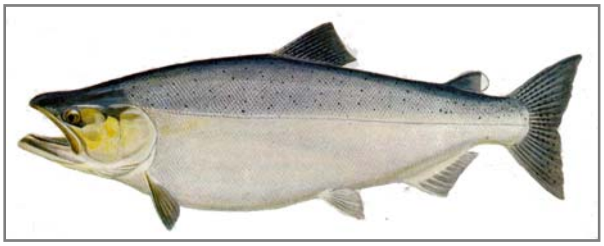
Porter, M. 2000. Noble Foundation Agricultural Division. AG News and Views: Wildlife. Cattails - Habitat or Hassle. Retrieved from http://www.noble.org/Ag/Wildlife/cattails/Index.htm

Wikipedia. 2007. Retrieved from http://en.wikipedia.org/wiki/Typha#References

Note: In the calculations, pondweeds and cattails are represented by the same ecological profile.

Ecological Profile: Chinook Salmon

General Description:



The Chinook salmon (*Oncorhynchus tshawytscha*) is blue-green on the back and top of the head with silvery sides and white ventral surfaces. It has black spots on its tail and the upper half of its body; its mouth is dark gray (Scott and Crossman 1998).

Chinook salmon are divided into two types of juveniles, ocean type and river type. Ocean type chinook migrate to salt water in the first year of their life. Stream type spends one full year in fresh water before migrating to the ocean. Once they spend a couple of years in the ocean, adult salmon grow large enough to escape most predators and return to their original streambeds to mate (Wikipedia 2007).

Size:
Adult fish average 84-91 cm in length; they average 4.5-23 kg in weight (Scott and Crossman 1998).

Feeding Habits:
Chinook feed on insects, amphipods, and other crustaceans while young, and primarily on other fish when older. Young salmon feed in streambeds for a short period of time until they are strong enough to journey out into the ocean and acquire more food (Wikipedia 2007).

Environment:
They are found in the benthopelagic environment (Froese and Pauly 2007).

Reference:

Froese, R. and D. Pauly. Editors. 2007. FishBase. World Wide Web electronic publication. Retrieved from http://www.fishbase.org/Summary/SpeciesSummary.php?id=2682 . Accessed on 1/10/2007.

Scott, W.B. and E.J. Crossman. 1998. Freshwater Fishes of Canada. Galt House Publication Ltd. Oakville, ON. Canada.

Wikipedia. 2007. Retrieved from http://en.wikipedia.org/wiki/Chinook_salmon. Accessed on 21/9/2007.

Ecological Profile: Common Loon

General Description

The Common Loon (*Gavia immer)* is the best known loon and its breeding range lies across most of Canada. Common Loons spend most of the time on water and have to pull themselves onto land to nest. They are efficient divers and can stay under water for almost a minute and dive to depths of 80 m. The Common Loon breeds in most of Canada. Common loons are migratory, leaving their breeding grounds beginning in September. It spends the nonbreeding season along the Pacific and Atlantic coasts of North America. (CWS 1994, Cornell 2003, Kirschbaum and Rodriguez 2002)

Size

Adults are large-bodied, weighing from 2.7 to over 6.3 kg (CWS 1994)
Common loons are 1.6 to 8.0 kg (Kirschbaum and Rodriguez 2002)
Weight 4134 grams (NatureServe 2007)
Weight: 2500-6100 g (Cornell 2003)
Adult body weight 4.134 kg (CCME 1996)

Based on the above information a typical loon is expected to weigh approximately 4 kg (NatureServe 2007, Cornell 2003).

Home Range:

The breeding territory of loon pairs ranges from 0.24 to 0.81 square kilometers. On their wintering grounds, individuals defend small feeding territories of 0.04 to 0.08 square kilometers during the day (Kirschbaum and Rodriguez 2002).
Lakes smaller than 80 ha generally support only one breeding pair (NatureServe 2007).

Feeding Habits:

Loons are predators; their diet in summer consists of fish, crayfish, frogs, snails, salamanders, and leeches. Adult loons prefer fish to other food, and seem to favour perch, suckers, catfish, sunfish, smelt, and minnows. They generally hunt in water 2 to 4 meters deep. Because they rely on sight, clear water is critical to common loons (CWS 1994, Kirschbaum and Rodriguez 2002, NatureServe 2007, Cornell 2003).

Based on the available information the loon, the principal source of food for loon is fish (this is assumed to comprise equally pelagic and benthic fish).

Food Consumption Rate:

Daily food consumption rate is 0.73 kg (ww)/d (CCME 1996 – calculated using allometric equation).
Allometric equation for birds (U.S. EPA 1993): FI (g (dw)/day) = $0.648\ Wt^{0.651}$ (g)

> Based on a body weight (Wt) of 4000 g the FI is 143 g (dw)/d or 720 g (ww)/d (moisture content of 80%)

Based on the above information the food consumption rate was taken to be 730 g (ww)/d.

Sediment Ingestion:

Data on sediment ingestion by loon were not found in the open literature. However, Beyer *et al.* (1994) provides a value of 2% for ring-necked duck and blue winged teal. Since the loon is piscivorous and would not ingest significant amounts of sediment this value was used. Based on a dry weight consumption rate of 143 g/d this corresponds to approximately 2.9 g/d.

Water Intake Rate:
Allometric equation for birds (U.S. EPA 1993): WI (L/day) = 0.059 $Wt^{0.67}$ (kg)
Based on a body weight (Wt) of 4 kg the WI is 0.15 L/d

Inhalation Rate:
Allometric equation for birds (U.S. EPA 1993): IR (m^3/day) = 0.4089 $Wt^{0.77}$ (kg)
Based on a body weight (Wt) of 4 kg the IR is 1.2 m^3/d

Summary Table:

Exposure Characteristics		
Body Weight (kg)	4	NatureServe 2007, Cornell 2003
Food Intake Rate (g (ww)/d)	730	CCME 1996
Sediment Ingestion Rate: (g/d) Fraction of ww diet:	 2.9 0.004	Beyer *et al.* 1994
Water Intake Rate (L/d)	0.15	U.S. EPA 1993 (allometric scaling)
Inhalation rate (m^3/d)	1.2	U.S. EPA 1993 (allometric scaling)
Fraction of time in area	0.5	Assumed (migratory)
Fractional Composition of Diet		
Fish - pelagic - benthic	0.5 0.5	Based on information from CWS 1986, NatureServe 2007 and Cornell 2003

References:

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Ecological Profile: Dwarf Willow

General Description
The Dwarf Willow (*Salix herbacea*) is the most common of a group of tiny creeping willows (family Salicaceae). It is the smallest tree in the world. It is adapted to survive in harsh arctic and sub-arctic environments, and has a wide distribution on both sides of the North Atlantic. Like the rest of the willows, Dwarf Willow is dioecious, with male and female catkins on separate plants (Argus et al. 1999).

Dwarf willow grows best on moist sites that are subject to periodic flooding and overflow (USDA 2002).

Size
Dwarf willow is a small to medium sized shrub growing only 1.8 to 2.4 m high (USDA 2002).

Faunal Associations
Arctic willow is food for Peary caribou, musk oxen and arctic hares.

References:

Argus, G.W. , C.L. McJannet and M.J. Dallwitz (1999 onwards). 'Salicaceae of the Canadian Arctic Archipelago: Descriptions, Illustrations, Identification, and Information Retrieval.' Version: 2nd November 2000.

United States Department of Agriculture (USDA). 2002. Natural Resources Conservation Services. Plant Fact Sheet. Dwarf Willow.

Ecological Profile: Earthworm

General Description

The glacial ice sheets that covered nearly all of Canada about 15,000 years ago wiped out virtually all of the native North American earthworm species that may have lived here. The current earthworm population (approximately 20 species) was brought here by early Europeans. Earthworms can have positive effects on soil structure and fertility in agricultural and garden ecosystems; however they may not be beneficial in hardwood forests. (Fox 2004, NRRI 2006)

Three major ecological groups of earthworm have been identified based on the feeding and burrowing behaviours of the different species (NRRI 2006):

- Epigeic: small (1-7 cm), feeds and lives in litter, does not burrow. Species found in the Great Lakes area include *Dendrobaena octaedra* and *Lumbricus rubellus*.
- Endogeic: small (2-12 cm), rich soil feeder, lives in top soil layer, extensive branching horizontal burrows. Species found in the Great Lakes area include *Aporrectodea caliginosa*, *Aporrectodea rosea* and *Octolasion tyrtaeum*.
- Anecic: large (adults are usually 12-20 cm), feeds in soil and litter, has extensive permanent vertical burrows up to 2m deep. In the Great Lakes region, there is only one anecic species of earthworm, the common night crawler (*Lumbricus terrestris*).

Earthworms live in the soil, but the types of soil they inhabit vary widely. As indicated above, some worm species occupy their place in the soil by moving vertically along permanent burrows (e.g. dew worm or night crawler). Other species such as *Aporrectodea* (garden worms) occupy the top soil layer and move horizontally. Fraser (2001) did not identify appreciable burrowing activity below 20 cm depth among three common earthworm species (epigeic and endogeic species). Other species such as the manure worm (*Eisenia foetida*) require soil with high carbon content (muck soils) or manures to survive (Tomlin 2006).

Earthworms derive their nutrition from many forms of organic matter in soil, things like decaying roots and leaves, and living organisms such as nematodes, protozoans, rotifers, bacteria and fungi. They also feed on the decomposing remains of other animals. They can consume, in just one day, up to one third of their own body weight. Earthworms respire through their skin, and therefore require humid conditions to prevent drying out. Like all invertebrates their body processes or metabolism slow down with falling temperatures. They hibernate at near freezing temperature. They react to advancing colder winter weather by burrowing deep; most earthworms do not survive being frozen (Fox 2004). Cocoons generally survive through the winter.

References:

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Ecological Profile: Gray Wolf

General Description

The gray wolf (*Canis lupus*) is a social animal and has a highly organized social structure centering on a dominant male and a dominant female. Gray wolves are one of the most wide ranging land animals. They occupy a wide variety of habitats, from arctic tundra to forest, prairie, and arid landscapes. The original range of the wolf consisted of the majority of the Northern hemisphere, however, gray wolf populations are now found only in a few areas of the contiguous United States, Alaska, Canada, Mexico (a small population), and Eurasia. They are mainly nocturnal (CWS 1993, Dewey and Smith 2002).

Size

Weigh between 20 and 75 kg (Dewey and Smith 2002).
Weight 40000 grams (40 kg) (NatureServe 2007).
43 kg (Schmidt and Gilbert 1978).

Based on the above information a typical wolf is expected to weigh 43 kg (Schmidt and Gilbert 1978).

Home Range:

Wolves are territorial. Each pack occupies an area that it will defend against intruders. Sizes of territories vary greatly and are dependent on the kind and abundance of prey available (CWS 1993). The territory of a pack ranges from 130 to 13,000 square kilometers (Dewey and Smith 2002).

Feeding Habits:

Gray wolves are carnivores. Wolves' chief prey are large mammals such as deer, moose, caribou, elk, bison, and muskox. Wolves also eat a variety of smaller mammals and birds, but these rarely make up more than a small part of their diet (CWS 1993, NatureServe 2007, Dewey and Smith 2002).

Based on the available information the wolf is assumed to consume moose and deer in equal proportion.

Food Consumption Rate:

Gray wolf in northeastern Alberta eat 5.5 kg/d (Fuller and Keith 1980).
Allometric equation for mammals (U.S. EPA 1993): FI (g (dw)/day) = $0.235\ Wt^{0.822}$ (g)

Based on a body weight of 43000 g the FI is 1500 g (dw)/d or 5000 g (ww)/d (moisture content of 70%)

Based on the above information the food consumption rate was taken to be 5.5 kg (ww)/d (Fuller and Keith 1980), this value agrees well with the allometric estimate.

Soil Ingestion:

Beyer *et al.* (1994) provides values of 2.8% for red fox which was used for the wolf in lieu of a species specific value. This should be a conservative assumption as the wolves hunt larger prey. Based on a dry weight consumption rate of 1650 g/d this corresponds to approximately 46 g/d.

Water Intake Rate:

Allometric equation for mammals (U.S. EPA 1993): WI (L/day) = $0.099\ Wt^{0.9}$ (kg)

Based on a body weight of 43 kg the WI is 2.9 L/d

Inhalation Rate:

Allometric equation for mammals (U.S. EPA 1993): IR (m^3/day) = $0.5458\ Wt^{0.8}$ (kg)

Based on a body weight of 43 kg the IR is 11 m^3/d

Ecological Profile: Gray Wolf

Summary Table:

Exposure Characteristics		
Body Weight (kg)	43	Schmidt and Gilbert 1978
Food Intake Rate (g (ww)/d)	5500	Fuller and Keith 1980
Soil Ingestion Rate: (g (dw)/d) Fraction of ww diet:	46 0.008	Beyer *et al.* 1994
Water Intake Rate (L/d)	2.9	U.S. EPA 1993 (allometric scaling)
Inhalation Rate (m^3/d)	11	U.S. EPA 1993 (allometric scaling)
Fraction of Time in Area	0.25	Assumed based on large home range
Fractional Composition of Diet		
Moose	0.5	Based on information from CWS 1993, NatureServe 2007, Dewey and Smith 2002
Deer	0.5	

References:

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Schmidt, J.L. and D.L. Gilbert 1978. *Big Game of North America, Ecology and Management.* Stackpole Books, Harrisburg, PA 17105.

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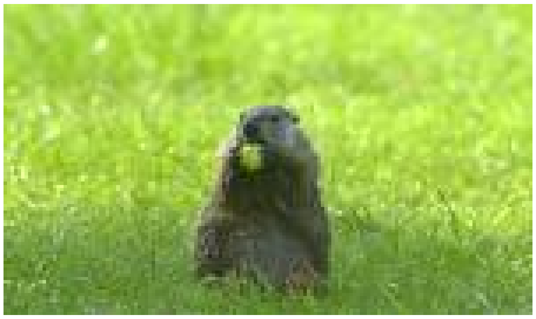
Ecological Profile: Groundhog



General Description

The groundhog or woodchuck (*Marmota monax*) is a rodent and belongs to the large group of mammals Rodentia, which includes squirrels, prairie dogs, and chipmunks. Typical habitat includes rolling farmland interspersed with grassy pastures, small woodlots, and brushy fencelines. Woodchucks hibernate and are partial to loam and sandy loam soils for burrowing. (CWS 1991, Light 2001)

Size

They commonly weigh 2 to 4 kg, and large ones may be heavier in the autumn (CWS 1991).
Woodchucks weigh between 3 and 5 kg (Light 2001).
Weight 6400 grams (6.4kg) (NatureServe 2007).

Based on the above information a typical groundhog is expected to weigh 4 kg (CWS 1991, Light 2001).

Home Range:

Home range averaged about 4 ha in males, 2 ha in female in a Connecticut study. Home range was 7.8 ha in a Quebec study and 4.1 ha in an Iowa study, for males, smaller in females (NatureServe 2007).

Feeding Habits:

Woodchucks prefer to eat fresh green vegetation and consume a wide variety of wild plants, clover and alfalfa, and garden vegetables if they can get them. They may consume insects, snails, invertebrates and birds eggs, but rarely (CWS 1991, NatureServe 2007, Little 2001).

Based on the available information the groundhog is assumed to consume terrestrial vegetation. This is likely to comprise forage during the summer.

Food Consumption Rate:

Allometric equation for mammals (U.S. EPA 1993): FI (g (dw)/day) = 0.235 $Wt^{0.822}$ (g)

Based on a body weight of 4000 g the FI is 215 g (dw)/d or 716 g (ww)/d (moisture content of 70%).

Based on the above information the food consumption rate was taken to be 716 g (ww)/d.

Soil Ingestion:

Beyer *et al.* (1994) provides values of 2.7% and 7.7% for prairie dogs of the total dry weight dietary intake; an average of 5.4% was thus used. Based on a dry weight consumption rate of 215 g/d this corresponds to approximately 11 g/d.

Water Intake Rate:

Allometric equation for mammals (U.S. EPA 1993): WI (L/day) = 0.099 $Wt^{0.9}$ (kg)

Based on a body weight of 4 kg the WI is 0.3 L/d.

Inhalation Rate:

Allometric equation for mammals (U.S. EPA 1993): IR (m^3/day) = 0.5458 $Wt^{0.8}$ (kg)

Based on a body weight of 4 kg the IR is 1.7 m^3/d

Ecological Profile: Groundhog

Summary Table:

Exposure Characteristics		
Body Weight (kg)	4	CWS 1991, Little 2001
Food Intake Rate (g (ww)/d)	716	U.S. EPA 1993 (allometric scaling)
Soil Ingestion Rate: (g (dw)/d) Fraction of ww diet:	 11 0.016	Beyer *et al.* 1994
Water Intake Rate (L/d)	0.3	U.S. EPA 1993 (allometric scaling)
Inhalation rate (m^3/d)	1.7	U.S. EPA 1993 (allometric scaling)
Fraction of time in area	1	Assumed
Fractional Composition of Diet		
Terrestrial Plants	1	CWS 1991

References:

Beyer, W. N., E. Connor, and S. Gerould. 1994. *Survey of Soil Ingestion by Wildlife.* Journal of Wildlife Management 58:375-382.

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Light, J. 2001. "Marmota monax" (On-line), Animal Diversity Web. Accessed September 17, 2007 at http://animaldiversity.ummz.umich.edu/site/accounts/information/Marmota_monax.html.

NatureServe. 2007. NatureServe Explorer: An online encyclopedia of life. Version 6.2. NatureServe, Arlington, Virginia. Available http://www.natureserve.org/explorer. 8 June (Accessed: September 17, 2007).

United States Environmental Protection Agency (U.S. EPA) 1993. *Wildlife Exposure Factors Handbook.* EPA/600/R-93/187.

Ecological Profile: Jack Pine

General Description
The Jack Pine (*Pinus banksiana*) is a North American pine with its native range in Canada east of the Rocky Mountains from Northwest Territories to Nova Scotia (Conifer Specialist Group 1998).

It is the dominant tree in southern boreal forest. Associates are almost always subdominant except for Aspen, Paper Birch, and Red Pine which may be co-dominant (BWCAW 2004).

This pine often forms pure stands on sandy or rocky soil. It is fire-adapted to stand-replacing fires, with the cones remaining closed for many years, until a natural forest fire kills the mature trees and opens the cones. These then reseed the burnt ground. The cones normally point forward along the branch, sometimes curling around it. Unopened cones are smooth and serotinous - the scales opening in fire or intense heat (Conifer Specialist Group 1998).

It usually grows in dry, acidic sandy soils with a lower pH limit of 4.0, but also loamy soil, thin soil over bedrock, peat, and soil over permafrost. It does not usually grow in moderately alkaline soil, but can grow in calcareous soils up to pH 8.2 if normal mycorrhizal fungi are present (BWCAW 2004).

Size
It is not a large tree, ranging from 9 to 22 m in height. Some Jack Pines are shrub-sized. The leaves are in fascicles of two, needle-like, twisted, slightly yellowish-green, and 2 to 4 cm long. The cones are 3 to 5 cm long (Conifer Specialist Group 1998).

Faunal Associations
White-tailed deer browse saplings and young trees and snowshoe hares feed on young seedlings. Porcupines feed on bark that often leads to deformed trees. Red squirrels, chipmunks, mice, goldfinches and robins consume seeds (USDA 2007).

References:

Conifer Specialist Group (1998). Pinus banksiana. 2006 IUCN Red List of Threatened Species.

The Boundary Waters Canoe Area Wilderness (BWCAW). 2004. Flora, Fauna, Earth, and Sky The Natural History of the Northwoods: Pinus banksiana Jack Pine. Retrieved from http://www.rook.org/earl/bwca/nature/trees/pinusbank.html.

United States Department of Agriculture (USDA). Natural Resources Conservation Services (NRCS). Plant Guide: Jack Pine. 2007. Retrieved from http://plants.usda.gov/plantguide/doc/pg_piba2.doc. Accessed on 24/9/2007.

Ecological Profile: Largemouth Bass

General Description:

The Largemouth bass (*Micropterus salmoides*) is a moderately large, robust fish. It is marked by a series of dark blotches forming a jagged horizontal stripe along the length of each side. It can also be totally black. In Canada, it occurs in central Ontario and southern British Columbia. The habitat of the largemouth bass is the upper levels of the warm water of small, shallow lakes, shallow bays of larger lakes, and more rarely, larger, slow rivers.

Size:
Most individuals seen in Canada are 12-36 cm in length and usually do not exceed 1.5 kg in weight.

Feeding Habits:
The largemouth bass's diet changes as it mature, consuming mostly small food items such as plankton and insects as juveniles. As adults their eating habits mature to include small fish, crayfish, and frogs. Largemouth bass have even been known to take small mammals such as mice, rats and small birds.

Environment:
They are found in the benthopelagic environment (Froese and Pauly 2007).

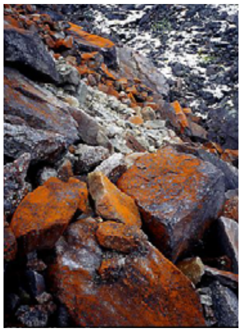
Reference:

Froese, R. and D. Pauly. Editors. 2007. FishBase. World Wide Web electronic publication. Retrieved from http://www.fishbase.org/Summary/SpeciesSummary.php?id=2682 . Accessed on 1/10/2007.

Scott, W.B. and E.J. Crossman. 1998. Freshwater Fishes of Canada. Galt House Publication Ltd. Oakville, ON. Canada.

Ecological Profile: Lichen

General Description



Lichens are symbiotic associations of a fungus (the mycobiont) with a photosynthetic partner (the photobiont also known as the phycobiont) that can produce food for the lichen from sunlight. The photobiont is usually either green algae or cyanobacteria (Ahmadjian 1993).

The algal or cyanobacterial cells are photosynthetic, and as in higher plants they reduce atmospheric carbon dioxide into organic carbon sugars to feed both symbionts. Both partners gain water and mineral nutrients mainly from the atmosphere, through rain and dust (Wikipedia 2007).

Lichens are often the first to settle in places lacking soil, constituting the sole vegetation in some extreme environments such as those found at high mountain elevations and at high latitudes. Some survive in the tough conditions of deserts, and others on frozen soil of the arctic regions (University of Sydney 2004).

Faunal Associations

Lichens may be eaten by some animals, such as caribou, living in arctic regions. The larvae of a large number of Lepidoptera species feed exclusively on lichens. These include Common Footman and Marbled Beauty (Wikipedia 2007).

Estimating Concentrations

Since lichen grow in areas without soil, the concentration is modelled in a different manner than other vegetation where the concentration is estimated from soil concentration and a transfer factor. In addition, lichen live for more than one season and thus can integrate contaminants over an extended duration. The approach for estimating concentration, along with the parameterization, was taken from the UTAP model (SENES 1987) and depends on the contaminant level in air.

$$C_v = C_a V_d F_{in} F_{rv} E_v \left[\frac{1 - \exp(-\lambda_{wv} t_v)}{Y_v \lambda_{wv}} \right]$$

where:

C_v	lichen concentration (Bq/g (wet weight))
C_a	air concentration (Bq/m^3)
V_d	deposition velocity (0.02 m/s)
F_{in}	fraction of the deposition that is intercepted (1.0)
F_{rv}	fraction of the total deposition retained on the surface (0.95)
E_v	fraction of the foliar deposition retained on edible portions (1.0)
λ_{wv}	decay constant accounting for weathering losses ($2.2\text{x}10^{-9}$ s^{-1})
t_v	duration of the plant exposure to atmospheric deposition ($1\text{x}10^{10}$ s)
Y_v	yield density (500 g (wet weight) $/m^2$)

The concentration in dust is assumed to be equal to the concentration in soil. The typical level of suspended particulate in air is taken to be 17 $\mu g/m^3$ based on available monitoring data collected from rural stations in Quebec through the National Air Pollution Surveillance (NAPS) Network (Environment Canada 2003). There is also the potential for transfer from water which as been entrained in air. The same calculation procedure was employed with a resuspended water body aerosol concentration (m^3 water per m^3 air) of 2.0E-09 as provided by BIOTRAC (Zach et al. 1996).

References:

Ahmadjian, V. 1993. *The Lichen Symbiosis*. New York: John Wiley & Sons.

Brodo, I.M., S.D. Sharnoff, and S. Sharnoff, 2001. Lichens of North America. Yale University Press, New Haven.

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Ecological Profile: Moose

General Description
Moose (*Alces alces*) are found on the rocky, wooded hillsides of the western mountain ranges; along the margins of lakes, muskegs, and streams of the boreal forest; and even on the northern tundra and in the aspen parkland of the prairies. Moose are quite at home in the water. They sometimes dive 5.5 m or more for plants growing on a lake or pond bottom. Moose are good swimmers, able to sustain a speed of 6 miles an hour. They move swiftly on land; adults can run as fast as 56 km/h (CWS 1997, Dewey *et al.* 2000).

Size
Big bulls weigh up to 600 kg in most of Canada (CWS 1997).
Moose weigh between 270 and 600 kg (Dewey *et al.* 2000).
Weight 630000 grams (630 kg) (NatureServe 2007).

Based on the above information a typical moose is expected to weigh 600 kg (CWS 1997).

Home Range:
Moose home ranges average 5 to 10 square kilometers (Dewey *et al.* 2000).
Based on radio-collared individuals in Copper River Delta in south-central Alaska, a mean value of 59 km^2 was calculated (MacCracken *et al.* 1997).
In Idaho, the home range for female moose has been observed to range from 15.5 to 25.9 km^2, and for male moose from 31 to 51.8 km^2 (Pierce and Peck 1984).

Feeding Habits:
Moose eat twigs, bark, roots and the shoots of woody plants, especially willows and aspens. In summer the moose's diet includes leaves, some upland plants, and water plants. They dip their heads under the surface of the water to feed on the lilies and other water plants. During the winter months, moose live almost solely on twigs and shrubs such as balsam fir, poplar, red osier dogwood, birch, willow, and red and striped maples (CWS 1997, Dewey *et al.* 2000). Browsing on leaves from deciduous trees and shrubs are the principal summer moose diet, while aquatic plants make up the remainder of the diet (LeResche and Davis 1973).

Based on the available information the moose is assumed to consume terrestrial vegetation (browse) and aquatic vegetation. This is likely to comprise primarily browse in the winter and primarily browse and aquatic plants in the summer. In general, this corresponds to 80% terrestrial vegetation (browse) and 20% aquatic plants on an annual basis.

Food Consumption Rate:
A large adult moose eats from 15 to 20 kg, green weight, of twigs each day in winter, and in summer eats from 25 to 30 kg of forage—twigs, leaves, shrubs, upland plants, and water plants (CWS 1997).
They require 20 kg of food per day (Dewey *et al.* 2000).
Allometric equation for mammals (U.S. EPA 1993): $FI\ (g\ (dw)/day) = 0.235\ Wt^{0.822}\ (g)$

Based on a body weight of 6E5 g the FI is 13000 g (dw)/d or 44000 g (ww)/d (moisture content of 70%).

Based on the above information the food consumption rate was taken to be 23 kg (ww)/d (CWS 1997) or 6.9 kg (dw)/d (moisture content of 70%). This value agrees well with that provided by Dewey *et al.* (2000).

Sediment Ingestion:
Beyer *et al.* (1994) provides a value of 2% for moose. Based on a dry weight consumption rate of 6900 g/d this corresponds to approximately 140 g/d. Due to the behaviour of consuming aquatic plants by pulling up the plant it is assumed that this ingestion is primarily sediment. There would be minimal soil ingested from the consumption of browse (twigs, leaves).

Water Intake Rate:
Allometric equation for mammals (U.S. EPA 1993): WI (L/day) = 0.099 $Wt^{0.9}$ (kg)
Based on a body weight of 600 kg the WI is 31 L/d

Inhalation Rate:
Allometric equation for mammals (U.S. EPA 1993): IR (m^3/day) = 0.5458 $Wt^{0.8}$ (kg)
Based on a body weight of 600 kg the IR is 91 m^3/d.

Summary Table:

Exposure Characteristics		
Body Weight (kg)	600	CWS 1997
Food Intake Rate (g (ww)/d)	23000	CWS 1997
Sediment Ingestion Rate: (g (dw)/d) Fraction of ww diet:	 140 0.006	Beyer *et al.* 1994
Water Intake Rate (L/d)	31	U.S. EPA 1993 (allometric scaling)
Inhalation Rate (m^3/d)	91	U.S. EPA 1993 (allometric scaling)
Fraction of Time in Area	1	Conservative assumption
Fractional Composition of Diet		
Terrestrial Plants	0.8	Assumed based on CWS 1997, Dewey et al. 2000, LeResche and Davis 1973
Aquatic Plants	0.2	

References:

Beyer, W. N., E. Connor, and S. Gerould. 1994. *Survey of Soil Ingestion by Wildlife.* Journal of Wildlife Management 58:375-382.

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Ecological Profile: Muskrat

General Description

The muskrat (*Ondatra zibethicus*) is a fairly large rodent commonly found in the wetlands and waterways of North America. They prefer fresh or brackish marshes, lakes, ponds, swamps, and other bodies of slow-moving water and are most abundant in areas with cattails. The water must be deep enough so that it will not freeze to the bottom during the winter, but shallow enough to permit growth of aquatic vegetation – generally between 1 and 2 m. In response to local conditions animals build lodges in certain areas and bank burrows in others (CWS 1987, Newell 2000, NatureServe 2007, U.S. EPA 1993).

Size

A full-grown animal weighs on the average about 1 kg but this varies considerably in various parts of North America (CWS 1987).
Muskrats weigh between 680 to 1800 g; avg. 1135.80 g (Newell 2000).
Weight: 1816 grams (NatureServe 2007).
U.S. EPA (1993) provides values from 4 studies; range for adults is 837 g (female) to 1480 g (male). The average of males and females from the 4 studies is 1174 g.

Based on the above information a typical muskrat is expected to weigh approximately 1.2 kg (U.S. EPA 1993).

Home Range:

Home range sizes relatively small. Seasonal home range varies from less than 0.1 ha to several hectares along linear waterways (NatureServe 2007).
Muskrats have relatively small home ranges that vary in configuration depending on the aquatic habitat (U.S. EPA 1993).

Feeding Habits:

Diet mainly consists of aquatic plants, particularly cattails, cordgrass, and bulrush. May also eat crustaceans and mollusks and a large number of mussels in some areas. Muskrats build rooted feeding platforms. The roots and basal portions of aquatic plants make up most of the muskrat's diet, although shoots, bulbs, tubers, stems, and leaves also are eaten (CWS 1987, NatureServe 2007, Newell 2000, U.S. EPA 1993).

Based on the available information the muskrat is assumed to consume aquatic vegetation and benthic invertebrates (e.g. mollusks). The U.S. EPA (1993) summarizes 3 studies that show a breakdown of the diet; aquatic vegetation is the primary food source with other representing between 1 and 3% of the diet.

Food Consumption Rate:

Muskrats consume about one-third of their weight every day (Newell 2000).
The U.S. EPA (1993) provides a food intake rate range of 0.26 to 0.34 g (ww)/d per g body weight (average is 0.3 g (ww)/(g d)). Based on a body weight of 1200 g the FI is 360 g (ww)/d or 72 g (dw)/d (moisture content of 80%).
Allometric equation for mammals (U.S. EPA 1993): FI (g (dw)/day) = $0.235\ Wt^{0.822}$ (g)

Based on a body weight of 1200 g the FI is 80 g (dw)/d or 400 g (ww)/d (moisture content of 80%)

Based on the above information the food consumption rate was taken to be 0.36 kg (ww)/d (360 g (ww)/d).

Sediment Ingestion:

Beyer *et al.* (1994) does not provide a value for muskrat therefore the value of 3.3% for mallard duck was used due to the similar diet pattern. Based on a dry weight consumption rate of 72 g/d this corresponds to approximately 2.4 g/d. Due to the aquatic habitat of this animal it is assumed that this ingestion is primarily sediment.

Water Intake Rate:
The U.S. EPA (1993) provides a water intake rate range of 0.98 g/d per g body. Based on a body weight of 1200 g the WI is 1180 g/d or 1.2 L/d.
Allometric equation for mammals (U.S. EPA 1993): WI (L/day) = $0.099\ Wt^{0.9}$ (kg)
Based on a body weight of 1.2 kg the WI is 0.1 L/d

The information summarized above indicates a wide range in the water consumption rate. To be conservative a consumption rate of 1.2 L/d (U.S. EPA 1993) was selected.

Inhalation Rate:
The U.S. EPA (1993) provides an average inhalation rate of 0.59 m^3/d.
Allometric equation for mammals (U.S. EPA 1993): IR (m^3/day) = $0.5458\ Wt^{0.8}$ (kg)
Based on a body weight of 1.2 kg the IR is 0.6 m^3/d

Based on the above information the inhalation rate was taken to be 0.6 m^3/d (U.S. EPA 1993), which agrees well with the allometric estimate.

Summary Table:

Exposure Characteristics		
Body Weight (kg)	1.2	U.S. EPA 1993
Food Intake Rate (g (ww)/d)	360	U.S. EPA 1993
Sediment Ingestion Rate: (g (dw)/d) Fraction of ww diet:	 2.4 0.007	Beyer *et al.* 1994
Water Intake Rate (L/d)	1.2	U.S. EPA 1993
Inhalation Rate (m^3/d)	0.6	U.S. EPA 1993
Fraction of Time in Area	1	Assumed
Fractional Composition of Diet		
Aquatic Plants	0.98	U.S. EPA 1993
Benthic Invertebrates	0.02	U.S. EPA 1993

References:

Beyer, W. N., E. Connor, and S. Gerould. 1994. *Survey of Soil Ingestion by Wildlife.* Journal of Wildlife Management 58:375-382.

Newell, T. 2000. "Ondatra zibethicus" (On-line), Animal Diversity Web. Accessed September 17, 2007 at http://animaldiversity.ummz.umich.edu/site/accounts/information/Ondatra_zibethicus.html.

Canadian Wildlife Service (CWS) 1987. *Hinterland Who's Who. Mammal Fact Sheet: Muskrat.* Available at: http://www.ffdp.ca/hww2.asp?id=96

NatureServe. 2007. NatureServe Explorer: An online encyclopedia of life. Version 6.2. NatureServe, Arlington, Virginia. Available http://www.natureserve.org/explorer. 8 June (Accessed: September 17, 2007).

United States Environmental Protection Agency (U.S. EPA) 1993. *Wildlife Exposure Factors Handbook.* EPA/600/R-93/187.

Ecological Profile: Northern Leopard Frog

General Description:
The Northern Leopard Frog (*Rana pipiens*) is a medium-sized green or brown frog with distinctive dark spots ringed with paler "halos." The frogs have large hind legs with dark bars, pale underparts, and prominent dorsolateral ridges that are paler than the back. This species was once quite common through parts of western Canada until declines started occurring during the 1970s. Many populations of Northern Leopard Frogs have not yet recovered from these declines (British Columbia Ministry of Environment 2007).

Northern leopard frogs are usually found in moist habitats along the edges of streams, springs, ponds and lakes. They like clear clean water in open or lightly wooded areas and rarely occur in dense forest. Their relatively large size helps them conserve water and this feature, along with their long legs and big feet, allows them to travel to fairly dry habitat, perhaps 0.5 km from water. In wet weather, or after heavy dew, these frogs may be found even farther from water (Alberta Sustainable Resources Development. 2002).

Size:
Adult Northern Leopard Frogs range from 5.5 to 10 cm from nose to rump. Females are somewhat larger than males (British Columbia Ministry of Environment 2007).

Home Range:
Adult Northern Leopard Frogs are semi-terrestrial and maintain home ranges of up to 600 square meters during the summer. The size of the range is related to the size of the frog. Within the home range, Northern Leopard Frogs spend much of their time in small clearings of damp soil, called forms, or in crevices if the habitat is forested (British Columbia Ministry of Environment 2007).

Feeding Habits:
The diet consists primarily of insects - beetles, ants, flies, and leafhoppers. Other invertebrate prey includes pillbugs, worms, snails and slugs. Adults often eat smaller frogs, including juveniles of their own species. Northern Leopard Frogs may occasionally consume other vertebrates; voles, birds, and even garter snakes have been found in the stomachs of large frogs (British Columbia Ministry of Environment 2007).

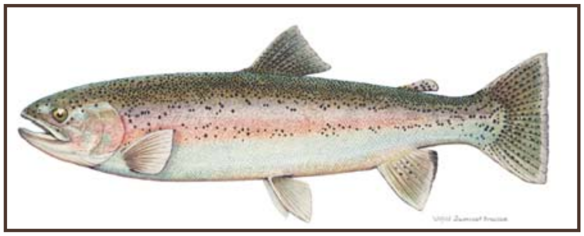
References:

Alberta Sustainable Resources Development. 2002. Natural Resources Service Nongame Management Program. Northern Leopard Frog. Retrieved from http://www.srd.gov.ab.ca/fishwildlife/speciesatrisk/selectedprofiles/northernleopardfrog.aspx

British Columbia Ministry of Environment. 2007. Environmental Stewardship Division. B.C. Frogwatch Program. Northern Leopard Frog. Retrieved from http://www.env.gov.bc.ca/wld/frogwatch/whoswho/factshts/northlep.htm

Ecological Profile: Rainbow Trout

General Description:



The rainbow trout (*Oncorhynchus mykiss*), also called the redband trout, is a species of salmonid native to tributaries of the Pacific Ocean in Asia and North. In Canada, it occurs outside British Columbia from the Avalon Peninsula of Newfoundland to Ontario and northern Alberta, and the Yukon Territory. Rainbow trout occur in well-oxygenated lakes and streams where the temperature normally doesn't rise above 21°C.

Size:
Rainbows range from 30 to 90 cm in length. The weight rarely exceeds 9 kg.

Feeding Habits:
Rainbow trout feed on various invertebrates including plankton, larger crustaceans, insects, snails and leeches and other fishes. The bottom organisms it consumes consist of mainly crustaceans and the larvae of all aquatic insects that occur in its habitat.

Environment:
They are found in the benthopelagic environment (Froese and Pauly 2007).

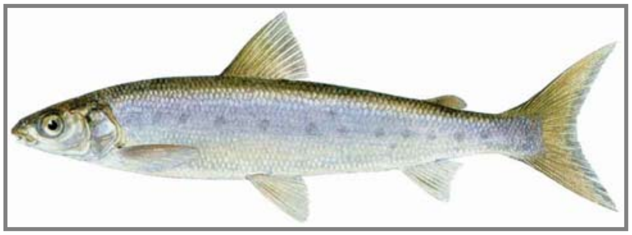
Reference:

Froese, R. and D. Pauly. Editors. 2007. FishBase. World Wide Web electronic publication. Retrieved from http://www.fishbase.org/Summary/SpeciesSummary.php?id=2682 . Accessed on 1/10/2007.

Scott, W.B. and E.J. Crossman. 1998. Freshwater Fishes of Canada. Galt House Publication Ltd. Oakville, ON. Canada.

Ecological Profile: Round Whitefish

General Description:



Round Whitefish (*Prosopium cylindraceum*) is a freshwater species of fish that is found in all the Great Lakes but Lake Erie (University of Wisconsin 2002). They are cigar-shaped with a strongly forked tail, short head, small mouth devoid of teeth, and a laterally "pinched" snout which projects beyond the lower jaw. Large, easily loosened scales cover their dark brown olive-green above and silvery below bodies (Environment Yukon 2007).

They inhabit shallow areas of lakes and clear streams, rarely entering brackish water, also in rivers with swift current and stony bottom. Migration is limited to movements associated with spawning (Froese and Pauly 2007).

Size:
Its size is generally between 23 and 48 cm long (Froese 2007). Few individuals today approach the 1.8- to 2.7 kg weight of the round whitefish caught in the 1800s. Its population levels, it is believed, have also declined (University of Wisconsin 2002).

Feeding Habits:
They are epipelagic and bottom feeders, feeding mostly on invertebrates, such as crustaceans, insect larvae, and fish eggs (Froese and Pauly 2007).

Environment:
They are found in the demersal environment (Froese and Pauly 2007).

References:

Environment Yukon. 2007. Retrieved from http://www.environmentyukon.gov.yk.ca/wildlifebiodiversity/fish/Round.php. Accessed on 19/9/2007.

Froese, R. and D. Pauly. Editors. 2007. FishBase. World Wide Web electronic publication. Retrieved from http://www.fishbase.org/Summary/SpeciesSummary.php?id=2682 . Accessed on 19/9/2007.

University of Wisconsin Sea Grant Institute Fish of the Great Lakes. 2002. Round Whitefish Prosopium cylindraceum. Retrieved from http://www.seagrant.wisc.edu/greatlakesfish/roundwhitefish.html. Accessed on 19/9/2007.

Ecological Profile: Ruffed Grouse

General Description

The Ruffed Grouse (*Bonasa umbellus)* is common throughout most of Canada. It is found wherever there are even small amounts of broad-leaved trees, especially poplars, birch, hop-hornbeam, and alders. The Ruffed Grouse doesn't like open fields, and rarely, if ever, is found there. Essentially a ground dwelling bird, the Ruffed Grouse can make short, rapid, twisting flights and can actually hover and make complete turns in the air. Population densities may fluctuate dramatically. Some populations exhibit an approximately 10-year cycle of abundance (CWS 1986, Haupt 2001, NatureServe 2007, Cornell 2003).

Size

The male Ruffed Grouse weighs about 500 g whereas the females are smaller (CWS 1986).
Weight 621 grams (NatureServe 2007).
Weight: 450 to 750 g (Cornell 2003).

Based on the above information a typical grouse is expected to weigh approximately 620 g (0.62 kg) (NatureServe 2007, Cornell 2003).

Home Range:

Does not migrate and, once established, lives all its life within a few hectares (CWS 1986).
Home range of brood about 6 to 19 ha, averages about 16 ha. In Missouri, home range was 104 ha in fall-winter, 67 ha in spring-summer. Examples of male and female home ranges have been reported to vary from 2 to 12 ha (NatureServe 2007).

Feeding Habits:

The Ruffed Grouse feeds on buds, leaves, and twigs. Adults also eat many herbaceous plants (especially in spring and summer), seeds, fruits (especially in fall and winter), nuts, flowers, buds, and leaves of trees and shrubs. During summer insects may comprise about 30% of diet of adults. Catkins and the buds of such broad-leaved trees as poplars, birch, hop-hornbeam, and alders are its staple winter food (CWS 1986, NatureServe 2007, Cornell 2003).

Based on the available information the grouse is assumed to consume terrestrial vegetation and insects (represented in the model by worms). Terrestrial vegetation is assumed to represent 80%, berries 10% and worms10% of the diet.

Food Consumption Rate:

Allometric equation for birds (U.S. EPA 1993): FI (g (dw)/day) = 0.648 $Wt^{0.651}$ (g)

Based on a body weight of 620 g the FI is 43 g (dw)/d or 140 g (ww)/d (moisture content of 70%)

Based on the above information the food consumption rate was taken to be 140 g (ww)/d.

Soil Ingestion:

Beyer *et al.* (1994) provides a value of 10.4% for a woodcock and 9.3% for wild turkey, the average of these values (9.9%) was used in lieu of species specific data. Based on a dry weight consumption rate of 43 g/d this corresponds to approximately 4.2 g/d.

Water Intake Rate:

Allometric equation for birds (U.S. EPA 1993): WI (L/day) = 0.059 $Wt^{0.67}$ (kg)

Based on a body weight of 0.62 kg the WI is 0.04 L/d

Inhalation Rate:

Allometric equation for birds (U.S. EPA 1993): IR (m^3/day) = 0.4089 $Wt^{0.77}$ (kg)

Based on a body weight of 0.62 kg the IR is 0.3 m^3/d

Ecological Profile: Ruffed Grouse

Summary Table:

Exposure Characteristics		
Body Weight (kg)	0.62	NatureServe 2007, Cornell 2003
Food Intake Rate (g (ww)/d)	140	U.S. EPA 1993 (allometric scaling)
Soil Ingestion Rate: (g (dw)/d) Fraction of ww diet:	 4.2 0.03	Beyer *et al.* 1994
Water Intake Rate (L/d)	0.04	U.S. EPA 1993 (allometric scaling)
Inhalation Rate (m^3/d)	0.3	U.S. EPA 1993 (allometric scaling)
Fraction of Time in Area	1	Assumed
Fractional Composition of Diet		
Terrestrial Plants	0.8	Based on information from CWS 1986, NatureServe 2007 and Cornell 2003
Berries	0.1	
Worms	0.1	

References:

Beyer, W. N., E. Connor, and S. Gerould. 1994. *Survey of Soil Ingestion by Wildlife.* Journal of Wildlife Management 58:375-382.

Canadian Wildlife Service (CWS) 1986. *Hinterland Who's Who. Bird Fact Sheet: Ruffed Grouse.* Available at: http://www.hww.ca/hww2.asp?id=62

Cornell 2003. *All About Birds. Bird Guide.* Cornell Lab of Ornithology. Accessed September 18, 2007 http://www.birds.cornell.edu/AllAboutBirds/BirdGuide/

Haupt, J. 2001. "Bonasa umbellus" (On-line), Animal Diversity Web. Accessed September 17, 2007 at http://animaldiversity.ummz.umich.edu/site/accounts/information/Bonasa_umbellus.html.

NatureServe. 2007. NatureServe Explorer: An online encyclopedia of life. Version 6.2. NatureServe, Arlington, Virginia. Available http://www.natureserve.org/explorer. 8 June (Accessed: September 17, 2007).

United States Environmental Protection Agency (U.S. EPA) 1993. *Wildlife Exposure Factors Handbook.* EPA/600/R-93/187.

Ecological Profile: Smallmouth Bass

General Description:

Small bass (*Micropterus dolomieu*) is a moderately large and robust fish. Their color is variable with size, condition and habitat. In clear, vegetated water or stained water they are darker with pronounced, contrasting markings, in turbid water lighter with vague markings.

Originally the smallmouth bass was restricted to the freshwaters of eastern central North America. In Canada, it occures in lakes and rivers in southern Nova scotia, New Brunswick, southern Quebec, Ontario, Manitoba, Saskatchewan and Vancouver.

Habitat varies with size and time of year. In the spring, adult fish congregate on the spawning ground. Later they are usually found in rocky and sandy areas of lakes and rivers, in moderately shallow water. In the heat of summer they usually retreat to greater depth.

Size:
Most individuals seen in Canada are 20-38 cm in length and usually not over 1.4 kg.

Feeding Habits:
In general, the food of adults of this species consists of insects, crayfish, and fishes. The smallmouth bass takes this variety of food from the surface, in the water mass, and off the bottom.

Young smallmouth bass are probably eaten by many predators, such as rock bass, yellow perch, sunfishes, catfishes, gar pike, suckers and turtles.

Environment:
They are found in the demersal environment (Froese and Pauly 2007).

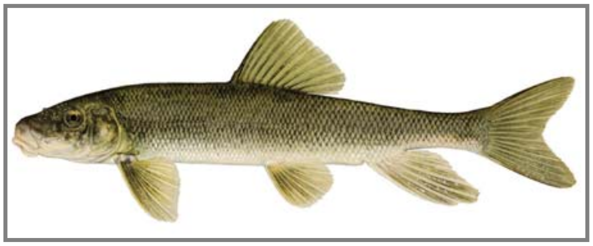
Reference:

Froese, R. and D. Pauly. Editors. 2007. FishBase. World Wide Web electronic publication. Retrieved from http://www.fishbase.org/Summary/SpeciesSummary.php?id=2682 . Accessed on 1/10/2007.

Scott, W.B. and E.J. Crossman. 1998. Freshwater Fishes of Canada. Galt House Publication Ltd. Oakville, ON. Canada.

Ecological Profile: White Sucker

General Description



The white sucker (*Catostomus commersonii*) is a torpedo-shaped fish distinguished by its sucker-like mouth. During spawning, the darkness on the back intensifies and the body becomes more golden in colour (Nova Scotia Fisheries and Aquaculture 2007).

The white sucker is a North American species found in freshwater lakes and streams from Labrador south to Georgia, west to Colorado and north through Alberta and British Columbia to the MacKenzie River delta (Nova Scotia Fisheries and Aquaculture 2007). It inhabits a wide range of habitats, from rocky pools and riffles of headwaters to large lakes (Froese 2007).

The white sucker is a bottom feeding fish and spends most of its time in shallow, warm waters. In bays, estuaries and tributary rivers, it makes its home in holes and areas around windfalls or other underwater obstructions (Michigan Department of Natural Resources 2007).

Size

They can grow to 63 cm and more than 3.2 kg but reach about 46 cm in Nova Scotia (Nova Scotia Fisheries and Aquaculture 2007).

Feeding Habits:

Fry (1.2 cm in length) feed on plankton and other small invertebrates; bottom feeding commences upon reaching a length of 1.6-1.8 cm. Preyed upon by birds, fishes, lamprey, and mammals. Flesh is white, flaky, and sweet (Froese 2007).

Environment:

They are found in the demersal environment (Froese and Pauly 2007).

References:

Froese, R. and D. Pauly. Editors. 2007. FishBase. World Wide Web electronic publication. www.fishbase.org . Accessed on 19/9/2007.

Michigan Department of Natural Resources. 2007. Retrieved from http://www.michigan.gov/dnr/0,1607,7-153-10364_18958-45693--,00.html. Accessed on 19/9/2007.

Nova Scotia Fisheries and Aquaculture, Inland Fisheries Division. 2007. White Sucker (*Catostomus commersoni*). Retrieved from http://www.gov.ns.ca/fish/sportfishing/species/sucker.shtml. Accessed on 19/9/2007.

Ecological Profile: White-Tailed Deer

General Description

The white-tailed deer (*Odocoileus virginianus*) is common through most of North America. Almost any forested or bushy area provides suitable habitat for white-tailed deer during the summer, but as snow deepens the deer concentrate in "deer yards," or areas that provide food and shelter from storms and deep snow. The white-tailed deer is a ruminant. The antlers of the mature male white-tail consist of a forward curving main beam from which single points project upward and often slightly inward (CWS 1990).

Size

Full grown male deer frequently exceed 1 m at shoulder height and 110 kg in weight, with exceptional individuals weighing up to 200 kg in the northern part of their range (CWS 1990).
Males 68 to 141 kg, females 41 to 96 kg (eNature 2005).
White-tailed deer weigh between 57 and 137 kg (Dewey 2003).
Weight 135000 grams (135 kg) (NatureServe 2007).

Based on the above information a typical deer is expected to weigh 110 kg (CWS 1990).

Home Range:

Sometimes the move from summer to winter range requires travelling many kilometres (CWS 1990).
Their home ranges are generally small, often a square kilometer or less (Dewey 2003).
Typically the home range of 16 to 120 ha varies with conditions, smallest in summer. Annual home range of sedentary populations' average 59 to 520 ha (NatureServe 2007).

Feeding Habits:

Whitetail deer feed on a variety of vegetation, depending on what is available in their habitat. In northern areas, during the spring and summer the white-tailed deer's diet consists of leafy material from a variety of woody plants, grasses, herbs, and forbs. They also consume mushrooms and berries. Even in winter white-tailed deer consume green forage where available. In colder weather, the deer depend largely on the twigs and buds that are within their reach. Even the most favourable winter concentration areas have a limited food supply. When snow is deeper than 40 cm, deer find it increasingly difficult to move about freely (CWS 1990, NatureServe 2007, Dewey 2003).

Based on the available information the deer is assumed to consume terrestrial vegetation. This is likely to comprise primarily browse in the winter and primarily forage in the summer.

Food Consumption Rate:

Eats 5 to 9 pounds (2.25 to 4 kg) of food per day (eNature 2005).

Allometric equation for mammals (U.S. EPA 1993): FI (g (dw)/day) = $0.235\ Wt^{0.822}$ (g)

> Based on a body weight of 1.1E5 g the FI is 3270 g (dw)/d or 10900 g (ww)/d (moisture content of 70%).

Based on the above information the food consumption rate was taken to be 10.9 kg (ww)/d.

Soil Ingestion:

Beyer *et al.* (1994) provides a value of <2% for white-tailed deer. Based on a dry weight consumption rate of 3270 g/d this corresponds to approximately 66 g/d.

Water Intake Rate:

Allometric equation for mammals (U.S. EPA 1993): WI (L/day) = $0.099\ Wt^{0.9}$ (kg)

> Based on a body weight of 110 kg the WI is 6.8 L/d

Inhalation Rate:

Allometric equation for mammals (U.S. EPA 1993): IR (m^3/day) = $0.5458\ Wt^{0.8}$ (kg)

> Based on a body weight of 110 kg the IR is 23 m^3/d

Ecological Profile: White-Tailed Deer

Summary Table:

Exposure Characteristics		
Body Weight (kg)	110	CWS 1990
Food Intake Rate (g (ww)/d)	10900	U.S. EPA 1993 (allometric scaling)
Water Intake Rate (L/d)	6.8	U.S. EPA 1993 (allometric scaling)
Soil Ingestion Rate: (g (dw)/d) Fraction of ww diet:	 66 0.006	Beyer *et al.* 1994
Inhalation Rate (m^3/d)	23	U.S. EPA 1993 (allometric scaling)
Fraction of Time in Area	1	Assumed
Fractional Composition of Diet		
Terrestrial Plants	1	CWS 1990

References:

Beyer, W. N., E. Connor, and S. Gerould. 1994. *Survey of Soil Ingestion by Wildlife.* Journal of Wildlife Management 58:375-382.

Canadian Wildlife Service (CWS) 1990. *Hinterland Who's Who. Mammal Fact Sheet: White-tailed Deer.* Available at: http://www.ffdp.ca/hww2.asp?id=106

Dewey, T. and Animal Diversity Web Staff. 2003. "*Odocoileus virginianus*" (On-line), Animal Diversity Web. Accessed September 17, 2007 at http://animaldiversity.ummz.umich.edu/site/accounts/information/Odocoileus_virginianus.html.

eNature 2005. *Field Guide: White-Tailed Deer*. Available at: http://www.enature.com/fieldguides/detail.asp?recnum=ma0046. (Accessed: September 24, 2007).

NatureServe. 2007. NatureServe Explorer: An online encyclopedia of life. Version 6.2. NatureServe, Arlington, Virginia. Available http://www.natureserve.org/explorer. 8 June (Accessed: September 17, 2007).

United States Environmental Protection Agency (U.S. EPA) 1993. *Wildlife Exposure Factors Handbook.* EPA/600/R-93/187.

Ecological Profile: Wild Turkey

General Description

Wild turkeys (*Meleagris gallopavo*) are one of the most widely distributed game bird species in North America. Wild turkeys are large, ground-dwelling birds. They prefer hardwood and mixed conifer-hardwood forests with scattered openings such as pastures, fields, orchards and seasonal marshes. Wild turkeys are diurnal and non-migratory. They are swift runners and fast fliers (McCullough and Kirschbaum 2001, NatureServe 2007, Cornell 2003).

Size

Male turkeys weigh 6800 to 11000 g (6.8 to 11 kg); hens usually weigh 3600 to 5400 g (3.6 to 5.4 kg) (McCullough and Kirschbaum 2001).
Weight 7400 grams (NatureServe 2007).
Weight: 2500 to 10800 g (Cornell 2003).

Based on the above information a typical wild turkey is expected to weigh approximately 7400 g (7.4 kg) (NatureServe 2007).

Home Range:

No information available.

Feeding Habits:

Wild turkeys are omnivorous. They primarily eat vegetable matter such as acorns, nuts, seeds, buds, leaves and fern fronds. They also eat ground-dwelling insects and salamanders, which account for about 10% of their diet. Wild turkeys forage primarily on the ground, though they occasionally mount shrubs and low trees to reach fruits and buds (McCullough and Kirschbaum 2001, Cornell 2003, NatureServe 2007).

Based on the available information the wild turkey is assumed to consume terrestrial vegetation and worms. Terrestrial vegetation is assumed to represent 90% and worms 10% of the diet.

Food Consumption Rate:

Allometric equation for birds (U.S. EPA 1993): FI (g (dw)/day) = 0.648 $Wt^{0.651}$ (g)

Based on a body weight of 7400 g the FI is 214 g (dw)/d or 710 g (ww)/d (moisture content of 70%)

Based on the above information the food consumption rate was taken to be 710 g (ww)/d.

Soil Ingestion:

Beyer *et al.* (1994) provides a value of 9.3% for wild turkey. Based on a dry weight consumption rate of 214 g/d this corresponds to approximately 20 g/d.

Water Intake Rate:

Allometric equation for birds (U.S. EPA 1993): WI (L/day) = 0.059 $Wt^{0.67}$ (kg)

Based on a body weight of 7.4 kg the WI is 0.23 L/d

Inhalation Rate:

Allometric equation for birds (U.S. EPA 1993): IR (m^3/day) = 0.4089 $Wt^{0.77}$ (kg)

Based on a body weight of 7.4 kg the IR is 1.9 m^3/d

Ecological Profile: Wild Turkey

Summary Table:

Exposure Characteristics		
Body Weight (kg)	7.4	NatureServe 2007
Food Intake Rate (g (ww)/d)	710	U.S. EPA 1993 (allometric scaling)
Soil Ingestion Rate: (g (dw)/d) Fraction of ww diet:	 20 0.028	Beyer *et al.* 1994
Water Intake Rate (L/d)	0.23	U.S. EPA 1993 (allometric scaling)
Inhalation Rate (m^3/d)	1.9	U.S. EPA 1993 (allometric scaling)
Fraction of Time in Area	1	Assumed
Fractional Composition of Diet		
Terrestrial Plants	0.9	Based on information from McCullough and Kirschbaum 2001, Cornell 2003, NatureServe 2007
Worms	0.1	

References:

Beyer, W. N., E. Connor, and S. Gerould. 1994. *Survey of Soil Ingestion by Wildlife.* Journal of Wildlife Management 58:375-382.

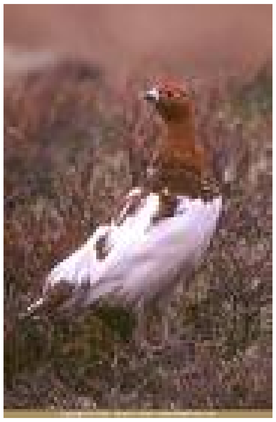
Cornell 2003. *All About Birds. Bird Guide.* Cornell Lab of Ornithology. Accessed September 18, 2007 http://www.birds.cornell.edu/AllAboutBirds/BirdGuide/

McCullough, J. and K. Kirschbaum. 2001. "Meleagris gallopavo" (On-line), Animal Diversity Web. Accessed September 18, 2007 at http://animaldiversity.ummz.umich.edu/site/accounts/information/Meleagris_gallopavo.html.

NatureServe. 2007. NatureServe Explorer: An online encyclopedia of life. Version 6.2. NatureServe, Arlington, Virginia. Available http://www.natureserve.org/explorer. 8 June (Accessed: September 17, 2007).

United States Environmental Protection Agency (U.S. EPA) 1993. *Wildlife Exposure Factors Handbook.* EPA/600/R-93/187.

Ecological Profile: Willow Ptarmigan



General Description
Ptarmigans are hardy members of the grouse family that spend most of their lives on the ground at or above the treeline. The Willow Ptarmigan (*Lagopus lagopus*) is a typical bird of the arctic tundra and is the largest and most numerous of the three ptarmigan species. It is found in open tundra, especially in areas heavily vegetated with grasses, mosses, herbs, and shrubs, less frequently in openings in boreal coniferous forest. The Willow Ptarmigan nests on the ground, on tundra, beaches, or near marshes. Ptarmigan are known for dramatically fluctuating population densities. (CWS 1994, NatureServe 2007, Cornell 2003).

Size
Weight 601 grams (NatureServe 2007).
Weight: 430 to 810 g (Cornell 2003).

Based on the above information a typical ptarmigan is expected to weigh approximately 620 g (0.62 kg) (NatureServe 2007, Cornell 2003).

Home Range:
Mainly permanent resident but somewhat migratory (NatureServe 2007).

Feeding Habits:
Ptarmigans are mostly plant eaters. In summer, the diet consists of a variety of vegetation consisting of leaves, flowers, buds and berries of a wide variety of tundra plants as well as catkins, seed capsules and bulblets. They also consume mosses and supplement their menu with insects and spiders when these are abundant. In winter the choice and quantity of food are reduced, and ptarmigans eat the buds, twigs, seeds and catkins of low willows, alders, and dwarf birches. (CWS 1994, NatureServe 2007, Cornell 2003, Weeden 1994).

Based on the available information the ptarmigan is assumed to consume terrestrial vegetation and insects (represented in the model by worms). Terrestrial vegetation is assumed to represent 80%, berries 10% and worms10% of the diet.

Food Consumption Rate:
Allometric equation for birds (U.S. EPA 1993): FI (g (dw)/day) = 0.648 $Wt^{0.651}$ (g)
Based on a body weight of 620 g the FI is 43 g (dw)/d or 140 g (ww)/d (moisture content of 70%)

Based on the above information the food consumption rate was taken to be 140 g (ww)/d.

Soil Ingestion:
Beyer *et al.* (1994) provides a value of 10.4% for a woodcock and 9.3% for wild turkey, the average of these values (9.9%) was used in lieu of species specific data. Based on a dry weight consumption rate of 43 g/d this corresponds to approximately 4.2 g/d.

Water Intake Rate:
Allometric equation for birds (U.S. EPA 1993): WI (L/day) = 0.059 $Wt^{0.67}$ (kg)
Based on a body weight of 0.62 kg the WI is 0.04 L/d

Inhalation Rate:
Allometric equation for birds (U.S. EPA 1993): IR (m^3/day) = 0.4089 $Wt^{0.77}$ (kg)
Based on a body weight of 0.62 kg the IR is 0.3 m^3/d

Ecological Profile: Willow Ptarmigan

Summary Table:

Exposure Characteristics		
Body Weight (kg)	0.62	NatureServe 2007, Cornell 2003
Food Intake Rate (g (ww)/d)	140	U.S. EPA 1993 (allometric scaling)
Soil Ingestion Rate: (g (dw)/d) Fraction of ww diet:	4.2 0.03	Beyer *et al.* 1994
Water Intake Rate (L/d)	0.04	U.S. EPA 1993 (allometric scaling)
Inhalation Rate (m^3/d)	0.3	U.S. EPA 1993 (allometric scaling)
Fraction of Time in Area	1	Assumed
Fractional Composition of Diet		
Terrestrial Plants	0.8	Based on information from CWS 1994, NatureServe 2007, Cornell 2003, Weeden 1994
Berries	0.1	
Worms	0.1	

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APPENDIX B: TRANSFER FACTORS

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Appendix B.1: Transfer Factor Database

Table B-1: Water-to-Sediment Distribution coefficients (Kds)

Radionuclide	Kd Central Estimate *	Kd Upper Estimate †	Units	Notes	Reference
C	2.00E+03	5.00E+04	L/kg	Calculated "upper estimate"	IAEA (1994)
Values Selected:	*2.00E+03*	*5.00E+04*	*L/kg*		*IAEA (1994)*
Cl	1.00E+00	2.50E+01	L/kg	Calculated "upper estimate"	Sheppard et al. (2004a)
	1.10E+01	2.75E+02	L/kg	Calculated "upper estimate"	Sheppard et al. (2004a)
Values Selected:	*1.10E+01*	*2.75E+02*	*L/kg*		*Sheppard et al. (2004a)*
Zr	1.00E+03	2.50E+04	L/kg	Calculated "upper estimate"	Bechtel Jacobs (1998)
	3.16E+03	1.00E+04	L/kg	Range: 1E3 to 1E4	IAEA (1994)
	1.00E+04	2.50E+05	L/kg	Calculated "upper estimate"	CSA (1987)
Values Selected:	*1.00E+04*	*2.50E+05*	*L/kg*		*CSA (1987)*
Nb	1.60E+02	4.00E+03	L/kg	Calculated "upper estimate"	Bechtel Jacobs (1998)
	1.00E+04	2.50E+05	L/kg	Calculated "upper estimate"	CSA (1987)
Values Selected:	*1.00E+04*	*2.50E+05*	*L/kg*		*CSA (1987)*
Tc	5.00E+00	1.25E+02	L/kg	Calculated "upper estimate"	Bechtel Jacobs (1998)
	1.00E+00	1.00E+02	L/kg	Range: 0 to 1E2	IAEA (1994)
	2.00E+02	5.00E+03	L/kg	Calculated "upper estimate"	CSA (1987)
Values Selected:	*2.00E+02*	*5.00E+03*	*L/kg*		*CSA (1987)*
I	1.00E+01	2.50E+02	L/kg	Calculated "upper estimate"	Bechtel Jacobs (1998)
	8.94E-01	8.00E+01	L/kg	Range: 0 to 8E1	IAEA (1994)
	1.14E+02	1.87E+02	L/kg	Range: 7.0E1 to 1.87E2 (Oxic)	Stephenson and Motycka (1995)
	3.24E+01	4.20E+01	L/kg	Range: 2.5E1 to 4.2E1 (Low - oxic)	Stephenson and Motycka (1995)
	4.25E+02	4.40E+02	L/kg	Range: 4.1E2 to 4.4E2 (Organic)	Evans and Hammad 1995 cited in Sheppard (2002)
	4.40E+00	1.10E+02	L/kg	Calculated "upper estimate" (Limestone)	Evans and Hammad 1995 cited in Sheppard (2002)
	2.19E+01	1.60E+02	L/kg	Range: 3.0E0 to 1.6E2	Bird et al. 1995 cited in Sheppard (2002)
	2.00E+02	5.00E+03	L/kg	Calculated "upper estimate"	CSA (1987)
Values	*4.25E+02*	*5.00E+03*	*L/kg*		*CSA (1987)*

Radionuclide	Kd Central Estimate *	Kd Upper Estimate †	Units	Notes	Reference
Selected:					
Cs	1.00E+03	2.50E+04	L/kg	Calculated "upper estimate"	Bechtel Jacobs (1998)
	2.00E+03	8.00E+04	L/kg	Range: 5E1 to 8E4	IAEA (1994)
	3.00E+04	7.50E+05	L/kg	Calculated "upper estimate"	CSA (1987)
Values Selected:	*3.00E+04*	*7.50E+05*	*L/kg*		*CSA (1987)*
Ra	5.00E+02	1.25E+04	L/kg	Calculated "upper estimate"	Bechtel Jacobs (1998)
	3.16E+02	1.00E+03	L/kg	Range: 1E2 to 1E3	IAEA (1994)
Values Selected:	*5.00E+02*	*1.25E+04*	*L/kg*		*Bechtel Jacobs (1998)*
Np	1.00E+01	2.50E+02	L/kg	Calculated "upper estimate"	Bechtel Jacobs (1998)
	4.47E+00	1.00E+02	L/kg	Range: 2E-1 to 1E2	IAEA (1994)
	2.58E+02	4.36E+02	L/kg	Geo mean. GSD= 1.3	Sheppard et al. (2004b)
	1.00E+01	1.00E+02	L/kg	Range: 2E-1 to 1E2	Sheppard et al. (2004b)
Values Selected:	*2.58E+02*	*4.36E+02*	*L/kg*		*Sheppard et al. (2004b)*
U	5.00E+01	1.25E+03	L/kg	Calculated "upper estimate"	Bechtel Jacobs (1998)
	1.41E+02	1.00E+03	L/kg	Range: 2E1 to 1E3	IAEA (1994)
	3.00E+04	7.50E+05	L/kg	Calculated "upper estimate"	CSA (1987)
	5.30E+03	1.33E+05	L/kg	Geo mean., GSD= 15	Sheppard et al. (2005a)
Values Selected:	*3.00E+04*	*7.50E+05*	*L/kg*		*CSA (1987)*
Pb	2.70E+02	6.75E+03	L/kg	Calculated "upper estimate"	Bechtel Jacobs (1998)
Values Selected:	*2.70E+02*	*6.75E+03*	*L/kg*		*Bechtel Jacobs (1998)*
Po	1.50E+02	3.75E+03	L/kg	Calculated "upper estimate"	Bechtel Jacobs (1998)
Values Selected:	*1.50E+02*	*3.75E+03*	*L/kg*		*Bechtel Jacobs (1998)*
Th	1.00E+04	1.00E+06	L/kg	Range: 1E3 to 1E6	IAEA (1994)
Values Selected:	*1.00E+04*	*1.00E+06*	*L/kg*		*IAEA (1994)*

Notes: GM = Geometric Mean; GSD = Geometric Standard Deviation.
* Central Estimate is either a geometric mean (GM), or the only available data point.
† Upper Estimate is the upper range or the GM* GSD^2 or the only available data point * 5^2. In each data set, if the GSD was larger than 5 (interpreted as an outlier), it was set equal to 5.
N/A - data not available.

Table B-2: Water-to-Aquatic Plant Transfer Factors

Units: L/kg Dry Weight

Radionuclide	TF as Expressed in Original Ref.			Notes	Reference	Expressed on Consistent Basis and Units**			
	Central Estimate TF*	Units	Basis			Central Estimate	Upper Estimate †	Unit	Basis
C	1.01E+05	L/kg	DW	Geo.Mean; GSD = 2.5	Bird and Schwartz (1996)	1.01E+05	6.31E+05	L/kg	DW
	4.50E+03	L/kg	FW	One value reported	U.S. DOE (2003)	3.00E+04	7.50E+05	L/kg	DW
Values Selected:					*Bird and Schwartz (1996) & U.S. DOE (2003)*	*1.01E+05*	*7.50E+05*	*L/kg*	*DW*
For comparison, IAEA (1985), as cited in FASSET (D1), recommends concentration factors for phytoplankton, macroalgae and zooplankton of 9E3 to 2E4									
Cl	5.00E+01	L/kg	FW	One value reported	U.S. DOE (2003)	3.33E+02	8.33E+03	L/kg	DW
Values Selected:					*U.S. DOE (2003)*	*3.33E+02*	*8.33E+03*	*L/kg*	*DW*
For comparison, IAEA (1985), as cited in FASSET (D1), recommends concentration factors for phytoplankton, macroalgae and zooplankton of 5E-2 to 1E0									
Zr	5.00E+03	L/kg	FW	One value reported	U.S. DOE (2003)	3.33E+04	8.33E+05	L/kg	DW
Values Selected:					*U.S. DOE (2003)*	*3.33E+04*	*8.33E+05*	*L/kg*	*DW*
Nb	5.00E+02	L/kg	FW	One value reported	U.S. DOE (2003)	3.33E+03	8.33E+04	L/kg	DW
Values Selected:					*U.S. DOE (2003)*	*3.33E+03*	*8.33E+04*	*L/kg*	*DW*
For comparison, IAEA (1985), as cited in FASSET (D1), recommends concentration factors for phytoplankton, macroalgae and zooplankton of 1E3 to 2E4									
Tc	2.00E+01	L/kg	DW	Geo.Mean; GSD = 6	Bird and Schwartz (1996)	2.00E+01	5.00E+02	L/kg	DW
	5.00E+03	L/kg	FW	One value reported	U.S. DOE (2003)	3.33E+04	8.33E+05	L/kg	DW
Values Selected:					*U.S. DOE (2003)*	*3.33E+04*	*8.33E+05*	*L/kg*	*DW*
For comparison, IAEA (1985), as cited in FASSET (D1), recommends concentration factors for phytoplankton, macroalgae and zooplankton of 5E0 to 1E3									
I	9.60E+02	L/kg	DW	Geo.Mean; GSD = 1.7	Bird and Schwartz (1996)	9.60E+02	2.77E+03	L/kg	DW
	3.00E+02	L/kg	FW	One value reported	U.S. DOE (2003)	2.00E+03	5.00E+04	L/kg	DW
Values Selected:					*U.S. DOE (2003)*	*2.00E+03*	*5.00E+04*	*L/kg*	*DW*
For comparison, IAEA (1985), as cited in FASSET (D1), recommends concentration factors for phytoplankton, macroalgae and zooplankton of 1E3 to 3E3									

Radionuclide	TF as Expressed in Original Ref.			Notes	Reference	Expressed on Consistent Basis and Units**			
	Central Estimate TF*	Units	Basis			Central Estimate	Upper Estimate †	Unit	Basis
Cs	5.20E+01	L/kg	FW	One value reported	Polikarpov (1966)	3.47E+02	8.67E+03	L/kg	DW
	9.80E+02	L/kg	DW	Geo.Mean; GSD = 23	Bird and Schwartz (1996)	9.80E+02	2.45E+04	L/kg	DW
	4.00E+03	L/kg	FW	One value reported	Polikarpov (1966)	2.67E+04	6.67E+05	L/kg	DW
	2.19E+02	kg/kg	DW	Mean; Range: 2E1 to 2.4E3	Polikarpov (1966)	2.19E+02	2.40E+03	L/kg	DW
	2.00E+01	L/kg	DW	One value reported	Polikarpov (1966)	2.00E+01	5.00E+02	L/kg	DW
	2.40E+03	L/kg	DW	One value reported	Polikarpov (1966)	2.40E+03	6.00E+04	L/kg	DW
	2.12E+04	L/kg	DW	One value reported	Environment Canada (2000)	2.12E+04	5.30E+05	L/kg	DW
	4.56E+02	kg/kg	FW	Range: 5.2E1 to 4E3	Polikarpov (1966)	3.04E+03	2.67E+04	L/kg	DW
	7.06E+02	L/kg	FW	One value reported	Polikarpov (1966)	4.71E+03	1.18E+05	L/kg	DW
	2.40E+03	L/kg	FW	One value reported	Hinton and Scott (1990)	1.60E+04	4.00E+05	L/kg	DW
	1.00E+03	L/kg	FW	One value reported	U.S. DOE (2003)	6.67E+03	1.67E+05	L/kg	DW
Values Selected:					*Polikarpov (1966)*	*2.67E+04*	*6.67E+05*	*L/kg*	*DW*
For comparison, IAEA (1985), as cited in FASSET (D1), recommends concentration factors for phytoplankton, macroalgae and zooplankton of 2E1 to 5E1									
Ra	1.56E+04	L/kg	DW	Geo.Mean; GSD = 2.4	Bird and Schwartz (1996)	1.56E+04	8.99E+04	L/kg	DW
	3.00E+04	L/kg	FW	One value reported	U.S. DOE (2003)	2.00E+05	5.00E+06	L/kg	DW
Values Selected:					*Bird and Schwartz (1996) & U.S. DOE (2003)*	*2.00E+05*	*5.00E+06*	*L/kg*	*DW*
For comparison, IAEA (1985), as cited in FASSET (D1), recommends concentration factors for phytoplankton, macroalgae and zooplankton of 1E2 to 2E3									
Np	3.00E+02	L/kg	FW	One value reported	U.S. DOE (2003)	2.00E+03	5.00E+04	L/kg	DW
Values Selected:					*U.S. DOE (2003)*	*2.00E+03*	*5.00E+04*	*L/kg*	*DW*
For comparison, IAEA (1985), as cited in FASSET (D1), recommends concentration factors for phytoplankton, macroalgae and zooplankton of 5E1 to 1E2									
U	1.75E+03	L/kg	DW	Geo.Mean; GSD = 2.2	Bird and Schwartz (1996)	1.75E+03	8.47E+03	L/kg	DW
	9.00E+02	L/kg	FW	One value reported	U.S. DOE (2003)	6.00E+03	1.50E+05	L/kg	DW
Values Selected:					*U.S. DOE (2003)*	*6.00E+03*	*1.50E+05*	*L/kg*	*DW*
For comparison, IAEA (1985), as cited in FASSET (D1), recommends concentration factors for phytoplankton, macroalgae and zooplankton of 5E0 to 1E2									

Radionuclide	TF as Expressed in Original Ref.			Notes	Reference	Expressed on Consistent Basis and Units**			
	Central Estimate TF*	Units	Basis			Central Estimate	Upper Estimate †	Unit	Basis
Pb	2.00E+03	L/kg	FW	One value reported	U.S. DOE (2003)	1.33E+04	3.33E+05	L/kg	DW
Pb	1.00E+03	L/kg	DW	Geo.Mean; GSD = 51	Bird and Schwartz 1996	1.00E+03	2.50E+04	L/kg	DW
Pb	1.60E+02	L/kg	FW	One value reported	Beak 1985	1.07E+03	2.67E+04	L/kg	DW
Values Selected:					*U.S. DOE (2003)*	*1.33E+04*	*3.33E+05*	*L/kg*	*DW*
For comparison, IAEA (1985), as cited in FASSET (D1), recommends concentration factors for phytoplankton, macroalgae and zooplankton of 1E3 to 7E3									
Po	2.00E+03	L/kg	FW	One value reported	U.S. DOE (2003)	1.33E+04	3.33E+05	L/kg	DW
Values Selected:					*U.S. DOE (2003)*	*1.33E+04*	*3.33E+05*	*L/kg*	*DW*
For comparison, IAEA (1985), as cited in FASSET (D1), recommends concentration factors for phytoplankton, macroalgae and zooplankton of 1E3 to 3E4									

Notes: GM = Geometric Mean; GSD = Geometric Standard Deviation; DW = Dry Weight; FW = Fresh Weight.
* Central Estimate is either a geometric mean (GM), or the only available data point.
† Upper Estimate is the upper range or the GM* GSD^2 or the only available data point * 5^2. In each data set, if the GSD was larger than 5 (interpreted as an outlier), it was set equal to 5.
** - Conversion between DW and FW based on moisture content of 0.85 (based on US EPA 1993).
N/A - data not available.

Table B-3: Water-to-Benthic Invertebrates Transfer Factors

Unit: L/kg Fresh Weight

Radionuclide	TF as Expressed in Original Ref.			Notes	Reference	Expressed on Consistent Basis and Units**			
	Central Estimate TF*	Units	Basis			Central Estimate	Upper Estimate †	Unit	Basis
C	9.00E+03	L/kg	FW	One value reported	U.S. DOE (2003)	9.00E+03	2.25E+05	L/kg	FW
Values Selected:					*U.S. DOE (2003)*	*9.00E+03*	*2.25E+05*	*L/kg*	*FW*
Cl	5.00E+01	L/kg	FW	One value reported	U.S. DOE (2003)	5.00E+01	1.25E+03	L/kg	FW
Values Selected:					*U.S. DOE (2003)*	*5.00E+01*	*1.25E+03*	*L/kg*	*FW*
Zr	5.00E+01	L/kg	FW	One value reported	U.S. DOE (2003)	5.00E+01	1.25E+03	L/kg	FW
Values Selected:					*U.S. DOE (2003)*	*5.00E+01*	*1.25E+03*	*L/kg*	*FW*
Nb	5.00E+01	L/kg	FW	One value reported	U.S. DOE (2003)	5.00E+01	1.25E+03	L/kg	FW
Values Selected:					*U.S. DOE (2003)*	*5.00E+01*	*1.25E+03*	*L/kg*	*FW*
Tc	1.00E+02	L/kg	FW	One value reported	U.S. DOE (2003)	1.00E+02	2.50E+03	L/kg	FW
Values Selected:					*U.S. DOE (2003)*	*1.00E+02*	*2.50E+03*	*L/kg*	*FW*
I	1.00E+02	L/kg	FW	One value reported	U.S. DOE (2003)	1.00E+02	2.50E+03	L/kg	FW
Values Selected:					*U.S. DOE (2003)*	*1.00E+02*	*2.50E+03*	*L/kg*	*FW*
Cs	5.46E+02	L/kg	DW	Range: 2.35E2 to 1.27E3	Polikarpov (1966)	1.09E+02	2.54E+02	L/kg	FW
	8.77E+02	L/kg	FW	Range: 7E1 to 1.1E4	Polikarpov (1966)	8.77E+02	1.10E+04	L/kg	FW
	1.20E+02	L/kg	FW	One value reported	Hinton and Scott (1990)	1.20E+02	3.00E+03	L/kg	FW
	6.00E+02	L/kg	FW	One value reported	Polikarpov (1966)	6.00E+02	1.50E+04	L/kg	FW
	5.00E+02	L/kg	FW	One value reported	U.S. DOE (2003)	5.00E+02	1.25E+04	L/kg	FW
Values					*Polikarpov (1966)*	*8.77E+02*	*1.50E+04*	*L/kg*	*FW*

Radionuclide	TF as Expressed in Original Ref.			Notes	Reference	Expressed on Consistent Basis and Units**			
	Central Estimate TF*	**Units**	**Basis**			**Central Estimate**	**Upper Estimate †**	**Unit**	**Basis**
Selected:									
Ra	1.00E+03	L/kg	FW	One value reported	U.S. DOE (2003)	1.00E+03	2.50E+04	L/kg	FW
Values Selected:					*U.S. DOE (2003)*	*1.00E+03*	*2.50E+04*	*L/kg*	*FW*
Np	3.00E+01	L/kg	FW	One value reported	U.S. DOE (2003)	3.00E+01	7.50E+02	L/kg	FW
Values Selected:					*U.S. DOE (2003)*	*3.00E+01*	*7.50E+02*	*L/kg*	*FW*
U	1.00E+02	L/kg	FW	One value reported	U.S. DOE (2003)	1.00E+02	2.50E+03	L/kg	FW
Values Selected:					*U.S. DOE (2003)*	*1.00E+02*	*2.50E+03*	*L/kg*	*FW*
Pb	1.00E+02	L/kg	FW	One value reported	U.S. EPA (1979)	1.00E+02	2.50E+03	L/kg	FW
	5.00E+02	L/kg	FW	One value reported	U.S. DOE (2003)	5.00E+02	1.25E+04	L/kg	FW
Values Selected:					*U.S. DOE (2003)*	*5.00E+02*	*1.25E+04*	*L/kg*	*FW*
Po	2.00E+04	L/kg	FW	One value reported	U.S. DOE (2003)	2.00E+04	5.00E+05	L/kg	FW
Values Selected:					*U.S. DOE (2003)*	*2.00E+04*	*5.00E+05*	*L/kg*	*FW*

Notes: GM = Geometric Mean; GSD = Geometric Standard Deviation; DW = Dry Weight; FW = Fresh Weight.
* Central Estimate is either a geometric mean (GM), or the only available data point
† Upper Estimate is the upper range or the GM* GSD^2 or the only available data point * 5^2. In each data set, if the GSD was larger than 5 (interpreted as an outlier), it was set equal to 5.
** - Conversion between DW and FW based on moisture content of (fraction; based on US EPA 1993): 0.8
N/A - data not available.

Table B-4: Water-to-Fish Transfer Factors

Unit: L/kg Fresh Weight

Radionuclide	TF as Expressed in Original Ref.			Notes	Reference	Expressed on Consistent Basis and Units**			
	Central Estimate TF*	Units	Basis			Central Estimate	Upper Estimate †	Unit	Basis
C	3.00E+05	L/kg	DW	One value reported	Bird and Schwartz (1996)	4.50E+04	1.13E+06	L/kg	FW
	5.00E+04	L/kg	FW	One value reported	NCRP (1996)	5.00E+04	1.25E+06	L/kg	FW
	5.00E+04	L/kg	FW	One value reported (limited data)	CSA (1987)	5.00E+04	1.25E+06	L/kg	FW
	1.58E+04	L/kg	FW	FW assumed; range 5E3 to 5E4	IAEA (1994)	1.58E+04	5.00E+04	L/kg	FW
Values Selected:					*NCRP (1996) / CSA (1987)*	*5.00E+04*	*1.25E+06*	*L/kg*	*FW*
For comparison, IAEA (1985), as cited in FASSET (D1), recommends a fish concentration factor of 2E4									

Cl	1.00E+03	L/kg	FW	One value reported	NCRP (1996)	1.00E+03	2.50E+04	L/kg	FW
	5.00E+01	L/kg	FW	Geo. Mean; GSD=12	Sheppard et al. (2004a)	5.00E+01	1.25E+03	L/kg	FW
	5.00E+01	L/kg	FW	One value reported	U.S. DOE (2003)	5.00E+01	1.25E+03	L/kg	FW
Values Selected:					*NCRP (1996)*	*1.00E+03*	*2.50E+04*	*L/kg*	*FW*
For comparison, IAEA (1985), as cited in FASSET (D1), recommends a fish concentration factor of 5E-2									

Zr	3.00E+02	L/kg	FW	One value reported	NCRP (1996)	3.00E+02	7.50E+03	L/kg	FW
	1.00E+02	L/kg	FW	One value reported	CSA (1987)	1.00E+02	2.50E+03	L/kg	FW
	3.00E+01	L/kg	FW	FW assumed; range 3E0 to 3E2	IAEA (1994)	3.00E+01	3.00E+02	L/kg	FW
Values Selected:					*NCRP (1996)*	*3.00E+02*	*7.50E+03*	*L/kg*	*FW*

Nb	3.00E+02	L/kg	FW	One value reported	NCRP (1996)	3.00E+02	7.50E+03	L/kg	FW
	1.00E+02	L/kg	FW	One value reported	CSA (1987)	1.00E+02	2.50E+03	L/kg	FW
	1.73E+03	L/kg	FW	FW assumed; range 1E2 to 3E4	IAEA (1994)	1.73E+03	3.00E+04	L/kg	FW
Values Selected:					*IAEA (1994)*	*1.73E+03*	*3.00E+04*	*L/kg*	*FW*
For comparison, IAEA (1985), as cited in FASSET (D1), recommends a fish concentration factor of 3E1									

Radionuclide	TF as Expressed in Original Ref.			Notes	Reference	Expressed on Consistent Basis and Units**			
	Central Estimate TF*	Units	Basis			Central Estimate	Upper Estimate †	Unit	Basis
Tc	2.50E+01	L/kg	DW	Geo.Mean; GSD=7.9	Bird and Schwartz (1996)	3.75E+00	9.38E+01	L/kg	FW
	2.00E+01	L/kg	FW	One value reported	NCRP (1996)	2.00E+01	5.00E+02	L/kg	FW
	3.00E+01	L/kg	FW	One value reported (limited data)	CSA (1987)	3.00E+01	7.50E+02	L/kg	FW
	1.26E+01	L/kg	FW	FW assumed; range 2E0 to 8E1	IAEA (1994)	1.26E+01	8.00E+01	L/kg	FW
Values Selected:					*CSA (1987)*	*3.00E+01*	*7.50E+02*	*L/kg*	*FW*
For comparison, IAEA (1985), as cited in FASSET (D1), recommends a fish concentration factor of 3E1									
I	3.00E+01	L/kg	DW	Geo.Mean; GSD=12.7	Bird and Schwartz (1996)	4.50E+00	1.13E+02	L/kg	FW
	4.00E+01	L/kg	FW	One value reported	NCRP (1996)	4.00E+01	1.00E+03	L/kg	FW
	5.00E+01	L/kg	FW	One value reported	CSA (1987)	5.00E+01	1.25E+03	L/kg	FW
	1.25E+02	L/kg	FW	One value reported	Chant (1999)	1.25E+02	3.13E+03	L/kg	FW
	1.12E+02	L/kg	FW	FW assumed; range 2E1 to 6E2	IAEA (1994)	1.12E+02	6.22E+02	L/kg	FW
	6.00E+00	L/kg	FW	Geo.Mean; GSD=12	Sheppard et al (2002)	6.00E+00	1.50E+02	L/kg	FW
Values Selected :					*Chant (1999)*	*1.25E+02*	*3.13E+03*	*L/kg*	*FW*
For comparison, IAEA (1985), as cited in FASSET (D1), recommends a fish concentration factor of 1E1									
Cs	3.80E+02	L/kg	DW	Geo.Mean; GSD=69	Bird and Schwartz (1996)	5.70E+01	1.43E+03	L/kg	FW
	2.00E+03	L/kg	FW	One value reported	NCRP (1996)	2.00E+03	5.00E+04	L/kg	FW
	2.64E+04	L/kg	FW	One value reported	Environment Canada (2000)	2.64E+04	6.61E+05	L/kg	FW
	3.00E+02	L/kg	FW	FW assumed; range 3E1 to 3E3	IAEA (1994)	3.00E+02	3.00E+03	L/kg	FW
	5.00E+02	L/kg	FW	One value reported	Polikarpov (1966)	5.00E+02	1.25E+04	L/kg	FW
	9.50E+03	L/kg	FW	One value reported	Polikarpov (1966)	9.50E+03	2.38E+05	L/kg	FW
Values Selected:					*Environment Canada (2000)*	*2.64E+04*	*6.61E+05*	*L/kg*	*FW*
For comparison, IAEA (1985), as cited in FASSET (D1), recommends a fish concentration factor of 1E2									
For comparison, the COG (2005) study presents a range of 6.66 to 41.6 and a mean of 16.6 (based on measurements in two locations)									

Radionuclide	TF as Expressed in Original Ref.			Notes	Reference	Expressed on Consistent Basis and Units**			
	Central Estimate TF*	Units	Basis			Central Estimate	Upper Estimate †	Unit	Basis
Ra	3.00E+01	L/kg	DW	Geo.Mean; GSD=7.3	Bird and Schwartz (1996)	4.50E+00	1.13E+02	L/kg	FW
	5.00E+01	L/kg	FW	One value reported	NCRP (1996)	5.00E+01	1.25E+03	L/kg	FW
	4.47E+01	L/kg	FW	FW assumed; range 1E1 to 2E2	IAEA (1994)	4.47E+01	2.00E+02	L/kg	FW
	1.50E+01	L/kg	FW	Geo.Mean; GSD=6.4	Sheppard et al. (2005b)	1.50E+01	3.75E+02	L/kg	FW
	5.00E+01	L/kg	FW	One value reported	U.S. DOE (2003)	5.00E+01	1.25E+03	L/kg	FW
Values Selected:					*NCRP (1996)*	*5.00E+01*	*1.25E+03*	*L/kg*	*FW*
For comparison, IAEA (1985), as cited in FASSET (D1), recommends a fish concentration factor of 5E2									
Np	3.00E+01	L/kg	FW	One value reported	NCRP (1996)	3.00E+01	7.50E+02	L/kg	FW
	1.00E+02	L/kg	FW	One value reported (limited data)	CSA (1987)	1.00E+02	2.50E+03	L/kg	FW
	1.73E+02	L/kg	FW	FW assumed; range 1E1 to 3E3	IAEA (1994)	1.73E+02	3.00E+03	L/kg	FW
	1.50E+02	L/kg	FW	Geo. Mean; GSD=12	Sheppard et al (2004b)	1.50E+02	3.75E+03	L/kg	FW
	2.10E+01	L/kg	FW	One value reported	U.S. DOE (2003)	2.10E+01	5.25E+02	L/kg	FW
Values Selected:					*IAEA (1994) & Sheppard et al (2004b)*	*1.73E+02*	*3.75E+03*	*L/kg*	*FW*
For comparison, IAEA (1985), as cited in FASSET (D1), recommends a fish concentration factor of 1E1									
U	6.20E+00	L/kg	DW	Geo.Mean; GSD=6.2	Bird and Schwartz (1996)	9.30E-01	2.33E+01	L/kg	FW
	1.00E+01	L/kg	FW	One value reported	NCRP (1996)	1.00E+01	2.50E+02	L/kg	FW
	2.00E+01	L/kg	FW	One value reported	CSA (1987)	2.00E+01	5.00E+02	L/kg	FW
	1.00E+01	L/kg	FW	FW assumed; range 2E0 to 5E1	IAEA (1994)	1.00E+01	5.00E+01	L/kg	FW
	2.70E+00	L/kg	FW	Geo.Mean; GSD=10	Sheppard et al (2005a)	2.70E+00	6.75E+01	L/kg	FW
Values Selected:					*CSA (1987)*	*2.00E+01*	*5.00E+02*	*L/kg*	*FW*
For comparison, IAEA (1985), as cited in FASSET (D1), recommends a fish concentration factor of 1E0									
Pb	4.00E+01	L/kg	DW	Geo.Mean; GSD=7.2	Bird and Schwartz (1996)	6.00E+00	1.50E+02	L/kg	FW
	3.00E+02	L/kg	FW	One value reported	NCRP (1996)	3.00E+02	7.50E+03	L/kg	FW
	1.73E+02	L/kg	FW	Range: 1E2 to 3E2	IAEA (1994)	1.73E+02	3.00E+02	L/kg	FW
	3.00E+02	L/kg	FW	One value reported	U.S. DOE (2003)	3.00E+02	7.50E+03	L/kg	FW
Values Selected:					*NCRP (1996)*	*3.00E+02*	*7.50E+03*	*L/kg*	*FW*
For comparison, IAEA (1985), as cited in FASSET (D1), recommends a fish concentration factor of 2E2									

Radionuclide	TF as Expressed in Original Ref.			Notes	Reference	Expressed on Consistent Basis and Units**			
	Central Estimate TF*	Units	Basis			Central Estimate	Upper Estimate †	Unit	Basis
Po	5.00E+01	L/kg	FW		U.S. DOE (2003)	5.00E+01	1.25E+03	L/kg	FW
	2.10E+02	L/kg	DW	Geo.Mean; GSD=3.5	Bird and Schwartz (1996)	3.15E+01	7.88E+02	L/kg	FW
	1.00E+02	L/kg	FW		NCRP (1996)	1.00E+02	2.50E+03	L/kg	FW
	5.00E+01	L/kg	FW	FW assumed; range:1E1 to 5E2	IAEA (1994)	5.00E+01	5.00E+02	L/kg	FW
Values Selected:					*NCRP (1996)*	*1.00E+02*	*2.50E+03*	*L/kg*	*FW*
For comparison, IAEA (1985), as cited in FASSET (D1), recommends a fish concentration factor of 2E3									

Notes:
Transfer factors for amphibians were set equal to fish transfer factors, except for Cs. The Cs water-to-amphibian transfer factor used was 4.8E2 L/kg, based on Ewing et al. (1996).
Fish TFs that are derived for tissues consumed by humans are likely acceptable for mammals (that don't eat bones). However, they may not result in conservative estimates of transfer to some birds.
GM = Geometric Mean; GSD = Geometric Standard Deviation; DW = Dry Weight; FW = Fresh Weight.
* Central Estimate is either a geometric mean (GM), or the only available data point
† Upper Estimate is the upper range or the $GM*GSD^2$ or the only available data point * 5^2. For data from Sheppard *et al.* (2002, 2004a, 2004b, 2005a, 2005b), the 'upper range' value is over-ridden by the $GM*GSD^2$ value. In each data set, if the GSD was larger than 5 (interpreted as an outlier), it was set equal to 5.
** - Conversion between DW and FW based on moisture content of (fraction; based on US EPA 1993): 0.85
N/A - data not available

Table B-5: Soil-to-Terrestrial Plant Transfer Factors

Unit: kg/kg Dry Weight

Radionuclide	TF as Expressed in Original Ref.			Notes	Reference	Expressed on Consistent Basis and Units**			
	Central Estimate TF*	Units	Basis			Central Estimate	Upper Estimate †	Unit	Basis
C	1.00E+00	kg/kg	DW	Geo.Mean	Sheppard et al. (1994)	1.00E+00	2.50E+01	kg/kg	DW
	-	kg/kg	DW	Modeled using specific activity	CSA (1987)	-	-	kg/kg	DW
				Modelled using specific activity	U.S. DOE (2003)			kg/kg	DW
	7.00E-01	kg/kg	DW	Leafy Vegetables	U.S. DOE (2003)	7.00E-01	1.75E+01	kg/kg	DW
	7.00E-01	kg/kg	DW	Fruit, Root Vegetables, Grain	U.S. DOE (2003)	7.00E-01	1.75E+01	kg/kg	DW
Values Selected for generic vegetation:					*Sheppard et al. (1994)*	*1.00E+00*	*2.50E+01*	*kg/kg*	*DW*
Values Selected for berries:					*U.S. DOE (2003)*	*7.00E-01*	*1.75E+01*	*kg/kg*	*DW*
Cl	1.00E+02	kg/kg	DW	Generic value , dry forage	NCRP (1996)	1.00E+02	2.50E+03	kg/kg	DW
	7.00E+01	kg/kg	DW	Vegetative portion (leaves+stems)	Baes et al. (1984)	7.00E+01	1.75E+03	kg/kg	DW
	7.00E+01	kg/kg	DW	Non-vegetative portion (fruit, seeds, tubers)	Baes et al. (1984)	7.00E+01	1.75E+03	kg/kg	DW
	2.00E+01	kg/kg	FW	Fresh vegetables	NCRP (1996)	6.67E+01	1.67E+03	kg/kg	DW
	7.00E+01	kg/kg	DW	Leafy Vegetables, Fruit, Root Vegetables, Grain	U.S. DOE (2003) (adopted value from Baes et al. 1984)	7.00E+01	1.75E+03	kg/kg	DW
	3.70E+00	kg/kg	FW	Geo. Mean; GSD=5.7 (Human)	Sheppard et al. (2004a)	1.23E+01	3.08E+02	kg/kg	DW
	4.20E+00	kg/kg	FW	Fresh vegetables	Sheppard et al. (2004a)	1.40E+01	3.50E+02	kg/kg	DW
Values Selected for generic vegetation:					*NCRP (1996)*	*1.00E+02*	*2.50E+03*	*kg/kg*	*DW*
Values Selected for berries:					*Baes et al. (1984)*	*7.00E+01*	*1.75E+03*	*kg/kg*	*DW*
Zr	7.20E-02	kg/kg	DW	Forage grass	CSA (1987)	7.20E-02	1.80E+00	kg/kg	DW
	1.00E-01	kg/kg	DW	Generic value , dry forage	NCRP (1996)	1.00E-01	2.50E+00	kg/kg	DW
	2.00E-03	kg/kg	DW	Vegetative portion (leaves+stems)	Baes et al. (1984)	2.00E-03	5.00E-02	kg/kg	DW
	5.00E-04	kg/kg	DW	Non-vegetative portion (fruit,	Baes et al. (1984)	5.00E-04	1.25E-02	kg/kg	DW

Radionuclide	TF as Expressed in Original Ref.			Notes	Reference	Expressed on Consistent Basis and Units**			
	Central Estimate TF*	Units	Basis			Central Estimate	Upper Estimate †	Unit	Basis
				seeds, tubers)					
	1.00E-03	kg/kg	DW	Leafy veg., fruit, root and grain	IAEA (1994)	1.00E-03	2.50E-02	kg/kg	DW
	7.70E-04	kg/kg	FW	Vegetables	CSA (1987)	2.57E-03	6.42E-02	kg/kg	DW
	1.00E-03	kg/kg	FW	Fresh vegetables	NCRP (1996)	3.33E-03	8.33E-02	kg/kg	DW
	1.00E-03	kg/kg	DW	Leafy Vegetables, Fruit, Root Vegetables, Grain	U.S. DOE (2003)	1.00E-03	2.50E-02	kg/kg	DW
Values Selected for generic vegetation:					*NCRP (1996)*	*1.00E-01*	*2.50E+00*	*kg/kg*	*DW*
Values Selected for berries:					*U.S. DOE (2003)*	*1.00E-03*	*2.50E-02*	*kg/kg*	*DW*
Nb	1.00E-01	kg/kg	DW	Generic value	NCRP (1996)	1.00E-01	2.50E+00	kg/kg	DW
	2.00E-01	kg/kg	DW	Forage grass	CSA (1987)	2.00E-01	5.00E+00	kg/kg	DW
	2.00E-02	kg/kg	DW	Vegetative portion (leaves+stems)	Baes et al. (1984)	2.00E-02	5.00E-01	kg/kg	DW
	5.00E-03	kg/kg	DW	Non-vegetative portion (fruit, seeds, tubers)	Baes et al. (1984)	5.00E-03	1.25E-01	kg/kg	DW
	1.00E-02	kg/kg	FW	Fresh vegetables	NCRP (1996)	3.33E-02	8.33E-01	kg/kg	DW
	5.00E-02	kg/kg	FW	Vegetables	CSA (1987)	1.67E-01	4.17E+00	kg/kg	DW
	2.50E-02	kg/kg	DW	Leafy Vegetables, Fruit, Root Vegetables, Grain	U.S. DOE (2003)	2.50E-02	6.25E-01	kg/kg	DW
Values Selected for generic vegetation:					*CSA (1987)*	*2.00E-01*	*5.00E+00*	*kg/kg*	*DW*
Values Selected for berries:					*U.S. DOE (2003)*	*2.50E-02*	*6.25E-01*	*kg/kg*	*DW*
For comparison, FASSET (D1) lists pasture concentration ratios of (4-10)E-3 (DW)									
Tc	4.00E+01	kg/kg	DW	Generic value , dry forage	NCRP (1996)	4.00E+01	1.00E+03	kg/kg	DW
	9.50E+00	kg/kg	DW	Vegetative portion (leaves+stems)	Baes et al. (1984)	9.50E+00	2.38E+02	kg/kg	DW
	1.50E+00	kg/kg	DW	Non-vegetative portion (fruit, seeds, tubers)	Baes et al. (1984)	1.50E+00	3.75E+01	kg/kg	DW
	5.00E+00	kg/kg	FW	Fresh vegetables	NCRP (1996)	1.67E+01	4.17E+02	kg/kg	DW
	2.10E+02	kg/kg	DW	Leafy Vegetables	U.S. DOE (2003)	2.10E+02	5.25E+03	kg/kg	DW
	1.50E+00	kg/kg	DW	Fruit	U.S. DOE (2003) (adopted value from Baes et al.	1.50E+00	3.75E+01	kg/kg	DW

Radionuclide	TF as Expressed in Original Ref.			Notes	Reference	Expressed on Consistent Basis and Units**			
	Central Estimate TF*	Units	Basis			Central Estimate	Upper Estimate †	Unit	Basis
					1984)				
	2.40E-01	kg/kg	DW	Root Vegetables	U.S. DOE (2003)	2.40E-01	6.00E+00	kg/kg	DW
	7.30E-01	kg/kg	DW	Grain	U.S. DOE (2003)	7.30E-01	1.83E+01	kg/kg	DW
Values Selected for generic vegetation:					*U.S. DOE (2003)*	*2.10E+02*	*5.25E+03*	*kg/kg*	*DW*
Values Selected for berries:					*Baes et al. (1984)*	*1.50E+00*	*3.75E+01*	*kg/kg*	*DW*
For comparison, FASSET (D1) lists pasture concentration ratios of (0.5-7)E1 (DW)									
For comparison, U.S. DOE (2000) lists bioaccumulation factor of 4E1 (DW; from Napier (1988))									
I	6.75E-02	kg/kg	DW	Range 2.4E-2 to 1.9E-1	Sheppard et al. (1993)	6.75E-02	1.90E-01	kg/kg	DW
	1.00E-01	kg/kg	DW	Generic value , dry forage	NCRP (1996)	1.00E-01	2.50E+00	kg/kg	DW
	1.60E-01	kg/kg	DW	Forage	CSA (1987)	1.60E-01	4.00E+00	kg/kg	DW
	1.50E-01	kg/kg	DW	Vegetative portion (leaves+stems)	Baes et al. (1984)	1.50E-01	3.75E+00	kg/kg	DW
	5.00E-02	kg/kg	DW	Non-vegetative portion (fruit, seeds, tubers)	Baes et al. (1984)	5.00E-02	1.25E+00	kg/kg	DW
	4.50E-03	kg/kg	FW	Vegetables	CSA (1987)	1.50E-02	3.75E-01	kg/kg	DW
	2.00E-02	kg/kg	FW	Fresh vegetables	NCRP (1996)	6.67E-02	1.67E+00	kg/kg	DW
	1.00E-01	kg/kg	DW	Leafy veg., fruit, root and grain	IAEA (1994)	1.00E-01	2.50E+00	kg/kg	DW
	4.00E-02	kg/kg	DW	Leafy Vegetables, Fruit, Root Vegetables, Grain	U.S. DOE (2003)	4.00E-02	1.00E+00	kg/kg	DW
	8.00E-03	kg/kg	FW	Geo. Mean; GSD=10	Sheppard et al. (2002)	2.67E-02	6.67E-01	kg/kg	DW
Values Selected for generic vegetation:					*CSA (1987)*	*1.60E-01*	*4.00E+00*	*kg/kg*	*DW*
Values Selected for berries:					*Baes et al. (1984)*	*5.00E-02*	*1.25E+00*	*kg/kg*	*DW*
For comparison, FASSET (D1) lists pasture concentration ratios of 1E-1 (DW)									
For comparison, U.S. DOE (2000) lists bioaccumulation factor of 4E-1 (DW)									
Cs	1.30E-01	kg/kg	DW	Forage grass	CSA (1987)	1.30E-01	3.25E+00	kg/kg	DW
	1.00E+00	kg/kg	DW	Generic value , dry forage	NCRP 1996	1.00E+00	2.50E+01	kg/kg	DW
	8.00E-02	kg/kg	DW	Vegetative portion (leaves+stems)	Baes et al. (1984)	8.00E-02	2.00E+00	kg/kg	DW
	3.00E-02	kg/kg	DW	Non-vegetative portion (fruit,	Baes et al. (1984)	3.00E-02	7.50E-01	kg/kg	DW

Radionuclide	TF as Expressed in Original Ref.			Notes	Reference	Expressed on Consistent Basis and Units**			
	Central Estimate TF*	Units	Basis			Central Estimate	Upper Estimate †	Unit	Basis
				seeds, tubers)					
	8.00E+02	kg/kg	DW	(uncertain)	Polikarpov (1966)	8.00E+02	2.00E+04	kg/kg	DW
	5.00E-03	kg/kg	FW	Vegetables	CSA (1987)	1.67E-02	4.17E-01	kg/kg	DW
	2.00E-01	kg/kg	FW	Fresh vegetables	NCRP (1996)	6.67E-01	1.67E+01	kg/kg	DW
	5.00E+01	kg/kg	FW	(uncertain)	Polikarpov (1966)	1.67E+02	4.17E+03	kg/kg	DW
	7.00E+01	kg/kg	FW	(uncertain)	Polikarpov (1966)	2.33E+02	5.83E+03	kg/kg	DW
	2.40E+02	kg/kg	FW	(uncertain)	Polikarpov (1966)	8.00E+02	2.00E+04	kg/kg	DW
	1.00E+03	kg/kg	FW	(uncertain)	Polikarpov (1966)	3.33E+03	8.33E+04	kg/kg	DW
	1.00E+00	kg/kg	DW	Leafy veg., fruit, root and grain	IAEA (1994)	1.00E+00	2.50E+01	kg/kg	DW
	4.60E-01	kg/kg	DW	Leafy Vegetables	U.S. DOE (2003)	4.60E-01	1.15E+01	kg/kg	DW
	2.20E-01	kg/kg	DW	Fruit	U.S. DOE (2003)	2.20E-01	5.50E+00	kg/kg	DW
	1.30E-01	kg/kg	DW	Root Vegetables	U.S. DOE (2003)	1.30E-01	3.25E+00	kg/kg	DW
	2.60E-02	kg/kg	DW	Grain	U.S. DOE (2003)	2.60E-02	6.50E-01	kg/kg	DW
Values Selected for generic vegetation:					*NCRP (1996) & IAEA (1994)*	*1.00E+00*	*2.50E+01*	*kg/kg*	*DW*
Values Selected for berries:					*U.S. DOE (2003)*	*2.20E-01*	*5.50E+00*	*kg/kg*	*DW*
For comparison, FASSET (D1) lists pasture concentration ratios of (5-40)E-3 (DW)									
For comparison, U.S. DOE (2000) lists bioaccumulation factor of 1E1 (DW)									
Ra	2.00E-01	kg/kg	FW	Generic value , dry forage	NCRP (1996)	6.67E-01	1.67E+01	kg/kg	DW
	1.50E-02	kg/kg	DW	Vegetative portion (leaves+stems)	Baes et al. (1984)	1.50E-02	3.75E-01	kg/kg	DW
	1.50E-02	kg/kg	DW	Non-vegetative portion (fruit, seeds, tubers)	Baes et al. (1984)	1.50E-02	3.75E-01	kg/kg	DW
	4.00E-02	kg/kg	FW	Fresh vegetables	NCRP (1996)	1.33E-01	3.33E+00	kg/kg	DW
	4.90E-02	kg/kg	DW	Leafy Vegetables	U.S. DOE (2003)	4.90E-02	1.23E+00	kg/kg	DW
	6.10E-03	kg/kg	DW	Fruit	U.S. DOE (2003)	6.10E-03	1.53E-01	kg/kg	DW
	2.00E-03	kg/kg	DW	Root Vegetables	U.S. DOE (2003)	2.00E-03	5.00E-02	kg/kg	DW
	1.20E-03	kg/kg	DW	Grain	U.S. DOE (2003)	1.20E-03	3.00E-02	kg/kg	DW
	9.50E-03	kg/kg	FW	Geo. Mean; GSD=11	Sheppard et al. (2005b)	3.17E-02	7.92E-01	kg/kg	DW
Values Selected for generic vegetation:					*NCRP (1996)*	*6.67E-01*	*1.67E+01*	*kg/kg*	*DW*
Values Selected for berries:					*U.S. DOE (2003)*	*4.90E-02*	*1.23E+00*	*kg/kg*	*DW*

Radionuclide	TF as Expressed in Original Ref.			Notes	Reference	Expressed on Consistent Basis and Units**			
	Central Estimate TF*	Units	Basis			Central Estimate	Upper Estimate †	Unit	Basis
For comparison, FASSET (D1) lists pasture concentration ratios of 7E-6 (DW)									
For comparison, U.S. DOE (2000) lists bioaccumulation factor of 1E-1 (DW)									
Np	1.00E-01	kg/kg	DW	Generic value , dry forage	NCRP (1996)	1.00E-01	2.50E+00	kg/kg	DW
	1.10E+00	kg/kg	DW	Forage grass	CSA (1987)	1.10E+00	2.75E+01	kg/kg	DW
	1.00E-01	kg/kg	DW	Vegetative portion (leaves+stems)	Baes et al. (1984)	1.00E-01	2.50E+00	kg/kg	DW
	1.00E-02	kg/kg	DW	Non-vegetative portion (fruit, seeds, tubers)	Baes et al. (1984)	1.00E-02	2.50E-01	kg/kg	DW
	2.00E-02	kg/kg	FW	Fresh vegetables	NCRP (1996)	6.67E-02	1.67E+00	kg/kg	DW
	6.90E-02	kg/kg	FW	Vegetables	CSA (1987)	2.30E-01	5.75E+00	kg/kg	DW
	3.20E-02	kg/kg	DW	Leafy Vegetables	U.S. DOE (2003)	3.20E-02	8.00E-01	kg/kg	DW
	1.00E-02	kg/kg	DW	Fruit	U.S. DOE (2003) (adopted value from Baes et al. 1984)	1.00E-02	2.50E-01	kg/kg	DW
	1.30E-02	kg/kg	DW	Root Vegetables	U.S. DOE (2003)	1.30E-02	3.25E-01	kg/kg	DW
	2.70E-03	kg/kg	DW	Grain	U.S. DOE (2003)	2.70E-03	6.75E-02	kg/kg	DW
	2.50E-03	kg/kg	FW	Geo. Mean; GSD=5.7	Sheppard et al. (2004b)	8.33E-03	2.08E-01	kg/kg	DW
Values Selected for generic vegetation:					*CSA (1987)*	*1.10E+00*	*2.75E+01*	*kg/kg*	*DW*
Values Selected for berries:					*Baes et al. (1984)*	*1.00E-02*	*2.50E-01*	*kg/kg*	*DW*
For comparison, FASSET (D1) lists pasture concentration ratios of (1-6.9)E-2 (DW)									
U	8.30E-03	kg/kg	DW	Forage grass	CSA (1987)	8.30E-03	2.08E-01	kg/kg	DW
	1.00E-01	kg/kg	DW	Generic value , dry forage	NCRP (1996)	1.00E-01	2.50E+00	kg/kg	DW
	8.50E-03	kg/kg	DW	Vegetative portion (leaves+stems)	Baes et al. (1984)	8.50E-03	2.13E-01	kg/kg	DW
	4.00E-03	kg/kg	DW	Non-vegetative portion (fruit, seeds, tubers)	Baes et al. (1984)	4.00E-03	1.00E-01	kg/kg	DW
	2.90E-04	kg/kg	FW	Forage grass	CSA (1987)	9.67E-04	2.42E-02	kg/kg	DW
	2.00E-03	kg/kg	FW	Fresh vegetables	NCRP (1996)	6.67E-03	1.67E-01	kg/kg	DW
	8.30E-03	kg/kg	DW	Leafy Vegetables	U.S. DOE (2003)	8.30E-03	2.08E-01	kg/kg	DW
	4.00E-03	kg/kg	DW	Fruit	U.S. DOE (2003) (adopted value from Baes et al.	4.00E-03	1.00E-01	kg/kg	DW

Radionuclide	TF as Expressed in Original Ref.			Notes	Reference	Expressed on Consistent Basis and Units**			
	Central Estimate TF*	Units	Basis			Central Estimate	Upper Estimate †	Unit	Basis
					1984)				
	1.20E-02	kg/kg	DW	Root Vegetables	U.S. DOE (2003)	1.20E-02	3.00E-01	kg/kg	DW
	1.30E-03	kg/kg	DW	Grain	U.S. DOE (2003)	1.30E-03	3.25E-02	kg/kg	DW
	1.70E-03	kg/kg	FW	Geo.Mean; GSD=10	Sheppard et al (2005a)	5.67E-03	1.42E-01	kg/kg	DW
Values Selected for generic vegetation:					*NCRP (1996)*	*1.00E-01*	*2.50E+00*	*kg/kg*	*DW*
Values Selected for berries:					*Baes et al. (1984)*	*4.00E-03*	*1.00E-01*	*kg/kg*	*DW*
For comparison, the maximum of 25 measurements in Port Hope Soil Study was 6.8E-1 (SENES 2007)									
For comparison, U.S. DOE (2000) lists bioaccumulation factor of 4E-3 (DW)									
Pb	4.50E-02	kg/kg	DW	Forage	U.S. EPA (1998) R6	4.50E-02	1.13E+00	kg/kg	DW
	1.00E-01	kg/kg	FW	Generic Value; Forage	NCRP (1996)	3.33E-01	8.33E+00	kg/kg	DW
	1.36E-02	kg/kg	DW	Fruit	U.S. EPA (1998) R6	1.36E-02	3.40E-01	kg/kg	DW
	9.00E-03	kg/kg	DW	Grain	U.S. EPA (1998) R6	9.00E-03	2.25E-01	kg/kg	DW
	9.00E-03	kg/kg	DW	Non-vegetative portion	Baes et al. (1984)	9.00E-03	2.25E-01	kg/kg	DW
	2.00E-02	kg/kg	DW	Root Vegetation	IAEA (1994)	2.00E-02	5.00E-01	kg/kg	DW
	9.00E-03	kg/kg	DW	Root Vegetation	U.S. EPA (1998) R6	9.00E-03	2.25E-01	kg/kg	DW
	1.00E-02	kg/kg	DW	Leafy vegetables, Fruit	U.S. DOE (2003)	1.00E-02	2.50E-01	kg/kg	DW
	4.50E-02	kg/kg	DW	Vegetative portion	Baes et al. (1984)	4.50E-02	1.13E+00	kg/kg	DW
	9.00E-02	kg/kg	DW	(uncertain)	NCRP (1989)	9.00E-02	2.25E+00	kg/kg	DW
	4.00E-03	kg/kg	FW	Fresh vegetables	NCRP (1996)	1.33E-02	3.33E-01	kg/kg	DW
	6.00E-03	kg/kg	DW	Root Vegetable	U.S. DOE (2003)	6.00E-03	1.50E-01	kg/kg	DW
	4.70E-03	kg/kg	DW	Grain	U.S. DOE (2003)	4.70E-03	1.18E-01	kg/kg	DW
Values Selected for generic vegetation:					*NCRP (1996)*	*3.33E-01*	*8.33E+00*	*kg/kg*	*DW*
Values Selected for berries:					*U.S. EPA (1998) R6*	*1.36E-02*	*3.40E-01*	*kg/kg*	*DW*
Po	1.00E-01	kg/kg	FW	Forage; Generic value	NCRP (1996)	3.33E-01	8.33E+00	kg/kg	DW
	1.20E-03	kg/kg	DW	Leafy vegetables, Fruit	U.S. DOE (2003)	1.20E-03	3.00E-02	kg/kg	DW
	2.50E-03	kg/kg	DW	Vegetative portion	Baes et al. (1984)	2.50E-03	6.25E-02	kg/kg	DW
	4.00E-04	kg/kg	DW	Non-vegetative portion	Baes et al. (1984)	4.00E-04	1.00E-02	kg/kg	DW
	1.00E-03	kg/kg	FW	Fresh vegetables	NCRP (1996)	3.33E-03	8.33E-02	kg/kg	DW
	7.00E-03	kg/kg	DW	Root vegetables	U.S. DOE (2003)	7.00E-03	1.75E-01	kg/kg	DW
	2.30E-03	kg/kg	DW	Grain	U.S. DOE (2003)	2.30E-03	5.75E-02	kg/kg	DW
Values Selected for generic vegetation:					*NCRP (1996)*	*3.33E-01*	*8.33E+00*	*kg/kg*	*DW*

Radionuclide	TF as Expressed in Original Ref.			Notes	Reference	Expressed on Consistent Basis and Units**			
	Central Estimate TF*	Units	Basis			Central Estimate	Upper Estimate †	Unit	Basis
Values Selected for berries:					*NCRP (1996)*	*3.33E-03*	*8.33E-02*	*kg/kg*	*DW*
For comparison, FASSET (D1) lists pasture concentration ratios of (0.2-90)E-3 (DW)									

Notes: GM = Geometric Mean; GSD = Geometric Standard Deviation; DW = Dry Weight; FW = Fresh Weight.
* Central Estimate is either a geometric mean (GM), or the only available data point.
† Upper Estimate is the upper range or the GM* GSD^2 or the only available data point * 5^2. In each data set, if the GSD was larger than 5 (interpreted as an outlier), it was set equal to 5.
** - Conversion between DW and FW based on moisture content of (fraction; based on US EPA 1993): 0.7
N/A - data not available
(a) Data from Polikarpov (1966) not included in selection as it was significantly higher than all other data sources. There have been issues with data from this author due to the translation from original reports in Russian.

Table B-6: Feed-to-Bird Transfer Factors

Unit: d/kg Fresh Weight

Radionuclide	TF as Expressed in Original Ref.			Notes	Reference	Expressed on Consistent Basis and Units**			
	Central Estimate TF*	Units	Basis			Central Estimate	Upper Estimate †	Unit	Basis
C	4.20E+00	d/kg	FW	One value reported	CSA (1987)	4.20E+00	1.05E+02	d/kg	FW
	6.40E+00	d/kg	FW	One value reported	Zach and Sheppard (1992)	6.40E+00	1.60E+02	d/kg	FW
Values Selected:					*Zach and Sheppard (1992)*	*6.40E+00*	*1.60E+02*	*d/kg*	*FW*
Cl	3.00E-02	d/kg	FW	One value reported	U.S. DOE (2003)	3.00E-02	7.50E-01	d/kg	FW
	2.00E+00	d/kg	FW	FW assumed, Geo. Mean; GSD=2.2	Sheppard et al. (2004a)	2.00E+00	9.68E+00	d/kg	FW
Values Selected:					*Sheppard et al. (2004a)*	*2.00E+00*	*9.68E+00*	*d/kg*	*FW*
Zr	6.00E-05	d/kg	FW	One value reported	IAEA (1994)	6.00E-05	1.50E-03	d/kg	FW
Values Selected:					*IAEA (1994)*	*6.00E-05*	*1.50E-03*	*d/kg*	*FW*
Nb	3.00E-04	d/kg	FW	One value reported	IAEA (1994)	3.00E-04	7.50E-03	d/kg	FW
	2.00E-03	d/kg	FW	One value reported	CSA (1987)	2.00E-03	5.00E-02	d/kg	FW
Values Selected:					*CSA (1987)*	*2.00E-03*	*5.00E-02*	*d/kg*	*FW*
Tc	7.75E-02	d/kg	FW	Range: 3E-2 to 2E-1	IAEA (1994)	7.75E-02	2.00E-01	d/kg	FW
Values Selected:					*IAEA (1994)*	*7.75E-02*	*2.00E-01*	*d/kg*	*FW*
I	1.00E-02	d/kg	FW	One value reported	IAEA (1994)	1.00E-02	2.50E-01	d/kg	FW
	2.00E-01	d/kg	FW	One value reported	CSA (1987)	2.00E-01	5.00E+00	d/kg	FW
	2.80E+00	d/kg	FW	One value reported	Zach and Sheppard (1992)	2.80E+00	7.00E+01	d/kg	FW
	7.50E+00	d/kg	FW	FW assumed, Geo. Mean; GSD=3.2	Sheppard et al (2002)	7.50E+00	7.68E+01	d/kg	FW
	5.00E-02	d/kg	FW	One value reported	U.S. DOE (2003)	5.00E-02	1.25E+00	d/kg	FW

Radionuclide	TF as Expressed in Original Ref.			Notes	Reference	Expressed on Consistent Basis and Units**			
	Central Estimate TF*	Units	Basis			Central Estimate	Upper Estimate †	Unit	Basis
Values Selected :					*Sheppard et al (2002)*	*7.50E+00*	*7.68E+01*	*d/kg*	*FW*
Cs	4.40E+00	d/kg	FW	One value reported	CSA (1987)	4.40E+00	1.10E+02	d/kg	FW
	1.73E+00	d/kg	FW	Range: 3E-1 to 1E1	IAEA (1994)	1.73E+00	1.00E+01	d/kg	FW
	1.40E+03	d/kg	FW	Range: 7E2 to 2.8E3	Polikarpov (1966)	1.40E+03	2.80E+03	d/kg	FW
	4.40E+00	d/kg	FW	One value reported	Zach and Sheppard (1992)	4.40E+00	1.10E+02	d/kg	FW
	3.00E+00	d/kg	FW	One value reported	U.S. DOE (2003)	3.00E+00	7.50E+01	d/kg	FW
Values Selected:					*Polikarpov (1966)*	*1.40E+03*	*2.80E+03*	*d/kg*	*FW*
Ra	3.33E-01	d/kg	FW	One value reported (calculated value)	Clulow et al. (1992)	3.33E-01	8.33E+00	d/kg	FW
	1.30E-01	d/kg	FW	FW assumed, Geo. Mean; GSD=7	Sheppard et al. (2005b)	1.30E-01	3.25E+00	d/kg	FW
	3.00E-02	d/kg	FW	One value reported	U.S. DOE (2003)	3.00E-02	7.50E-01	d/kg	FW
Values Selected:					*Clulow et al. (1992)*	*3.33E-01*	*8.33E+00*	*d/kg*	*FW*
Np	6.00E-03	d/kg	FW	One value reported	U.S. DOE (2003)	6.00E-03	1.50E-01	d/kg	FW
	2.00E-02	d/kg	FW	FW assumed, Geo. Mean; GSD=3.2	Sheppard et al. (2004b)	2.00E-02	2.05E-01	d/kg	FW
Values Selected:					*Sheppard et al. (2004b)*	*2.00E-02*	*2.05E-01*	*d/kg*	*FW*
U	5.48E-01	d/kg	FW	Range: 3E-1 to 1E0	IAEA (1994)	5.48E-01	1.00E+00	d/kg	FW
	1.20E+00	d/kg	FW	One value reported	CSA (1987)	1.20E+00	3.00E+01	d/kg	FW
	1.20E+00	d/kg	FW	FW assumed, Geo. Mean; GSD=3.2	Sheppard et al (2005a)	1.20E+00	1.23E+01	d/kg	FW
	1.00E+00	d/kg	FW	One value reported	U.S. DOE (2003)	1.00E+00	2.50E+01	d/kg	FW
Values Selected:					*CSA (1987)*	*1.20E+00*	*3.00E+01*	*d/kg*	*FW*

Radionuclide	TF as Expressed in Original Ref.			Notes	Reference	Expressed on Consistent Basis and Units**			
	Central Estimate TF*	Units	Basis			Central Estimate	Upper Estimate †	Unit	Basis
Pb	8.00E-01	d/kg	FW	One value reported	U.S. DOE (2003)	8.00E-01	2.00E+01	d/kg	FW
Values Selected:					*U.S. DOE (2003)*	*8.00E-01*	*2.00E+01*	*d/kg*	*FW*

Po	2.30E+00	d/kg	FW	One value reported	U.S. DOE (2003)	2.30E+00	5.75E+01	d/kg	FW
Values Selected:					*U.S. DOE (2003)*	*2.30E+00*	*5.75E+01*	*d/kg*	*FW*

Notes: GM = Geometric Mean; GSD = Geometric Standard Deviation; DW = Dry Weight; FW = Fresh Weight.
* Central Estimate is either a geometric mean (GM), or the only available data point
† Upper Estimate is the upper range or the GM* GSD^2 or the only available data point * 5^2. In each data set, if the GSD was larger than 5 (interpreted as an outlier), it was set equal to 5.
** - Conversion between DW and FW based on moisture content of (fraction; based on US EPA 1993): 68
N/A - data not available

Table B-7: Feed-to-Mammal transfer Factors

Unit: d/kg Fresh Weight

Radionuclide	TF as Expressed in Original Ref.			Notes	Reference	Expressed on Consistent Basis and Units**			
	Central Estimate TF*	Units	Basis			Central Estimate	Upper Estimate †	Unit	Basis
C	6.40E-02	d/kg	FW	One value reported; beef	CSA (1987)	6.40E-02	1.60E+00	d/kg	FW
	1.80E-01	d/kg	FW	One value reported; pork	CSA (1987)	1.80E-01	4.50E+00	d/kg	FW
	6.40E-02	d/kg	FW	One value reported; deer, muskrat	Zach and Sheppard (1992)	6.40E-02	1.60E+00	d/kg	FW
Values Selected for Allometric Scaling:					*CSA (1987)*	*6.40E-02*	*1.60E+00*	*d/kg*	*FW*
Cl	2.00E-02	d/kg	FW	One value reported; beef	IAEA (1994)	2.00E-02	5.00E-01	d/kg	FW
	4.00E-02	d/kg	FW	One value reported; beef	NCRP (1996)	4.00E-02	1.00E+00	d/kg	FW
	8.00E-02	d/kg	FW	One value reported; beef	Baes et al. (1984)	8.00E-02	2.00E+00	d/kg	FW
	2.00E-02	d/kg	FW	FW assumed, Geo. Mean; GSD=2.2; beef	Sheppard et al. (2004a)	2.00E-02	9.68E-02	d/kg	FW
Values Selected for Allometric Scaling:					*Baes et al. (1984)*	*8.00E-02*	*2.00E+00*	*d/kg*	*FW*
Zr	1.00E-06	d/kg	FW	One value reported; beef	IAEA (1994)	1.00E-06	2.50E-05	d/kg	FW
	1.00E-06	d/kg	FW	One value reported; beef	NCRP (1996)	1.00E-06	2.50E-05	d/kg	FW
	5.50E-03	d/kg	FW	One value reported; beef	Baes et al. (1984)	5.50E-03	1.38E-01	d/kg	FW
	2.00E-02	d/kg	FW	One value reported; beef	CSA (1987)	2.00E-02	5.00E-01	d/kg	FW
Values Selected for Allometric Scaling:					*CSA (1987)*	*2.00E-02*	*5.00E-01*	*d/kg*	*FW*
Nb	3.00E-07	d/kg	FW	One value reported; beef	IAEA (1994)	3.00E-07	7.50E-06	d/kg	FW
	3.00E-07	d/kg	FW	One value reported; beef	NCRP (1996)	3.00E-07	7.50E-06	d/kg	FW
	2.50E-01	d/kg	FW	One value reported; beef	Baes et al. (1984)	2.50E-01	6.25E+00	d/kg	FW
	2.50E-01	d/kg	FW	One value reported; beef	CSA (1987)	2.50E-01	6.25E+00	d/kg	FW
	3.17E-03	d/kg	FW	Range: 1.9E-3 to 5.3E-3; pork	IAEA (1994)	3.17E-03	5.30E-03	d/kg	FW
Values Selected for Allometric Scaling:					*Baes et al. (1984) / CSA (1987)*	*2.50E-01*	*6.25E+00*	*d/kg*	*FW*

Radionuclide	TF as Expressed in Original Ref.			Notes	Reference	Expressed on Consistent Basis and Units**			
	Central Estimate TF*	Units	Basis			Central Estimate	Upper Estimate †	Unit	Basis
Tc	1.00E-05	d/kg	FW	1E-4 (Tc-95m); 1E-6 (Tc-99m) ; beef	IAEA (1994)	1.00E-05	1.00E-04	d/kg	FW
	1.00E-04	d/kg	FW	One value reported; beef	NCRP (1996)	1.00E-04	2.50E-03	d/kg	FW
	8.50E-03	d/kg	FW	One value reported; beef	Baes et al. (1984)	8.50E-03	2.13E-01	d/kg	FW
	1.41E-04	d/kg	FW	Range: 1E-4 to 2E-4; pork	IAEA (1994)	1.41E-04	2.00E-04	d/kg	FW
Values Selected for Allometric Scaling:					*Baes et al. (1984)*	*8.50E-03*	*2.13E-01*	*d/kg*	*FW*
I	3.60E-03	d/kg	FW	One value reported; beef	CSA (1987)	3.60E-03	9.00E-02	d/kg	FW
	7.00E-03	d/kg	FW	One value reported; beef	Baes et al. (1984)	7.00E-03	1.75E-01	d/kg	FW
	1.87E-02	d/kg	FW	Range: 7E-3 to 5E-2; beef	IAEA (1994)	1.87E-02	5.00E-02	d/kg	FW
	4.00E-02	d/kg	FW	One value reported; beef	NCRP (1996)	4.00E-02	1.00E+00	d/kg	FW
	7.71E-04	d/kg	FW	Range: 1.8E-4 to 3.3E-3; pork	IAEA (1994)	7.71E-04	3.30E-03	d/kg	FW
	3.30E-03	d/kg	FW	One value reported; pork	CSA (1987)	3.30E-03	8.25E-02	d/kg	FW
	7.00E-03	d/kg	FW	One value reported; deer, muskrat	Zach and Sheppard (1992)	7.00E-03	1.75E-01	d/kg	FW
	1.20E-02	d/kg	FW	FW assumed, Geo. Mean; GSD=3.2; beef	Sheppard et al (2002)	1.20E-02	1.23E-01	d/kg	FW
Values Selected for Allometric Scaling:					*NCRP (1996)*	*4.00E-02*	*1.00E+00*	*d/kg*	*FW*
Cs	2.00E-02	d/kg	FW	One value reported; beef	Baes et al. (1984)	2.00E-02	5.00E-01	d/kg	FW
	2.60E-02	d/kg	FW	One value reported; beef	CSA (1987)	2.60E-02	6.50E-01	d/kg	FW
	2.45E-02	d/kg	FW	Range: 1E-2 to 6E-2; beef	IAEA (1994)	2.45E-02	6.00E-02	d/kg	FW
	5.00E-02	d/kg	FW	One value reported; beef	NCRP (1996)	5.00E-02	1.25E+00	d/kg	FW
	1.82E-01	d/kg	FW	Range: 3E-2 to 1.1E0; pork	IAEA (1994)	1.82E-01	1.10E+00	d/kg	FW
	2.50E-01	d/kg	FW	One value reported; pork	CSA (1987)	2.50E-01	6.25E+00	d/kg	FW
	1.20E-02	d/kg	FW	One value reported; deer, muskrat	Zach and Sheppard (1992)	1.20E-02	3.00E-01	d/kg	FW
	2.60E-02	d/kg	FW	One value reported; deer, muskrat	Zach and Sheppard (1992)	2.60E-02	6.50E-01	d/kg	FW
Values Selected for Allometric Scaling:					*NCRP (1996)*	*5.00E-02*	*1.25E+00*	*d/kg*	*FW*

Radionuclide	TF as Expressed in Original Ref.			Notes	Reference	Expressed on Consistent Basis and Units**			
	Central Estimate TF*	Units	Basis			Central Estimate	Upper Estimate †	Unit	Basis
Ra	2.50E-04	d/kg	FW	One value reported; beef	Baes et al. (1984)	2.50E-04	6.25E-03	d/kg	FW
	1.58E-03	d/kg	FW	Range: 5E-4 to 5E-3; beef	IAEA (1994)	1.58E-03	5.00E-03	d/kg	FW
	1.00E-03	d/kg	FW	One value reported; beef	NCRP (1996)	1.00E-03	2.50E-02	d/kg	FW
	9.00E-04	d/kg	FW	One value reported; beef	U.S. DOE (2003)	2.88E-04	7.20E-03		
	9.00E-04	d/kg	FW	FW assumed, Geo. Mean; GSD=3.2; beef	Sheppard et al. (2005b)	9.00E-04	9.22E-03	d/kg	FW
Values Selected for Allometric Scaling:					*IAEA (1994), NCRP (1996)*	*1.58E-03*	*2.50E-02*	*d/kg*	*FW*
Np	5.50E-05	d/kg	FW	One value reported; beef	Baes et al. (1984)	5.50E-05	1.38E-03	d/kg	FW
	2.00E-04	d/kg	FW	One value reported; beef	CSA (1987)	2.00E-04	5.00E-03	d/kg	FW
	1.00E-03	d/kg	FW	One value reported; beef	IAEA (1994)	1.00E-03	2.50E-02	d/kg	FW
	1.00E-03	d/kg	FW	One value reported; beef	NCRP (1996)	1.00E-03	2.50E-02	d/kg	FW
	2.00E-04	d/kg	FW	FW assumed, Geo. Mean; GSD=3.2; beef	Sheppard et al. (2004b)	2.00E-04	2.05E-03	d/kg	FW
Values Selected:					*IAEA (1994) & NCRP (1996)*	*1.00E-03*	*2.50E-02*	*d/kg*	*FW*
U	2.00E-04	d/kg	FW	One value reported; beef	Baes et al. (1984)	2.00E-04	5.00E-03	d/kg	FW
	3.00E-04	d/kg	FW	One value reported; beef	IAEA (1994)	3.00E-04	7.50E-03	d/kg	FW
	8.00E-04	d/kg	FW	One value reported; beef	NCRP (1996)	8.00E-04	2.00E-02	d/kg	FW
	4.00E-02	d/kg	FW	One value reported; pork	CSA (1987)	4.00E-02	1.00E+00	d/kg	FW
	6.20E-02	d/kg	FW	One value reported; pork	IAEA (1994)	6.20E-02	1.55E+00	d/kg	FW
	4.00E-04	d/kg	FW	FW assumed, Geo. Mean; GSD=3.2; beef	Sheppard et al (2005a)	4.00E-04	4.10E-03	d/kg	FW
Values Selected for Allometric Scaling:					*NCRP (1996)*	*8.00E-04*	*2.00E-02*	*d/kg*	*FW*
Pb	3.00E-04	d/kg	FW	One value reported; beef	Baes et al. (1984)	3.00E-04	7.50E-03	d/kg	FW
	4.00E-04	d/kg	FW	Range: 1.0E-4 to 7.0E-4; beef	IAEA (1994)	4.00E-04	7.00E-04	d/kg	FW
	8.00E-04	d/kg	FW	One value reported; beef	NCRP (1996)	8.00E-04	2.00E-02	d/kg	FW
	1.00E-03	d/kg	FW	One value reported; caribou	Thomas et al. (1994)	1.00E-03	2.50E-02	d/kg	FW

Radionuclide	TF as Expressed in Original Ref.			Notes	Reference	Expressed on Consistent Basis and Units**			
	Central Estimate TF*	Units	Basis			Central Estimate	Upper Estimate †	Unit	Basis
	1.40E-01	d/kg	FW	One value reported; hare	Thomas (1997)	1.40E-01	3.50E+00	d/kg	FW
	5.00E-02	d/kg	FW	One value reported; otter	Letourneau (1987)	5.00E-02	1.25E+00	d/kg	FW
	3.60E-04	d/kg	FW	One value reported; pork	NC DEHNR (1997)	3.60E-04	9.00E-03	d/kg	FW
	3.60E-04	d/kg	FW	One value reported; pork	U.S. EPA (1998) R6	3.60E-04	9.00E-03	d/kg	FW
	8.50E-02	d/kg	FW	One value reported; wolf	Thomas et al. (1994)	8.50E-02	2.13E+00	d/kg	FW
	4.00E-04	d/kg	FW	One value reported; beef	U.S. DOE (2003)	4.00E-04	1.00E-02	d/kg	FW
Values Selected for Allometric Scaling:					*NCRP (1996)*	*8.00E-04*	*2.00E-02*	*d/kg*	*FW*

Po	9.50E-05	d/kg	FW	One value reported	Baes et al. (1984)	9.50E-05	2.38E-03	d/kg	FW
	2.80E-03	d/kg	FW	Range: 6.0E-4 to 5.0E-3	IAEA (1994)	2.80E-03	5.00E-03	d/kg	FW
	5.00E-03	d/kg	FW	One value reported	NCRP (1996)	5.00E-03	1.25E-01	d/kg	FW
	5.00E-03	d/kg	FW	One value reported	U.S. DOE (2003)	5.00E-03	1.25E-01	d/kg	FW
Values Selected for Allometric Scaling:					*NCRP (1996), U.S. DOE (2003)*	*5.00E-03*	*1.25E-01*	*d/kg*	*FW*

Notes: GM = Geometric Mean; GSD = Geometric Standard Deviation; DW = Dry Weight; FW = Fresh Weight.
* Central Estimate is either a geometric mean (GM), or the only available data point
† Upper Estimate is the upper range or the GM* GSD^2 or the only available data point * 5^2. In each data set, if the GSD was larger than 5 (interpreted as an outlier), it was set equal to 5.
** - Conversion between DW and FW based on moisture content of (fraction; based on US EPA 1993): 68
N/A - data not available.

Appendix B.2: Allometric Scaling of TFs for Birds and Mammals

In general, the approach taken for the estimating the exposure of radiological and non-radiological contaminants to non-human biota is to model the intake of a contaminant by the biota (in mg/d or Bq/d) and then use a transfer factor (d/kg) to obtain a body or flesh concentration where necessary. Many toxicity values for non-radiological contaminants are expressed as intake rates rather than tissue residues. Therefore, the assessment of non-radiological and radiological contaminants can be carried out in parallel with the flesh concentrations being important for estimating internal radiological dose while intakes are used for assessment of non-radiological contaminants.

Transfer factors are generally only available in literature for agricultural animals such as beef and poultry. There is a potential issue when applying these generic transfer factors to non-human biota of varying sizes. Other sources, e.g. FASSET, generally use concentration ratios to estimate concentrations in animal flesh. Although information can be extracted from these sources the concentration ratios cannot be directly applied.

To obtain a more appropriate transfer factor, allometric scaling can be applied to the transfer factor with a relationship of -0.75. This approach is consistent with the allometric scaling for intake rates and inhalation by wildlife, as used in the ecological profiles (U.S. EPA 1993), which has shown a similar relationship. Allometric scaling of transfer factors has been discussed by others (e.g. Nalezinski *et al.* 1996, Higley *et al.* 2003) as a useful method for deriving transfer factors for biota. It is acknowledged that not all radionuclides would scale to the same factor,, as shown by the U.S. DOE (2002). However, the use of the -0.75 factor is a conservative approach. Other factors that can be found in the literature (e.g. 0.25 may be appropriate for actinides) would result in smaller predicted transfer factors for smaller biota than the reference animal. As most of the ecological receptors are smaller than cattle, the -0.75 is used as a conservative approach.

The scaling can be applied as follows:

$$TF_w = TF_A \left(\frac{BW_w}{BW_A} \right)^{-0.75}$$

where:

- TF_w Transfer factor for wildlife (d/kg)
- TF_A Transfer factor for animal available from literature (d/kg)
- BW_w Body weight of wildlife (kg)
- BW_A Body weight of animal (kg)

Scaling for the selected bird species was conducted from a selected reference bird species while scaling for the selected mammalian species was conducted from a reference mammal species.

Transfer factors are generally derived for domestic agricultural animals (cattle and poultry). The body weight of cattle is taken as the average of dairy cattle (mature weight of a typical Holstein is 650 kg (NRC 2001)) and beef cattle (average weight approximately 400 kg (NRC 2000, CCA 1999). This corresponds to an overall cattle weight of 525 kg. The transfer factors used in this study were likely derived for beef cows; therefore, the use of a combined dairy cattle and beef cattle transfer factor is conservative, due to the larger body weight.

For chickens, according to the Chicken Farmers of Canada (CFC), chickens are ready for market at approximately 2 kg (CFC, 2007). The typical body weight at 42 days is 2.7 kg (Havenstein *et al.,* 2003); this value was used in the calculations.

Note that this approach provides transfer factors that are consistent with the limited amount of measured values that are available. This can be illustrated using the transfer factor for lead. A feed to beef transfer 0.0004 d/kg can be obtained from literature (IAEA 1994). Using a body weight of 400 kg for cattle and 0.03 kg for a vole allometric scaling can be applied. This provides a predicted transfer factor for a vole of 0.5 d/kg. Measurements taken for voles have demonstrated a transfer factor for lead of 0.14 d/kg (Thomas 1997). The difference in the transfer factor for small mammal (0.5 d/kg) compared to that for beef (0.0004 d/kg) demonstrates that, although there is uncertainty in the scaling, there is a need to adjust the transfer factors, particularly when the body size are significantly different. Using the same extrapolation approach a TF for radium uptake by a vole can be calculated to be 2.4 d/kg compared to a measured value of 2.5 d/kg (Thomas 1997). Information on the uptake of contaminants by small mammals can also be obtained from Sample *et al.* (1998), which provides concentration ratios for different types of small mammals (herbivore, insectivore, omnivore and general). Using the characteristics of a vole the transfer factor can be estimated from information provided by Sample *et al.* (1998) and compared to the predictions from the allometric scaling. Many of the contaminants (e.g. Fe, Se) are shown to be well-represented by the predicted TF using allometric scaling.

There is limited data available on avian species; however, the same scaling factor appears to be appropriate. Clulow *et al.* 1992 measured a concentration ratio of 0.075 on a fresh weight basis for grouse. Using the appropriate intake rate a transfer factor of 0.3 d/kg can be determined. Using the poultry value (provided in Table B-6 of 0.13 d/kg, Sheppard *et al.,* 2005b), the TF for radium exposure to a grouse is estimated to be 0.4 d/kg.

A further validation of this approach was undertaken using measured data from a minesite in northern Canada. Extensive monitoring has been undertaken on soil, different vegetation types and biota for contaminants such as arsenic, cadmium, copper, lead, manganese and zinc (Gartner Lee 2006). The intake of the contaminants by different biota has also been assessed (SENES 2006). Figure B.1 provides a summary of the estimated transfer factors from the measured data and the predicted transfer factors following the allometric scaling. The figure shows that, although there is uncertainty in the approach, the allometric scaling provides a reasonable estimate of the transfer factors.

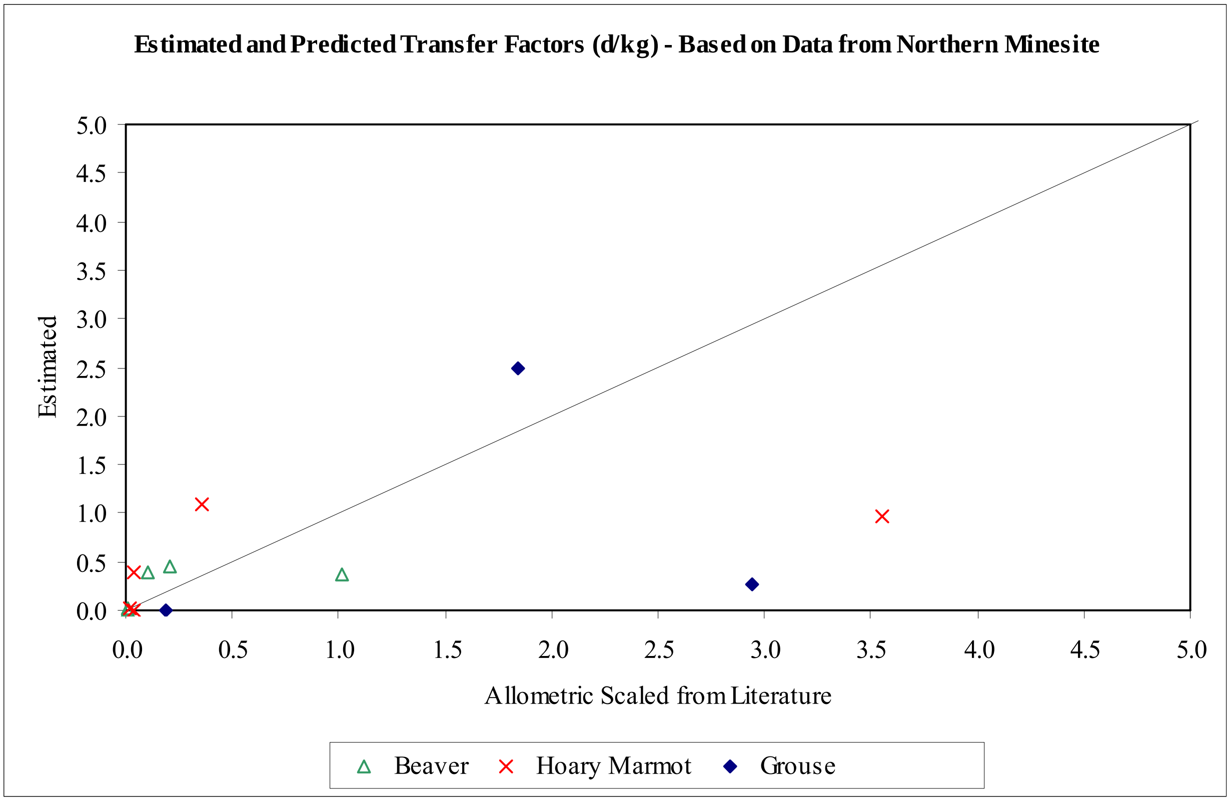

Figure B.1: Verification of Approach to Estimate Transfer Factors for Non-Human Biota

Due to the lack of available transfer factors for different non-human biota for all elements, it is recommended that allometric scaling of the transfer factors based on beef or chicken is used. This approach provides a reasonable estimate of the transfer factor that can be used to calculate the concentration of non-human biota.

It should also be noted that N288.1 *Guidelines for Calculating Derived Release Limits for Radioactive Material in Airborne and Liquid Effluents for Normal Operation of Nuclear Facilities* is in development. This document presents TFs for non-human biota including deer and rabbit as well as other generic and site-specific transfer factors (e.g. vegetation). This document can be reviewed for inclusion in the database once it is publicly available.

When the allometric equations for the transfer factor are combined with the allometric equation for food intake, it results in generally a constant trans-species ratio between whole-body and dietary activity concentrations (e.g. Beresford 2007). This approach would be appropriate however, as data in literature is generally reported as transfer factors, as opposed to concentration ratios, the use of the selected approach allowed a larger database to be selected.

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APPENDIX C: DOSE COEFFICIENTS

LIST OF TABLES

Appendix C.1: Dose Coefficients (DCs) From Amiro (1997) and Comparison to FASSET (2003) and U.S. DOE DC's (2002)

Table C.1: Internal DC's for a Generic Biota (Gy/y per Bq/kg)

Radionuclide	Amiro (1997)	U.S. DOE (2002)
C-14	2.5E-07	N/A
Cl-36	1.4E-06	N/A
Zr-93	9.9E-08	N/A
Nb-94	8.8E-06	N/A
Tc-99	5.1E-07	5.1E-07
I-129	4.5E-07	4.5E-07
Cs-135	3.4E-07	3.4E-07
Ra-226	2.5E-05	4.9E-04
Np-237	2.5E-05	N/A
U-238	2.6E-05	4.3E-04
Pb-210	2.2E-06	N/A
Po-210	2.7E-05	N/A

N/A = Data not available
Shading indicates where FASSET (2003) or U.S. DOE (2002) value for a radionuclide is greater (i.e., more conservative) than Amiro (1997) value.
See Appendix C.2 for discussion of assumptions used in the derivation of DCs.

Table C.2: Internal DC's for Terrestrial Biota (FASSET (2003), Table 3-12, Gy/y per Bq/kg)

Radionuclide	Earthworm	Mouse	Mole	Rabbit	Red fox	Row deer	Cattle
C-14	2.5E-07	2.5E-07	2.5E-07	2.5E-07	2.5E-07	2.5E-07	2.5E-07
Cl-36	1.3E-06	1.3E-06	1.4E-06	1.4E-06	1.4E-06	1.4E-06	1.4E-06
Zr-93	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Nb-94	9.6E-07	1.2E-06	1.3E-06	2.1E-06	2.6E-06	3.5E-06	6.0E-06
Tc-99	5.1E-07	5.0E-07	5.1E-07	5.1E-07	5.1E-07	5.1E-07	5.1E-07
I-129	3.3E-07	3.6E-07	3.7E-07	3.9E-07	4.0E-07	4.2E-07	4.4E-07
Cs-135	3.4E-07	3.4E-07	3.4E-07	3.4E-07	3.4E-07	3.4E-07	3.4E-07
Ra-226	1.2E-04	1.2E-04	1.2E-04	1.3E-04	1.3E-04	1.3E-04	1.3E-04
Np-237	2.5E-05	2.5E-05	2.5E-05	2.5E-05	2.5E-05	2.5E-05	2.5E-05
U-238	2.1E-05	2.1E-05	2.1E-05	2.1E-05	2.1E-05	2.1E-05	2.1E-05
Pb-210	2.0E-06	2.1E-06	2.1E-06	2.2E-06	2.2E-06	2.2E-06	2.2E-06
Po-210	2.7E-05	2.7E-05	2.7E-05	2.7E-05	2.7E-05	2.7E-05	2.7E-05

N/A = Data not available
Shading indicates where FASSET (2003) value for a radionuclide is greater (i.e., more conservative) than Amiro (1997) value for generic biota.
See Appendix C.2 for discussion of assumptions used in the derivation of DCs.

Table C.3: Internal DC’s for Freshwater Ecosystem (FASSET (2003), Table 4-7, Gy/y per Bq/kg)

Radionuclide	Phytoplankton	Zooplankton	Vascular plant	Amphibian	Pelagic fish	Benthic fish	Mammal	Bird
C-14	1.9E-08	2.4E-07	2.1E-07	2.5E-07	2.5E-07	2.5E-07	2.5E-07	2.5E-07
Cl-36	4.4E-09	7.1E-07	3.3E-07	1.3E-06	1.4E-06	1.4E-06	1.4E-06	1.4E-06
Zr-93	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Nb-94	6.8E-09	6.1E-07	3.6E-07	1.1E-06	1.4E-06	1.8E-06	2.4E-06	2.7E-06
Tc-99	1.1E-08	4.4E-07	3.2E-07	5.1E-07	5.1E-07	5.1E-07	5.1E-07	5.1E-07
I-129	6.2E-08	3.2E-07	2.8E-07	3.5E-07	3.6E-07	3.8E-07	3.9E-07	4.0E-07
Cs-135	1.5E-08	3.2E-07	2.5E-07	3.4E-07	3.4E-07	3.4E-07	3.4E-07	3.4E-07
Ra-226	1.5E-04	1.5E-04	1.5E-04	1.6E-04	1.6E-04	1.6E-04	1.6E-04	1.6E-04
Np-237	2.4E-05	2.5E-05	2.5E-05	2.5E-05	2.5E-05	2.5E-05	2.5E-05	2.5E-05
U-238	4.6E-05	4.6E-05	4.6E-05	5.0E-05	5.0E-05	5.0E-05	5.0E-05	5.0E-05
Pb-210	6.7E-08	8.8E-07	4.8E-07	2.0E-06	2.1E-06	2.1E-06	2.1E-06	2.1E-06
Po-210	2.7E-05	2.7E-05	2.7E-05	2.7E-05	2.7E-05	2.7E-05	2.7E-05	2.7E-05

N/A = Data not available
Shading indicates where FASSET (2003) value for a radionuclide is greater (i.e., more conservative) than Amiro (1997) value.
See Appendix C.2 for discussion of assumptions used in the derivation of DCs.

Table C.4: External DC's for Exposure in Water (Gy/y Per Bq/m^3)

Radio-nuclide	Amiro (1997)	From FASSET (2003), Table 4-8 (Freshwater ecosystem)									DOE (2000)
	Generic Biota	Phyto-plankton	Zoo-plankton	Vascular plant	Amphibian	Pelagic fish	Benthic fish	Mammal	Bird	Max	Aquatic Animals
C-14	6.5E-12	2.3E-10	1.2E-11	4.0E-11	4.2E-13	2.4E-13	1.4E-13	7.4E-14	6.1E-14	2.3E-10	1.2E-10
Cl-36	5.8E-10	1.4E-09	6.7E-10	1.1E-09	3.5E-11	1.8E-11	1.1E-11	6.2E-12	5.2E-12	1.4E-09	N/A
Zr-93	0.0E+00	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Nb-94	6.6E-09	8.8E-09	8.1E-09	8.4E-09	7.7E-09	7.4E-09	7.1E-09	6.5E-09	6.1E-09	8.8E-09	4.3E-09
Tc-99	8.6E-11	5.0E-10	7.6E-11	1.9E-10	2.6E-12	1.4E-12	8.4E-13	4.5E-13	3.7E-13	5.0E-10	2.1E-10
I-129	1.2E-10	3.8E-10	1.3E-10	1.7E-10	1.1E-10	8.8E-11	7.6E-11	5.5E-11	5.1E-11	3.8E-10	2.0E-10
Cs-135	2.7E-07	3.2E-10	2.8E-11	8.2E-11	9.6E-13	5.2E-13	3.0E-13	1.6E-13	1.3E-13	3.2E-10	1.4E-10
Ra-226	3.2E-11	1.6E-08	1.3E-08	1.4E-08	8.8E-09	8.4E-09	7.9E-09	7.2E-09	6.8E-09	1.6E-08	6.8E-09
Np-237	1.6E-10	2.4E-09	1.4E-09	1.7E-09	1.1E-09	1.1E-09	9.6E-10	8.7E-10	8.1E-10	2.4E-09	1.3E-09
U-238	2.0E-09	4.6E-09	3.7E-09	4.1E-09	6.4E-10	3.9E-10	2.8E-10	1.8E-10	1.7E-10	4.6E-09	2.3E-09
Pb-210	6.1E-10	2.1E-09	1.2E-09	1.7E-09	9.6E-11	5.3E-11	3.6E-11	2.0E-11	1.8E-11	2.1E-09	1.1E-09
Po-210	3.4E-14	4.4E-14	4.3E-14	4.3E-14	4.2E-14	4.0E-14	3.9E-14	3.5E-14	3.3E-14	4.4E-14	N/A

N/A = Data not available
Shading indicates where FASSET (2003) or U.S. DOE (2000) value for a radionuclide is greater (i.e., more conservative) than Amiro (1997) value.
See Appendix C.2 for discussion of assumptions used in the derivation of DCs.

Table C.5: External DC's for Exposure in Soil for a Generic Biota (Gy/y per Bq/kg)

Radionuclide	Amiro (1997)	US DOE (2002)
C-14	9.8E-09	2.5E-07
Cl-36	8.7E-07	N/A
Zr-93	0.0E+00	N/A
Nb-94	9.8E-06	8.6E-06
Tc-99	1.3E-07	4.3E-07
I-129	1.8E-07	4.0E-07
Cs-135	4.0E-08	2.8E-07
Ra-226	4.8E-08	1.4E-05
Np-237	2.3E-07	2.5E-06
U-238	3.1E-06	4.6E-06
Pb-210	9.1E-07	N/A
Po-210	5.2E-11	N/A

N/A = Data not available
Shading indicates where FASSET (2003) or U.S. DOE (2002) value for a radionuclide is greater (i.e., more conservative) than Amiro (1997) value. See Appendix C.2 for discussion of assumptions used in the derivation of DCs.

Table C.6: External DC's for Organisms On Soil (FASSET (2003), Table 3-9, Gy/y per Bq/kg)

Radionuclide	Earthworm	Mouse	Mole	Rabbit	Red fox	Row deer	Cattle	Herbiv. bird	Carniv. bird
C-14	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Cl-36	2.7E-10	2.7E-10	2.7E-10	2.4E-10	2.3E-10	1.8E-10	7.1E-11	2.5E-10	2.0E-10
Zr-93	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Nb-94	2.8E-06	2.8E-06	2.8E-06	2.5E-06	2.4E-06	1.8E-06	7.6E-07	2.6E-06	2.1E-06
Tc-99	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
I-129	1.5E-08	1.5E-08	1.5E-08	1.3E-08	1.1E-08	7.6E-09	1.5E-09	1.2E-08	7.7E-09
Cs-135	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Ra-226	3.0E-06	3.0E-06	3.0E-06	2.7E-06	2.5E-06	2.0E-06	8.8E-07	2.8E-06	2.3E-06
Np-237	3.4E-08	3.4E-08	3.3E-08	3.0E-08	2.7E-08	1.8E-08	4.6E-09	2.9E-08	2.2E-08
U-238	7.5E-10	7.4E-10	7.4E-10	6.4E-10	5.7E-10	3.1E-10	5.3E-11	2.8E-10	8.2E-11
Pb-210	3.1E-09	3.0E-09	3.0E-09	2.6E-09	2.3E-09	1.3E-09	2.5E-10	1.6E-09	1.1E-09
Po-210	1.5E-11	1.5E-11	1.5E-11	1.3E-11	1.2E-11	9.6E-12	4.1E-12	1.4E-11	1.1E-11

N/A = Data not available
Shading indicates where FASSET (2003) value for a radionuclide is greater (i.e., more conservative) than Amiro (1997) value.
See Appendix C.2 for discussion of assumptions used in the derivation of DCs.

Table C.7: External DC's for Organisms in Soil (FASSET (2003), Table 3-10, Gy/y per Bq/kg)

Radionuclide	Earthworm	Mouse	Mole	Rabbit	Red fox
C-14	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Cl-36	3.3E-10	2.7E-10	2.5E-10	1.8E-10	1.2E-10
Zr-93	N/A	N/A	N/A	N/A	N/A
Nb-94	3.8E-06	3.0E-06	2.8E-06	2.0E-06	1.4E-06
Tc-99	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
I-129	1.7E-08	4.8E-09	4.0E-09	6.4E-10	3.1E-10
Cs-135	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Ra-226	4.0E-06	3.2E-06	3.2E-06	2.4E-06	1.7E-06
Np-237	2.9E-08	2.0E-08	1.9E-08	1.2E-08	8.2E-09
U-238	1.3E-10	2.0E-11	1.8E-11	1.1E-11	6.5E-12
Pb-210	1.7E-09	9.6E-10	9.6E-10	5.0E-10	3.1E-10
Po-210	2.0E-11	1.6E-11	1.5E-11	1.1E-11	7.5E-12

N/A = Data not available
Shading indicates where FASSET (2003) value for a radionuclide is greater (i.e., more conservative) than Amiro (1997) value.
See Appendix C.2 for discussion of assumptions used in the derivation of DCs.

Appendix C.2: Differences in Amiro (1997) and FASSET (2003)/ U.S. DOE (2002)

This section of the Appendix compares the DCs from Amiro (1997) to those from FASSET (2003) and U.S. DOE (2002). Table C.8 summarizes the assumptions made in the derivation of DCs in the different references. Table C.9 discusses cases where the DC from FASSET (2003) or U.S. DOE (2002) is larger than the DC from Amiro (1997).

Table C.8: Assumptions used in Derivation of DC's in Different References

Parameter	Amiro 1997	FASSET 2003 (deliverable 3)	U.S. DOE 2002 (module 3)
Biota	Generic (from ant to elephant)	Different organisms: for the reference organisms, the shape was approximated by spheres, cylinders, and, in most cases, ellipsoids. For biota in the terrestrial environment, specific exposure conditions are defined for biota that live in and those that live on soil.	Generic: the exposed organism is assumed to be very small (less than the mean free path of the electron emitted in decay). This assumption results in overestimates of external dose rates for any finite-sized organism, because the attenuation of photons and electrons in transport through an organism is ignored.
Weighting	Unweighted	Unweighted	Weighted for internal
Suggested Weighting Factors	α: 20	α-:10, low-β: 3, β- and γ-: 1	α: 20
Radiation type	Sum of the contributions of α-, β- and γ- radiation	Sum of the contributions of α-, low-β, β- and γ- radiation	-
Energy	Based on ICRP 1983	Based on ICRP 1983	For external: based on Kocher 1980; which for most radionuclides is in good agreement with ICRP 1983; For internal from ICRP 1983

Parameter	Amiro 1997	FASSET 2003 (deliverable 3)	U.S. DOE 2002 (module 3)
Decay	Include energies from all progeny with half-lives of less than 1 day within the DCF value of the parent; otherwise define separate DCF value	A number of radionuclides (90Sr, 95Zr, 106Ru, 131I, 144Ce, 210Pb, 226Ra, 227Th, 228Th, 234Th, 235U, 237Np, 238U, 238Pu and 241Pu) have one or more radioactive decay products. The dose from some of these is included by specifically merging the decay modes and branching ratios, if the half-life of the relevant daughters was found to be very small compared with that of the parent, meaning that they should rapidly reach secular equilibrium.	Several radionuclides - including Sr-90, Zr-95, Sb-125, Cs-137, Ce-144, Pb-210, Ra-226, Ra-228, Ac-227, Th-228, Th-229, U-235, U-238, Np-237, and Am-243 - have radioactive decay products that are sufficiently short-lived that the decay products are assumed to be in secular equilibrium with the parent radionuclide in each environmental medium. For these radionuclides, the external dose coefficients are the sum of the values for the parent and its indicated short-lived decay products, taking into account the branching fractions in the decay of the parent.
Internal Distribution	Radionuclides are uniformly distributed throughout the organism.	Radionuclides are homogeneously distributed in the organism.	-
Internal-absorption	Absorption of all emitted radiations within the body	The whole energy of gamma radiation is absorbed within the organism.	All radiations emitted in the decay of radionuclides in an organism are absorbed in the organism
Geometry for Immersion in air	The receptor is located 1 m above the plane boundary, immersed in a semi-infinite, uniformly contaminated body of air of density 1.189 kg/m^3 (birds can be suspended in an infinite volume of contaminated air ==> underestimate by factor of 2)	-	-
Geometry for Immersion in water	The receptor is submerged 0.1m below the surface of a semi-infinite, uniformly contaminated body of water	The organism is immersed in an infinite absorbing medium with the stated concentration.	The source is infinite (the organism is located 100 percent of the time at the water-sediment interface. Thus, it is assumed that the organism was exposed at the boundary of two semi-infinite and uniformly contaminated media.)

Parameter	Amiro 1997	FASSET 2003 (deliverable 3)	U.S. DOE 2002 (module 3)
Geometry for Immersion in soil/ sediment	The receptor is submerged 10 cm below the surface of a semi-infinite, uniformly contaminated body of soil/sediment	The DCCs for external exposure in the terrestrial environment are given for organisms living on the soil, for planar radiation sources with a surface roughness of 3 mm, a volume source due to the homogeneous contamination of the upper 10 cm of soil. For organisms living in the soil, the organisms live in the centre of a homogeneously contaminated layer of a thickness of 50 cm.	The source is infinite (the organism is immersed 100% of the time in an infinite and uniformly contaminated source region.)
Geometry for Immersion in vegetation	Identical to air immersion	-	-
External-absorption	Most organisms have epidermal layer that partially shields the body from electron radiation, but allows for penetration of photon energy; alpha particles are unimportant in external dosimetry.	Organism - specific: smaller organisms are more exposed than larger organisms due to the more effective self-shielding of the latter. The differences in external dose rate for organisms living on soil is a factor of 3 to 4 between earthworm and cattle. For organisms living in soil the difference is only a factor of 2 to 3, since the difference in size is less. The differences in dose rates are more pronounced for low energy -emitters, since for such photons the effect of self-shielding is more important.	The assumption of a very small organism results in overestimates of external dose rates for any finite-sized organism, because the attenuation of photons and electrons in transport through an organism is ignored.

Table C.9: Ratio of DC in FASSET and U.S. DOE to DC in Amiro; shown where Ratio>1

DC type	Radionuclide	Average FASSET/ Amiro	DC's for which biota are higher in FASSET?	Possible explanation of Amiro (1997) vs FASSET (2003)	U.S. DOE/ Amiro	Possible explanation of Amiro (1997) vs U.S. DOE (2002)
Internal	Ra-226	6	All biota	Decay products of Ra-226 and U-238 not included in Amiro, but some are included in FASSET	20	The U.S. DOE’s default internal dose factors include a dose modifying factor of 20 for alpha particles and the alpha-emitting progeny of chain-decaying nuclides.
	U-238	2	Aquatic biota		20	

DC type	Radionuclide	Average FASSET/ Amiro	DC's for which biota are higher in FASSET?	Possible explanation of Amiro (1997) vs FASSET (2003)	U.S. DOE/ Amiro	Possible explanation of Amiro (1997) vs U.S. DOE (2002)
External-water	C-14	14	Aquatic plants	* Geometry: FASSET assumes an infinite body of water, Amiro assumes a semi-infinite body. * Decay products of Ra-226, Np-237 and U-238 not included in Amiro, but some are included in FASSET	18	*: U.S. DOE assumes a very small organism, Amiro assumes a generic organism; the depth in tissue for calculating the electron dose rate assumed by Amiro is considerably less conservative than the assumption in U.S. DOE of exposure at the surface of a very small organism, because the minimum electron energy that results in a non-zero dose at a depth of 70 µm is about 70 keV (Kocher and Eckerman 1981) but all such lower-energy electrons are taken into account in U.S. DOE (U.S. DOE 2002 pM3-9). * Geometry: U.S. DOE assumes a semi-infinite body of water and a semi-infinite body of sediment, Amiro assumes a semi-infinite body of water. * Decay products of Ra-226 (except for Pb-201), U-238 and Np-237 are included in U.S. DOE but not in Amiro * Energies of photons and electrons from different references
	Cl-36	2	Aquatic plants		-	
	Nb-94	1.2	Aquatic plants& fish		-	
	Tc-99	3	Aquatic plants		2	
	I-129	2	Aquatic plants		2	
	Cs-135	5	Aquatic plants		5	
	Ra-226	320	Aquatic biota		213	
	Np-237	8	Aquatic biota		8	
	U-238	279	Aquatic biota		364	

DC type	Radionuclide	Average FASSET/ Amiro	DC's for which biota are higher in FASSET?	Possible explanation of Amiro (1997) vs FASSET (2003)	U.S. DOE/ Amiro	Possible explanation of Amiro (1997) vs U.S. DOE (2002)
External-on/in soil	Ra-226	54	Terrestrial biota	Geometry: FASSET assumes a source depth of up to 50 cm, whereas Amiro assumes a depth of 10 cm	292	Geometry: U.S. DOE assumes that the organism is immersed 100% of the time in an infinite and uniformly contaminated source region; whereas Amiro assumes a depth of 10 cm
	C-14				26	
	Tc-99				3	
	I-129				2	
	Cs-135				7	
	Np-237				11	
	U-238				485	

Appendix C.3: Selection of DC's

This section of the Appendix shows the DCs selected for the Central and Upper Estimate calculations. Details of progeny and relative biological effectiveness (RBE, weighting factors as discussed in Section 4) are also presented.

Table C.10: Selected Weighting Factors

Type	Upper	Reference	Central	Reference
Alpha	40	As recommended in Environment Canada and Health Canada (2003).	20	Chambers et al. (2002)

Table C.11: Radiation Mode and Decay Progeny and DCs for each Radionuclide

Radionuclide	Decay	Decay product	Internal (Gy/y per Bq/kg)	External-water (Gy/y per Bq/m^3)	External-soil (Gy/y per Bq/kg)
C-14	Beta		2.5E-07	6.5E-12	9.8E-09
Cl-36	Beta		1.4E-06	5.8E-10	8.7E-07
Zr-93	Beta		9.9E-08	0.0E+00	0.0E+00
Nb-94	Beta		8.8E-06	6.6E-09	9.8E-06
Tc-99	Beta		5.1E-07	8.6E-11	1.3E-07
I-129	Beta		4.5E-07	1.2E-10	1.8E-07
Cs-135	Beta		3.4E-07	2.7E-11	4.0E-08
Ra-226	Alpha	Rn-222	2.5E-05	3.2E-11	4.8E-08
Np-237	Alpha		2.5E-05	1.6E-10	2.3E-07
U-238	Alpha	Th-234	2.2E-05	6.3E-12	9.5E-09
Rn-222	Alpha	Po-218	1.12E-04	8.91E-09	1.34E-05
Pb-210	Beta	Bi-210	2.17E-07	2.21E-11	3.32E-08
Bi-210	Beta	Po-210	1.97E-06	5.86E-10	8.79E-07
Po-210	Alpha	Pb-206	2.73E-05	3.44E-14	5.16E-11
Th-234	Beta	Pa-234	4.56E-06	2.04E-09	3.06E-06

Table C.12: Selected DC's for the Upper Estimate Case

Radionuclide	Internal DC * (Gy/y per Bq/kg)	Selected Weighted Internal DC ** (Gy/y per Bq/kg)	Selected External-Water DC (Gy/y per Bq/m^3) §	Selected External-Soil DC (Gy/y per Bq/kg) §
C-14	2.5E-07	2.5E-07	1.2E-10	2.5E-07
Cl-36	1.4E-06	1.4E-06	4.0E-10	2.2E-10
Zr-93	9.9E-08	9.9E-08	0.0E+00	0.0E+00
Nb-94	8.8E-06	8.8E-06	7.5E-09	8.6E-06
Tc-99	5.1E-07	5.1E-07	2.1E-10	4.3E-07
I-129	4.5E-07	4.5E-07	2.0E-10	4.0E-07
Cs-135	3.4E-07	3.4E-07	1.4E-10	2.8E-07
Ra-226	2.5E-05	9.8E-04	1.0E-08	1.4E-05
Np-237	2.5E-05	1.0E-03	1.3E-09	2.5E-06
U-238	2.6E-05	1.0E-03	2.3E-09	4.6E-06
Pb-210	2.2E-06	2.2E-06	1.1E-09	2.2E-06
Po-210	2.7E-05	1.1E-03	4.0E-14	1.3E-11

* Amiro (1997); No progenies included.

** Internal DC × Weighting Factor (a Weighting Factor of 40 for Alpha).
(see Table C.10 for weighting factors and Table C.11 for the radiation type for each radionuclide)

† For U-238 and Pb-210 the progenies are also included:
For U-238, Weighted Internal DC= U-238 Internal DC ×Alpha Weighting Factor + Th-234 Internal DC = 2.16E-05 × 40 + 4.56E-06 = 8.7E-04.
For Pb-210, Weighted Internal DC = Pb-210 Internal DC + Bi-210 Internal DC (no weighting factors) = 2.19E-06 + 1.97E-06 = 4.16E-06.

§ The higher of FASSET (2003) values over all biota, U.S. DOE (2002) and Amiro (1997).

Table C.13: Selected DC's for the Central Estimate Case

Radionuclide	Internal DC * (Gy/y per Bq/kg)	Selected Weighted Internal DC ** (Gy/y per Bq/kg)	Selected External-Water DC (Gy/y per Bq/m^3)	Selected External-Soil DC (Gy/y per Bq/kg)
C-14	2.5E-07	2.5E-07	6.5E-12	9.8E-09
Cl-36	1.4E-06	1.4E-06	5.8E-10	8.7E-07
Zr-93	9.9E-08	9.9E-08	0.0E+00	0.0E+00
Nb-94	8.8E-06	8.8E-06	6.6E-09	9.8E-06
Tc-99	5.1E-07	5.1E-07	8.6E-11	1.3E-07
I-129	4.5E-07	4.5E-07	1.2E-10	1.8E-07
Cs-135	3.4E-07	3.4E-07	2.7E-07	4.0E-08
Ra-226	2.5E-05	4.9E-04	3.2E-11	4.8E-08
Np-237	2.5E-05	5.0E-04	1.6E-10	2.3E-07
U-238	2.6E-05	5.2E-04	2.0E-09	3.1E-06
Pb-210	2.2E-06	2.2E-06	6.1E-10	9.1E-07
Po-210	2.7E-05	5.5E-04	3.4E-14	5.2E-11

Reference: Amiro (1997).
* No progenies included.
** Internal DC * Weighting Factor (a Weighting Factor of 20 for Alpha).
For example calculations see the second footnote to Table C.12
† For U-238 and Pb-210 the progenies are also included.

Table C.14: Comparison of DC's for the Upper Estimate Case to the Higher of Average of FASSET (2003) Values and U.S. DOE (2002) Values

a) For radionuclides with no radioactive daughter

Radionuclide	Weighted Internal DC (Gy/y per Bq/kg) Selected *	Weighted Internal DC (Gy/y per Bq/kg) Compared to **	External-water DC (Gy/y per Bq/m^3) Selected *	External-water DC (Gy/y per Bq/m^3) Compared to **	External-soil DC (Gy/y per Bq/kg) Selected *	External-soil DC (Gy/y per Bq/kg) Compared to **
C-14	2.5E-07	2.3E-07	1.2E-10	1.2E-10	2.5E-07	2.5E-07
Cl-36	1.4E-06	1.2E-06	4.0E-10	4.0E-10	2.2E-10	1.9E-10
Zr-93	9.9E-08	N/A	0.0E+00	N/A	0.0E+00	N/A
Nb-94	8.8E-06	1.9E-06	7.5E-09	7.5E-09	8.6E-06	8.6E-06
Tc-99	5.1E-07	5.1E-07	2.1E-10	2.1E-10	4.3E-07	4.3E-07
I-129	4.5E-07	4.5E-07	2.0E-10	2E-10	4.0E-07	4.0E-07
Cs-135	3.4E-07	3.4E-07	1.4E-10	1.4E-10	2.8E-07	2.8E-07
Np-237	1.0E-03	2.5E-05	1.3E-09	1.3E-09	2.5E-06	2.5E-06
Po-210	1.1E-03	2.7E-05	4.0E-14	4.0E-14	1.3E-11	1.3E-11

b) For radionuclides with radioactive daughters (progenies are included)

Radionuclide	**Weighted Internal DC (Gy/y per Bq/kg)**		**External-water DC (Gy/y per Bq/m^3)**		**External-soil DC (Gy/y per Bq/kg)**	
	Selected *	**Compared to **, †**	**Selected ***	**Compared to *****	**Selected *, †**	**Compared to *****
Ra-226	9.8E-04	1.4E-03	1.0E-08	1.0E-08	1.4E-05	1.4E-05
U-238	1.0E-03	4.3E-04	2.3E-09	2.3E-09	4.6E-06	4.6E-06
Pb-210	2.2E-06	2.2E-06	1.1E-09	6.5E-10	2.2E-06	1.6E-09

* Amiro (1997)
** The higher of [average of FASSET (2003) values over all biota] *10 (i.e. Alpha Weighting Factor) and U.S. DOE (2002) value (Weighting Factor included).
† Approximate for Ra-226, since Pb-210 has no alpha radiation.
*** The higher of [average of FASSET (2003) values over all biota] and US DOE (2002) value.

APPENDIX D: COMPARISON OF NECs TO OTHER LITERATURE VALUES

The general approach taken of comparing conservative NECs to measured/modelled media concentrations and expressing the as a ratio (summed for multiple radionuclides) is compatible with that taken by the U.S. DOE (RESRAD-BIOTA) and the European-funded ERICA Integrated Approach. This Appendix provides a comparison to the Biota Concentration Guide (BCG) values derived in U.S. DOE (2000) and the Environmental Media Concentration Limits (EMCLs) presented in ERICA (2007).

Appendix D.1 Comparison to U.S. DOE BCGs

The approach used by the U.S. DOE involves derivation of Biota Concentration Guides (BCGs) in Bq/kg of Bq/m^3, defined as:

$$BCG = \frac{Dose\ Limit}{(Internal\ Dose) + (External\ Dose_{soil/sed}) + External\ Dose_{water}}$$

The table below compares the Central and Upper Estimate NECs derived in the present study to the U.S. DOE BCGs for water, sediment and soil. In the table, values shown in bold are BCGs that are not between the Central and Upper NEC values.

(a) Water

Radionuclide	NECs - All Ecosystems (Bq/L)		Water BCG (Bq/L) for Co-Located Water and Sediment	Water BCG (Bq/L) for Co-Located Water and Soil
	Central	Upper		
C-14	1.34E+02	2.69E-02	**N/A**	**N/A**
Cl-36	4.83E+02	2.78E+00	**N/A**	**N/A**
Zr-93	1.77E+03	1.75E+00	**N/A**	**N/A**
Nb-94	2.95E+01	4.54E-03	**N/A**	**N/A**
Tc-99	3.43E+02	7.95E-01	**2.00E+04**	**6.00E+05**
I-129	3.20E+03	3.23E+00	1.00E+03	**2.00E+05**
Cs-135	1.06E-01	2.13E-03	**2.00E+01**	**3.00E+05**
Ra-226	5.93E-02	5.86E-04	6.00E-03	**1.00E+01**
Np-237	5.84E+00	5.77E-02	**N/A**	**N/A**
U-238	1.86E+00	2.30E-02	**8.00E+00**	**2.00E+04**
Pb-210	2.00E+02	4.27E+00	**N/A**	**N/A**
Po-210	8.02E-01	7.04E-03	**N/A**	**N/A**

(b) Sediment

Radionuclide	NECs - All Ecosystems (Bq/kg DW)		Sediment BCG (Bq/kg, assumed DW)
	Central	Upper	
C-14	1.78E+06	2.84E+05	**N/A**
Cl-36	3.10E+05	4.10E+04	**N/A**
Zr-93	7.05E+07	5.04E+06	**N/A**
Nb-94	5.39E+05	1.87E+03	**N/A**
Tc-99	7.46E+06	2.97E+06	**2.00E+07**
I-129	1.63E+07	1.17E+06	**1.00E+06**
Cs-135	7.08E+05	3.54E+05	**2.00E+04**
Ra-226	2.04E+03	9.27E+02	**6.00E+00**
Np-237	3.45E+04	1.06E+03	**N/A**
U-238	5.38E+05	1.08E+04	**8.00E+03**
Pb-210	4.84E+05	6.25E+03	**N/A**
Po-210	2.76E+01	5.62E+03	**N/A**

(c) Soil

Radionuclide	NECs - All Ecosystems (Bq/kg DW)		Soil BCG (Bq/kg, assumed DW)
	Central	Upper	
C-14	5.86E+06	2.39E+02	**N/A**
Cl-36	9.26E+03	3.76E-01	**N/A**
Zr-93	3.01E+07	8.38E+04	**N/A**
Nb-94	3.68E+04	3.03E+00	**N/A**
Tc-99	2.71E+04	4.29E+01	**6.00E+08**
I-129	1.21E+06	2.36E+03	**2.00E+08**
Cs-135	3.03E+02	8.48E+00	**3.00E+08**
Ra-226	6.06E+03	2.51E+02	**1.00E+04**
Np-237	5.30E+03	5.02E+01	**N/A**
U-238	5.70E+03	4.15E+01	**2.00E+07**
Pb-210	3.69E+05	3.71E+03	**N/A**
Po-210	5.46E+03	3.03E+01	**N/A**

Notes:
Bold indicates where the EMCL value is not between the Central and Upper NEC values.

As seen in the above table, most of the BCGs are not within the range of Central and Upper NEC values. All of the BCGs that are outside the range of NECs are greater than the NEC values.

Section 7 of this report presented estimated environmental concentrations from various Postclosure Safety Assessment studies. If these concentrations are compared to the BCGs, it can be seen that all of the estimated Postclosure Safety Assessment concentrations are below the BCGs.

Appendix D.2 Comparison to ERICA EMCLs

The approach used by ERICA involves derivation of Environmental Media Concentration Limits (EMCLs) in Bq/L or Bq/kg of medium, defined as follows:

$$EMCL = \frac{PNEDR}{F}$$

Where:

PNEDR = Predicted No Effects Dose Rate or screening dose-rate (μGy h^{-1}); and
F is the dose rate that an organism will receive for the case of a unit concentration in environmental media (μGy h^{-1} per Bq l^{-1} or kg of medium).

The table below compares the Central and Upper Estimate NECs derived in the present study to the ERICA EMCLs for water, sediment and soil. In the table, values shown in bold are EMCLs that are not between the Central and Upper NEC values.

Table D.2 Comparison of NECs to EMCLs

(a) Water

Radionuclide	NECs - All Ecosystems (Bq/L)		EMCL (Bq/L) Freshwater
	Central	Upper	
C-14	1.34E+02	2.69E-02	1.56E+01
Cl-36	4.83E+02	2.78E+00	1.06E+02
Zr-93	1.77E+03	1.75E+00	**N/A**
Nb-94	2.95E+01	4.54E-03	**4.44E-03**
Tc-99	3.43E+02	7.95E-01	5.05E+01
I-129	3.20E+03	3.23E+00	2.75E+01
Cs-135	1.06E-01	2.13E-03	**5.52E+00**
Ra-226	5.93E-02	5.86E-04	1.40E-02
Np-237	5.84E+00	5.77E-02	**3.05E-03**
U-238	1.86E+00	2.30E-02	4.93E-02
Pb-210	2.00E+02	4.27E+00	**7.87E-02**
Po-210	8.02E-01	7.04E-03	**2.71E-03**

(b) Sediment

Radionuclide	NECs - All Ecosystems (Bq/kg DW)		EMCL (Bq/kg DW) Freshwater
	Central	Upper	
C-14	1.78E+06	2.84E+05	**1.18E+01**
Cl-36	3.10E+05	4.10E+04	**1.32E+01**
Zr-93	7.05E+07	5.04E+06	**N/A**
Nb-94	5.39E+05	1.87E+03	1.09E+04
Tc-99	7.46E+06	2.97E+06	**4.00E+01**
I-129	1.63E+07	1.17E+06	**1.64E+03**
Cs-135	7.08E+05	3.54E+05	**4.07E+04**
Ra-226	2.04E+03	9.27E+02	**4.20E+01**
Np-237	3.45E+04	1.06E+03	**5.18E-03**
U-238	5.38E+05	1.08E+04	**3.75E-01**
Pb-210	4.84E+05	6.25E+03	**1.24E+03**
Po-210	2.76E+01	5.62E+03	**9.17E+03**

(c) Soil

Radionuclide	NECs - All Ecosystems (Bq/kg DW)		EMCL (Bq/kg DW)
	Central	Upper	
C-14	5.86E+06	2.39E+02	**N/A**
Cl-36	9.26E+03	3.76E-01	1.47E+03
Zr-93	3.01E+07	8.38E+04	**N/A**
Nb-94	3.68E+04	3.03E+00	1.12E+04
Tc-99	2.71E+04	4.29E+01	2.11E+03
I-129	1.21E+06	2.36E+03	**4.26E+02**
Cs-135	3.03E+02	8.48E+00	**1.92E+04**
Ra-226	6.06E+03	2.51E+02	**2.27E+02**
Np-237	5.30E+03	5.02E+01	3.77E+02
U-238	5.70E+03	4.15E+01	1.51E+03
Pb-210	3.69E+05	3.71E+03	3.88E+03
Po-210	5.46E+03	3.03E+01	**2.52E+01**

Notes:
Bold indicates where the EMCL value is not between the Central and Upper NEC values.

As seen in the above table, Many of the EMCL values are similar to (or between) the Central and Upper Estimate NECs. Those that are not between the NEC values are typically less than the NECs.

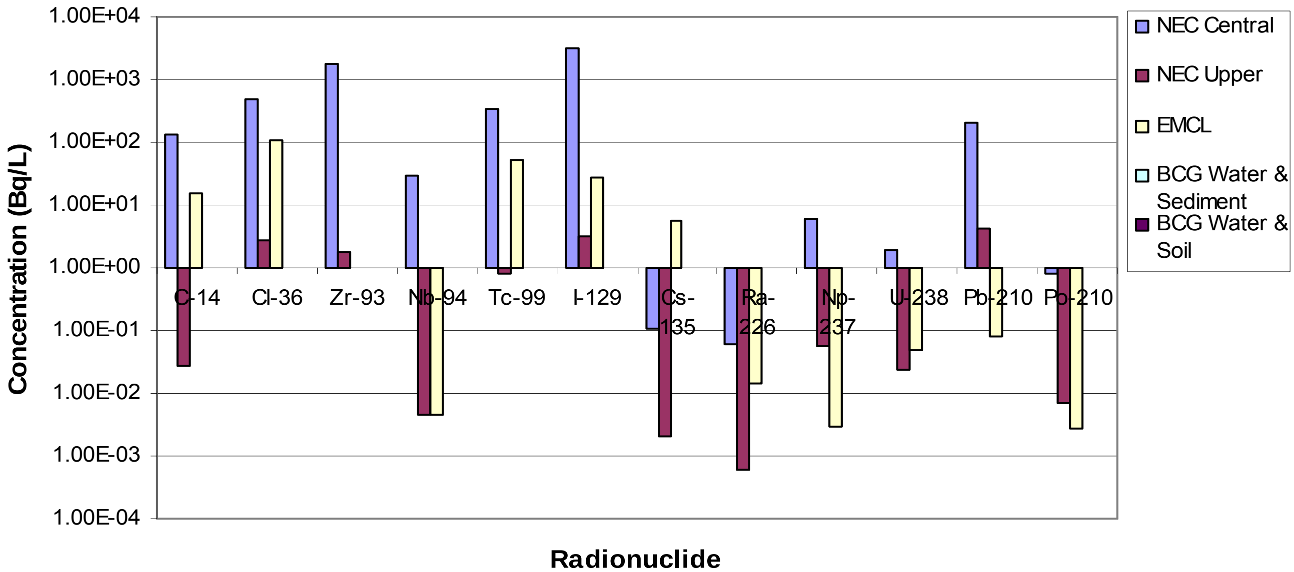
Section 7 of this report presented estimated environmental concentrations from various Postclosure Safety Assessment studies. If these concentrations are compared to the EMCLs, it can be seen that all of the estimated Postclosure Safety Assessment concentrations are below the EMCLs.

Appendix D.3 Conclusions

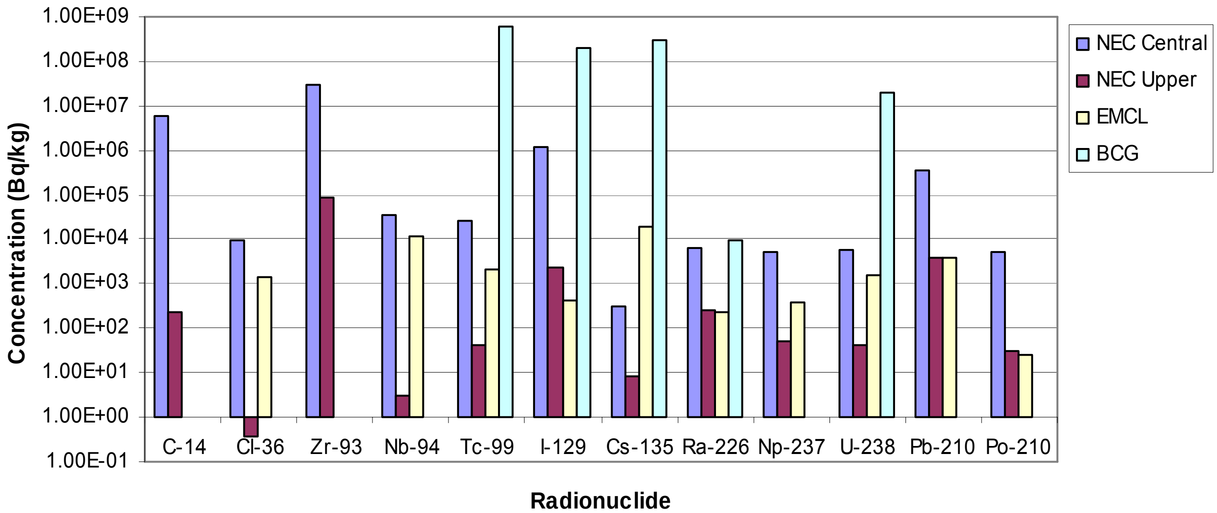
The following figure presents a comparison of the Central Estimate and Upper Estimate NECs to the BCGs and EMCLs.

Figure D.1 - Comparison of NECs to Other Concentration Limits

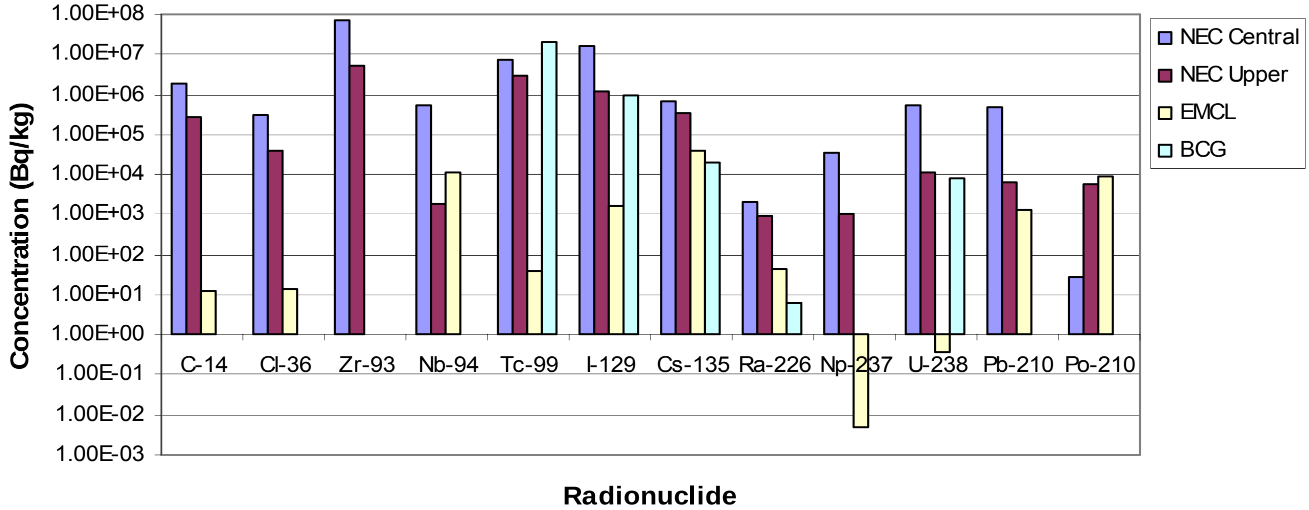
a) Water



b) Soil



c) Sediment



The comparison in this appendix shows that while these approaches are similar in concept, the results are not the same. This is due to numerous factors, such as different modelling parameters and different definitions of effects. For example, in the derivation of ERICA EMCLs, the incremental screening dose rate was set to 10 µGy h^{-1} for all ecosystems; however, the ERICA (2007) Tool does allow for user-inputted variation in this value. The effect benchmarks (ENEVs) selected for the present study are specific to biota groups and are from a variety of sources/effects. For example, the UNSCEAR/IAEA values are applicable to the most exposed individuals within a population, whereas the Garnier-Laplace values are EDR_{10} (dose rate giving 10% change in observed effect) and HDR_5 (hazardous dose rate giving 10% effect to 5% of species) values.

References for Appendix D:

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