APPENDIX L

Ecological Receptor Parameters

Table of Contents

Tables

1.0 WILDLIFE EXPOSURE FACTORS

The following text is drawn largely from the United States Environmental Protection Agency (US EPA) document Wildlife Exposure Factors Handbook (US EPA 1993).

2.0 FOOD INGESTION RATES

Food ingestion rates vary with many factors, including metabolic rate, energy devoted to growth and reproduction, composition of diet, and environment. For homeotherms (including birds and mammals), metabolic rate generally decreases with increasing body mass. Metabolic rates are generally higher in winter than in summer (although true hibernators lower their metabolic rate during winter). Birds tend to have higher metabolic rates than mammals due to their small size, and the energetic demands of flight.

2.1 BIRD FOOD INGESTION RATES

For birds, Nagy (1987) calculated food ingestion (FI) rates in grams dry matter per day from metabolizable energy (ME, jK/g or kcal/g in diet) and field metabolic rate (FMR) as a function of body weight (Wt, grams) as follows:

$FI = 0.648\ Wt^{0.651}$ (all birds);
$FI = 0.398\ Wt^{0.850}$ (passerines);
$FI = 0.301\ Wt^{0.751}$ (non-passerines); and
$FI = 0.495\ Wt^{0.704}$ (seabirds).

2.2 MAMMAL FOOD INGESTION RATES

For placental mammals, Nagy (1987) calculated FI rates in grams dry matter per day as follows:

$FI = 0.235\ Wt^{0.822}$ (all mammals);
$FI = 0.621\ Wt^{0.564}$ (rodents); and
$FI = 0.577\ Wt^{0.727}$ (herbivores).

Herbivores tend to consume more food than carnivores on a dry weight basis due to the lower energy content of the herbivore diet; on an energy basis (kcal/day), the ingestion rates of herbivores and carnivores of equivalent size are similar.

3.0 WATER INGESTION RATES

Water requirements depend upon the rate at which animals lose water to the environment due to evaporation and excretion. Loss rates depend on various factors including body size, ambient temperature, and physiological adaptations for conserving water. Drinking water is only one way in which animals meet their water requirements (some animals are capable of maintaining their water balance from the water content of food alone). In general, birds drink less water per day than do mammals, because birds can conserve water by excreting nitrogen as uric acid instead of urea or ammonia.

3.1 BIRD WATER INGESTION RATES

For birds, Calder and Braun (1983) calculated water ingestion (WI) rates in litres per day (L/d) based on 21 species ranging from 0.011 to 3.15 kg body weight, as follows:

$FI = 0.059\ Wt^{0.67}$ (all birds), where Wt is body weight in kg.

Birds that eat a dry (seed) diet would generally have a slightly higher drinking water requirement than birds that eat soil invertebrates or succulent vegetation.

3.2 MAMMAL WATER INGESTION RATES

For mammals, Calder and Braun (1983) calculated water ingestion (WI) rates in litres per day (L/d) for mammals, as follows:

$FI = 0.099\ Wt^{0.90}$ (all mammals), where Wt is body weight in kg.

4.0 SOIL AND SEDIMENT INGESTION RATES

Soil and/or sediment is ingested by virtually all species of wildlife. In most cases ingestion occurs incidentally during foraging (*e.g.,* soil deposited on foliage consumed by herbivores, or adhering to the surface of soil dwelling invertebrates being preyed upon), or other aspects of animal behaviour (*e.g.,* burrowing). Soil/sediment ingestion may also occur intentionally (*e.g.,* some ungulates will consume soil to obtain minerals when food is sparse; MacDonald and Gunn 2004). The work of Beyer *et al.* (1994) is heavily relied upon for obtaining dietary percentages of soil intake used in ecological risk assessments. Beyer *et al.* (1994) estimated dietary percentages of soil ingestion for 28 species based upon estimates of dietary digestibility, and the acid insoluble ash content of food, soil, and scat. For most risk assessments, percent dietary soil ingestion for a specific ecological receptor is derived using an estimated value from one of these 28 species (the species most similar to the receptor in both diet and behaviour). Of the species assessed in Beyer *et al.* (1994), only the red fox has a diet consisting of a large proportion of meat. No fish-eating species were assessed for soil ingestion. There is, however, a key limitation to the data provided by Beyer *et al.*(1994), and it is that data are not available for many commonly used ecological receptor species, and that the data provided are limited to specific observations.

4.1 ESTIMATING SOIL/SEDIMENT INGESTION

To make the Beyer *et al.* (1994) data more general, the dietary percentages of soil and sediment ingestion were estimated for each ecological receptor using the dietary composition and approximations of percent soil/sediment content for each component. The percent soil/sediment was derived using selected species and their respective soil ingestion estimates reported primarily by Beyer *et al.* (1994). Various literature sources were reviewed to estimate the dietary composition for each species. Diets were compartmentalized into:

- terrestrial plants: browse (*e.g.,* shrubs, woody plants, leaves, flowers);
- terrestrial plants: forage (*e.g.,* grasses, mosses, lichens);
- terrestrial invertebrates;
- mammals/birds;
- aquatic plants;
- aquatic invertebrates; and
- fish.

Based on knowledge of existing studies, a generous range of plausible percentages for the soil/sediment content of each dietary component was derived. Using Monte Carlo sampling techniques (via Crystal Ball® 2000 software), the percentage range for each dietary compartment was assigned a uniform distribution. For each sampling of percent soil/sediment content, the resulting estimate of ingestion was calculated for all species based upon their individual dietary compositions. The difference between this percent soil/sediment estimate and the value reported in the literature was calculated, and the sum of the squared difference for each species was determined. Crystal Ball was used to create 1,000 combinations of percent soil/sediment content for each dietary component. Based on the sum of square differences, the mean percent soil/sediment content of each dietary component for the lowest 1% (10 combinations) and 5% (50 combinations) were derived. There was little or no difference between the two sets of estimates, so the mean values based on the best 50 combinations as judged by the lowest sum of squares deviations from the original data provided by Beyer *et al.,* (1994) was selected. Using these mean soil/sediment values, and the dietary composition for each ecological receptor, estimates of the dietary percentage of soil and sediment ingestion were calculated.

The estimation of soil/sediment ingestion for each ecological receptor is based on the percent sediment values derived for each dietary component. However, certain aspects of animal behavior may additionally contribute to the potential for soil ingestion. For example, while nesting, belted kingfishers burrow into steep shoreline banks, thereby increasing the opportunity for incidental soil ingestion. For ecological receptors which exhibit behaviours that are perceived to confer an additional source of soil/sediment ingestion, professional judgment was used to adjust their estimated ingestion levels accordingly.

Table 1: Percent Soil and Sediment Contents for Each Dietary Compartment

Dietary Component	Soil / Sediment Content (%)
Terrestrial Plants (Browse)	1.1
Terrestrial Plants (Forage)	6.5
Terrestrial Invertebrates	4.9
Mammals, Birds	1.1
Aquatic Plants	7.5
Aquatic Invertebrates	9.1
Fish	2.5

4.2 RAPTORS, PISCIVORES, AND AERIAL INSECTIVORES

The percent of diet that is soil/sediment is estimated for raptorial species using the procedure outlined above. Soil ingestion is not generally considered an important exposure pathway for these species. Sample and Suter (1994) and Sample *et al.* (1997) conclude the amount of soil consumed by raptors is negligible. Soil/sediment ingestion has not been assessed in the current literature for piscivores.

Similar to piscivores, soil ingestion by aerial insectivores has not been addressed in the current literature, and is often considered negligible in risk assessments (Sample and Suter 1994). However, it is likely that flying insects contain traces of soil/sediment in their gut (especially recently emerged insects). Consequently, flying insects were assigned a soil content (or sediment content, depending on origin of emergence) of 1%.

5.0 ECOLOGICAL RECEPTOR CHARACTERISTICS

The following mammalian species (given in alphabetical order) were identified as ecological receptors for quantitative risk evaluation in the ERA:

- Eastern cottontail rabbit (*Sylvilagus floridanus*);
- Masked shrew (*Sorex cinereus*);
- Meadow vole (*Microtus pennsylvanicus*);
- Mink (*Mustela vison*);
- Muskrat (*Ondatra zibethicus*);
- Red fox (*Vulpes vulpes*); and
- White-tailed deer (*Odocoileus virginianus*).

The following avian species (given in alphabetical order) were identified for quantitative risk evaluation in the ERA:

- American robin (*Turdus migratorius*);
- Belted kingfisher (*Ceryle alcyon*);
- Great blue heron (*Ardea Herodias*);
- Mallard duck (*Anas platyrhynchos*);
- Red-tailed hawk (*Buteo jamaicensis*); and
- Wild turkey (*Meleagris gallopavo*).

5.1 EASTERN COTTONTAIL RABBIT

General Parameters		
Body weight	1.2	kg
Food intake rate	2.40E-01	kg wet-wt/day
Water intake rate	1.20E-01	L/day
Ingestion of Soil		
Fraction diet that is dry solid	4.25E-01	

Fraction of food intake rate	3.83E-02	
Ingestion rate	3.90E-03	kg dry-wt/day
Intake factor (IFing-sl)	3.25E-03	kg/kg-day
Ingestion of Terrestrial Plants		
Fraction of food intake rate	1.00E+00	
Ingestion rate	2.40E-01	kg wet-wt/day
Intake factor (IFing-tp)	2.00E-01	kg/kg-day
Ingestion of Surface Water		
Ingestion rate	1.20E-01	L/day
Intake factor (IFing-sw)	1.00E-01	L/kg-day

5.2 MASKED SHREW

General Parameters		
Body weight	0.005	kg
Food intake rate	3.00E-03	kg wet-wt/day
Water intake rate	1.00E-03	L/day
Ingestion of Soil		
Fraction diet that is dry solid	3.02E-01	
Fraction of food intake rate	4.89E-02	
Ingestion rate	4.44E-05	kg dry-wt/day
Intake factor (IFing-sl)	8.87E-03	kg/kg-day
Ingestion of Terrestrial Plants		
Fraction of food intake rate	2.50E-02	
Ingestion rate	7.50E-05	kg wet-wt/day
Intake factor (IFing-tp)	1.50E-02	kg/kg-day
Ingestion of Terrestrial Invertebrates		
Fraction of food intake rate	9.75E-01	
Ingestion rate	2.93E-03	kg wet-wt/day
Intake factor (IFing-ti)	5.85E-01	kg/kg-day
Ingestion of Surface Water		
Ingestion rate	1.00E-03	L/day
Intake factor (IFing-sw)	2.00E-01	L/kg-day

5.3 MEADOW VOLE

General Parameters		
Body weight	0.042	kg
Food intake rate	1.10E-02	kg wet-wt/day
Water intake rate	6.00E-03	L/day
Ingestion of Soil		
Fraction diet that is dry solid	4.80E-01	
Fraction of food intake rate	5.96E-02	
Ingestion rate	3.15E-04	kg dry-wt/day
Intake factor (IFing-sl)	7.49E-03	kg/kg-day
Ingestion of Terrestrial Plants		
Fraction of food intake rate	9.80E-01	
Ingestion rate	1.08E-02	kg wet-wt/day
Intake factor (IFing-tp)	2.57E-01	kg/kg-day
Ingestion of Terrestrial Invertebrates		
Fraction of food intake rate	2.00E-02	
Ingestion rate	2.20E-04	kg wet-wt/day

Intake factor (IFing-ti)	5.24E-03	kg/kg-day
Ingestion of Surface Water		
Ingestion rate	6.00E-03	L/day
Intake factor (IFing-sw)	1.43E-01	L/kg-day

5.4 MINK

General Parameters		
Body weight	0.85	kg
Food intake rate	2.20E-01	kg wet-wt/day
Water intake rate	9.00E-02	L/day
Ingestion of Soil		
Fraction diet that is dry solid	2.80E-01	
Fraction of food intake rate	5.81E-03	
Ingestion rate	3.58E-04	kg dry-wt/day
Intake factor (IFing-sl)	4.21E-04	kg/kg-day
Ingestion of Terrestrial Mammals/Birds		
Fraction of food intake rate	5.50E-01	
Ingestion rate	1.21E-01	kg wet-wt/day
Intake factor (IFing-tm)	1.42E-01	kg/kg-day
Ingestion of Surface Water		
Ingestion rate	9.00E-02	L/day
Intake factor (IFing-sw)	1.06E-01	L/kg-day
Ingestion of Freshwater Sediment		
Fraction diet that is dry solid	2.80E-01	
Fraction of food intake rate	1.26E-02	
Ingestion rate	7.77E-04	kg dry-wt/day
Intake factor (IFing-sed)	9.14E-04	kg/kg-day
Ingestion of Freshwater Benthic Invertebrates		
Fraction of food intake rate	1.00E-01	
Ingestion rate	2.20E-02	kg wet-wt/day
Intake factor (IFing-ai)	2.59E-02	kg/kg-day
Ingestion of Freshwater Fish		
Fraction of food intake rate	3.50E-01	
Ingestion rate	7.70E-02	kg wet-wt/day
Intake factor (IFing-fsh)	9.06E-02	kg/kg-day

5.5 MUSKRAT

General Parameters		
Body weight	1.17	kg
Food intake rate	1.20E-01	kg wet-wt/day
Water intake rate	1.10E-01	L/day
Ingestion of Soil		
Fraction diet that is dry solid	2.75E-01	
Fraction of food intake rate	3.01E-03	
Ingestion rate	9.93E-05	kg dry-wt/day
Intake factor (IFing-sl)	8.49E-05	kg/kg-day
Ingestion of Terrestrial Plants		
Fraction of food intake rate	1.25E-01	

Ingestion rate	1.50E-02	kg wet-wt/day
Intake factor (IFing-tp)	1.28E-02	kg/kg-day
Ingestion of Terrestrial Mammals/Birds		
Fraction of food intake rate	2.50E-02	
Ingestion rate	3.00E-03	kg wet-wt/day
Intake factor (IFing-tm)	2.56E-03	kg/kg-day
Ingestion of Surface Water		
Ingestion rate	1.10E-01	L/day
Intake factor (IFing-sw)	9.40E-02	L/kg-day
Ingestion of Freshwater Sediment		
Fraction diet that is dry solid	2.75E-01	
Fraction of food intake rate	6.22E-02	
Ingestion rate	2.05E-03	kg dry-wt/day
Intake factor (IFing-sed)	1.75E-03	kg/kg-day
Ingestion of Freshwater Aquatic Plants		
Fraction of food intake rate	8.00E-01	
Ingestion rate	9.60E-02	kg wet-wt/day
Intake factor (IFing-ap)	8.21E-02	kg/kg-day
Ingestion of Freshwater Benthic Invertebrates		
Fraction of food intake rate	2.50E-02	
Ingestion rate	3.00E-03	kg wet-wt/day
Intake factor (IFing-ai)	2.56E-03	kg/kg-day
Ingestion of Freshwater Fish		
Fraction of food intake rate	2.50E-02	
Ingestion rate	3.00E-03	kg wet-wt/day
Intake factor (IFing-fsh)	2.56E-03	kg/kg-day

5.6 RED FOX

General Parameters		
Body weight	4.5	kg
Food intake rate	7.60E-01	kg wet-wt/day
Water intake rate	3.83E-01	L/day
Ingestion of Soil		
Fraction diet that is dry solid	3.15E-01	
Fraction of food intake rate	1.25E-02	
Ingestion rate	3.00E-03	kg dry-wt/day
Intake factor (IFing-sl)	6.66E-04	kg/kg-day
Ingestion of Terrestrial Plants		
Fraction of food intake rate	1.00E-01	
Ingestion rate	7.60E-02	kg wet-wt/day
Intake factor (IFing-tp)	1.69E-02	kg/kg-day
Ingestion of Terrestrial Invertebrates		
Fraction of food intake rate	5.00E-02	
Ingestion rate	3.80E-02	kg wet-wt/day
Intake factor (IFing-ti)	8.44E-03	kg/kg-day
Ingestion of Terrestrial Mammals/Birds		
Fraction of food intake rate	8.50E-01	
Ingestion rate	6.46E-01	kg wet-wt/day
Intake factor (IFing-tm)	1.44E-01	kg/kg-day
Ingestion of Surface Water		
Ingestion rate	3.83E-01	L/day
Intake factor (IFing-sw)	8.51E-02	L/kg-day

5.7 WHITE-TAILED DEER

General Parameters		
Body weight	60	kg
Food intake rate	4.60E+00	kg wet-wt/day
Water intake rate	3.94E+00	L/day
Ingestion of Soil		
Fraction diet that is dry solid	3.74E-01	
Fraction of food intake rate	2.20E-02	
Ingestion rate	3.78E-02	kg dry-wt/day
Intake factor (IFing-sl)	6.31E-04	kg/kg-day
Ingestion of Terrestrial Plants		
Fraction of food intake rate	1.00E+00	
Ingestion rate	4.60E+00	kg wet-wt/day
Intake factor (IFing-tp)	7.67E-02	kg/kg-day
Ingestion of Surface Water		
Ingestion rate	3.94E+00	L/day
Intake factor (IFing-sw)	6.57E-02	L/kg-day

5.8 AMERICAN ROBIN

General Parameters		
Body weight	0.08	kg
Food intake rate	6.50E-02	kg wet-wt/day
Water intake rate	1.00E-02	L/day
Ingestion of Soil		
Fraction diet that is dry solid	2.57E-01	
Fraction of food intake rate	2.90E-02	
Ingestion rate	4.85E-04	kg dry-wt/day
Intake factor (IFing-sl)	6.06E-03	kg/kg-day
Ingestion of Terrestrial Plants		
Fraction of food intake rate	5.23E-01	
Ingestion rate	3.40E-02	kg wet-wt/day
Intake factor (IFing-tp)	4.25E-01	kg/kg-day
Ingestion of Terrestrial Invertebrates		
Fraction of food intake rate	4.78E-01	
Ingestion rate	3.10E-02	kg wet-wt/day
Intake factor (IFing-ti)	3.88E-01	kg/kg-day
Ingestion of Surface Water		
Ingestion rate	1.00E-02	L/day
Intake factor (IFing-sw)	1.25E-01	L/kg-day

5.9 BELTED KINGFISHER

General Parameters		
Body weight	0.15	kg
Food intake rate	6.00E-02	kg wet-wt/day
Water intake rate	2.00E-02	L/day

Ingestion of Soil		
Fraction diet that is dry solid	2.78E-01	
Fraction of food intake rate	5.00E-02	
Ingestion rate	8.35E-04	kg dry-wt/day
Intake factor (IFing-sl)	5.57E-03	kg/kg-day
Ingestion of Terrestrial Invertebrates		
Fraction of food intake rate	5.00E-02	
Ingestion rate	3.00E-03	kg wet-wt/day
Intake factor (IFing-ti)	2.00E-02	kg/kg-day
Ingestion of Terrestrial Mammals/Birds		
Fraction of food intake rate	1.00E-01	
Ingestion rate	6.00E-03	kg wet-wt/day
Intake factor (IFing-tm)	4.00E-02	kg/kg-day
Ingestion of Surface Water		
Ingestion rate	2.00E-02	L/day
Intake factor (IFing-sw)	1.33E-01	L/kg-day
Ingestion of Freshwater Sediment		
Fraction diet that is dry solid	2.78E-01	
Fraction of food intake rate	2.07E-02	
Ingestion rate	3.45E-04	kg dry-wt/day
Intake factor (IFing-sed)	2.30E-03	kg/kg-day
Ingestion of Freshwater Benthic Invertebrates		
Fraction of food intake rate	1.50E-01	
Ingestion rate	9.00E-03	kg wet-wt/day
Intake factor (IFing-ai)	6.00E-02	kg/kg-day
Ingestion of Freshwater Fish		
Fraction of food intake rate	7.00E-01	
Ingestion rate	4.20E-02	kg dry-wt/day
Intake factor (IFing-fsh)	2.80E-01	kg/kg-day

5.10 GREAT BLUE HERON

General Parameters		
Body weight	2.23	kg
Food intake rate	4.00E-01	kg wet-wt/day
Water intake rate	1.01E-01	L/day
Ingestion of Soil		
Fraction diet that is dry solid	2.82E-01	
Fraction of food intake rate	1.06E-04	
Ingestion rate	1.20E-05	kg dry-wt/day
Intake factor (IFing-sl)	5.36E-06	kg/kg-day
Ingestion of Terrestrial Mammals/Birds		
Fraction of food intake rate	1.00E-02	
Ingestion rate	4.00E-03	kg wet-wt/day
Intake factor (IFing-tm)	1.79E-03	kg/kg-day
Ingestion of Surface Water		
Ingestion rate	1.01E-01	L/day
Intake factor (IFing-sw)	4.53E-02	L/kg-day
Ingestion of Freshwater Sediment		
Fraction diet that is dry solid	2.82E-01	
Fraction of food intake rate	1.41E-02	
Ingestion rate	1.59E-03	kg dry-wt/day
Intake factor (IFing-sed)	7.13E-04	kg/kg-day
Ingestion of Freshwater Benthic Invertebrates		

Fraction of food intake rate	5.00E-02	
Ingestion rate	2.00E-02	kg wet-wt/day
Intake factor (IFing-ai)	8.97E-03	kg/kg-day
Ingestion of Freshwater Fish		
Fraction of food intake rate	9.40E-01	
Ingestion rate	3.76E-01	kg dry-wt/day
Intake factor (IFing-fsh)	1.69E-01	kg/kg-day

5.11 MALLARD DUCK

General Parameters		
Body weight	1.16	kg
Food intake rate	6.10E-01	kg wet-wt/day
Water intake rate	7.00E-02	L/day
Ingestion of Soil		
Fraction diet that is dry solid	2.61E-01	
Fraction of food intake rate	2.75E-03	
Ingestion rate	4.38E-04	kg dry-wt/day
Intake factor (IFing-sl)	3.77E-04	kg/kg-day
Ingestion of Terrestrial Plants		
Fraction of food intake rate	1.25E-01	
Ingestion rate	7.63E-02	kg wet-wt/day
Intake factor (IFing-tp)	6.57E-02	kg/kg-day
Ingestion of Surface Water		
Ingestion rate	7.00E-02	L/day
Intake factor (IFing-sw)	6.03E-02	L/kg-day
Ingestion of Freshwater Sediment		
Fraction diet that is dry solid	2.61E-01	
Fraction of food intake rate	7.77E-02	
Ingestion rate	1.24E-02	kg dry-wt/day
Intake factor (IFing-sed)	1.07E-02	kg/kg-day
Ingestion of Freshwater Aquatic Plants		
Fraction of food intake rate	1.25E-01	
Ingestion rate	7.63E-02	kg wet-wt/day
Intake factor (IFing-ap)	6.57E-02	kg/kg-day
Ingestion of Freshwater Benthic Invertebrates		
Fraction of food intake rate	7.50E-01	
Ingestion rate	4.58E-01	kg wet-wt/day
Intake factor (IFing-ai)	3.94E-01	kg/kg-day

5.12 RED-TAILED HAWK

General Parameters		
Body weight	1.1	kg
Food intake rate	1.90E-01	kg wet-wt/day
Water intake rate	6.00E-02	L/day
Ingestion of Soil		
Fraction diet that is dry solid	3.28E-01	
Fraction of food intake rate	1.06E-02	
Ingestion rate	6.59E-04	kg dry-wt/day

Intake factor (IFing-sl)	5.99E-04	kg/kg-day
Ingestion of Terrestrial Mammals/Birds		
Fraction of food intake rate	1.00E+00	
Ingestion rate	1.90E-01	kg wet-wt/day
Intake factor (IFing-tm)	1.73E-01	kg/kg-day
Ingestion of Surface Water		
Ingestion rate	6.00E-02	L/day
Intake factor (IFing-sw)	5.45E-02	L/kg-day

5.13 WILD TURKEY

General Parameters		
Body weight	4.2	kg
Food intake rate	9.20E-01	kg wet-wt/day
Water intake rate	1.54E-01	L/day
Ingestion of Soil		
Fraction diet that is dry solid	5.20E-01	
Fraction of food intake rate	5.83E-02	
Ingestion rate	2.79E-02	kg dry-wt/day
Intake factor (IFing-sl)	6.64E-03	kg/kg-day
Ingestion of Terrestrial Plants		
Fraction of food intake rate	9.00E-01	
Ingestion rate	8.28E-01	kg wet-wt/day
Intake factor (IFing-tp)	1.97E-01	kg/kg-day
Ingestion of Terrestrial Invertebrates		
Fraction of food intake rate	1.00E-01	
Ingestion rate	9.20E-02	kg wet-wt/day
Intake factor (IFing-ti)	2.19E-02	kg/kg-day
Ingestion of Surface Water		
Ingestion rate	1.54E-01	L/day
Intake factor (IFing-sw)	3.67E-02	L/kg-day

6.0 AMPHIBIANS AND REPTILES

It is widely accepted that amphibians are highly sensitive to environmental and chemical stressors. Due to their unique life history, amphibians may be exposed to contaminants from both aquatic and terrestrial systems: early lifestages (*i.e.,* embryonic and larval stages) of amphibians are typically confined to aquatic habitats and after larvae metamorphose into air-breathing adults, they disperse from the water to occupy a variety of terrestrial habitat types (*e.g.,* arboreal, fossorial, semi-aquatic). Complete dissociation from water is never achieved, and adults will re-visit aquatic habitats each year during the breeding season. Therefore, during the course of a year most amphibians will be exposed to environmental contaminants in the air, water, soil, sediment, and diet (which also changes during development). Additionally, the permeability of amphibian skin increases their potential exposure to, and uptake of, environmental contaminants.

To perform a quantitative ecological risk assessment, appropriate toxicological data (*i.e.,* chronic data, species specific) for ecological receptors is required. Toxicological information for amphibians and reptiles is available from several publications including: Ecotoxicology of Amphibians and Reptiles (Sparling *et al.* 2000); RATL: A Database of Reptile and Amphibian Toxicity Literature (Pauli *et al.* 2000) which updates the older Canadian Wildlife Service report A Review and Evaluation of the

Amphibian Toxicological Literature (1989): Technical Report Series No. 61; and Ecotoxicity of Chemicals to Amphibians (Devillers and Exbrayat 1992). The USEPA's ECOTOX (www.epa.gov/ECOTOX) database (2008) also contains numerous results of amphibian and reptile toxicity tests and the California Wildlife Biology, Exposure Factor, and Toxicity Database (Cal/Ecotox; http://www.oehha.ca.gov/cal_ecotox/default.htm) contains a few references to limited physiological and toxicity data for amphibians and reptiles. A review of these sources confirms that for most organic contaminants, with the possible exception of polychlorinated biphenyls (PCBs), organochlorine pesticides (OCs) and some metals, there is a paucity of information on chronic toxicology and bioavailability of contaminants. Mainly body burden and acute toxicity (exposure durations of 96 hours or less) to contaminants is available, and the vast majority of laboratory amphibian toxicity tests have focussed on effects to embryonic and larval lifestages occurring from water-borne contaminant exposure only. Chronic toxicity information is rarely available. Given the global decline in amphibian populations, on-going research is being conducted on the effects of specific chemical stresses on amphibians (and reptiles), however individual studies are not generally acceptable as the basis of toxicity data for quantitative ERA.

In some cases, acute data is used in ERA to assess chronic effects, but only when it is scientifically defensible to do so (*e.g.,* acute to chronic ratios are known). For most aquatic lifestage amphibians, the primary routes of exposure are uptake and dermal absorption of dissolved contaminants in the water column, and this is the focus of laboratory tests. However, larval lifestages are also exposed to contaminants in sediment and dietary items so data derived from laboratory testing will generally underestimate actual exposure for these lifestages in the field. Although embryonic and larval lifestages are recognized as being sensitive to environmental contaminants, Birge *et al.* and Suter *et al.* (1975 and 1987 respectively in Sparling *et al.* 2000) note that egg complement (number of viable eggs produced per female) and fecundity are the most sensitive endpoints during the life history of organisms. These endpoints are related to maternal (*i.e.,* adult terrestrial) exposure and accumulation of environmental contaminants. The different habitats and dietary composition associated with adult amphibians often result in dramatic changes to exposure pathways. Immersive aquatic laboratory studies of adults are much less prevalent than larval stage and are not very useful for ERAs since they do not consider all relevant pathways. A proper risk assessment of adult amphibians requires consideration of exposure from soil and sediment (dermal contact and ingestion), water (dermal contact), air (cutaneous and lung respiration), and diet (Sparling *et al.* 2000). In addition to these, dermal exposure acquired from soil, sediment and/or water during hibernation can potentially lead to sub-lethal effects (ENSR 2004).

In the absence of species-specific chronic data or dose-response relationships, representative surrogate species are often utilized in ERA. Due to the similarity of exposure pathways (*i.e.,* sediment, water) with embryonic and larval amphibian lifestages, fish appear to be the mostly likely surrogates for amphibians. However, a comparison of toxicity tests between similar developmental stages of rainbow trout and various amphibian species seems to suggest that the two Classes aren't as similar as expected. Birge *et al.* (1975) showed that for organic compounds, amphibians were more sensitive 35% of time, compared to 52% of the time for inorganic compounds. The comparative sensitivity of specific compounds showed extreme interspecies variation. For example, amphibian LC50s for mercury ranged from roughly one fifth of the rainbow trout LC50 (*G. carolineus*) to 40 times higher (*M. salmoides*). The unpredictable relationship between fish and amphibian toxicity make it extremely difficult to use fish as surrogate receptors for evaluating risks to amphibians. Given the state of amphibian toxicological data, it is difficult to assess the chronic effects of contaminants on amphibians

(ENSR 2004). As such, appropriate amphibian-specific data does not appear to be available for use in quantitative ERA.

The assessment of contaminant risks to reptiles is complicated by many of the same issues which surround amphibian assessments, with the major limiting factor again being the availability of applicable toxicity data. Indeed, reptiles have received even less ecotoxicological research attention than amphibians. In a review of vertebrate toxicological data from 1972 to 1998, less than 3% of studies were conducted with amphibians and only 1.4% for reptiles (Sparling *et al.* 2000). Again, the majority of ecotoxicity studies have focused on tissue contamination in field collected organisms. These studies are generally not relevant for use in risk assessment because they do not provide any information on the relationship between external dose and effects. The life-history of reptiles is not nearly as complex as amphibians, though they do exhibit certain unique characteristics which would require consideration for performing a risk assessment; turtles are completely oviparous, whereas squamates (*i.e.,* lizards and snakes) exhibit both viviparity and oviparity (Niewiarowski 2000). Reptiles deposit eggs in soil in close proximity to water. During this period, the developing embryos may potentially be exposed to contaminants in the soil (e.g., through dermal contact), having adverse consequences on development (Unrine *et al*. 2004). The limited data available for reptilian species cannot be overcome through the use of surrogate species within the same class. Additionally, given the lack of knowledge on comparative toxicity between reptiles and other classes, there is little basis for making assumptions on reptilian toxicity cross-class, even when conservative uncertainty factors are applied.

The current state of knowledge does not permit a proper quantitative assessment of chronic risks from chemical stressors to amphibians and reptiles. The majority of available toxicity data is from acute studies, and relates water concentrations to lethal endpoints. This information is useful for evaluating the embryonic lifestage, but does not consider additional exposure pathways associated with larval and adult amphibians. To date, the current state of knowledge on toxicology, and exposure characterization (*e.g.,* from diffusion across the amphibian skin) are simply not adequate to permit an assessment of risk to adult amphibians. Due to the dramatic changes in exposure pathways associated with development, it is not adequate to assess only one lifestage, regardless of its sensitivity to chemical stressors. Additionally, the unique physiology and life-history of amphibians complicate the use of surrogate receptors to assess amphibian risk.

7.0 COMMUNITY-BASED VECS

7.1 TERRESTRIAL PLANTS

To evaluate the risks presented to plants by COPCs emitted by the Project, existing and predicted soil concentrations were compared against phytotoxicity benchmarks. These benchmarks were derived to be protective of most plants species, acknowledging the variability associated with phytotoxicity resulting from soil conditions.

7.2 TERRESTRIAL SOIL INVERTEBRATES

Specific species of terrestrial invertebrates were not assessed in this ERA. Existing and predicted soil concentrations were compared to benchmark toxicity values derived to be protective of most terrestrial invertebrate species.

7.3 FRESHWATER FISH AND BENTHIC INVERTEBRATES

For the purposes of this ERA, individual fish species and freshwater invertebrates were not considered as potential receptors. Rather, fish and invertebrates as a whole were considered. This is reasonable since the benchmarks used to evaluate aquatic receptors are based on the most sensitive reported toxicological data from the literature and are designed to be protective of all aquatic life.

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