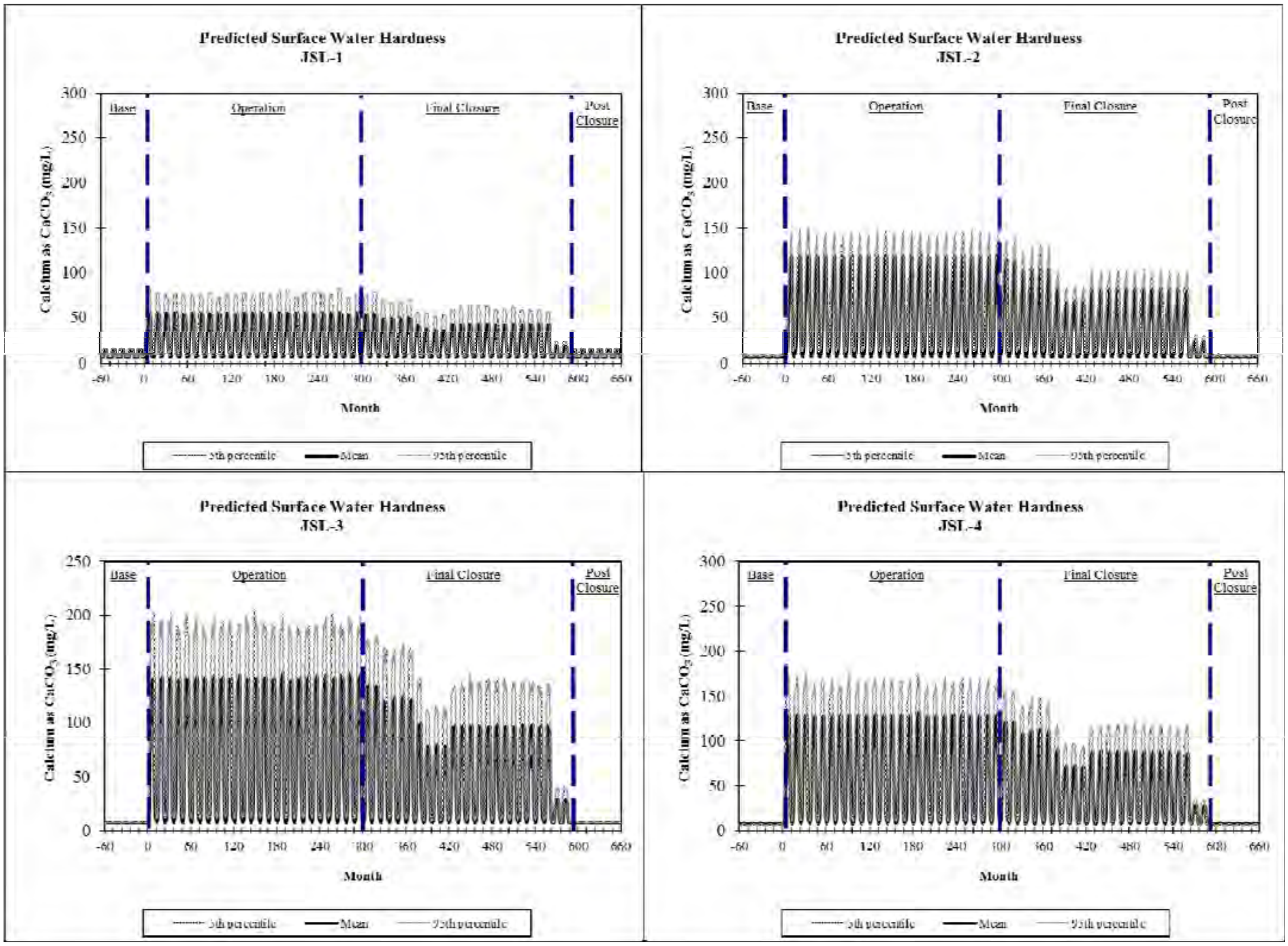


Figure 7.2-1 Water Quality Predictions (Cont'd)

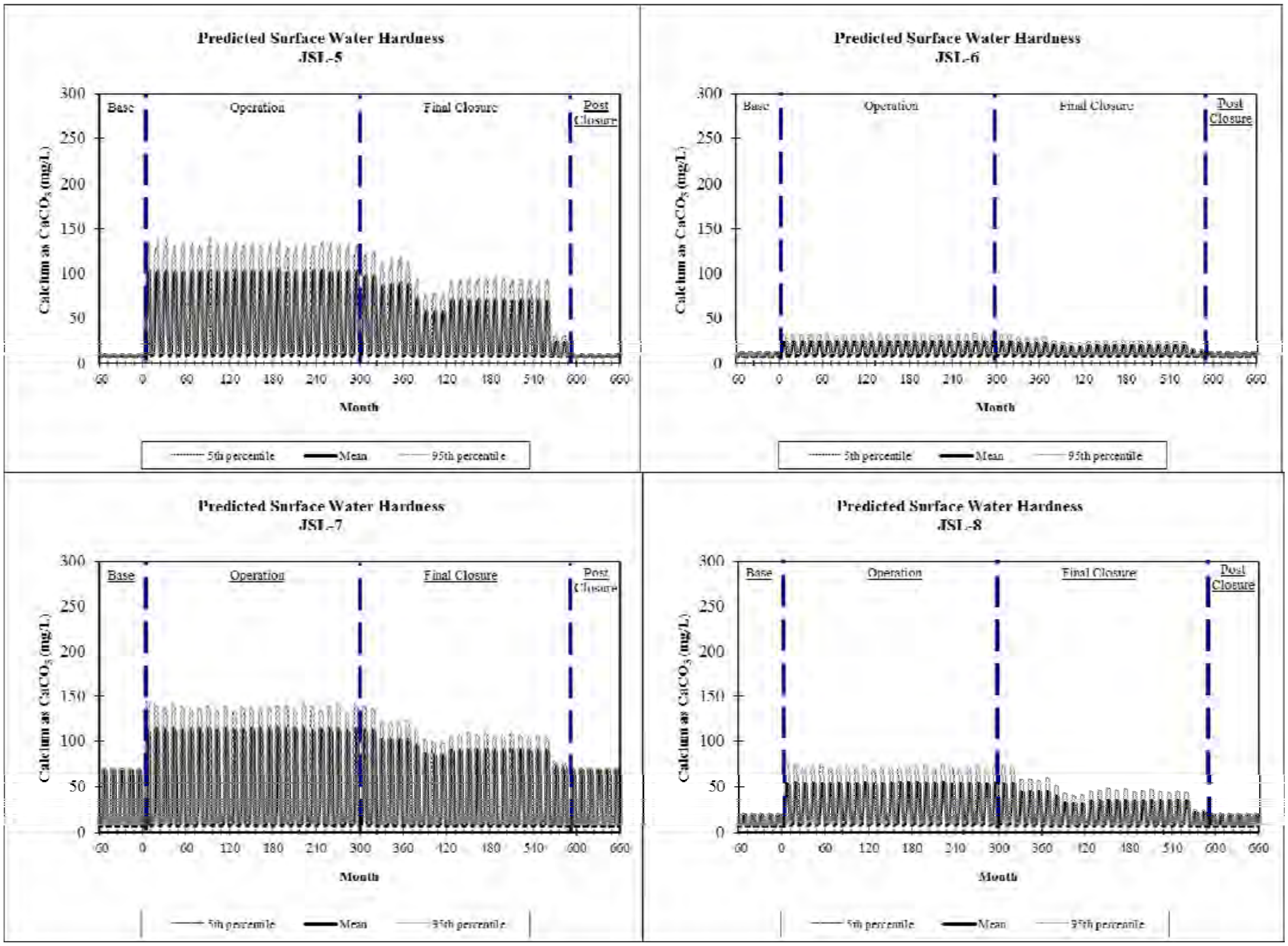


Figure 7.2-1 Water Quality Predictions (Cont'd)

Table 7.2-1 Summary of Cadmium Water Concentrations and Appropriate Criteria for the Summer and Winter Periods

	Estimated Hardness (mg/L)	Calculated Cadmium Water Quality Criterion(a) (µg/L)	Estimated Maximum Cadmium Concentration in Water (µg/L)	
			Mean	95th Percentile
JSL-1				
Summer	8	0.04	0.02	0.03
Winter	55	0.10	0.09	0.15
JSL-4				
Summer	10	0.04	0.03	0.04
Winter	130	0.20	0.14	0.21
Note: a Water quality criterion calculated using CCME equation				

Predicted water quality for copper and zinc indicates that effluent from the Project has limited influence on the water quality in Judge Sissons Lake segments; however, copper concentrations in JSL-7 and JSL-8 exceed the WQG and zinc concentrations in JSL-7 exceed the WQG. These are baseline conditions.

For selenium, predicted water concentrations in Judge Sissons Lake are below the WQG of 1 µg/L, with the exception of JSL-7. Under baseline conditions, seasonal fluctuations of selenium in water in JSL-7 are indicated to closely approach the WQG. During the operation and final closure phases of the Project, predicted water concentrations of selenium in JSL-7 increase slightly above the WQG due to effluent discharge. While the CCME WQG is exceeded, it is noted that the draft selenium guideline from the U.S. EPA of 1.3 µg/L (U.S. EPA 2014) is not exceeded in JSL-7, which suggests that potential effects on aquatic life in this segment would be limited.

The lake water concentrations are predicted to be the highest during winter ice cover when water flows, volumes and dissolved oxygen levels are reduced. Climate change could potentially reduce the thickness and duration of the ice cover in Judge Sissons Lake thereby reducing seasonal fluctuations in predicted water concentrations.

7.2.1 Predicted Downstream Impacts on Water Quality

An analysis was completed to evaluate the potential impacts on water quality downstream of Judge Sissons Lake. Judge Sissons Lake is part of the Anigaq River watershed and the Anigaq River ultimately drains into the western edge of Baker Lake, which in turn drains into Chesterfield Inlet and finally into Hudson Bay.

The outlet of Judge Sissons Lake is JSL-4 and the mean annual discharge from Judge Sissons Lake is 4.289 m^3/s (Appendix 5A). Mean daily discharge data from an hydrometric station (Environment Canada station name: 06MA007) located about 1 km downstream of Audra Lake was characterized to evaluate the potential impacts on water quality from natural water flow out of Judge Sissons Lake. Mean daily discharge data collected for 14 years between 1984 and 2010 was characterized by an average daily discharge rate of 14.976 m^3/s.

Table 7.2-2 shows the estimated incremental downsteam water concentrations as a result of a dilution of the water from the outlet of Judge Sissons Lake (JSL-4). Baseline water quality and WQG are also provided, as available. From the table, it can be seen that the predicted incremental downstream water concentrations are well below the available WQG for all COPC.

Table 7.2-2 Predicted Impact on Downstream Water Quality

Constituent	Units	Baseline WQ	WQG	WQ at Outlet (JSL-4)[j]		ΔC Downstream WQ	
				Max Mean	Max 95th	Max Mean	Max 95th
Uranium	µg/L	0.1	15[a]	0.1	0.2	0.04	0.05
Thorium-230	Bq/L	0.006	0.6[b]	0.006	0.006	0.002	0.002
Lead-210	Bq/L	0.011	0.2[b]	0.011	0.011	0.003	0.003
Radium-226	Bq/L	0.004	0.11[c]	0.004	0.004	0.001	0.001
Polonium-210	Bq/L	0.005	0.1[b]	0.005	0.005	0.001	0.001
Arsenic	µg/L	0.2	5[a]	0.2	0.3	0.07	0.09
Cadmium	µg/L	0.0015	0.04 [d]	0.05	0.07	0.01	0.02
Cobalt	µg/L	0.065	4[e]	0.07	0.09	0.02	0.02
Copper	µg/L	0.8	2.0 [f]	0.80	0.80	0.23	0.23
Lead	µg/L	0.1	1.0 [g]	0.10	0.11	0.03	0.03
Molybdenum	µg/L	0.1	73[a]	1.1	1.9	0.3	0.5
Nickel	µg/L	0.6	25.0 [h]	0.6	0.6	0.2	0.2
Selenium	µg/L	0.1	1.0[a]	0.13	0.15	0.04	0.04
Zinc	µg/L	4.0	30[a]	4.0	4.0	1.1	1.1
Ammonia (un-ionized)	mg/L	0.0002[i]	0.019[a]	0.001	0.001	<0.001	<0.001
Chloride	mg/L	0.6	120[a]	7.1	10.9	2.0	3.1
Sulphate	mg/L	0.6	128[e]	24	36	7	10
TDS	mg/L	24.6	500[b]	53	71	15	20
Hardness (Ca as $CaCO_3$)	mg/L	2.8	-	20	27	6	8

Note:

Calculated based on the assumption of a mean annual flow of 4.289 m3/s out of JSL-4 and a mean annual flow of 14.976 m3/s at the downstream Anigaq River station.

a = Canadian Water Quality Guideline.

b = Canadian Drinking Water Quality Guideline.

c = Saskatchewan Surface Water Quality Objective for the Protection of Aquatic Life

d = The guidelines for cadmium are hardness-dependent; at hardnesses ranging from 0 to 17 mg/L as $CaCO_3$, the guideline is 0.04 µg/L.

e = British Columbia Water Quality Guideline

f = The guidelines for copper are hardness-dependent; at hardnesses ranging from 0 to 82 mg/L as $CaCO_3$, the guideline is 2 µg/L.

g = The guidelines for lead are hardness-dependent; at hardnesses ranging from 0 to 60 mg/L as $CaCO_3$, the guideline is 1 µg/L.

h = The guidelines for nickel are hardness-dependent; at hardnesses ranging from 0 to 60 mg/L as $CaCO_3$, the guideline is 25 µg/L.

i = converted to un-ionized ammonia, assuming a temperature of 10 degrees C and pH of 7.5.

j = Maximum mean and 95th percentile summer concentrations were assumed for the assessment of downstream water quality because outflow from Judge Sissons Lake does not occur in the winter.

µg/L = micrograms per litre; Bq/L = Bequerels per litre; mg/L – milligrams per litre

7.3 Predicted Sediment Quality

Table 7.3-1 presents the maximum mean monthly predicted sediment concentrations in the eight segment of Judge Sissons Lake for each of the four phases of the bounding effluent release scenario (O1Ex22). The four phases of effluent release are: baseline conditions (pre-operation), operation phase, final closure phase, and post-closure phase.

The baseline results provide the sediment quality in each segment under natural conditions.

The operation phase shows the predicted sediment quality results under the assumed effluent release for the extended operation of Option 1, which considers discharge of the Kiggavik WTP to JSL-2 and Sissons WTP to JSL-8. Generally, the sediment is not affected by the effluent contribution to the Judge Sissons water column; however, there are changes in sediment quality predicted for uranium, arsenic, cadmium, molybdenum, and selenium.

The final closure phase represents the predicted sediment quality under the bounding case decommissioning scenario with 22-years of Main Zone consolidation. As effluent releases are gradually decreased through this phase, Table 7.3-1 shows that sediment quality is predicted to gradually return to baseline levels. The system is predicted to respond relatively quickly to changes in effluent release.

Finally, the post-closure phase shows the recovery of predicted sediment quality for Judge Sissons Lake after effluent releases have stopped. Again, the system responds quickly and returns to baseline/pre-operation conditions. The water effluent scenario assessed for the Project does not have long-term impacts on the sediment quality of Judge Sissons Lake.

Table 7.3-2 presents a summary of the maximum predicted mean and 95th percentile sediment concentrations over the duration of the assessment (i.e., all four phases of the effluent release scenario). The associated sediment quality guidelines are indicated in Table 7.3-2. For the COPC with sediment quality guidelines available, predicted sediment concentrations of all COPC were below the guidelines in all segments of Judge Sissons Lake, with the exception of arsenic, copper, and nickel.

For arsenic, the mean and 95th percentile predicted concentrations are above the CCME ISQG of 5.9 µg/g in all segments of Judge Sissons Lake. Baseline concentrations of arsenic in Judge Sissons Lake are approximately 8.2 µg/g and exceed the CCME ISQG without Project influences.Table 7.3-1 indicates that arsenic concentrations in sediment are predicted to increase slightly over the duration of the Project. The maximum 95th percentile concentrations of arsenic in the sediment of several Judge Sissons Lake segments are predicted to marginally exceed the Thompson et al. (2005) LEL of

9.8 µg/g. Predicted arsenic concentrations in sediment are well below the SEL and PEL of 346.4 and 17 µg/g, respectively and are well below the IC_{25} based on growth of 174 µg/g (Liber et al. 2011).

For copper, the maximum 95th percentile predicted concentrations in all segments of Judge Sissons Lake and the maximum mean predicted concentration in JSL-7 exceed the Thompson et al. (2005) LEL of 22.2 µg/g. Exceedances of the CCME ISQG of 35.7 µg/g for copper are not predicted. It is noted that the mean baseline levels of copper in sediment are close to the LEL and the project has little influence on the sediment concentrations (Table 7.3-1). Predicted copper concentrations in sediment are well below the SEL and PEL of 268.8 and 197 µg/g, respectively.

The 95th percentile predicted concentrations of nickel in sediment are slightly elevated compared to the Thompson et al. (2005) LEL of 23.4 µg/g during all phases of the assessment, including baseline. Predicted nickel concentrations in sediment are well below the severe effects level (SEL) of 484 µg/g and the IC_{25} based on growth of 189 µg/g (Liber et al. 2011). As with the other COPC discussed, baseline also exceed guidelines and the project has little influence on the sediment concentrations (Table 7.3-1).

Table 7.3-1 Maximum Predicted Mean Sediment Concentrations in Each Phase of the Assessment

COPC	Units	JSL-1				JSL-2				JSL-3			
		Base	Oper.	Final	Post	Base	Oper.	Final	Post	Base	Oper.	Final	Post
U	µg/g	2.5	2.5	2.4	2.3	2.7	2.7	2.7	2.6	2.7	2.7	2.7	2.5
Th-230	Bq/g	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
Pb-210	Bq/g	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Ra-226	Bq/g	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
Po-210	Bq/g	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
As	µg/g	8.2	8.3	8.3	8.2	8.2	8.6	8.8	8.7	8.2	8.5	8.6	8.5
Cd	µg/g	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Co	µg/g	6	6	5	5	6	6	6	7	6	6	6	6
Cu	µg/g	21.5	21.8	21.9	21.9	21.5	21.6	21.9	21.9	21.5	21.3	21.5	21.5
Pb	µg/g	9	9	9	9	9	9	10	10	9	9	9	9
Mo	µg/g	1.3	3.6	3.7	2.5	1.3	5.0	5.2	3.7	1.3	4.3	4.4	2.7
Ni	µg/g	22	22	22	22	22	23	23	23	22	22	22	22
Se	µg/g	0.4	0.5	0.5	0.4	0.4	0.5	0.5	0.4	0.4	0.5	0.5	0.4
Zn	µg/g	61.7	62.9	63.9	64.1	63.2	64.2	66.8	67.4	61.2	62.2	64.2	64.7
COPC	Units	JSL-4				JSL-5				JSL-6			
		Base	Oper.	Final	Post	Base	Oper.	Final	Post	Base	Oper.	Final	Post
U	µg/g	2.7	2.7	2.7	2.6	2.7	2.8	2.8	2.7	2.5	2.5	2.4	2.3
Th-230	Bq/g	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
Pb-210	Bq/g	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Ra-226	Bq/g	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
Po-210	Bq/g	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
As	µg/g	8.2	8.4	8.5	8.4	8.2	8.4	8.4	8.4	8.0	8.0	8.0	8.0
Cd	µg/g	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Co	µg/g	6	6	6	**6**	6	6	6	**6**	6	6	5	5
Cu	µg/g	21.5	21.5	21.7	21.7	21.5	21.8	22.0	22.0	21.5	21.6	21.7	21.7
Pb	µg/g	9	9	9	10	9	9	10	10	9	9	9	9
Mo	µg/g	1.3	3.7	3.8	**2.5**	1.3	3.2	3.3	2.3	1.3	2.3	2.3	1.7
Ni	µg/g	22	22	23	23	22	23	23	23	22	22	22	22
Se	µg/g	0.4	0.5	0.5	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
Zn	µg/g	63.2	63.8	66.4	66.9	63.2	65.4	68.5	69.2	61.1	62.2	63.2	63.3
COPC	Units	JSL-7				JSL-8							
		Base	Oper.	Final	Post	Base	Oper.	Final	Post				
U	µg/g	2.7	2.9	2.9	**2.7**	2.7	3.4	3.5	2.6				
Th-230	Bq/g	0.04	0.05	0.05	0.05	0.04	0.04	0.04	0.04				
Pb-210	Bq/g	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1				
Ra-226	Bq/g	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04				

Table 7.3-1 Maximum Predicted Mean Sediment Concentrations in Each Phase of the Assessment

Po-210	Bq/g	0.1	0.1	0.1	**0.1**	0.1	0.1	0.1	0.1				
As	µg/g	8.2	8.5	8.5	8.5	8.2	8.3	8.3	8.1				
Cd	µg/g	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2				
Co	µg/g	6	6	5	5	6	6	5	5				
Cu	µg/g	22.1	23.4	23.6	23.7	21.6	22.0	22.1	22.1				
Pb	µg/g	9	9	9	9	9	9	9	9				
Mo	µg/g	1.4	2.2	2.3	1.7	1.3	2.9	3.0	1.7				
Ni	µg/g	23	23	24	24	22	22	23	23				
Se	µg/g	0.5	0.5	0.5	0.5	0.4	0.4	0.4	0.4				
Zn	µg/g	65.3	72.7	75.7	76.1	63.2	64.4	65.7	65.9				

Table 7.3-2 Maximum Predicted Mean and 95th Percentile Sediment Concentrations

COPC	Units	SQG						JSL-1		JSL-2	
		Thompson		CCME		Liber					
		LEL	SEL	ISQG	PEL	NOEC	IC25	Mean	95th	Mean	95th
U	µg/g	104.4	5874.1	-	-	-	964	2.7	2.7	2.7	3.4
Th-230	Bq/g	-	-	-	-	-	-	0.04	0.05	0.04	0.05
Pb-210	Bq/g	0.9	20.8	-	-	-	-	0.07	0.07	0.07	0.07
Ra-226	Bq/g	0.6	14.4	-	-	-	-	0.04	0.05	0.04	0.04
Po-210	Bq/g	0.8	12.1	-	-	-	-	0.07	0.07	0.07	0.07
As	µg/g	9.8	346.4	5.9	17	**-**	174	**8.3**	**9.3**	**8.8**	**10.5**
Cd	µg/g	-	-	0.6	3.5	-	-	0.2	0.2	0.2	0.2
Co	µg/g	-	-	-	-	-	-	5.6	5.6	6.5	6.7
Cu	µg/g	22.2	268.8	35.7	197	-	-	21.9	**24.1**	21.9	**24.5**
Pb	µg/g	36.7	412.4	35	91.3	-	-	9.4	9.4	9.6	10.1
Mo	µg/g	13.8	1238.5	-	-	3589	-	3.7	6.1	5.2	9.1
Ni	µg/g	23.4	484	-	-	-	189	22.4	**24.2**	22.8	**25.8**
Se	µg/g	1.9	16.1	-	-	-	-	0.5	0.6	0.5	0.6
Zn	µg/g	-	-	123	315	-	-	64.1	75.2	67.4	82.4

COPC	Units	SQG						JSL-3		JSL-4	
		Thompson		CCME		Liber					
		LEL	SEL	ISQG	PEL	NOEC	IC25	Mean	95th	Mean	95th
U	µg/g	104.4	5874.1	-	-	-	964	2.7	3.5	2.7	3.6
Th-230	Bq/g	-	-	-	-	-	-	0.04	0.05	0.04	0.05
Pb-210	Bq/g	0.9	20.8	-	-	-	-	0.07	0.07	0.07	0.07
Ra-226	Bq/g	0.6	14.4	-	-	-	-	0.04	0.04	0.04	0.04
Po-210	Bq/g	0.8	12.1	-	-	-	-	0.07	0.07	0.07	0.07
As	µg/g	9.8	346.4	5.9	17	**-**	174	**8.6**	**10.3**	**8.5**	**10.2**
Cd	µg/g	-	-	0.6	3.5	-	-	0.2	0.2	0.2	0.2
Co	µg/g	-	-	-	-	-	-	6.4	6.6	6.3	6.6
Cu	µg/g	22.2	268.8	35.7	197	-	-	21.5	**23.6**	21.7	**24.5**
Pb	µg/g	36.7	412.4	35	91.3	-	-	9.4	10.1	9.5	10.2
Mo	µg/g	13.8	1238.5	-	-	3589	-	4.4	7.2	3.8	6.0
Ni	µg/g	23.4	484	-	-	-	189	22.5	**25.3**	22.6	**25.8**
Se	µg/g	1.9	16.1	-	-	-	-	0.5	0.6	0.5	0.6
Zn	µg/g	-	-	123	315	-	-	64.7	78.9	66.9	84.0

Table 7.3-2 Maximum Predicted Mean and 95th Percentile Sediment Concentrations

COPC	Units	SQG						JSL-5		JSL-6	
		Thompson		CCME		Liber					
		LEL	SEL	ISQG	PEL	NOEC	IC25	Mean	95th	Mean	95th
U	µg/g	104.4	5874.1	-	-	-	964	2.8	3.7	2.7	2.8
Th-230	Bq/g	-	-	-	-	-	-	0.04	0.05	0.04	0.05
Pb-210	Bq/g	0.9	20.8	-	-	-	-	0.07	0.07	0.07	0.07
Ra-226	Bq/g	0.6	14.4	-	-	-	-	0.04	0.05	0.04	0.04
Po-210	Bq/g	0.8	12.1	-	-	-	-	0.07	0.07	0.07	0.07
As	µg/g	9.8	346.4	5.9	17	**-**	174	**8.4**	**10.0**	**8.2**	**8.7**
Cd	µg/g	-	-	0.6	3.5	-	-	0.2	0.2	0.2	0.2
Co	µg/g	-	-	-	-	-	-	6.2	6.4	5.6	5.6
Cu	µg/g	22.2	268.8	35.7	197	-	-	22.0	**25.0**	21.7	**23.9**
Pb	µg/g	36.7	412.4	35	91.3	-	-	9.6	10.3	9.4	9.4
Mo	µg/g	13.8	1238.5	-	-	3589	-	3.3	4.8	2.3	3.2
Ni	µg/g	23.4	484	-	-	-	189	22.7	**26.1**	22.4	**24.0**
Se	µg/g	1.9	16.1	-	-	-	-	0.4	0.6	0.4	0.5
Zn	µg/g	-	-	123	315	-	-	69.2	87.8	63.3	74.4
COPC	**Units**	**SQG**						**JSL-7**		**JSL-8**	
		Thompson		**CCME**		**Liber**					
		LEL	**SEL**	**ISQG**	**LEL**	**NOEC**	**IC25**	**Mean**	**95th**	**Mean**	**95th**
U	µg/g	104.4	5874.1	-	-	-	964	2.9	3.3	3.5	4.3
Th-230	Bq/g	-	-	-	-	-	-	0.05	0.06	0.04	0.06
Pb-210	Bq/g	0.9	20.8	-	-	-	-	0.07	0.08	0.07	0.07
Ra-226	Bq/g	0.6	14.4	-	-	-	-	0.04	0.05	0.04	0.05
Po-210	Bq/g	0.8	12.1	-	-	-	-	0.07	0.08	0.07	0.07
As	µg/g	9.8	346.4	5.9	17	**-**	174	**8.5**	**9.7**	**8.3**	**9.1**
Cd	µg/g	-	-	0.6	3.5	-	-	0.2	0.2	0.2	0.2
Co	µg/g	-	-	-	-	-	-	5.6	5.7	5.6	5.6
Cu	µg/g	22.2	268.8	35.7	197	-	-	**23.7**	**26.4**	22.1	**24.5**
Pb	µg/g	36.7	412.4	35	91.3	-	-	9.4	9.8	9.4	9.4
Mo	µg/g	13.8	1238.5	-	-	3589	-	2.3	2.9	3.0	4.6
Ni	µg/g	23.4	484	-	-	-	189	**23.8**	**26.7**	22.5	**24.6**
Se	µg/g	1.9	16.1	-	-	-	-	0.5	0.7	0.4	0.6
Zn	µg/g	-	-	123	315	-	-	76.1	95.2	65.9	77.8
Note: **BOLD SHADED** values exceed the LEL/ISQG sediment guidelines.											

7.4 Predicted Soil Quality

Using the soil model described in Section 2.9.1, soil concentrations were predicted for the duration of the assessment at various locations around the Project area. Table 7.4-1 presents a summary of the maximum predicted mean and 95th percentile soil concentrations over the duration of the assessment for the Kiggavik site, LAA, RAA, and Baker Lake areas. The soil quality guidelines (SQG) for agricultural and residential/parkland from CCME (1999) are also provided in Table 7.4-1. All predicted soil concentrations are below the available SQG in all phases of the assessment. Soil baseline concentrations are also provided in Table 7.4-1 to illustrate that there is very little change in soil concentrations predicted as a result of the Project.

Table 7.4-1 Maximum Predicted Mean and 95th Percentile Soil Concentrations

		SQG		Baseline	Predicted Soil Concentrations							
					Kiggavik Camp		LAA		RAA		Baker Lake	
COPC	Units	Ag.	Res/Prk		Mean	95th	Mean	95th	Mean	95th	Mean	95th
U	µg/g	23	23	1.2	1.3	1.4	1.2	1.3	1.2	1.3	1.2	1.3
Th-230	Bq/g	-	-	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
Pb-210	Bq/g	-	-	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Ra-226	Bq/g	-	-	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
Po-210	Bq/g	-	-	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
As	µg/g	12	12	3.8	3.8	4.2	3.8	4.2	3.8	4.2	3.8	4.2
Cd	µg/g	1.4	10	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Co	µg/g	40	50	4.0	4.0	4.4	4.0	4.4	4.0	4.4	4.0	4.4
Cu	µg/g	63	63	8.9	9.0	9.9	9.0	9.9	9.0	9.9	9.0	9.9
Pb	µg/g	70	140	13.7	13.7	15.1	13.7	15.1	13.7	15.1	13.7	15.1
Mo	µg/g	5	10	1.8	1.8	2.0	1.8	2.0	1.8	2.0	1.8	2.0
Ni	µg/g	50	50	12.4	12.4	13.7	12.4	13.7	12.4	13.7	12.4	13.7
Se	µg/g	1	1	0.8	0.8	0.9	0.8	0.9	0.8	0.9	0.8	0.9
Zn	µg/g	200	200	14.2	14.2	15.7	14.2	15.7	14.2	15.7	14.2	15.7
Note: Soil Quality Guidelines (SQG) for Agricultural and Residential/Parkland from CCME (1999).												

7.5 Predicted Terrestrial Vegetation Quality

7.5.1 Exposure to COPC

Terrestrial vegetation concentrations were predicted for the assessment period using the terrestrial vegetation model described in Section 2.9.3. Tables 7.5-1 through 7.5-4 present the maximum predicted mean and 95th percentile lichen, browse, forage, and berry concentrations for the Kiggavik site, LAA, RAA, and Baker Lake areas over the assessment period. The predicted concentrations of browse and forage are compared to concentrations that are associated with phytotoxicity.

All predicted browse and forage concentrations are below the available phytotoxic benchmarks, with the exception of predicted zinc concentrations in browse and forage and cobalt and copper in browse at the four assessment locations. The values that are above the benchmark are attributable due to baseline levels; the project emissions are having little affect on the concentrations as shown by a comparison of the mean values at different locations provided in the table. This indicates that no change is expected on vegetation as a result of emissions from the Project for these COPC and thus no adverse effects are expected.

There is a lack of available phytotoxicity values for some COPC in browse and forage as well as for lichen and berries. For browse, forage and berries, with the exception of uranium at the Kiggavik camp site, there is expected to be little change between the measured baseline concentrations and the Project increment. This indicates that no change is expected on vegetation as a result of emissions from the Project for these COPC. In addition, all predicted soil concentrations, including uranium, are expected to be below the available Soil Quality Guidelines, which are set to protect vegetation. Thus, no adverse effects on vegetation are expected.

For lichen, there is the potential for a measureable change in concentration of several COPC at the Kiggavik camp (used to represent on-site vegetation). Unfortunately there are no appropriate benchmarks in which to judge the potential for an effect. Lichens exhibit a range of tolerances to metals. Some species of Cladonia, Peltigera, and Stereocaulon can tolerate high levels of metals, and may even be found growing on mining spoils or other metal-enriched substrates (USDA Forest Service 2011). To place the results in context, the estimated lichen concentrations were compared to measurements collected from exposed areas near another uranium mine site (McClean). In general, with the exception of on-site locations the estimated concentration is either close to baseline or within the range experienced at other sites. A formal evaluation of the health of lichen at the McClean site has not been undertaken but there is a relative abundance of reindeer lichen at exposure sites and field staff have not reported any obvious signs of stress. Based on the available information, it is not expected that there would be widespread effects on lichen; however, it is uncertain whether there will be any effects on lichen on the Kiggavik Project site due to metal accumulation. The potential food-chain impacts for animals that consume lichen is addressed in Section 8.

Table 7.5-1 Maximum Predicted Mean and 95th Percentile Lichen Concentrations

COPC	Units	Phytotoxic Concentration[a]		Baseline	Predicted Lichen Concentrations							
					Kiggavik Camp		LAA		RAA		Baker Lake	
		dw	ww		Mean	95th	Mean	95th	Mean	95th	Mean	95th
U	µg/g ww	-	-	0.03	43.9	121	3.5	9.7	0.7	2.0	0.1	0.2
Th-230	Bq/g ww	-	-	0.001	0.10	0.27	0.008	0.02	0.002	0.01	0.001	0.002
Pb-210	Bq/g ww	-	-	0.37	1.0	2.3	0.42	1.0	0.38	0.9	0.37	0.9
Ra-226	Bq/g ww	-	-	0.001	0.22	0.53	0.02	0.04	0.00	0.01	0.001	0.00
Po-210	Bq/g ww	-	-	0.61	2.9	7.7	0.79	2.1	0.65	1.68	0.61	1.57
As	µg/g ww	-	-	0.23	0.3	0.9	0.3	0.6	0.2	0.6	0.2	0.6
Cd	µg/g ww	-	-	0.27	7.0	17.8	1.7	4.2	0.6	1.4	0.3	0.7
Co	µg/g ww	-	-	0.53	4.2	10.5	0.9	2.2	0.6	1.5	0.5	1.3
Cu	µg/g ww	-	-	2.3	2.4	6.0	2.3	5.9	2.3	5.8	2.3	5.8
Pb	µg/g ww	-	-	0.44	0.9	2.4	0.5	1.2	0.4	1.2	0.4	1.2
Mo	µg/g ww	-	-	0.09	0.3	0.7	0.1	0.3	0.1	0.2	0.1	0.2
Ni	µg/g ww	-	-	1.3	8.0	21.1	2.1	5.3	1.4	3.4	1.3	3.1
Se	µg/g ww	-	-	0.24	0.4	1.2	0.3	0.7	0.2	0.7	0.2	0.7
Zn	µg/g ww	-	-	22.4	27	76	23	64	22	63	22	63

Note:
a = no applicable phytotoxic concentrations available for lichen.

Table 7.5-2 Maximum Predicted Mean and 95th Percentile Browse Concentrations

COPC	Units	Phytotoxic Concentration dw	Phytotoxic Concentration ww [a]	Baseline	Predicted Browse Concentrations: Kiggavik Camp Mean	Kiggavik Camp 95th	LAA Mean	LAA 95th	RAA Mean	RAA 95th	Baker Lake Mean	Baker Lake 95th
U	µg/g ww	-	-	0.001	0.020	0.044	0.003	0.005	0.002	0.004	0.001	0.004
Th-230	Bq/g ww	-	-	0.0003	0.0006	0.0011	0.0004	0.0007	0.0003	0.0007	0.0003	0.0007
Pb-210	Bq/g ww	-	-	0.04	0.04	0.07	0.04	0.07	0.04	0.07	0.04	0.07
Ra-226	Bq/g ww	-	-	0.001	0.0017	0.003	0.0014	0.003	0.0014	0.003	0.0014	0.003
Po-210	Bq/g ww	-	-	0.04	0.04	0.08	0.04	0.07	0.04	0.07	0.04	0.07
As	µg/g ww	3 [b]	1.4	0.20	0.2	1.0	0.2	1.0	0.2	1.0	0.2	1.0
Cd	µg/g ww	5 [b,c]	2.3	0.44	0.4	1.1	0.4	1.1	0.4	1.1	0.4	1.1
Co	µg/g ww	3 [d]	1.4	0.60	0.60	**2.4**	0.60	**2.4**	0.60	**2.4**	0.60	**2.4**
Cu	µg/g ww	25 [b]	10.5	6.7	6.8	**15.1**	6.8	**15.1**	6.8	**15.1**	6.8	**15.1**
Pb	µg/g ww	20 [d]	9.3	0.25	0.3	0.6	0.2	0.6	0.2	0.6	0.2	0.6
Mo	µg/g ww	10 [c]	4.7	0.46	0.5	1.9	0.5	1.9	0.5	1.9	0.5	1.9
Ni	µg/g ww	50 [b]	21	1.7	1.7	6.1	1.7	6.1	1.7	6.1	1.7	6.1
Se	µg/g ww	-	-	0.01	0.01	0.04	0.01	0.04	0.01	0.04	0.01	0.04
Zn	µg/g ww	100 [c]	47	**170**	**170**	**390**	**170**	**390**	**170**	**390**	**170**	**390**

Note: **BOLD SHADED** values exceed the phytotoxic levels.

a = dry weight (dw) concentrations converted to wet weight (ww) concentrations using an assumed moisture content of 53%.

b = Phytotoxic conc. In plant foliage. Langmuir, D., P. Chrostowski, B. Vigneault and R. Chaney 2004. Issue Paper on the Environmental Chemistry of Metals. Submitted to U.S. Environmental Protection Agency, Risk Assessment Forum, Washington, DC. ERG, Lexington, MA.

c = Leaf tissue concentration in plants that are neither sensitive or tolerant McBride, M.B. 1994 Environmental Chemistry of Soils. Oxford University Press Inc. New York, NY.

d = Upper Critical Level in leaves and shoots of spring barley associated with reduced yield. Davis, R.D., P.H.T. Beckett and E. Wollan 1978. Critical Levels of Twenty Potentially Toxic Elements in Young Spring Barley. Plant Soil 49: 395-408.

Table 7.5-3 Maximum Predicted Mean and 95th Percentile Forage Concentrations

COPC	Units	Phytotoxic Concentration		Baseline	Predicted Forage Concentrations							
					Kiggavik Camp		LAA		RAA		Baker Lake	
		dw	ww [a]		Mean	95th	Mean	95th	Mean	95th	Mean	95th
U	µg/g ww	-	-	0.08	0.10	0.3	0.08	0.3	0.08	0.3	0.08	0.3
Th-230	Bq/g ww	-	-	0.01	0.01	0.03	0.01	0.03	0.01	0.03	0.01	0.03
Pb-210	Bq/g ww	-	-	0.15	0.15	0.54	0.15	0.54	0.15	0.54	0.15	0.54
Ra-226	Bq/g ww	-	-	0.01	0.01	0.02	0.01	0.02	0.01	0.02	0.01	0.02
Po-210	Bq/g ww	-	-	0.07	0.07	0.21	0.07	0.21	0.07	0.21	0.07	0.21
As	µg/g ww	3 [b]	1.4	0.07	0.07	0.3	0.07	0.3	0.07	0.3	0.07	0.3
Cd	µg/g ww	5 [b,c]	2.3	0.08	0.08	0.2	0.08	0.2	0.08	0.2	0.08	0.2
Co	µg/g ww	3 [d]	1.4	0.21	0.21	0.7	0.21	0.7	0.21	0.7	0.21	0.7
Cu	µg/g ww	25 [b]	10.5	3.0	3.1	7.5	3.1	7.5	3.1	7.5	3.1	7.5
Pb	µg/g ww	20 [d]	9.3	0.36	0.36	1.2	0.36	1.2	0.36	1.2	0.36	1.2
Mo	µg/g ww	10 [c]	4.7	0.66	0.66	2.3	0.66	2.3	0.66	2.3	0.66	2.3
Ni	µg/g ww	50 [b]	21	1.3	1.3	4.2	1.3	4.2	1.3	4.2	1.3	4.2
Se	µg/g ww	-	-	0.20	0.20	0.4	0.20	0.4	0.20	0.4	0.20	0.4
Zn	µg/g ww	100 [c]	47	19.4	19.4	**49.9**	19.4	**49.9**	19.4	**49.9**	19.4	**49.9**

Note: **BOLD SHADED** values exceed the phytotoxic levels.

a = dry weight (dw) concentrations converted to wet weight (ww) concentrations using an assumed moisture content of 53%.

b = Phytotoxic conc. In plant foliage. Langmuir, D., P. Chrostowski, B. Vigneault and R. Chaney 2004. Issue Paper on the Environmental Chemistry of Metals. Submitted to U.S. Environmental Protection Agency, Risk Assessment Forum, Washington, DC. ERG, Lexington, MA.

c = Leaf tissue concentration in plants that are neither sensitive or tolerant McBride, M.B. 1994 Environmental Chemistry of Soils. Oxford University Press Inc. New York, NY.

d = Upper Critical Level in leaves and shoots of spring barley associated with reduced yield. Davis, R.D., P.H.T. Beckett and E. Wollan 1978. Critical Levels of Twenty Potentially Toxic Elements in Young Spring Barley. Plant Soil 49: 395-408.

Table 7.5-4 Maximum Predicted Mean and 95th Percentile Berry Concentrations

COPC	Units	Phytotoxic Concentration[a] dw	Phytotoxic Concentration[a] ww	Baseline	Kiggavik Camp Mean	Kiggavik Camp 95th	LAA Mean	LAA 95th	RAA Mean	RAA 95th	Baker Lake Mean	Baker Lake 95th
U	µg/g ww	-	-	0.002	0.1	0.4	0.01	0.04	0.004	0.01	0.002	0.004
Th-230	Bq/g ww	-	-	0.001	0.003	0.008	0.001	0.006	0.001	0.006	0.001	0.006
Pb-210	Bq/g ww	-	-	0.002	0.004	0.008	0.002	0.004	0.002	0.004	0.002	0.004
Ra-226	Bq/g ww	-	-	0.0002	0.002	0.005	0.0004	0.0008	0.0002	0.0007	0.0002	0.0007
Po-210	Bq/g ww	-	-	0.001	0.003	0.007	0.001	0.002	0.001	0.002	0.001	0.002
As	µg/g ww	-	-	0.03	0.03	0.09	0.03	0.09	0.03	0.09	0.03	0.09
Cd	µg/g ww	-	-	0.02	0.04	0.07	0.02	0.06	0.02	0.05	0.02	0.05
Co	µg/g ww	-	-	0.04	0.04	0.10	0.04	0.09	0.04	0.09	0.04	0.09
Cu	µg/g ww	-	-	1.5	1.6	4.7	1.6	4.7	1.6	4.7	1.6	4.7
Pb	µg/g ww	-	-	0.05	0.06	0.1	0.05	0.1	0.05	0.1	0.05	0.1
Mo	µg/g ww	-	-	0.08	0.09	0.3	0.08	0.3	0.08	0.3	0.08	0.3
Ni	µg/g ww	-	-	0.60	0.61	2.0	0.60	2.0	0.60	2.0	0.60	2.0
Se	µg/g ww	-	-	0.004	0.004	0.013	0.004	0.013	0.004	0.013	0.004	0.013
Zn	µg/g ww	-	-	14.9	14.9	49.2	14.9	49.2	14.9	49.2	14.9	49.2

Note:
a = no applicable phytotoxic concentrations available for berry.

Table 7.5-5 Comparison of Lichen Concentrations to Other Locations

COPC	Units	Average Estimated Lichen Concentration					Average Measured Lichen Concentration		
		Baseline	Kiggavik Camp	LAA	RAA	Baker Lake	JEB	McClean	Sue
U	µg/g ww	0.03	43.9	3.5	0.7	0.1	1.3	3.2	8.4
Th-230	Bq/g ww	0.001	0.10	0.008	0.002	0.001	0.015	0.04	0.1
Pb-210	Bq/g ww	0.37	1.0	0.42	0.38	0.37	0.19	0.21	0.3
Ra-226	Bq/g ww	0.001	0.22	0.02	0.00	0.001	0.018	0.05	0.2
Po-210	Bq/g ww	0.61	2.9	0.79	0.65	0.61	0.17	0.18	0.3
As	µg/g ww	0.23	0.3	0.3	0.2	0.2	0.3	2.4	4.9
Cd	µg/g ww	0.27	7.0	1.7	0.6	0.3	0.03	0.05	0.06
Co	µg/g ww	0.53	4.2	0.9	0.6	0.5	0.04	0.1	0.2
Cu	µg/g ww	2.3	2.4	2.3	2.3	2.3	0.5	0.9	1.0
Pb	µg/g ww	0.44	0.9	0.5	0.4	0.4	0.2	1.8	3.2
Mo	µg/g ww	0.09	0.3	0.1	0.1	0.1	0.1	0.3	0.7
Ni	µg/g ww	1.3	8.0	2.1	1.4	1.3	0.5	3.1	6.0
Se	µg/g ww	0.24	0.4	0.3	0.2	0.2	0.04	0.05	0.06
Zn	µg/g ww	22.4	27	23	22	22	6.7	7.0	7.7

7.5.2 Exposure to NO_x and SO_2

Appendix 4B Air Quality described the air quality modelling completed for the assessment. The maximum incremental concentrations of NO_2 and SO_2 are presented inTable 7.5-6. Also shown in the table are levels associated with effects on vegetation provided by the World Health Organization (WHO).

Table 7.5-6 Assessment of Potential Effects on Vegetation Due to NO_2 and SO_2

Receptor Name	NO_2 (µg/m^3)	SO_2 (µg/m^3)	
	Incremental Annual Maximum	**Incremental 24-hr Maximum**	**Incremental Annual Maximum**
Accommodation Complex	10.4	15.4	0.6
Judge Sissons Lake Cabin	0.80	0.8	0.03
Community of Baker Lake	0.04	0.04	0.001
Phytotoxicity Benchmark (µg/m^3)	19	100	20[a] 10

Note:

Annual concentrations were obtained from Period 2 which had the highest SO_2 and NO_x emission rates. During this period there is open pit mining of Main Zone West pit at Kiggavik and Andrew Lake at Sissons as well as the milling of ores from East Zone, Centre Zone and Main Zone pits.

* The phytotoxicity values for NOx (annual average of 30 µg/m^3) have been converted to a NO_2 concentration (assuming NO_2 represents 63% of NOx) for comparison to model results.

a 20 µg/m^3 is selected for forests and natural vegetation; 10 µg/m^3 is selected for lichen

As can be seen in the table, 24-hour and annual maximum concentrations of SO_2 are well within the limits of applicable criteria. Therefore no effects on vegetation are expected as a result of exposure to SO_2 from the Kiggavik Project. Similarly, annual NO_2 concentrations meet applicable criteria at all of the selected locations.

8 Results for Ecological Risk Assessment

The risk characterization phase combines the information gathered in the exposure and toxicity assessment phases and characterizes the potential for adverse ecological effects.

The risk characterization phase combines the information gathered in the exposure and toxicity assessment phases and characterizes the potential for adverse ecological effects. This section of the report evaluates the risks to ecological species via comparison of exposure levels to toxicity reference values.

Potential toxic effects of COPC can be measured at different levels of biological and ecological organization. In this study, the potential ecological impacts of different COPC on receptors in the aquatic environment were characterized by the calculation of screening index (SI) values. SI values provide an integrated description of the potential hazard, the exposure (or dose) response relationship and the exposure evaluation (U.S. EPA 1992, AIHC 1992). A SI is calculated by dividing the predicted concentration by the selected toxicity reference value for each receptor. It should be noted that the SI values reported in this section are not estimates of the probability of ecological impact. Rather, the SI values are positively correlated with the potential of an effect, that is, higher index values imply greater potential of an effect. A SI value of 1.0 was used to examine the potential adverse effects of COPC as the assessment is based on the application of chronic effects concentration endpoints. SI values less than 1.0 indicate that the predicted levels are below the corresponding benchmarks. Values greater than 1.0 suggest that there is a potential of observing adverse effects on some species. The probabilistic framework for the assessment captures uncertainty in the model inputs and the evaluation of potential effects at the mean and 95th percentile levels provides a range of the conditions that may occur.

The use of a screening index (also can be termed a hazard quotient or risk quotient) approach is common in ecological risk assessments. An SI integrates an understanding of the fate and transport of a contaminant, the exposure of the ecological species and the toxicity of the contaminant. For some COPC only a small change from baseline is acceptable, while for other less toxic COPC wildlife can tolerate larger changes. An SI approach is particularly valuable in predictive assessments where other lines of evidence are unavailable.

8.1 Aquatic Receptors

The aquatic receptors chosen for the assessment represent several trophic levels in aquatic ecosystems. The chronic effects concentration endpoints for the aquatic species are generally equivalent to an EC_{20} (see Section 6.3). The aquatic SI values for all species were estimated for the chosen assessment locations for the predicted mean (most expected) and 95th percentile (upper bound) COPC concentrations in the receiving waters.

8.1.1 Exposure to Non-Radioactive Constituents

Aquatic SI values were calculated for each of segment of Judge Sissons Lake and are summarized in Table 8.1-1. The maximum predicted mean and 95th percentile water concentrations over the assessment period in each segment were used for the calculation of the SI values. Therefore, the SI values presented in Table 8.1-1 represent the predicted worst-case results over the entire Project.

The **bold shading** in Table 8.1-1 indicates SI values that are above 1.0. Aquatic SI values were calculated using the maximum monthly mean and 95th percentile predicted concentrations. All COPC have predicted SI values less than 1.0 for all segments of Judge Sissons Lake, with the exception of cadmium for zooplankton, copper for benthic invertebrates, zooplankton, predator fish, and forage fish, zinc for phytoplankton, benthic invertebrates, zooplankton, predator fish and forage fish, and sulphate for zooplankton.

The exceedances of the selected benchmarks for copper and zinc in JSL-7 are due to baseline concentrations in the area. There is no difference between the mean and 95th percentile SI values because the effluent discharge from the Project has little impact on the predicted water concentrations. JSL-7 is a shallow segment and therefore experiences the largest variation between summer and winter concentrations (Figure 7.2-1). As discussed, aquatic SI values were calculated using the maximum monthly mean and 95th percentile predicted concentrations. Due to winter ice cover, water concentrations during the winter months are predicted to increase because of a reduced volume of free-flowing water. Therefore, the winter concentrations in JSL-7 are the highest and a potential issue was identified in this segment although it reflects baseline conditions.

The release of treated effluent to Judge Sissons Lake does affect the expected concentration of cadmium. As seen in Table 8.1-1 a potential issue for zooplankton exposure to cadmium was identified in all segments of Judge Sissons Lake. An important consideration in the determination of the potential toxicity of cadmium is the hardness. The natural condition of Judge Sissons Lake is very low hardness water. However, as shown in Figure 7.2-1 the release of treated effluent will raise the hardness to 100 to 200 mg/L. Under these conditions the toxicity of cadmium will be ameliorated. At a hardness of 100 mg/L the lowest toxicity value for zooplankton available (USGS 2010) is 0.23 µg/L. The SI values for cadmium exposure to zooplankton based on this TRV is shown in Table 8.1-2. This table shows that there are still some potential issues as SI values above 1 are identified for JSL-2 and JSL-3 at the maximum 95th percentile predicted concentrations; however the magnitude of the potential effect is less and these segments represent 11% of the total lake area. As shown in Table 7.2-1, the concentration of cadmium in the summer is expected to remain below the applicable water quality guideline. Only the 95th percentile concentration in winter could exceed the applicable guideline. During the winter zooplankton are expected to be present as eggs and thus would not be as affected by exposure to cadmium. Overall, it is not expected that there would be any effect on biota in Judge Sisson Lake.

Table 8.1-2 also identified some potential for effects to zooplankton due to exposure to sulphate in JSL-3 and JSL-4 (95th percentile only). The largest SI value is 1.3 for the 95th percentile in JSL-3.

Hardness has an ameliorating effect on sulphate toxicity and this was demonstrated in the recent review of information and derivation of guidelines completed by the BC MOE (2013). Based on consideration of the marginal exceedance of a non-hardness adjusted TRV and that sulphate levels are expected to meet the BC WQG, no effects are expected due to the presence of sulphate.

The toxicity reference values for selenium are for exposure to water only. Exposures for bioaccumulative COPC such as selenium can occur through pathways other than water alone and may be related primarily to the diet. Because it is recognized that selenium has the ability to bioaccumulate through aquatic food webs, a comparison to a fish tissue concentration of 2 µg/g (ww) (U.S.EPA 2004) was done. Predicted fish concentrations in the segments of Judge Sissons Lake are presented in Table 8.1-3. As seen from Table 8.1-3, all selenium concentrations are below a value of 2 µg/g (ww), indicating that there are no potential effects in fish due to bioaccumulation of selenium. It is noted that the U.S. EPA recently revised the values used in the assessment of selenium exposure to aquatic biota (U.S. EPA 2014). In lentic systems (i.e., lakes) a value of 1.3 µg/L is provided as a comparison point. The predicted water concentrations are below this value. The fish tissue concentration was revised to 11.8 µg/g dry weight (2.4 µg/g ww), which is similar to the value selected for this assessment.

As selenium levels in the discharge are low, there is little change to the concentration of selenium predicted for Judge Sissons Lake and the fish are assumed, based on field data, to be able to regulate the uptake of selenium within this range. Figure 8.1-1 provides a comparison between the predictions from the hockey stick model and the measured fish concentrations for selenium from samples collected from northern Saskatchewan and the local area. From this figure it is apparent that selenium concentrations in fish are expected to be relatively constant below a water concentration of approximately 0.4 µg/L. On average, the concentrations in Judge Sissons Lake are below this concentration. Similar behaviour has been observed by others (e.g., Brix et al. 2005). This behavior has been attributed to the fact that selenium is an essential element and will therefore be actively regulated over a range of concentrations. Therefore, the concentrations shown in Table 8.1-3 for selenium in fish are similar in all segments of the lake and are based on the minimum fish concentration shown in Table 5.1-3.

Table 8.1-1 Predicted Aquatic Screening Index Values for Non-Radioactive Constituents

	JSL-1		JSL-2		JSL-3		JSL-4		JSL-5		JSL-6		JSL-7		JSL-8	
	Mean	95th	Mean	95th	Mean	95th	Mean	95th	Mean	95th	Mean	95th	Mean	95th	Mean	95th
Uranium																
Aquatic Plants	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Phytoplankton	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Benthic Invertebrates	<0.01	0.01	<0.01	0.01	<0.01	0.01	<0.01	0.01	<0.01	0.01	<0.01	0.01	0.05	0.07	0.03	0.05
Zooplankton	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.02	0.03	0.01	0.02
Predator Fish	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Forage Fish	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Arsenic																
Aquatic Plants	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Phytoplankton	0.12	0.15	0.10	0.13	0.08	0.12	0.08	0.10	0.08	0.10	0.08	0.09	0.42	0.45	0.14	0.17
Benthic Invertebrates	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.02	0.02	<0.01	<0.01
Zooplankton	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Predator Fish	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Forage Fish	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.02	0.02	<0.01	<0.01
Cadmium																
Aquatic Plants	<0.01	<0.01	0.01	0.02	0.01	0.02	<0.01	0.01	<0.01	0.01	<0.01	<0.01	<0.01	0.01	<0.01	<0.01
Phytoplankton	0.03	0.05	0.06	0.09	0.05	0.09	0.05	0.07	0.04	0.07	0.02	0.03	0.04	0.07	0.02	0.03
Benthic Invertebrates	0.20	0.31	0.34	0.53	0.32	0.57	0.28	0.44	0.23	0.40	0.10	0.17	0.22	0.40	0.11	0.20
Zooplankton	**1.44**	**2.24**	**2.40**	**3.81**	**2.30**	**4.06**	**2.01**	**3.13**	**1.67**	**2.88**	0.73	**1.23**	**1.59**	**2.85**	0.81	**1.44**
Predator Fish	0.17	0.26	0.28	0.44	0.27	0.47	0.23	0.37	0.19	0.34	0.09	0.14	0.19	0.33	0.09	0.17
Forage Fish	0.01	0.02	0.02	0.04	0.02	0.04	0.02	0.03	0.02	0.03	<0.01	0.01	0.02	0.03	<0.01	0.01
Cobalt																
Aquatic Plants	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.01	0.01	<0.01	<0.01
Phytoplankton	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Benthic Invertebrates	0.04	0.06	0.03	0.05	0.03	0.03	0.02	0.03	0.03	0.03	0.03	0.03	0.16	0.16	0.05	0.05
Zooplankton	0.04	0.05	0.03	0.04	0.02	0.03	0.02	0.02	0.02	0.02	0.02	0.03	0.13	0.13	0.04	0.04
Predator Fish	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Forage Fish	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Copper																
Aquatic Plants	0.05	0.05	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.04	0.04	0.21	0.21	0.06	0.06
Phytoplankton	0.19	0.19	0.12	0.12	0.11	0.11	0.11	0.11	0.12	0.12	0.16	0.16	0.85	0.85	0.24	0.24
Benthic Invertebrates	0.44	0.44	0.28	0.28	0.25	0.25	0.25	0.25	0.28	0.28	0.36	0.36	**1.95**	**1.95**	0.55	0.55
Zooplankton	0.43	0.43	0.27	0.27	0.24	0.24	0.24	0.24	0.28	0.28	0.35	0.35	**1.90**	**1.90**	0.54	0.54
Predator Fish	0.44	0.44	0.28	0.28	0.25	0.25	0.25	0.25	0.28	0.28	0.36	0.36	**1.95**	**1.95**	0.55	0.55
Forage Fish	0.29	0.29	0.18	0.19	0.16	0.17	0.17	0.17	0.19	0.19	0.24	0.24	**1.30**	**1.30**	0.37	0.37
Lead																
Aquatic Plants	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01

Table 8.1-1 Predicted Aquatic Screening Index Values for Non-Radioactive Constituents

	JSL-1		JSL-2		JSL-3		JSL-4		JSL-5		JSL-6		JSL-7		JSL-8	
	Mean	95th	Mean	95th	Mean	95th	Mean	95th	Mean	95th	Mean	95th	Mean	95th	Mean	95th
Phytoplankton	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Benthic Invertebrates	0.23	0.25	0.15	0.18	0.13	0.15	0.13	0.14	0.15	0.16	0.18	0.19	0.98	0.98	0.28	0.28
Zooplankton	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.02	0.02	<0.01	<0.01
Predator Fish	0.02	0.02	0.01	0.01	<0.01	0.01	<0.01	0.01	0.01	0.01	0.01	0.01	0.07	0.07	0.02	0.02
Forage Fish	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Molybdenum																
Aquatic Plants	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Phytoplankton	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Benthic Invertebrates	0.01	0.02	0.01	0.02	0.01	0.02	<0.01	0.02	<0.01	0.02	<0.01	<0.01	0.01	0.03	<0.01	0.02
Zooplankton	0.01	0.02	0.02	0.03	0.01	0.02	0.01	0.02	<0.01	0.02	<0.01	<0.01	0.02	0.03	0.01	0.02
Predator Fish	0.02	0.03	0.02	0.03	0.02	0.03	0.01	0.02	0.01	0.02	<0.01	0.01	0.02	0.03	0.01	0.02
Forage Fish	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Nickel																
Aquatic Plants	0.02	0.02	0.01	0.01	0.01	0.01	<0.01	0.01	0.01	0.01	0.01	0.01	0.07	0.07	0.02	0.02
Phytoplankton	0.01	0.02	0.01	0.01	<0.01	0.01	<0.01	<0.01	<0.01	0.01	0.01	0.01	0.06	0.06	0.02	0.02
Benthic Invertebrates	0.03	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.11	0.11	0.03	0.03
Zooplankton	0.04	0.04	0.03	0.03	0.02	0.03	0.02	0.02	0.02	0.03	0.03	0.03	0.15	0.16	0.04	0.04
Predator Fish	0.02	0.02	0.02	0.02	0.01	0.02	0.01	0.01	0.01	0.02	0.02	0.02	0.09	0.10	0.03	0.03
Forage Fish	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.01	0.01	<0.01	<0.01
Selenium																
Aquatic Plants	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Phytoplankton	<0.01	0.01	<0.01	0.01	<0.01	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.03	0.03	<0.01	0.01
Benthic Invertebrates	0.03	0.03	0.03	0.03	0.02	0.03	0.02	0.03	0.02	0.03	0.02	0.02	0.10	0.11	0.03	0.03
Zooplankton	0.03	0.03	0.03	0.03	0.02	0.03	0.02	0.03	0.02	0.03	0.02	0.02	0.10	0.11	0.03	0.03
Predator Fish	n/a[a]	n/a[a]	n/a[a]	n/a[a]	n/a[a]	n/a[a]	n/a[a]	n/a[a]	n/a[a]	n/a[a]	n/a[a]	n/a[a]	n/a[a]	n/a[a]	n/a[a]	n/a[a]
Forage Fish	n/a[a]	n/a[a]	n/a[a]	n/a[a]	n/a[a]	n/a[a]	n/a[a]	n/a[a]	n/a[a]	n/a[a]	n/a[a]	n/a[a]	n/a[a]	n/a[a]	n/a[a]	n/a[a]
Zinc																
Aquatic Plants	0.08	0.08	0.05	0.05	0.04	0.04	0.04	0.04	0.05	0.05	0.06	0.06	0.34	0.34	0.09	0.09
Phytoplankton	0.29	0.29	0.18	0.19	0.16	0.16	0.17	0.17	0.19	0.19	0.24	0.24	**1.30**	**1.30**	0.37	0.37
Benthic Invertebrates	0.29	0.29	0.18	0.19	0.16	0.16	0.17	0.17	0.19	0.19	0.24	0.24	**1.30**	**1.30**	0.37	0.37
Zooplankton	0.29	0.29	0.18	0.19	0.16	0.16	0.17	0.17	0.19	0.19	0.24	0.24	**1.30**	**1.30**	0.37	0.37
Predator Fish	0.29	0.29	0.18	0.19	0.16	0.16	0.17	0.17	0.19	0.19	0.24	0.24	**1.30**	**1.30**	0.37	0.37
Forage Fish	0.25	0.25	0.16	0.16	0.14	0.14	0.14	0.14	0.16	0.16	0.21	0.21	**1.11**	**1.11**	0.31	0.31
Un-ionized Ammonia																
Aquatic Plants	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Phytoplankton	<0.01	<0.01	<0.01	0.01	<0.01	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01

Table 8.1-1 Predicted Aquatic Screening Index Values for Non-Radioactive Constituents

	JSL-1		JSL-2		JSL-3		JSL-4		JSL-5		JSL-6		JSL-7		JSL-8	
	Mean	95th	Mean	95th	Mean	95th	Mean	95th	Mean	95th	Mean	95th	Mean	95th	Mean	95th
Benthic Invertebrates	0.02	0.04	0.05	0.07	0.06	0.10	0.04	0.06	0.03	0.05	<0.01	0.01	0.02	0.03	0.01	0.02
Zooplankton	0.02	0.03	0.04	0.05	0.05	0.07	0.03	0.05	0.02	0.03	<0.01	<0.01	0.02	0.02	0.01	0.02
Predator Fish	0.03	0.05	0.06	0.10	0.08	0.13	0.05	0.08	0.04	0.06	0.01	0.02	0.03	0.04	0.02	0.03
Forage Fish	0.01	0.02	0.03	0.05	0.04	0.07	0.03	0.04	0.02	0.03	<0.01	<0.01	0.01	0.02	<0.01	0.02
Chloride																
Aquatic Plants	0.02	0.03	0.04	0.05	0.05	0.08	0.05	0.07	0.04	0.05	<0.01	0.01	0.04	0.06	0.03	0.05
Phytoplankton	0.03	0.06	0.09	0.11	0.11	0.17	0.10	0.14	0.08	0.11	0.02	0.02	0.08	0.13	0.06	0.10
Benthic Invertebrates	0.14	0.23	0.36	0.46	0.45	0.71	0.41	0.58	0.32	0.46	0.06	0.10	0.33	0.53	0.24	0.40
Zooplankton	0.07	0.11	0.18	0.23	0.22	0.35	0.20	0.29	0.16	0.23	0.03	0.05	0.16	0.26	0.12	0.20
Predator Fish	0.05	0.09	0.14	0.18	0.18	0.28	0.16	0.23	0.13	0.18	0.02	0.04	0.13	0.21	0.09	0.16
Forage Fish	0.09	0.15	0.23	0.30	0.29	0.46	0.26	0.38	0.21	0.30	0.04	0.06	0.21	0.34	0.15	0.26
Sulphate																
Aquatic Plants	0.09	0.15	0.20	0.26	0.24	0.36	0.21	0.30	0.17	0.23	0.03	0.04	0.08	0.13	0.05	0.09
Phytoplankton	0.06	0.11	0.15	0.19	0.18	0.27	0.16	0.22	0.12	0.17	0.02	0.03	0.06	0.10	0.04	0.07
Benthic Invertebrates	0.07	0.11	0.16	0.20	0.19	0.28	0.17	0.24	0.13	0.18	0.02	0.03	0.06	0.10	0.04	0.07
Zooplankton	0.29	0.49	0.68	0.88	0.81	**1.22**	0.72	**1.01**	0.56	0.77	0.09	0.14	0.28	0.44	0.18	0.30
Predator Fish	0.08	0.13	0.18	0.23	0.21	0.32	0.19	0.27	0.15	0.20	0.02	0.04	0.07	0.12	0.05	0.08
Forage Fish	0.14	0.24	0.33	0.43	0.40	0.60	0.35	0.50	0.27	0.38	0.04	0.07	0.14	0.22	0.09	0.15

Note: **BOLD SHADING** indicates an exceedance of 1.0
a – assessed on the basis of bioaccumulation in flesh, see Table 8.1-3.

Table 8.1-2 SI Values for Cadmium Exposure to Zooplankton, Hardness Adjusted

Segment	Mean	95^{th} Percentile
JSL-1	0.44	0.68
JSL-2	0.73	**1.16**
JSL-3	0.70	**1.23**
JSL-4	0.61	0.95
JSL-5	0.51	0.88
JSL-6	0.22	0.38
JSL-7	0.48	0.87
JSL-8	0.25	0.44

Note: **BOLD SHADING** indicates an exceedance of 1.0
SI values calculated using a TRV of 0.23 µg/L which is based on a hardness of 100 mg/L

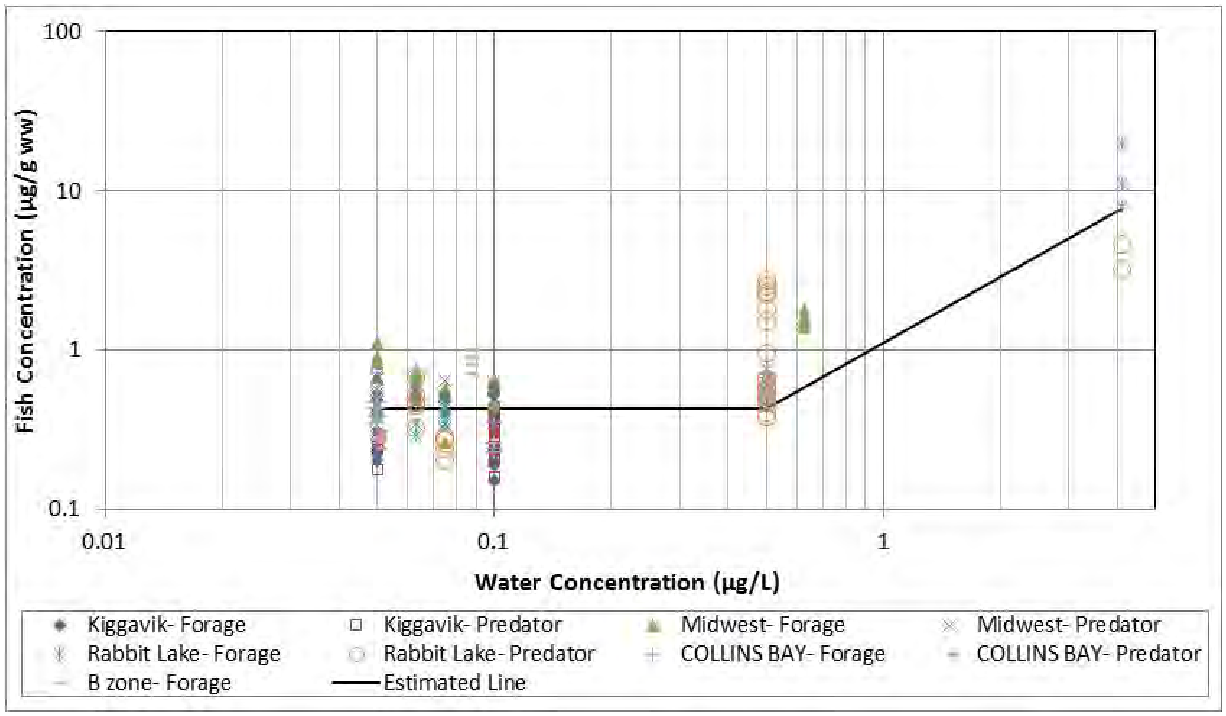


Figure 8.1-1 Comparison of Measured Fish Concentrations and Water Concentrations – Selenium

Table 8.1-3 Predicted Selenium Concentrations in Fish Tissue

Result	Predicted Selenium Concentrations in Fish Tissue (µg/g ww) – Judge Sissons Lake							
	JSL-1	JSL-2	JSL-3	JSL-4	JSL-5	JSL-6	JSL-7	JSL-8
Mean	0.44	0.45	0.45	0.44	0.44	0.43	0.45	0.43
95^{th} Percentile	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80

8.1.2 Radiological Dose

To assess the potential adverse effects of radionuclides to the aquatic environment, the predicted mean and 95th percentile water and sediment concentrations were used to estimate the radiological dose to aquatic receptors in Judge Sissons Lake. The results for dose equivalents calculated with RBE values of 10 and 40 are presented for comparison in Table 8.1-3. Attachment H provides the details of the dose calculation. As presented in Section 6.3.2, the value of 9.6 mGy/d from CSA (2012) was considered for the dose rate guideline for all aquatic receptors. A value greater than 1 indicates that the dose rate guideline for an aquatic receptor is exceeded.

Table 8.1-4 presents the results of the assessment for radiological dose to aquatic receptors. From Table 8.1-4, it can be seen that all calculated doses for aquatic receptors are well below thee dose rate guideline, since the calculated screening index values are all well below 1. The largest screening index value (0.16) was calculated for phytoplankton in JSL-7.The screening index values in Table 8.1-4 represent the maximum predicted exposure over the Project. Therefore, no potential negative effects to aquatic receptors from radiological dose are predicted from the Project.

Table 8.1-4 Results of Radiological Assessment for Aquatic Receptors

	Predicted Screening Index Values	
	RBE=10	
	Average	**95th Percentile**
Baseline		
Predatory Fish	<0.001	<0.001
Forage Fish	<0.001	<0.001
Aquatic Plant - Leaves	<0.001	<0.001
Aquatic Plant - Roots	0.001	0.001
Benthic Invertebrates	0.003	0.003
Phytoplankton	0.016	0.016
Zooplankton	0.004	0.004
JSL-1		
Predatory Fish	<0.001	<0.001
Forage Fish	<0.001	<0.001
Aquatic Plant - Leaves	0.002	0.002
Aquatic Plant - Roots	0.002	0.002
Benthic Invertebrates	0.003	0.004
Phytoplankton	0.035	0.036
Zooplankton	0.008	0.009
JSL-2		
Predatory Fish	<0.001	<0.001
Forage Fish	<0.001	<0.001
Aquatic Plant - Leaves	0.001	0.001
Aquatic Plant - Roots	0.002	0.002
Benthic Invertebrates	0.002	0.003
Phytoplankton	0.022	0.023
Zooplankton	0.005	0.006
JSL-3		
Predatory Fish	<0.001	<0.001
Forage Fish	<0.001	<0.001

Table 8.1-4 Results of Radiological Assessment for Aquatic Receptors

	Predicted Screening Index Values	
	RBE=10	
	Average	95th Percentile
Aquatic Plant - Leaves	0.001	0.001
Aquatic Plant - Roots	0.001	0.002
Benthic Invertebrates	0.002	0.002
Phytoplankton	0.020	0.022
Zooplankton	0.005	0.006
JSL-4		
Predatory Fish	<0.001	<0.001
Forage Fish	<0.001	<0.001
Aquatic Plant - Leaves	0.001	0.001
Aquatic Plant - Roots	0.001	0.002
Benthic Invertebrates	0.002	0.002
Phytoplankton	0.020	0.021
Zooplankton	0.005	0.005
JSL-5		
Predatory Fish	<0.001	<0.001
Forage Fish	<0.001	<0.001
Aquatic Plant - Leaves	0.001	0.001
Aquatic Plant - Roots	0.002	0.002
Benthic Invertebrates	0.002	0.003
Phytoplankton	0.023	0.024
Zooplankton	0.006	0.006
JSL-6		
Predatory Fish	<0.001	<0.001
Forage Fish	<0.001	<0.001
Aquatic Plant - Leaves	0.002	0.002
Aquatic Plant - Roots	0.002	0.002
Benthic Invertebrates	0.003	0.003
Phytoplankton	0.028	0.029
Zooplankton	0.007	0.007
JSL-7		
Predatory Fish	0.002	0.002
Forage Fish	0.002	0.002
Aquatic Plant - Leaves	0.009	0.009
Aquatic Plant - Roots	0.010	0.010
Benthic Invertebrates	0.015	0.016

Table 8.1-4 Results of Radiological Assessment for Aquatic Receptors

	Predicted Screening Index Values	
	RBE=10	
	Average	**95th Percentile**
Phytoplankton	0.155	0.162
Zooplankton	0.037	0.040
JSL-8		
Predatory Fish	<0.001	<0.001
Forage Fish	<0.001	<0.001
Aquatic Plant - Leaves	0.003	0.003
Aquatic Plant - Roots	0.003	0.003
Benthic Invertebrates	0.005	0.006
Phytoplankton	0.045	0.052
Zooplankton	0.011	0.013

8.2 Terrestrial Receptors

This section presents the results of the risk characterization for terrestrial receptors assessed in the study area. In the assessment of risks to the terrestrial receptors, both aquatic and terrestrial exposure pathways for the COPC were taken into account. Hence, for all terrestrial receptors, the total intakes account for all major pathways. The fraction of time in the area is accounted for in the assessment with the remainder of the time the receptor is assumed to be exposed to baseline conditions. The inhalation pathway is not considered for terrestrial receptors, as this is generally an insignificant pathway for ecological receptors. The indirect pathways resulting from dust (e.g., dust settling on vegetation that is consumed by biota) are included in the assessment.

The water quality and pathways models are coupled and were run probabilistically to permit uncertainty in the input parameters to be explicitly accounted for in the model predictions for terrestrial ecological receptors. Results from air quality modelling (discussed separately in Appendix 4B Air Quality) were input to the pathways model. The magnitude of the uncertainties in the model parameters is reflected in the values assigned to the input parameter distributions discussed in prior sections and in the attachments. The pathways modeling results presented below are based on 200 trials, and the arithmetic mean (most expected) and 95th percentile (upper bound) results are provided.

8.2.1 Exposure to Non-Radioactive Constituents

Potential effects can be measured at different levels of biological and ecological organization. Screening index values provide an integrated description of the potential hazard, the exposure (or dose)-response relationship, and the exposure evaluation (U.S. EPA 1992, AIHC 1992). In this study, adverse effects from exposure to COPC were characterized by the value of a simple screening index. This index was calculated by dividing the predicted exposure by the toxicity reference value for each ecological receptor, as shown in equation (8.2- 1).

$$Screening\,Index = \frac{Dose}{Toxicity\,Benchmark} \qquad (8.2\text{-}1)$$

The screening index values reported in this section are not estimates of the probability of ecological effect. Rather, the index values are positively correlated with the potential of an effect, i.e., higher index values imply a greater potential of an effect. Different magnitudes of the screening index have been used in other studies to screen for potential ecological effects. A screening index value of 1.0 has been used in some instances (e.g., Suter 1991) and is used in this study. The potential ecological effects of COPC were evaluated for the mean and 95th percentile results from the probabilistic risk assessment. The probabilistic framework for the assessment captures uncertainty in the model inputs and the evaluation of potential effects at the mean and 95th percentile levels provides a range of the conditions that may occur.

8.2.1.1 Herbivore Mammals

Table 8.2-1 presents the results for caribou in the LAA (average of 1.1% of the time) and the RAA (average of 4.7% of the time). The atmospheric pathway is an important pathway of exposure for caribou since their diet is composed mainly of lichen. Constituent concentrations in lichen are linked directly to constituents in air through direct deposition and nutrient uptake from air. While there are some increases in screening index values during the operation phase of the assessment, all predicted screening index values for caribou are below 1.0 in both the LAA and RAA.

Table 8.2-1 Screening Index Values for Non-Radionuclide Intakes by Caribou

LAA	Toxicity Benchmarks (mg/(kg d))		Base				Kiggavik Project Year 10 of Operation				Kiggavik Project Year 5 of Final Closure				Kiggavik Project Year 15 of Final Closure				Kiggavik Project Year 5 of Post Closure			
			SIs - LOAELs		SIs - NOAELs		SIs - LOAELs		SIs - NOAELs		SIs - LOAELs		SIs - NOAELs		SIs - LOAELs		SIs - NOAELs		SIs - LOAELs		SIs - NOAELs	
	LOAELs	NOAELs	Average	95th	Average	95th	Average	95th	Average	95th	Average	95th	Average	95th	Average	95th	Average	95th	Average	95th	Average	95th
Arsenic	14.40	-	<0.001	0.002	-	-	<0.001	0.002	-	-	<0.001	0.002	-	-	<0.001	0.002	-	-	<0.001	0.002	-	-
Cadmium	1.00	0.77	0.013	0.029	0.017	0.038	0.015	0.030	0.019	0.039	0.013	0.029	0.017	0.038	0.013	0.029	0.017	0.038	0.013	0.029	0.017	0.038
Cobalt	20.20	-	0.001	0.003	-	-	0.001	0.003	-	-	0.001	0.003	-	-	0.001	0.003	-	-	0.001	0.003	-	-
Copper	1.50	-	0.094	0.182	-	-	0.094	0.182	-	-	0.094	0.182	-	-	0.094	0.182	-	-	0.094	0.182	-	-
Lead	15.00	-	0.002	0.004	-	-	0.002	0.004	-	-	0.002	0.004	-	-	0.002	0.004	-	-	0.002	0.004	-	-
Molybdenum	4.10	-	0.002	0.005	-	-	0.002	0.005	-	-	0.002	0.005	-	-	0.002	0.005	-	-	0.002	0.005	-	-
Nickel	9.80	3.40	0.007	0.014	0.019	0.040	0.007	0.014	0.020	0.041	0.007	0.014	0.019	0.040	0.007	0.014	0.019	0.040	0.007	0.014	0.019	0.040
Selenium	0.33	0.17	0.032	0.071	0.061	0.137	0.032	0.071	0.061	0.137	0.032	0.071	0.061	0.137	0.032	0.071	0.061	0.137	0.032	0.071	0.061	0.137
Uranium	5.60	2.80	<0.001	<0.001	<0.001	0.001	<0.001	0.002	0.002	0.004	<0.001	<0.001	<0.001	0.001	<0.001	<0.001	<0.001	0.001	<0.001	<0.001	<0.001	0.001
Zinc	75.90	37.90	0.025	0.049	0.049	0.097	0.025	0.049	0.049	0.097	0.025	0.049	0.049	0.097	0.025	0.049	0.049	0.097	0.025	0.049	0.049	0.097

Fraction of time in area: 0.011

RAA	Toxicity Benchmarks (mg/(kg d))		Base				Kiggavik Project Year 10 of Operation				Kiggavik Project Year 5 of Final Closure				Kiggavik Project Year 15 of Final Closure				Kiggavik Project Year 5 of Post Closure			
			SIs - LOAELs		SIs - NOAELs		SIs - LOAELs		SIs - NOAELs		SIs - LOAELs		SIs - NOAELs		SIs - LOAELs		SIs - NOAELs		SIs - LOAELs		SIs - NOAELs	
	LOAELs	NOAELs	Average	95th	Average	95th	Average	95th	Average	95th	Average	95th	Average	95th	Average	95th	Average	95th	Average	95th	Average	95th
Arsenic	14.40	-	<0.001	0.002	-	-	<0.001	0.002	-	-	<0.001	0.002	-	-	<0.001	0.002	-	-	<0.001	0.002	-	-
Cadmium	1.00	0.77	0.013	0.029	0.017	0.038	0.014	0.030	0.018	0.039	0.013	0.029	0.017	0.038	0.013	0.029	0.017	0.038	0.013	0.029	0.017	0.038
Cobalt	20.20	-	0.001	0.003	-	-	0.001	0.003	-	-	0.001	0.003	-	-	0.001	0.003	-	-	0.001	0.003	-	-
Copper	1.50	-	0.094	0.182	-	-	0.094	0.182	-	-	0.094	0.182	-	-	0.094	0.182	-	-	0.094	0.182	-	-
Lead	15.00	-	0.002	0.004	-	-	0.002	0.004	-	-	0.002	0.004	-	-	0.002	0.004	-	-	0.002	0.004	-	-
Molybdenum	4.10	-	0.002	0.005	-	-	0.002	0.005	-	-	0.002	0.005	-	-	0.002	0.005	-	-	0.002	0.005	-	-
Nickel	9.80	3.40	0.007	0.014	0.019	0.040	0.007	0.014	0.019	0.041	0.007	0.014	0.019	0.040	0.007	0.014	0.019	0.040	0.007	0.014	0.019	0.040
Selenium	0.33	0.17	0.032	0.071	0.061	0.137	0.032	0.071	0.061	0.137	0.032	0.071	0.061	0.137	0.032	0.071	0.061	0.137	0.032	0.071	0.061	0.137
Uranium	5.60	2.80	<0.001	<0.001	<0.001	0.001	<0.001	0.001	0.001	0.003	<0.001	<0.001	<0.001	0.001	<0.001	<0.001	<0.001	0.001	<0.001	<0.001	<0.001	0.001
Zinc	75.90	37.90	0.025	0.049	0.049	0.097	0.025	0.049	0.049	0.097	0.025	0.049	0.049	0.097	0.025	0.049	0.049	0.097	0.025	0.049	0.049	0.097

Fraction of time in area: 0.047

Brown lemmings consume herbaceous vegetation, berries, and lichen. The lemming acts as a surrogate species for other small herbivore mammals, such as the vole. Table 8.2-2 presents the results for lemming living in the Rock Lake Watershed, Judge Sissons Lake in the vicinity of the Kiggavik WTP discharge (i.e., JSL-2), the Kiggavik Camp, and Judge Sissons Lake in the vicinity of the Sissons WTP discharge (i.e., JSL-8). The results show that all predicted screening index values are below 1.0 for the lemmings in the Rock Lake Watershed, Judge Sissons Lake in the vicinity of the Kiggavik WTP discharge, and Judge Sissons Lake in the vicinity of the Sissons WTP discharge. For the lemming at the Kiggavik Camp, screening index values above 1.0 are predicted at the 95th percentile level and NOAEL for uranium in Year 10 of Operation. The screening index value for uranium is only slightly above 1.0 and the screening index value for the LOAEL is below 1.0. Considering that this exceedance is at the 95th percentile level and for the NOAEL, it is not expected that there would be population effects on lemmings living in the Kiggavik Camp. Further, in Year 5 of Closure, the 95th percentile screening index value for the lemming is below 1.0 again, and therefore, any potential effects would not be long-term.

Muskoxen were selected for the assessment because they have been an integral part of the Inuit lifestyle for centuries as one animal can provide a great amount of meat, a warm versatile hide, and soft insulating fur. Table 8.2-3 presents the results for muskoxen living 10% of the time at Judge Sissons Lake in the vicinity of the Kiggavik WTP discharge (i.e., JSL-2) and Judge Sissons Lake in the vicinity of the Sissons WTP discharge (i.e., JSL-8). All screening index values are less than 1.0 and show limited potential for effects from the Project on muskoxen in these areas.

Arctic ground squirrels consume browse and herbaceous vegetation. They have a significant role in food chain effects, since they are part of the diet of larger predatory species. The Arctic hare is also a common species for the area and was identified as a possible human food source; however, the hare has essentially the same diet as the Arctic ground squirrel. Therefore, exposures to the Arctic hare are captured with the inclusion of the Arctic ground squirrel in the assessment. The Arctic ground squirrel also serves as a surrogate for Arctic hare in the human diet. Table 8.2-4 presents the results for the squirrel living in the Rock Lake Watershed, Judge Sissons Lake in the vicinity of the Kiggavik WTP discharge (i.e., JSL-2), the Kiggavik Camp, and Judge Sissons Lake in the vicinity of the Sissons WTP discharge (i.e., JSL-8). The results show that all predicted screening index values are below 1.0.

8.2.1.2 Omnivore Mammals

The bear is an important indicator of potential effects of atmospheric deposition on the terrestrial environment (and transfer to terrestrial vegetation, berries and soil) as well as emissions to the aquatic environment (and uptake by fish).Table 8.2-5 presents the results for a grizzly bear spending 50% of its time in the LAA. All predicted screening index values are below 1.0 which indicates that there are no potential effects on grizzly bear from the Project.

Table 8.2-2 Screening Index Values for Non-Radionuclide Intakes by Lemming

Rock Lake Watershed	Toxicity Benchmarks (mg/(kg d))		Base				Kiggavik Project Year 10 of Operation				Kiggavik Project Year 5 of Final Closure				Kiggavik Project Year 15 of Final Closure				Kiggavik Project Year 5 of Post Closure			
			SIs - LOAELs		SIs - NOAELs		SIs - LOAELs		SIs - NOAELs		SIs - LOAELs		SIs - NOAELs		SIs - LOAELs		SIs - NOAELs		SIs - LOAELs		SIs - NOAELs	
	LOAELs	NOAELs	Average	95th	Average	95th	Average	95th	Average	95th	Average	95th	Average	95th	Average	95th	Average	95th	Average	95th	Average	95th
Arsenic	14.20	8.10	0.002	0.007	0.004	0.012	0.002	0.007	0.004	0.012	0.002	0.007	0.004	0.012	0.002	0.007	0.004	0.012	0.002	0.007	0.004	0.012
Cadmium	1.00	0.77	0.040	0.081	0.052	0.105	0.071	0.147	0.092	0.190	0.040	0.081	0.052	0.105	0.040	0.081	0.052	0.105	0.040	0.081	0.052	0.105
Cobalt	13.39	5.22	0.007	0.015	0.018	0.039	0.007	0.016	0.018	0.040	0.007	0.015	0.018	0.039	0.007	0.015	0.018	0.039	0.007	0.015	0.018	0.039
Copper	194.00	100.00	0.005	0.012	0.010	0.022	0.005	0.012	0.010	0.023	0.005	0.012	0.010	0.023	0.005	0.012	0.010	0.023	0.005	0.012	0.010	0.023
Lead	188.00	25.50	<0.001	0.002	0.006	0.015	<0.001	0.002	0.006	0.015	<0.001	0.002	0.006	0.015	<0.001	0.002	0.006	0.015	<0.001	0.002	0.006	0.015
Molybdenum	1.90	-	0.105	0.331	-	-	0.106	0.331	-	-	0.106	0.331	-	-	0.106	0.331	-	-	0.106	0.331	-	-
Nickel	11.60	6.20	0.040	0.101	0.075	0.190	0.042	0.102	0.078	0.191	0.040	0.101	0.075	0.190	0.040	0.101	0.075	0.190	0.040	0.101	0.075	0.190
Selenium	0.63	0.33	0.103	0.201	0.196	0.384	0.104	0.203	0.198	0.387	0.103	0.201	0.196	0.384	0.103	0.201	0.196	0.384	0.103	0.201	0.196	0.384
Uranium	5.60	2.80	0.005	0.015	0.009	0.029	0.019	0.045	0.038	0.089	0.005	0.015	0.009	0.030	0.005	0.015	0.009	0.029	0.005	0.015	0.009	0.029
Zinc	249.00	215.00	0.029	0.060	0.034	0.069	0.029	0.060	0.034	0.069	0.029	0.060	0.034	0.069	0.029	0.060	0.034	0.069	0.029	0.060	0.034	0.069

Fraction of time in area: 1.0

JSL @ Kiggavik	Toxicity Benchmarks (mg/(kg d))		Base				Kiggavik Project Year 10 of Operation				Kiggavik Project Year 5 of Final Closure				Kiggavik Project Year 15 of Final Closure				Kiggavik Project Year 5 of Post Closure			
			SIs - LOAELs		SIs - NOAELs		SIs - LOAELs		SIs - NOAELs		SIs - LOAELs		SIs - NOAELs		SIs - LOAELs		SIs - NOAELs		SIs - LOAELs		SIs - NOAELs	
	LOAELs	NOAELs	Average	95th	Average	95th	Average	95th	Average	95th	Average	95th	Average	95th	Average	95th	Average	95th	Average	95th	Average	95th
Arsenic	14.20	8.10	0.002	0.007	0.004	0.012	0.002	0.007	0.004	0.012	0.002	0.007	0.004	0.012	0.002	0.007	0.004	0.012	0.002	0.007	0.004	0.012
Cadmium	1.00	0.77	0.040	0.081	0.052	0.105	0.066	0.137	0.086	0.178	0.040	0.081	0.052	0.105	0.040	0.081	0.052	0.105	0.040	0.081	0.052	0.105
Cobalt	13.39	5.22	0.007	0.015	0.018	0.039	0.007	0.016	0.018	0.040	0.007	0.015	0.018	0.039	0.007	0.015	0.018	0.039	0.007	0.015	0.018	0.039
Copper	194.00	100.00	0.005	0.012	0.010	0.022	0.005	0.012	0.010	0.023	0.005	0.012	0.010	0.023	0.005	0.012	0.010	0.023	0.005	0.012	0.010	0.023
Lead	188.00	25.50	<0.001	0.002	0.006	0.015	<0.001	0.002	0.006	0.015	<0.001	0.002	0.006	0.015	<0.001	0.002	0.006	0.015	<0.001	0.002	0.006	0.015
Molybdenum	1.90	-	0.105	0.331	-	-	0.106	0.331	-	-	0.106	0.331	-	-	0.106	0.331	-	-	0.106	0.331	-	-
Nickel	11.60	6.20	0.040	0.101	0.075	0.190	0.041	0.102	0.077	0.191	0.040	0.101	0.075	0.190	0.040	0.101	0.075	0.190	0.040	0.101	0.075	0.190
Selenium	0.63	0.33	0.103	0.201	0.196	0.384	0.104	0.202	0.198	0.386	0.103	0.201	0.196	0.384	0.103	0.201	0.196	0.384	0.103	0.201	0.196	0.384
Uranium	5.60	2.80	0.005	0.015	0.009	0.029	0.017	0.041	0.033	0.082	0.005	0.015	0.009	0.029	0.005	0.015	0.009	0.029	0.005	0.015	0.009	0.029
Zinc	249.00	215.00	0.029	0.060	0.034	0.069	0.029	0.060	0.034	0.069	0.029	0.060	0.034	0.069	0.029	0.060	0.034	0.069	0.029	0.060	0.034	0.069

Fraction of time in area: 1.0

Kiggavik Camp Watershed	Toxicity Benchmarks (mg/(kg d))		Base				Kiggavik Project Year 10 of Operation				Kiggavik Project Year 5 of Final Closure				Kiggavik Project Year 15 of Final Closure				Kiggavik Project Year 5 of Post Closure			
			SIs - LOAELs		SIs - NOAELs		SIs - LOAELs		SIs - NOAELs		SIs - LOAELs		SIs - NOAELs		SIs - LOAELs		SIs - NOAELs		SIs - LOAELs		SIs - NOAELs	
	LOAELs	NOAELs	Average	95th	Average	95th	Average	95th	Average	95th	Average	95th	Average	95th	Average	95th	Average	95th	Average	95th	Average	95th
Arsenic	14.20	8.10	0.002	0.007	0.004	0.012	0.003	0.007	0.005	0.012	0.002	0.007	0.004	0.012	0.002	0.007	0.004	0.012	0.002	0.007	0.004	0.012
Cadmium	1.00	0.77	0.040	0.081	0.052	0.105	0.289	0.686	0.375	0.891	0.040	0.081	0.052	0.105	0.040	0.081	0.052	0.105	0.040	0.081	0.052	0.105
Cobalt	13.39	5.22	0.007	0.015	0.018	0.039	0.009	0.018	0.022	0.045	0.007	0.015	0.018	0.039	0.007	0.015	0.018	0.039	0.007	0.015	0.018	0.039
Copper	194.00	100.00	0.005	0.012	0.010	0.022	0.005	0.012	0.010	0.023	0.005	0.012	0.010	0.023	0.005	0.012	0.010	0.023	0.005	0.012	0.010	0.023
Lead	188.00	25.50	<0.001	0.002	0.006	0.015	<0.001	0.002	0.006	0.015	<0.001	0.002	0.006	0.015	<0.001	0.002	0.006	0.015	<0.001	0.002	0.006	0.015
Molybdenum	1.90	-	0.105	0.331	-	-	0.106	0.333	-	-	0.106	0.331	-	-	0.106	0.331	-	-	0.106	0.331	-	-
Nickel	11.60	6.20	0.040	0.101	0.075	0.190	0.047	0.105	0.087	0.196	0.040	0.101	0.075	0.190	0.040	0.101	0.075	0.190	0.040	0.101	0.075	0.190
Selenium	0.63	0.33	0.103	0.201	0.196	0.384	0.106	0.206	0.203	0.393	0.103	0.201	0.196	0.384	0.103	0.201	0.196	0.384	0.103	0.201	0.196	0.384

Table 8.2-2 Screening Index Values for Non-Radionuclide Intakes by Lemming

Uranium	5.60	2.80	0.005	0.015	0.009	0.029	0.277	0.681	0.553	**1.361**	0.005	0.016	0.010	0.032	0.005	0.016	0.010	0.031	0.005	0.015	0.010	0.031
Zinc	249.00	215.00	0.029	0.060	0.034	0.069	0.029	0.060	0.034	0.069	0.029	0.060	0.034	0.069	0.029	0.060	0.034	0.069	0.029	0.060	0.034	0.069

Fraction of time in area: 1.0

JSL @ Sissons	Toxicity Benchmarks (mg/(kg d))		Base				Kiggavik Project Year 10 of Operation				Kiggavik Project Year 5 of Final Closure				Kiggavik Project Year 15 of Final Closure				Kiggavik Project Year 5 of Post Closure			
			SIs - LOAELs		SIs - NOAELs		SIs - LOAELs		SIs - NOAELs		SIs - LOAELs		SIs - NOAELs		SIs - LOAELs		SIs - NOAELs		SIs - LOAELs		SIs - NOAELs	
	LOAELs	NOAELs	Average	95th	Average	95th	Average	95th	Average	95th	Average	95th	Average	95th	Average	95th	Average	95th	Average	95th	Average	95th
Arsenic	14.20	8.10	0.002	0.007	0.004	0.012	0.003	0.007	0.004	0.012	0.002	0.007	0.004	0.012	0.002	0.007	0.004	0.012	0.002	0.007	0.004	0.012
Cadmium	1.00	0.77	0.040	0.081	0.052	0.105	0.109	0.241	0.142	0.312	0.040	0.081	0.052	0.105	0.040	0.081	0.052	0.105	0.040	0.081	0.052	0.105
Cobalt	13.39	5.22	0.007	0.015	0.018	0.039	0.008	0.016	0.019	0.041	0.007	0.015	0.018	0.039	0.007	0.015	0.018	0.039	0.007	0.015	0.018	0.039
Copper	194.00	100.00	0.005	0.012	0.010	0.022	0.005	0.012	0.010	0.023	0.005	0.012	0.010	0.023	0.005	0.012	0.010	0.023	0.005	0.012	0.010	0.023
Lead	188.00	25.50	<0.001	0.002	0.006	0.015	<0.001	0.002	0.006	0.015	<0.001	0.002	0.006	0.015	<0.001	0.002	0.006	0.015	<0.001	0.002	0.006	0.015
Molybdenum	1.90	-	0.105	0.331	-	-	0.106	0.331	-	-	0.106	0.331	-	-	0.106	0.331	-	-	0.106	0.331	-	-
Nickel	11.60	6.20	0.040	0.101	0.075	0.190	0.043	0.103	0.081	0.193	0.040	0.101	0.075	0.190	0.040	0.101	0.075	0.190	0.040	0.101	0.075	0.190
Selenium	0.63	0.33	0.103	0.201	0.196	0.384	0.105	0.204	0.200	0.390	0.103	0.201	0.196	0.384	0.103	0.201	0.196	0.384	0.103	0.201	0.196	0.384
Uranium	5.60	2.80	0.005	0.015	0.009	0.029	0.033	0.075	0.067	0.151	0.005	0.015	0.009	0.030	0.005	0.015	0.009	0.030	0.005	0.015	0.009	0.030
Zinc	249.00	215.00	0.029	0.060	0.034	0.069	0.029	0.060	0.034	0.069	0.029	0.060	0.034	0.069	0.029	0.060	0.034	0.069	0.029	0.060	0.034	0.069

Fraction of time in area: 1.0

Note: **BOLD SHADING** indicates a screening index exceedance of 1.0

Table 8.2-3 Screening Index Values for Non-Radionuclide Intakes by Muskoxen

JSL @ Kiggavik	Toxicity Benchmarks (mg/(kg d))		Base				Kiggavik Project Year 10 of Operation				Kiggavik Project Year 5 of Final Closure				Kiggavik Project Year 15 of Final Closure				Kiggavik Project Year 5 of Post Closure			
			SIs - LOAELs		SIs - NOAELs		SIs - LOAELs		SIs - NOAELs		SIs - LOAELs		SIs - NOAELs		SIs - LOAELs		SIs - NOAELs		SIs - LOAELs		SIs - NOAELs	
	LOAELs	NOAELs	Average	95th	Average	95th	Average	95th	Average	95th	Average	95th	Average	95th	Average	95th	Average	95th	Average	95th	Average	95th
Arsenic	14.40	-	0.001	0.004	-	-	0.001	0.004	-	-	0.001	0.004	-	-	0.001	0.004	-	-	0.001	0.004	-	-
Cadmium	1.00	0.77	0.034	0.092	0.044	0.119	0.034	0.092	0.044	0.119	0.034	0.092	0.044	0.119	0.034	0.092	0.044	0.119	0.034	0.092	0.044	0.119
Cobalt	20.20	-	0.002	0.008	-	-	0.002	0.008	-	-	0.002	0.008	-	-	0.002	0.008	-	-	0.002	0.008	-	-
Copper	1.50	-	0.322	0.730	-	-	0.322	0.730	-	-	0.322	0.730	-	-	0.322	0.730	-	-	0.322	0.730	-	-
Lead	15.00	-	0.002	0.004	-	-	0.002	0.004	-	-	0.002	0.004	-	-	0.002	0.004	-	-	0.002	0.004	-	-
Molybdenum	4.10	-	0.009	0.028	-	-	0.009	0.028	-	-	0.009	0.028	-	-	0.009	0.028	-	-	0.009	0.028	-	-
Nickel	9.80	3.40	0.014	0.032	0.040	0.091	0.014	0.032	0.040	0.091	0.014	0.032	0.040	0.091	0.014	0.032	0.040	0.091	0.014	0.032	0.040	0.091
Selenium	0.33	0.17	0.007	0.016	0.014	0.030	0.007	0.016	0.014	0.030	0.007	0.016	0.014	0.030	0.007	0.016	0.014	0.030	0.007	0.016	0.014	0.030
Uranium	5.60	2.80	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Zinc	75.90	37.90	0.158	0.371	0.316	0.742	0.158	0.371	0.316	0.742	0.158	0.371	0.316	0.742	0.158	0.371	0.316	0.742	0.158	0.371	0.316	0.742

Fraction of time in area: 0.1

JSL @ Sissons	Toxicity Benchmarks (mg/(kg d))		Base				Kiggavik Project Year 10 of Operation				Kiggavik Project Year 5 of Final Closure				Kiggavik Project Year 15 of Final Closure				Kiggavik Project Year 5 of Post Closure			
			SIs - LOAELs		SIs - NOAELs		SIs - LOAELs		SIs - NOAELs		SIs - LOAELs		SIs - NOAELs		SIs - LOAELs		SIs - NOAELs		SIs - LOAELs		SIs - NOAELs	
	LOAELs	NOAELs	Average	95th	Average	95th	Average	95th	Average	95th	Average	95th	Average	95th	Average	95th	Average	95th	Average	95th	Average	95th
Arsenic	14.40	-	0.001	0.004	-	-	0.001	0.004	-	-	0.001	0.004	-	-	0.001	0.004	-	-	0.001	0.004	-	-
Cadmium	1.00	0.77	0.034	0.092	0.044	0.119	0.034	0.092	0.044	0.119	0.034	0.092	0.044	0.119	0.034	0.092	0.044	0.119	0.034	0.092	0.044	0.119
Cobalt	20.20	-	0.002	0.008	-	-	0.002	0.008	-	-	0.002	0.008	-	-	0.002	0.008	-	-	0.002	0.008	-	-
Copper	1.50	-	0.322	0.730	-	-	0.322	0.730	-	-	0.322	0.730	-	-	0.322	0.730	-	-	0.322	0.730	-	-
Lead	15.00	-	0.002	0.004	-	-	0.002	0.004	-	-	0.002	0.004	-	-	0.002	0.004	-	-	0.002	0.004	-	-
Molybdenum	4.10	-	0.009	0.028	-	-	0.009	0.028	-	-	0.009	0.028	-	-	0.009	0.028	-	-	0.009	0.028	-	-
Nickel	9.80	3.40	0.014	0.032	0.040	0.091	0.014	0.032	0.040	0.091	0.014	0.032	0.040	0.091	0.014	0.032	0.040	0.091	0.014	0.032	0.040	0.091
Selenium	0.33	0.17	0.007	0.016	0.014	0.030	0.007	0.016	0.014	0.030	0.007	0.016	0.014	0.030	0.007	0.016	0.014	0.030	0.007	0.016	0.014	0.030
Uranium	5.60	2.80	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Zinc	75.90	37.90	0.158	0.371	0.316	0.742	0.158	0.371	0.316	0.742	0.158	0.371	0.316	0.742	0.158	0.371	0.316	0.742	0.158	0.371	0.316	0.742

Fraction of time in area: 0.1

Table 8.2-4 Screening Index Values for Non-Radionuclide Intakes by Squirrel

Rock Lake Watershed	Toxicity Benchmarks (mg/(kg d))		Base				Kiggavik Project Year 10 of Operation				Kiggavik Project Year 5 of Final Closure				Kiggavik Project Year 15 of Final Closure				Kiggavik Project Year 5 of Post Closure			
			SIs - LOAELs		SIs - NOAELs		SIs - LOAELs		SIs - NOAELs		SIs - LOAELs		SIs - NOAELs		SIs - LOAELs		SIs - NOAELs		SIs - LOAELs		SIs - NOAELs	
	LOAELs	NOAELs	Average	95th	Average	95th	Average	95th	Average	95th	Average	95th	Average	95th	Average	95th	Average	95th	Average	95th	Average	95th
Arsenic	14.20	8.10	<0.001	0.003	0.002	0.005	<0.001	0.003	0.002	0.005	<0.001	0.003	0.002	0.005	<0.001	0.003	0.002	0.005	<0.001	0.003	0.002	0.005
Cadmium	1.00	0.77	0.013	0.033	0.017	0.042	0.013	0.033	0.018	0.042	0.013	0.033	0.017	0.042	0.013	0.033	0.017	0.042	0.013	0.033	0.017	0.042
Cobalt	13.39	5.22	0.002	0.006	0.006	0.016	0.002	0.006	0.006	0.016	0.002	0.006	0.006	0.016	0.002	0.006	0.006	0.016	0.002	0.006	0.006	0.016
Copper	194.00	100.00	0.003	0.006	0.005	0.012	0.003	0.006	0.005	0.012	0.003	0.006	0.005	0.012	0.003	0.006	0.005	0.012	0.003	0.006	0.005	0.012
Lead	188.00	25.50	<0.001	<0.001	0.003	0.007	<0.001	<0.001	0.003	0.007	<0.001	<0.001	0.003	0.007	<0.001	<0.001	0.003	0.007	<0.001	<0.001	0.003	0.007
Molybdenum	1.90	-	0.050	0.136	-	-	0.050	0.136	-	-	0.050	0.136	-	-	0.050	0.136	-	-	0.050	0.136	-	-
Nickel	11.60	6.20	0.021	0.049	0.039	0.091	0.021	0.049	0.039	0.091	0.021	0.049	0.039	0.091	0.021	0.049	0.039	0.091	0.021	0.049	0.039	0.091
Selenium	0.63	0.33	0.036	0.073	0.069	0.140	0.036	0.073	0.069	0.140	0.036	0.073	0.069	0.140	0.036	0.073	0.069	0.140	0.036	0.073	0.069	0.140
Uranium	5.60	2.80	0.002	0.006	0.004	0.012	0.002	0.006	0.004	0.012	0.002	0.006	0.004	0.012	0.002	0.006	0.004	0.012	0.002	0.006	0.004	0.012
Zinc	249.00	215.00	0.018	0.041	0.021	0.048	0.018	0.041	0.021	0.048	0.018	0.041	0.021	0.048	0.018	0.041	0.021	0.048	0.018	0.041	0.021	0.048

Fraction of time in area: 1.0

JSL @ Kiggavik	Toxicity Benchmarks (mg/(kg d))		Base				Kiggavik Project Year 10 of Operation				Kiggavik Project Year 5 of Final Closure				Kiggavik Project Year 15 of Final Closure				Kiggavik Project Year 5 of Post Closure			
			SIs - LOAELs		SIs - NOAELs		SIs - LOAELs		SIs - NOAELs		SIs - LOAELs		SIs - NOAELs		SIs - LOAELs		SIs - NOAELs		SIs - LOAELs		SIs - NOAELs	
	LOAELs	NOAELs	Average	95th	Average	95th	Average	95th	Average	95th	Average	95th	Average	95th	Average	95th	Average	95th	Average	95th	Average	95th
Arsenic	14.20	8.10	<0.001	0.003	0.002	0.005	<0.001	0.003	0.002	0.005	<0.001	0.003	0.002	0.005	<0.001	0.003	0.002	0.005	<0.001	0.003	0.002	0.005
Cadmium	1.00	0.77	0.013	0.033	0.017	0.042	0.013	0.033	0.017	0.042	0.013	0.033	0.017	0.042	0.013	0.033	0.017	0.042	0.013	0.033	0.017	0.042
Cobalt	13.39	5.22	0.002	0.006	0.006	0.016	0.002	0.006	0.006	0.016	0.002	0.006	0.006	0.016	0.002	0.006	0.006	0.016	0.002	0.006	0.006	0.016
Copper	194.00	100.00	0.003	0.006	0.005	0.012	0.003	0.006	0.005	0.012	0.003	0.006	0.005	0.012	0.003	0.006	0.005	0.012	0.003	0.006	0.005	0.012
Lead	188.00	25.50	<0.001	<0.001	0.003	0.007	<0.001	<0.001	0.003	0.007	<0.001	<0.001	0.003	0.007	<0.001	<0.001	0.003	0.007	<0.001	<0.001	0.003	0.007
Molybdenum	1.90	-	0.050	0.136	-	-	0.050	0.136	-	-	0.050	0.136	-	-	0.050	0.136	-	-	0.050	0.136	-	-
Nickel	11.60	6.20	0.021	0.049	0.039	0.091	0.021	0.049	0.039	0.091	0.021	0.049	0.039	0.091	0.021	0.049	0.039	0.091	0.021	0.049	0.039	0.091
Selenium	0.63	0.33	0.036	0.073	0.069	0.140	0.036	0.073	0.069	0.140	0.036	0.073	0.069	0.140	0.036	0.073	0.069	0.140	0.036	0.073	0.069	0.140
Uranium	5.60	2.80	0.002	0.006	0.004	0.012	0.002	0.006	0.004	0.012	0.002	0.006	0.004	0.012	0.002	0.006	0.004	0.012	0.002	0.006	0.004	0.012
Zinc	249.00	215.00	0.018	0.041	0.021	0.048	0.018	0.041	0.021	0.048	0.018	0.041	0.021	0.048	0.018	0.041	0.021	0.048	0.018	0.041	0.021	0.048

Fraction of time in area: 1.0

Kiggavik Camp Watershed	Toxicity Benchmarks (mg/(kg d))		Base				Kiggavik Project Year 10 of Operation				Kiggavik Project Year 5 of Final Closure				Kiggavik Project Year 15 of Final Closure				Kiggavik Project Year 5 of Post Closure			
			SIs - LOAELs		SIs - NOAELs		SIs - LOAELs		SIs - NOAELs		SIs - LOAELs		SIs - NOAELs		SIs - LOAELs		SIs - NOAELs		SIs - LOAELs		SIs - NOAELs	
	LOAELs	NOAELs	Average	95th	Average	95th	Average	95th	Average	95th	Average	95th	Average	95th	Average	95th	Average	95th	Average	95th	Average	95th
Arsenic	14.20	8.10	<0.001	0.003	0.002	0.005	<0.001	0.003	0.002	0.005	<0.001	0.003	0.002	0.005	<0.001	0.003	0.002	0.005	<0.001	0.003	0.002	0.005
Cadmium	1.00	0.77	0.013	0.033	0.017	0.042	0.014	0.033	0.019	0.043	0.013	0.033	0.017	0.042	0.013	0.033	0.017	0.042	0.013	0.033	0.017	0.042
Cobalt	13.39	5.22	0.002	0.006	0.006	0.016	0.002	0.006	0.006	0.016	0.002	0.006	0.006	0.016	0.002	0.006	0.006	0.016	0.002	0.006	0.006	0.016
Copper	194.00	100.00	0.003	0.006	0.005	0.012	0.003	0.006	0.005	0.012	0.003	0.006	0.005	0.012	0.003	0.006	0.005	0.012	0.003	0.006	0.005	0.012
Lead	188.00	25.50	<0.001	<0.001	0.003	0.007	<0.001	<0.001	0.003	0.007	<0.001	<0.001	0.003	0.007	<0.001	<0.001	0.003	0.007	<0.001	<0.001	0.003	0.007
Molybdenum	1.90	-	0.050	0.136	-	-	0.050	0.136	-	-	0.050	0.136	-	-	0.050	0.136	-	-	0.050	0.136	-	-
Nickel	11.60	6.20	0.021	0.049	0.039	0.091	0.021	0.049	0.039	0.091	0.021	0.049	0.039	0.091	0.021	0.049	0.039	0.091	0.021	0.049	0.039	0.091

Table 8.2-4 Screening Index Values for Non-Radionuclide Intakes by Squirrel

Selenium	0.63	0.33	0.036	0.073	0.069	0.140	0.036	0.073	0.069	0.140	0.036	0.073	0.069	0.140	0.036	0.073	0.069	0.140	0.036	0.073	0.069	0.140
Uranium	5.60	2.80	0.002	0.006	0.004	0.012	0.004	0.009	0.008	0.019	0.002	0.006	0.004	0.012	0.002	0.006	0.004	0.012	0.002	0.006	0.004	0.012
Zinc	249.00	215.00	0.018	0.041	0.021	0.048	0.018	0.041	0.021	0.048	0.018	0.041	0.021	0.048	0.018	0.041	0.021	0.048	0.018	0.041	0.021	0.048

Fraction of time in area: 1.0

JSL @ Sissons	Toxicity Benchmarks (mg/(kg d))		Base				Kiggavik Project Year 10 of Operation				Kiggavik Project Year 5 of Final Closure				Kiggavik Project Year 15 of Final Closure				Kiggavik Project Year 5 of Post Closure			
			SIs - LOAELs		SIs - NOAELs		SIs - LOAELs		SIs - NOAELs		SIs - LOAELs		SIs - NOAELs		SIs - LOAELs		SIs - NOAELs		SIs - LOAELs		SIs - NOAELs	
	LOAELs	NOAELs	Average	95th	Average	95th	Average	95th	Average	95th	Average	95th	Average	95th	Average	95th	Average	95th	Average	95th	Average	95th
Arsenic	14.20	8.10	<0.001	0.003	0.002	0.005	<0.001	0.003	0.002	0.005	<0.001	0.003	0.002	0.005	<0.001	0.003	0.002	0.005	<0.001	0.003	0.002	0.005
Cadmium	1.00	0.77	0.013	0.033	0.017	0.042	0.014	0.033	0.018	0.043	0.013	0.033	0.017	0.042	0.013	0.033	0.017	0.042	0.013	0.033	0.017	0.042
Cobalt	13.39	5.22	0.002	0.006	0.006	0.016	0.002	0.006	0.006	0.016	0.002	0.006	0.006	0.016	0.002	0.006	0.006	0.016	0.002	0.006	0.006	0.016
Copper	194.00	100.00	0.003	0.006	0.005	0.012	0.003	0.006	0.005	0.012	0.003	0.006	0.005	0.012	0.003	0.006	0.005	0.012	0.003	0.006	0.005	0.012
Lead	188.00	25.50	<0.001	<0.001	0.003	0.007	<0.001	<0.001	0.003	0.007	<0.001	<0.001	0.003	0.007	<0.001	<0.001	0.003	0.007	<0.001	<0.001	0.003	0.007
Molybdenum	1.90	-	0.050	0.136	-	-	0.050	0.136	-	-	0.050	0.136	-	-	0.050	0.136	-	-	0.050	0.136	-	-
Nickel	11.60	6.20	0.021	0.049	0.039	0.091	0.021	0.049	0.039	0.091	0.021	0.049	0.039	0.091	0.021	0.049	0.039	0.091	0.021	0.049	0.039	0.091
Selenium	0.63	0.33	0.036	0.073	0.069	0.140	0.036	0.073	0.069	0.140	0.036	0.073	0.069	0.140	0.036	0.073	0.069	0.140	0.036	0.073	0.069	0.140
Uranium	5.60	2.80	0.002	0.006	0.004	0.012	0.002	0.006	0.004	0.012	0.002	0.006	0.004	0.012	0.002	0.006	0.004	0.012	0.002	0.006	0.004	0.012
Zinc	249.00	215.00	0.018	0.041	0.021	0.048	0.018	0.041	0.021	0.048	0.018	0.041	0.021	0.048	0.018	0.041	0.021	0.048	0.018	0.041	0.021	0.048

Fraction of time in area: 1.0

Table 8.2-5 Screening Index Values for Non-Radionuclide Intakes by Grizzly Bear

LAA	Toxicity Benchmarks (mg/(kg d))		Base				Kiggavik Project Year 10 of Operation				Kiggavik Project Year 5 of Final Closure				Kiggavik Project Year 15 of Final Closure				Kiggavik Project Year 5 of Post Closure			
			SIs - LOAELs		SIs - NOAELs		SIs - LOAELs		SIs - NOAELs		SIs - LOAELs		SIs - NOAELs		SIs - LOAELs		SIs - NOAELs		SIs - LOAELs		SIs - NOAELs	
	LOAELs	NOAELs	Average	95th	Average	95th	Average	95th	Average	95th	Average	95th	Average	95th	Average	95th	Average	95th	Average	95th	Average	95th
Arsenic	3.10	1.50	0.006	0.004	0.012	0.002	0.006	0.004	0.012	0.002	0.006	0.004	0.012	0.002	0.006	0.004	0.012	0.002	0.006	0.004	0.012	<0.001
Cadmium	1.00	0.77	0.021	0.012	0.028	0.010	0.022	0.013	0.028	0.010	0.022	0.013	0.028	0.010	0.022	0.012	0.028	0.010	0.021	0.012	0.028	<0.001
Cobalt	13.39	5.22	0.003	0.002	0.008	<0.001	0.003	0.002	0.008	<0.001	0.003	0.002	0.008	<0.001	0.003	0.002	0.008	<0.001	0.003	0.002	0.008	<0.001
Copper	11.50	5.90	0.031	0.030	0.060	0.015	0.031	0.030	0.061	0.015	0.031	0.030	0.061	0.015	0.031	0.030	0.061	0.015	0.031	0.030	0.061	<0.001
Lead	50.00	-	<0.001	-	-	<0.001	<0.001	-	-	<0.001	<0.001	-	-	<0.001	<0.001	-	-	<0.001	<0.001	-	-	<0.001
Molybdenum	1.90	-	0.017	-	-	0.006	0.017	-	-	0.006	0.017	-	-	0.006	0.017	-	-	0.006	0.017	-	-	<0.001
Nickel	112.00	45.00	<0.001	0.001	0.002	<0.001	<0.001	0.001	0.002	<0.001	<0.001	0.001	0.002	<0.001	<0.001	0.001	0.002	<0.001	<0.001	0.001	0.002	<0.001
Selenium	0.21	-	0.063	-	-	0.038	0.063	-	-	0.038	0.063	-	-	0.037	0.063	-	-	0.037	0.063	-	-	<0.001
Uranium	5.60	2.80	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Zinc	34.90	-	0.222	-	-	0.107	0.222	-	-	0.107	0.222	-	-	0.107	0.222	-	-	0.107	0.222	-	-	<0.001

Fraction of time in area: 0.5

8.2.1.3 Insectivore Mammals

The masked shrew relies heavily on insects for food, with a small portion of the diet from lichen. Table 8.2-6 presents the results for the shrew living in the Rock Lake Watershed, Judge Sissons Lake in the vicinity of the Kiggavik WTP discharge (i.e., JSL-2), the Kiggavik Camp, and Judge Sissons Lake in the vicinity of the Sissons WTP discharge (i.e., JSL-8). The results show that all predicted screening index values are below 1.0 for the shrew in the Rock Lake Watershed and Judge Sissons Lake in the vicinity of the Sissons WTP discharge. For the shrew at the Kiggavik Camp, a screening index value above 1.0 is predicted at the 95th percentile level and NOAEL for uranium in Year 10 of Operation. The screening index value for uranium is only slightly above 1.0 and the screening index values for the LOAEL are below 1.0. Considering that this exceedance is at the 95th percentile level and for the NOAEL, it is not expected that there would be adverse effects on shrews living in the Kiggavik Camp. Further, in Year 5 of Closure, screening index values for the shrew are below 1.0 again. For the shrew in the vicinity of the Kiggavik WTP discharge at Judge Sissons Lake, screening index values marginally above 1.0 are predicted at the 95th percentile and LOAEL for molybdenum in Year 10 of Operation and Year 5 of Final Closure. By Year 5 Post Closure the SI is expected to be below 1. Considering the minor exceedance at only the 95th percentile and only near the Kiggavik discharge, no population level effects are expected.

8.2.1.4 Carnivore Mammals

Arctic fox were selected since they consume small terrestrial animals and birds and are an important species for trappers in the area. Predicted exposures to the fox represent exposure to other scavenger mammals. Table 8.2-7 presents the results for a fox 100% of its time in the LAA. All predicted screening index values are below 1.0 which indicates that there are no potential effects on fox from the Project.

Gray wolf was selected since the diet contains caribou and muskoxen. Wolves and wolf dens have been observed within the project area. Table 8.2-8 presents the results for wolf living 50% of the time in the LAA and 100% in the RAA. The results show that all screening index values are below 1.0 in both areas, with the exception of zinc. In both the LAA and RAA, zinc intakes by the wolf exceed the LOAEL (there is no NOAEL benchmark available) at the 95th percentile value at baseline levels and the SI values do not change over the duration of the assessment. This indicates that the elevated SI is due to baseline levels of zinc measured in the environment and is not being affected by the Project. The exceedance of the LOAEL at a baseline level indicates that the benchmark may be overly conservative. Zinc is a physiologically essential element and these types of elements tend to be well regulated in organisms.

Wolverines were identified as an important species for the area and are carnivorous scavengers. The wolverine is a member of the weasel family and has the largest home range of carnivores of its size. The diet of the wolverine consists of small mammals and birds and carrion (caribou and muskoxen). Table 8.2-9presents the results for wolverine living 50% of the time in the LAA and 100% in the RAA. The results show that all screening index values are below 1.0 in both areas.

Table 8.2-6 Screening Index Values for Non-Radionuclide Intakes by Shrew

Rock Lake Watershed	Toxicity Benchmarks (mg/(kg d))		Base				Kiggavik Project Year 10 of Operation				Kiggavik Project Year 5 of Final Closure				Kiggavik Project Year 15 of Final Closure				Kiggavik Project Year 5 of Post Closure			
			SIs - LOAELs		SIs - NOAELs		SIs - LOAELs		SIs - NOAELs		SIs - LOAELs		SIs - NOAELs		SIs - LOAELs		SIs - NOAELs		SIs - LOAELs		SIs - NOAELs	
	LOAELs	NOAELs	Average	95th	Average	95th	Average	95th	Average	95th	Average	95th	Average	95th	Average	95th	Average	95th	Average	95th	Average	95th
Arsenic	14.20	8.10	0.028	0.071	0.049	0.124	0.028	0.071	0.050	0.125	0.028	0.071	0.050	0.125	0.028	0.071	0.050	0.125	0.028	0.071	0.050	0.125
Cadmium	1.00	0.77	0.018	0.040	0.024	0.052	0.049	0.124	0.064	0.161	0.018	0.040	0.024	0.052	0.018	0.040	0.024	0.052	0.018	0.040	0.024	0.052
Cobalt	13.39	5.22	0.017	0.043	0.043	0.111	0.017	0.044	0.044	0.112	0.017	0.043	0.043	0.111	0.017	0.043	0.043	0.111	0.017	0.043	0.043	0.111
Copper	194.00	100.00	0.034	0.061	0.067	0.119	0.034	0.061	0.067	0.119	0.034	0.061	0.067	0.119	0.034	0.061	0.067	0.119	0.034	0.061	0.067	0.119
Lead	188.00	25.50	<0.001	0.002	0.006	0.017	<0.001	0.002	0.006	0.018	<0.001	0.002	0.006	0.018	<0.001	0.002	0.006	0.018	<0.001	0.002	0.006	0.018
Molybdenum	1.90	-	0.042	0.120	-	-	0.043	0.121	-	-	0.043	0.121	-	-	0.043	0.121	-	-	0.043	0.121	-	-
Nickel	11.60	6.20	0.057	0.176	0.107	0.329	0.059	0.178	0.110	0.332	0.057	0.176	0.107	0.330	0.057	0.176	0.107	0.330	0.057	0.176	0.107	0.330
Selenium	0.63	0.33	0.103	0.281	0.196	0.536	0.104	0.282	0.199	0.539	0.103	0.282	0.197	0.539	0.103	0.282	0.197	0.539	0.103	0.282	0.197	0.539
Uranium	5.60	2.80	0.008	0.013	0.016	0.027	0.022	0.043	0.045	0.086	0.008	0.013	0.016	0.027	0.008	0.013	0.016	0.027	0.008	0.013	0.016	0.027
Zinc	249.00	215.00	0.082	0.249	0.095	0.288	0.082	0.250	0.095	0.290	0.082	0.250	0.095	0.290	0.082	0.250	0.095	0.290	0.082	0.250	0.095	0.290

Fraction of time in area: 1.0

JSL @ Kiggavik	Toxicity Benchmarks (mg/(kg d))		Base				Kiggavik Project Year 10 of Operation				Kiggavik Project Year 5 of Final Closure				Kiggavik Project Year 15 of Final Closure				Kiggavik Project Year 5 of Post Closure			
			SIs - LOAELs		SIs - NOAELs		SIs - LOAELs		SIs - NOAELs		SIs - LOAELs		SIs - NOAELs		SIs - LOAELs		SIs - NOAELs		SIs - LOAELs		SIs - NOAELs	
	LOAELs	NOAELs	Average	95th	Average	95th	Average	95th	Average	95th	Average	95th	Average	95th	Average	95th	Average	95th	Average	95th	Average	95th
Arsenic	14.20	8.10	0.028	0.070	0.049	0.123	0.034	0.085	0.060	0.148	0.034	0.088	0.059	0.154	0.033	0.085	0.057	0.149	0.028	0.070	0.049	0.123
Cadmium	1.00	0.77	0.018	0.040	0.024	0.052	0.077	0.161	0.100	0.209	0.052	0.117	0.068	0.152	0.047	0.107	0.061	0.138	0.018	0.040	0.024	0.052
Cobalt	13.39	5.22	0.017	0.045	0.044	0.116	0.020	0.053	0.052	0.137	0.020	0.054	0.051	0.138	0.019	0.052	0.049	0.132	0.017	0.045	0.044	0.116
Copper	194.00	100.00	0.034	0.060	0.066	0.117	0.034	0.060	0.066	0.117	0.034	0.060	0.066	0.117	0.034	0.060	0.066	0.117	0.034	0.060	0.066	0.117
Lead	188.00	25.50	<0.001	0.002	0.006	0.018	<0.001	0.003	0.006	0.019	<0.001	0.003	0.006	0.019	<0.001	0.002	0.006	0.018	<0.001	0.002	0.006	0.018
Molybdenum	1.90	-	0.042	0.119	-	-	0.407	**1.236**	-	-	0.429	**1.385**	-	-	0.355	**1.098**	-	-	0.042	0.119	-	-
Nickel	11.60	6.20	0.057	0.174	0.106	0.326	0.059	0.179	0.111	0.335	0.058	0.176	0.109	0.329	0.057	0.176	0.107	0.329	0.057	0.174	0.106	0.326
Selenium	0.63	0.33	0.102	0.279	0.195	0.533	0.119	0.319	0.228	0.609	0.121	0.354	0.231	0.676	0.115	0.315	0.219	0.601	0.102	0.279	0.196	0.533
Uranium	5.60	2.80	0.008	0.013	0.016	0.027	0.021	0.038	0.041	0.076	0.008	0.014	0.017	0.028	0.008	0.013	0.016	0.027	0.008	0.013	0.016	0.027
Zinc	249.00	215.00	0.082	0.246	0.095	0.285	0.082	0.246	0.095	0.285	0.082	0.246	0.095	0.285	0.082	0.246	0.095	0.285	0.082	0.246	0.095	0.285

Fraction of time in area: 1.0

Kiggavik Camp Watershed	Toxicity Benchmarks (mg/(kg d))		Base				Kiggavik Project Year 10 of Operation				Kiggavik Project Year 5 of Final Closure				Kiggavik Project Year 15 of Final Closure				Kiggavik Project Year 5 of Post Closure			
			SIs - LOAELs		SIs - NOAELs		SIs - LOAELs		SIs - NOAELs		SIs - LOAELs		SIs - NOAELs		SIs - LOAELs		SIs - NOAELs		SIs - LOAELs		SIs - NOAELs	
	LOAELs	NOAELs	Average	95th	Average	95th	Average	95th	Average	95th	Average	95th	Average	95th	Average	95th	Average	95th	Average	95th	Average	95th
Arsenic	14.20	8.10	0.026	0.065	0.046	0.115	0.027	0.066	0.047	0.115	0.026	0.065	0.046	0.115	0.026	0.065	0.046	0.115	0.026	0.065	0.046	0.115
Cadmium	1.00	0.77	0.018	0.040	0.024	0.052	0.268	0.709	0.347	0.921	0.018	0.040	0.024	0.052	0.018	0.040	0.024	0.052	0.018	0.040	0.024	0.052
Cobalt	13.39	5.22	0.016	0.043	0.042	0.110	0.018	0.045	0.046	0.115	0.016	0.043	0.042	0.110	0.016	0.043	0.042	0.110	0.016	0.043	0.042	0.110
Copper	194.00	100.00	0.032	0.056	0.062	0.109	0.032	0.056	0.062	0.109	0.032	0.056	0.062	0.109	0.032	0.056	0.062	0.109	0.032	0.056	0.062	0.109
Lead	188.00	25.50	<0.001	0.002	0.006	0.017	<0.001	0.002	0.006	0.017	<0.001	0.002	0.006	0.017	<0.001	0.002	0.006	0.017	<0.001	0.002	0.006	0.017
Molybdenum	1.90	-	0.039	0.111	-	-	0.040	0.112	-	-	0.039	0.111	-	-	0.039	0.111	-	-	0.039	0.111	-	-
Nickel	11.60	6.20	0.053	0.163	0.100	0.305	0.060	0.169	0.112	0.316	0.053	0.163	0.100	0.305	0.053	0.163	0.100	0.305	0.053	0.163	0.100	0.305
Selenium	0.63	0.33	0.097	0.261	0.185	0.498	0.101	0.262	0.192	0.500	0.097	0.261	0.185	0.498	0.097	0.261	0.185	0.498	0.097	0.261	0.185	0.498
Uranium	5.60	2.80	<0.001	0.001	0.002	0.002	0.270	0.642	0.539	**1.283**	<0.001	0.001	0.002	0.003	<0.001	0.001	0.002	0.003	<0.001	0.001	0.002	0.003
Zinc	249.00	215.00	0.077	0.230	0.089	0.266	0.077	0.230	0.089	0.266	0.077	0.230	0.089	0.266	0.077	0.230	0.089	0.266	0.077	0.230	0.089	0.266

Table 8.2-6 Screening Index Values for Non-Radionuclide Intakes by Shrew

Fraction of time in area: 1.0

JSL @ Sissons	Toxicity Benchmarks (mg/(kg d))		Base				Kiggavik Project Year 10 of Operation				Kiggavik Project Year 5 of Final Closure				Kiggavik Project Year 15 of Final Closure				Kiggavik Project Year 5 of Post Closure			
			SIs - LOAELs		SIs - NOAELs		SIs - LOAELs		SIs - NOAELs		SIs - LOAELs		SIs - NOAELs		SIs - LOAELs		SIs - NOAELs		SIs - LOAELs		SIs - NOAELs	
	LOAELs	NOAELs	Average	95th	Average	95th	Average	95th	Average	95th	Average	95th	Average	95th	Average	95th	Average	95th	Average	95th	Average	95th
Arsenic	14.20	8.10	0.029	0.072	0.051	0.127	0.033	0.086	0.059	0.151	0.031	0.081	0.054	0.141	0.030	0.074	0.052	0.130	0.029	0.072	0.051	0.127
Cadmium	1.00	0.77	0.018	0.040	0.024	0.052	0.099	0.234	0.128	0.304	0.030	0.059	0.038	0.077	0.028	0.057	0.036	0.075	0.018	0.040	0.024	0.052
Cobalt	13.39	5.22	0.018	0.047	0.045	0.120	0.018	0.048	0.047	0.124	0.018	0.047	0.046	0.121	0.018	0.047	0.046	0.120	0.018	0.047	0.045	0.120
Copper	194.00	100.00	0.035	0.062	0.068	0.121	0.035	0.062	0.068	0.121	0.035	0.062	0.068	0.121	0.035	0.062	0.068	0.121	0.035	0.062	0.068	0.121
Lead	188.00	25.50	<0.001	0.002	0.007	0.018	<0.001	0.002	0.007	0.018	<0.001	0.002	0.007	0.018	<0.001	0.002	0.007	0.018	<0.001	0.002	0.007	0.018
Molybdenum	1.90	-	0.043	0.123	-	-	0.272	0.796	-	-	0.203	0.654	-	-	0.108	0.327	-	-	0.043	0.123	-	-
Nickel	11.60	6.20	0.058	0.180	0.109	0.337	0.062	0.183	0.116	0.343	0.059	0.181	0.110	0.338	0.059	0.180	0.110	0.337	0.058	0.180	0.109	0.337
Selenium	0.63	0.33	0.105	0.289	0.201	0.551	0.113	0.308	0.216	0.588	0.110	0.307	0.210	0.585	0.108	0.299	0.207	0.571	0.105	0.289	0.201	0.551
Uranium	5.60	2.80	0.008	0.014	0.016	0.028	0.046	0.086	0.092	0.171	0.013	0.023	0.026	0.046	0.008	0.014	0.016	0.028	0.008	0.014	0.016	0.028
Zinc	249.00	215.00	0.084	0.254	0.098	0.294	0.084	0.254	0.098	0.294	0.084	0.254	0.098	0.294	0.084	0.254	0.098	0.294	0.084	0.254	0.098	0.294

Fraction of time in area: 1.0

Note: **BOLD SHADING** indicates a screening index exceedance of 1.0

Table 8.2-7 Screening Index Values for Non-Radionuclide Intakes by Fox

LAA	Toxicity Benchmarks (mg/(kg d))		Base				Kiggavik Project Year 10 of Operation				Kiggavik Project Year 5 of Final Closure				Kiggavik Project Year 15 of Final Closure				Kiggavik Project Year 5 of Post Closure			
			SIs - LOAELs		SIs - NOAELs		SIs - LOAELs		SIs - NOAELs		SIs - LOAELs		SIs - NOAELs		SIs - LOAELs		SIs - NOAELs		SIs - LOAELs		SIs - NOAELs	
	LOAELs	NOAELs	Average	95th	Average	95th	Average	95th	Average	95th	Average	95th	Average	95th	Average	95th	Average	95th	Average	95th	Average	95th
Arsenic	3.10	1.50	0.003	0.008	0.006	0.017	0.003	0.009	0.007	0.018	0.003	0.010	0.007	0.020	0.003	0.009	0.006	0.018	0.003	0.008	0.006	0.017
Cadmium	1.00	0.77	0.005	0.012	0.006	0.015	0.010	0.023	0.013	0.029	0.006	0.013	0.007	0.017	0.005	0.013	0.007	0.017	0.005	0.012	0.006	0.015
Cobalt	13.39	5.22	0.001	0.003	0.003	0.007	0.001	0.003	0.003	0.007	0.001	0.003	0.003	0.007	0.001	0.003	0.003	0.007	0.001	0.003	0.003	0.007
Copper	11.50	5.90	0.056	0.132	0.109	0.257	0.056	0.132	0.109	0.258	0.056	0.133	0.109	0.259	0.056	0.133	0.109	0.260	0.056	0.133	0.109	0.260
Lead	50.00	-	<0.001	<0.001	-	-	<0.001	<0.001	-	-	<0.001	<0.001	-	-	<0.001	<0.001	-	-	<0.001	<0.001	-	-
Molybdenum	1.90	-	0.008	0.022	-	-	0.014	0.029	-	-	0.014	0.030	-	-	0.012	0.027	-	-	0.008	0.022	-	-
Nickel	112.00	45.00	<0.001	<0.001	<0.001	0.002	<0.001	<0.001	<0.001	0.002	<0.001	<0.001	<0.001	0.002	<0.001	<0.001	<0.001	0.002	<0.001	<0.001	<0.001	0.002
Selenium	0.21	-	0.286	0.915	-	-	0.297	0.982	-	-	0.298	0.984	-	-	0.294	0.920	-	-	0.286	0.915	-	-
Uranium	5.60	2.80	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.002	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Zinc	34.90	-	0.147	0.435	-	-	0.147	0.436	-	-	0.147	0.436	-	-	0.147	0.436	-	-	0.147	0.436	-	-

Fraction of time in area: 1.0

Table 8.2-8 Screening Index Values for Non-Radionuclide Intakes by Wolf

LAA	Toxicity Benchmarks (mg/(kg d))		Base				Kiggavik Project Year 10 of Operation				Kiggavik Project Year 5 of Final Closure				Kiggavik Project Year 15 of Final Closure				Kiggavik Project Year 5 of Post Closure			
			SIs - LOAELs		SIs - NOAELs		SIs - LOAELs		SIs - NOAELs		SIs - LOAELs		SIs - NOAELs		SIs - LOAELs		SIs - NOAELs		SIs - LOAELs		SIs - NOAELs	
	LOAELs	NOAELs	Average	95th	Average	95th	Average	95th	Average	95th	Average	95th	Average	95th	Average	95th	Average	95th	Average	95th	Average	95th
Arsenic	3.10	1.50	0.003	0.008	0.006	0.017	0.003	0.008	0.006	0.017	0.003	0.008	0.006	0.017	0.003	0.008	0.006	0.017	0.003	0.008	0.006	0.017
Cadmium	1.00	0.77	0.003	0.010	0.004	0.013	0.003	0.010	0.004	0.013	0.003	0.010	0.004	0.013	0.003	0.010	0.004	0.013	0.003	0.010	0.004	0.013
Cobalt	13.39	5.22	<0.001	0.001	<0.001	0.003	<0.001	0.001	<0.001	0.003	<0.001	0.001	<0.001	0.003	<0.001	0.001	<0.001	0.003	<0.001	0.001	<0.001	0.003
Copper	11.50	5.90	0.068	0.195	0.132	0.380	0.068	0.195	0.132	0.380	0.068	0.195	0.132	0.380	0.068	0.195	0.132	0.380	0.068	0.195	0.132	0.380
Lead	50.00	-	<0.001	<0.001	-	-	<0.001	<0.001	-	-	<0.001	<0.001	-	-	<0.001	<0.001	-	-	<0.001	<0.001	-	-
Molybdenum	1.90	-	0.003	0.012	-	-	0.003	0.012	-	-	0.003	0.012	-	-	0.003	0.012	-	-	0.003	0.012	-	-
Nickel	112.00	45.00	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Selenium	0.21	-	0.061	0.176	-	-	0.061	0.176	-	-	0.061	0.176	-	-	0.061	0.176	-	-	0.061	0.176	-	-
Uranium	5.60	2.80	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Zinc	34.90	-	0.522	**1.456**	-	-	0.522	**1.456**	-	-	0.522	**1.456**	-	-	0.522	**1.456**	-	-	0.522	**1.456**	-	-

Fraction of time in area: 0.33

RAA	Toxicity Benchmarks (mg/(kg d))		Base				Kiggavik Project Year 10 of Operation				Kiggavik Project Year 5 of Final Closure				Kiggavik Project Year 15 of Final Closure				Kiggavik Project Year 5 of Post Closure			
			SIs - LOAELs		SIs - NOAELs		SIs - LOAELs		SIs - NOAELs		SIs - LOAELs		SIs - NOAELs		SIs - LOAELs		SIs - NOAELs		SIs - LOAELs		SIs - NOAELs	
	LOAELs	NOAELs	Average	95th	Average	95th	Average	95th	Average	95th	Average	95th	Average	95th	Average	95th	Average	95th	Average	95th	Average	95th
Arsenic	3.10	1.50	0.003	0.008	0.006	0.017	0.003	0.008	0.006	0.017	0.003	0.008	0.006	0.017	0.003	0.008	0.006	0.017	0.003	0.008	0.006	0.017
Cadmium	1.00	0.77	0.003	0.010	0.004	0.013	0.003	0.010	0.004	0.013	0.003	0.010	0.004	0.013	0.003	0.010	0.004	0.013	0.003	0.010	0.004	0.013
Cobalt	13.39	5.22	<0.001	0.001	<0.001	0.003	<0.001	0.001	<0.001	0.003	<0.001	0.001	<0.001	0.003	<0.001	0.001	<0.001	0.003	<0.001	0.001	<0.001	0.003
Copper	11.50	5.90	0.068	0.195	0.132	0.380	0.068	0.195	0.132	0.380	0.068	0.195	0.132	0.380	0.068	0.195	0.132	0.380	0.068	0.195	0.132	0.381
Lead	50.00	-	<0.001	<0.001	-	-	<0.001	<0.001	-	-	<0.001	<0.001	-	-	<0.001	<0.001	-	-	<0.001	<0.001	-	-
Molybdenum	1.90	-	0.003	0.012	-	-	0.003	0.012	-	-	0.003	0.012	-	-	0.003	0.012	-	-	0.003	0.012	-	-
Nickel	112.00	45.00	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Selenium	0.21	-	0.061	0.176	-	-	0.061	0.176	-	-	0.061	0.176	-	-	0.061	0.176	-	-	0.061	0.176	-	-
Uranium	5.60	2.80	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Zinc	34.90	-	0.522	**1.456**	-	-	0.522	**1.456**	-	-	0.522	**1.456**	-	-	0.522	**1.456**	-	-	0.522	**1.456**	-	-

Fraction of time in area: 0.33

Note: **BOLD SHADING** indicates a screening index exceedance of 1.0

Table 8.2-9 Screening Index Values for Non-Radionuclide Intakes by Wolverine

LAA	Toxicity Benchmarks (mg/(kg d))		Base				Kiggavik Project Year 10 of Operation				Kiggavik Project Year 5 of Final Closure				Kiggavik Project Year 15 of Final Closure				Kiggavik Project Year 5 of Post Closure			
			SIs - LOAELs		SIs - NOAELs		SIs - LOAELs		SIs - NOAELs		SIs - LOAELs		SIs - NOAELs		SIs - LOAELs		SIs - NOAELs		SIs - LOAELs		SIs - NOAELs	
	LOAELs	NOAELs	Average	95th	Average	95th	Average	95th	Average	95th	Average	95th	Average	95th	Average	95th	Average	95th	Average	95th	Average	95th
Arsenic	3.10	1.50	0.002	0.003	0.003	0.007	0.002	0.003	0.003	0.007	0.002	0.003	0.003	0.007	0.002	0.003	0.003	0.007	0.002	0.003	0.003	0.007
Cadmium	1.00	0.77	0.004	0.011	0.005	0.014	0.006	0.016	0.008	0.021	0.004	0.011	0.005	0.014	0.004	0.011	0.005	0.014	0.004	0.011	0.005	0.014
Cobalt	13.39	5.22	<0.001	0.002	0.002	0.006	<0.001	0.002	0.002	0.006	<0.001	0.002	0.002	0.006	<0.001	0.002	0.002	0.006	<0.001	0.002	0.002	0.006
Copper	11.50	5.90	0.033	0.084	0.064	0.163	0.033	0.084	0.064	0.164	0.033	0.084	0.064	0.164	0.033	0.084	0.064	0.164	0.033	0.084	0.064	0.164
Lead	50.00	-	<0.001	<0.001		-	<0.001	<0.001		-	<0.001	<0.001		-	<0.001	<0.001		-	<0.001	<0.001		-
Molybdenum	1.90	-	0.006	0.020		-	0.006	0.021		-	0.006	0.021		-	0.006	0.021		-	0.006	0.021		-
Nickel	112.00	45.00	<0.001	<0.001	<0.001	0.001	<0.001	<0.001	<0.001	0.001	<0.001	<0.001	<0.001	0.001	<0.001	<0.001	<0.001	0.001	<0.001	<0.001	<0.001	0.001
Selenium	0.21	-	0.027	0.065		-	0.028	0.065		-	0.027	0.065		-	0.027	0.065		-	0.027	0.065		-
Uranium	5.60	2.80	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Zinc	34.90	-	0.149	0.416		-	0.149	0.417		-	0.149	0.417		-	0.149	0.417		-	0.149	0.417		-

Fraction of time in area: 0.33

RAA	Toxicity Benchmarks (mg/(kg d))		Base				Kiggavik Project Year 10 of Operation				Kiggavik Project Year 5 of Final Closure				Kiggavik Project Year 15 of Final Closure				Kiggavik Project Year 5 of Post Closure			
			SIs - LOAELs		SIs - NOAELs		SIs - LOAELs		SIs - NOAELs		SIs - LOAELs		SIs - NOAELs		SIs - LOAELs		SIs - NOAELs		SIs - LOAELs		SIs - NOAELs	
	LOAELs	NOAELs	Average	95th	Average	95th	Average	95th	Average	95th	Average	95th	Average	95th	Average	95th	Average	95th	Average	95th	Average	95th
Arsenic	3.10	1.50	0.002	0.003	0.003	0.007	0.002	0.003	0.003	0.007	0.002	0.003	0.003	0.007	0.002	0.003	0.003	0.007	0.002	0.003	0.003	0.007
Cadmium	1.00	0.77	0.004	0.011	0.005	0.014	0.005	0.012	0.006	0.016	0.004	0.011	0.005	0.014	0.004	0.011	0.005	0.014	0.004	0.011	0.005	0.014
Cobalt	13.39	5.22	<0.001	0.002	0.002	0.006	<0.001	0.002	0.002	0.006	<0.001	0.002	0.002	0.006	<0.001	0.002	0.002	0.006	<0.001	0.002	0.002	0.006
Copper	11.50	5.90	0.033	0.084	0.064	0.163	0.033	0.084	0.064	0.164	0.033	0.084	0.064	0.164	0.033	0.084	0.064	0.165	0.033	0.084	0.064	0.165
Lead	50.00	-	<0.001	<0.001		-	<0.001	<0.001		-	<0.001	<0.001		-	<0.001	<0.001		-	<0.001	<0.001		-
Molybdenum	1.90	-	0.006	0.020		-	0.006	0.021		-	0.006	0.021		-	0.006	0.021		-	0.006	0.021		-
Nickel	112.00	45.00	<0.001	<0.001	<0.001	0.001	<0.001	<0.001	<0.001	0.001	<0.001	<0.001	<0.001	0.001	<0.001	<0.001	<0.001	0.001	<0.001	<0.001	<0.001	0.001
Selenium	0.21	-	0.027	0.065		-	0.028	0.065		-	0.027	0.065		-	0.027	0.065		-	0.027	0.065		-
Uranium	5.60	2.80	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Zinc	34.90	-	0.149	0.416		-	0.149	0.417		-	0.149	0.417		-	0.149	0.417		-	0.149	0.417		-

Fraction of time in area: 0.33

8.2.1.5 Aquatic Birds

Table 8.2-10 presents the results for long-tailed duck living 100% of the time in Judge Sissons Lake in the vicinity of the Kiggavik WTP discharge (i.e., JSL-2), and Judge Sissons Lake in the vicinity of the Sissons WTP discharge (i.e., JSL-8). The results show that all predicted screening index values are less than 1.0, which suggests a negligible potential for effects on ducks associated with discharge from the Project.

Table 8.2-11 presents the results for merganser living 100% of the time in Judge Sissons Lake in the vicinity of the Kiggavik WTP discharge (i.e., JSL-2), and Judge Sissons Lake in the vicinity of the Sissons WTP discharge (i.e., JSL-8). The results show that all predicted screening index values are less than 1.0, which suggests a negligible potential for effects on ducks associated with discharge from the Project.

Table 8.2-12 presents the results for northern pintail living 100% of the time in Judge Sissons Lake in the vicinity of the Kiggavik WTP discharge (i.e., JSL-2), and Judge Sissons Lake in the vicinity of the Sissons WTP discharge (i.e., JSL-8). The results show that all predicted screening index values, with the exception of arsenic, are less than 1.0. In both JSL-2 and JSL-8, arsenic intakes by the northern pintail exceed the LOAEL (there is no NOAEL benchmark available) at the 95th percentile value at baseline levels. Although the SI values increase slightly through the Project phases, the exceedances are due to baseline levels in the environment. This indicates that the elevated SI is due to baseline levels of arsenic measured in the environment and is not being affected by the Project. The exceedance of the LOAEL at a baseline level indicates that the benchmark may be overly conservative. Overall, the results suggest a negligible potential for effects on ducks associated with discharge from the Project.

8.2.1.6 Terrestrial Birds

Peregrine falcon is relatively common and nests within the Kiggavik RAA (Appendix 6C). Exposures to the falcon represent potential exposures to other similar species, such as the short-eared owl. The short-eared owl is also a species of special concern identified within the Sissons Lease area, but it is not specifically considered in the assessment. Table 8.2-13 presents the results for falcon in the LAA and RAA (33% of the time). All predicted screening index values are below 1.0, with the exception of selenium. In both the LAA and RAA, selenium intakes by the falcon exceed the LOAEL and NOAEL at the 95th percentile value at baseline levels. Although the SI values increase slightly through the Project phases, the exceedances are due to baseline levels in the environment and SI exceedances are not a result of the Project discharges. Therefore, there are no potential effects expected on falcon from the Project. The results of the assessment for falcon indicate that adverse effects on the short-eared owl would not be expected from the Project.

Lapland longspurs consume seeds and insects and represent other small songbirds that might be present in the area. Table 8.2-14 presents the results for Lapland longspur living 100% of the time in each of the Rock Lake Watershed, Judge Sissons Lake in the vicinity of the Kiggavik WTP discharge (i.e., JSL-2), the Kiggavik Camp, and Judge Sissons Lake in the vicinity of the Sissons WTP discharge (i.e., JSL-8). The results show that all screening index values are below 1.0 in all areas, with the exception of copper and zinc. In each of the four assessment locations, copper intakes by the longspur exceed the NOAEL at the 95th percentile value and zinc intakes by the longspur exceed the LOAEL (there is NOAEL benchmark available) at the average and 95th percentile value over the duration of the assessment, including baseline. Further, the exceedance of the LOAEL for zinc at a baseline level indicates that the benchmark maybe be overly conservative. Therefore, the elevated SI values are due to baseline levels of copper and zinc measured in the environment and the Project is not expected to have any impact on the Lapland longspur. There is a slight increase in the screening index value over the assessment period, but it is not significant and would not be discernable from the natural variability in the baseline.

Table 8.2-10 Screening Index Values for Non-Radionuclide Intakes by Long-Tailed Duck

JSL @ Kiggavik	Toxicity Benchmarks (mg/(kg d))		Base				Kiggavik Project Year 10 of Operation				Kiggavik Project Year 5 of Final Closure				Kiggavik Project Year 15 of Final Closure				Kiggavik Project Year 5 of Post Closure			
			SIs - LOAELs		SIs - NOAELs		SIs - LOAELs		SIs - NOAELs		SIs - LOAELs		SIs - NOAELs		SIs - LOAELs		SIs - NOAELs		SIs - LOAELs		SIs - NOAELs	
	LOAELs	NOAELs	Average	95th	Average	95th	Average	95th	Average	95th	Average	95th	Average	95th	Average	95th	Average	95th	Average	95th	Average	95th
Arsenic	3.60	-	0.104	0.304	-	-	0.140	0.393	-	-	0.138	0.412	-	-	0.131	0.366	-	-	0.104	0.304	-	-
Cadmium	2.37	1.47	<0.001	0.002	0.002	0.003	0.019	0.053	0.031	0.086	0.020	0.054	0.032	0.086	0.017	0.044	0.028	0.071	<0.001	0.002	0.002	0.003
Cobalt	148.00	14.80	0.001	0.003	0.011	0.031	0.001	0.004	0.015	0.040	0.002	0.004	0.015	0.040	0.001	0.004	0.014	0.037	0.001	0.003	0.012	0.031
Copper	27.00	24.10	0.202	0.383	0.226	0.429	0.202	0.383	0.226	0.429	0.202	0.383	0.226	0.429	0.202	0.383	0.226	0.429	0.202	0.383	0.226	0.429
Lead	11.80	6.51	0.009	0.031	0.017	0.056	0.010	0.031	0.017	0.057	0.010	0.032	0.018	0.058	0.010	0.032	0.017	0.057	0.009	0.031	0.017	0.056
Molybdenum	20.83	-	0.003	0.008	-	-	0.047	0.126	-	-	0.050	0.133	-	-	0.040	0.115	-	-	0.003	0.008	-	-
Nickel	10.70	14.60	0.050	0.141	0.036	0.104	0.052	0.152	0.038	0.111	0.052	0.150	0.038	0.110	0.051	0.146	0.037	0.107	0.050	0.141	0.036	0.104
Selenium	1.37	1.18	0.038	0.113	0.044	0.131	0.049	0.142	0.056	0.164	0.050	0.148	0.058	0.172	0.046	0.140	0.054	0.163	0.038	0.113	0.045	0.131
Uranium	-	16.00	-	-	0.002	0.004	-	-	0.003	0.005	-	-	0.003	0.004	-	-	0.002	0.004	-	-	0.002	0.004
Zinc	62.70	-	0.268	0.916	-	-	0.268	0.916	-	-	0.268	0.916	-	-	0.268	0.916	-	-	0.268	0.916	-	-

Fraction of time in area: 1.0

JSL @ Sissons	Toxicity Benchmarks (mg/(kg d))		Base				Kiggavik Project Year 10 of Operation				Kiggavik Project Year 5 of Final Closure				Kiggavik Project Year 15 of Final Closure				Kiggavik Project Year 5 of Post Closure			
			SIs - LOAELs		SIs - NOAELs		SIs - LOAELs		SIs - NOAELs		SIs - LOAELs		SIs - NOAELs		SIs - LOAELs		SIs - NOAELs		SIs - LOAELs		SIs - NOAELs	
	LOAELs	NOAELs	Average	95th	Average	95th	Average	95th	Average	95th	Average	95th	Average	95th	Average	95th	Average	95th	Average	95th	Average	95th
Arsenic	3.60	-	0.112	0.327	-	-	0.129	0.360	-	-	0.120	0.337	-	-	0.114	0.332	-	-	0.112	0.327	-	-
Cadmium	2.37	1.47	<0.001	0.002	0.002	0.003	0.005	0.014	0.008	0.022	0.005	0.014	0.008	0.022	0.005	0.013	0.007	0.021	<0.001	0.002	0.002	0.003
Cobalt	148.00	14.80	0.001	0.003	0.012	0.033	0.001	0.003	0.012	0.033	0.001	0.003	0.012	0.033	0.001	0.003	0.012	0.033	0.001	0.003	0.012	0.033
Copper	27.00	24.10	0.217	0.412	0.243	0.461	0.217	0.412	0.243	0.461	0.217	0.412	0.243	0.461	0.217	0.412	0.243	0.461	0.217	0.412	0.243	0.461
Lead	11.80	6.51	0.010	0.033	0.018	0.060	0.010	0.033	0.018	0.060	0.010	0.033	0.018	0.060	0.010	0.033	0.018	0.060	0.010	0.033	0.018	0.060
Molybdenum	20.83	-	0.003	0.009	-	-	0.023	0.060	-	-	0.017	0.049	-	-	0.009	0.024	-	-	0.003	0.009	-	-
Nickel	10.70	14.60	0.053	0.152	0.039	0.111	0.053	0.153	0.039	0.112	0.053	0.152	0.039	0.111	0.053	0.152	0.039	0.112	0.053	0.152	0.039	0.111
Selenium	1.37	1.18	0.041	0.120	0.047	0.139	0.043	0.127	0.050	0.148	0.043	0.126	0.050	0.146	0.042	0.123	0.049	0.143	0.041	0.120	0.047	0.139
Uranium	-	16.00	-	-	0.003	0.004	-	-	0.005	0.010	-	-	0.004	0.007	-	-	0.003	0.004	-	-	0.003	0.004
Zinc	62.70	-	0.288	0.985	-	-	0.288	0.985	-	-	0.288	0.985	-	-	0.288	0.985	-	-	0.288	0.985	-	-

Fraction of time in area: 1.0

Table 8.2-11 Screening Index Values for Non-Radionuclide Intakes by Merganser

JSL @ Kiggavik	Toxicity Benchmarks (mg/(kg d))		Base				Kiggavik Project Year 10 of Operation				Kiggavik Project Year 5 of Final Closure				Kiggavik Project Year 15 of Final Closure				Kiggavik Project Year 5 of Post Closure			
			SIs - LOAELs		SIs - NOAELs		SIs - LOAELs		SIs - NOAELs		SIs - LOAELs		SIs - NOAELs		SIs - LOAELs		SIs - NOAELs		SIs - LOAELs		SIs - NOAELs	
	LOAELs	NOAELs	Average	95th	Average	95th	Average	95th	Average	95th	Average	95th	Average	95th	Average	95th	Average	95th	Average	95th	Average	95th
Arsenic	3.60	-	0.010	0.029	-	-	0.010	0.029	-	-	0.010	0.029	-	-	0.010	0.029	-	-	0.010	0.029	-	-
Cadmium	2.37	1.47	0.004	0.020	0.006	0.033	0.005	0.020	0.008	0.033	0.005	0.020	0.009	0.033	0.005	0.020	0.008	0.033	0.004	0.020	0.006	0.033
Cobalt	148.00	14.80	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Copper	27.00	24.10	0.004	0.009	0.005	0.010	0.004	0.009	0.005	0.010	0.005	0.009	0.005	0.010	0.005	0.009	0.005	0.010	0.005	0.009	0.005	0.010
Lead	11.80	6.51	0.002	0.004	0.003	0.008	0.002	0.004	0.003	0.008	0.002	0.004	0.003	0.008	0.002	0.004	0.003	0.008	0.002	0.004	0.003	0.008
Molybdenum	20.83	-	<0.001	<0.001	-	-	<0.001	0.001	-	-	<0.001	0.001	-	-	<0.001	0.001	-	-	<0.001	0.001	-	-
Nickel	10.70	14.60	0.001	0.003	<0.001	0.002	0.001	0.003	<0.001	0.002	0.001	0.003	<0.001	0.002	0.001	0.003	<0.001	0.002	0.001	0.003	<0.001	0.002
Selenium	1.37	1.18	0.137	0.269	0.159	0.312	0.144	0.269	0.167	0.312	0.145	0.269	0.169	0.312	0.142	0.269	0.165	0.312	0.137	0.269	0.159	0.312
Uranium	-	16.00	-	-	<0.001	<0.001	-	-	<0.001	<0.001	-	-	<0.001	<0.001	-	-	<0.001	<0.001	-	-	<0.001	<0.001
Zinc	62.70	-	0.047	0.078	-	-	0.047	0.078	-	-	0.047	0.078	-	-	0.047	0.078	-	-	0.047	0.078	-	-

Fraction of time in area: 1.0

JSL @ Sissons	Toxicity Benchmarks (mg/(kg d))		Base				Kiggavik Project Year 10 of Operation				Kiggavik Project Year 5 of Final Closure				Kiggavik Project Year 15 of Final Closure				Kiggavik Project Year 5 of Post Closure			
			SIs - LOAELs		SIs - NOAELs		SIs - LOAELs		SIs - NOAELs		SIs - LOAELs		SIs - NOAELs		SIs - LOAELs		SIs - NOAELs		SIs - LOAELs		SIs - NOAELs	
	LOAELs	NOAELs	Average	95th	Average	95th	Average	95th	Average	95th	Average	95th	Average	95th	Average	95th	Average	95th	Average	95th	Average	95th
Arsenic	3.60	-	0.010	0.029	-	-	0.010	0.029	-	-	0.010	0.029	-	-	0.010	0.029	-	-	0.010	0.029	-	-
Cadmium	2.37	1.47	0.004	0.020	0.006	0.033	0.004	0.020	0.006	0.033	0.004	0.020	0.006	0.033	0.004	0.020	0.006	0.033	0.004	0.020	0.006	0.033
Cobalt	148.00	14.80	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Copper	27.00	24.10	0.004	0.009	0.005	0.010	0.005	0.009	0.005	0.010	0.005	0.009	0.005	0.010	0.005	0.009	0.005	0.010	0.005	0.009	0.005	0.010
Lead	11.80	6.51	0.002	0.004	0.003	0.008	0.002	0.004	0.003	0.008	0.002	0.004	0.003	0.008	0.002	0.004	0.003	0.008	0.002	0.004	0.003	0.008
Molybdenum	20.83	-	<0.001	<0.001	-	-	<0.001	0.001	-	-	<0.001	0.001	-	-	<0.001	<0.001	-	-	<0.001	<0.001	-	-
Nickel	10.70	14.60	0.001	0.003	<0.001	0.002	0.001	0.003	<0.001	0.002	0.001	0.003	<0.001	0.002	0.001	0.003	<0.001	0.002	0.001	0.003	<0.001	0.002
Selenium	1.37	1.18	0.138	0.269	0.160	0.312	0.140	0.269	0.162	0.312	0.139	0.269	0.162	0.312	0.139	0.269	0.161	0.312	0.138	0.269	0.160	0.312
Uranium	-	16.00	-	-	<0.001	<0.001	-	-	<0.001	<0.001	-	-	<0.001	<0.001	-	-	<0.001	<0.001	-	-	<0.001	<0.001
Zinc	62.70	-	0.049	0.081	-	-	0.049	0.081	-	-	0.049	0.081	-	-	0.049	0.081	-	-	0.049	0.081	-	-

Fraction of time in area: 1.0

Table 8.2-12 Screening Index Values for Non-Radionuclide Intakes by Northern Pintail

JSL @ Kiggavik	Toxicity Benchmarks (mg/(kg d))		Base				Kiggavik Project Year 10 of Operation				Kiggavik Project Year 5 of Final Closure				Kiggavik Project Year 15 of Final Closure				Kiggavik Project Year 5 of Post Closure			
			SIs - LOAELs		SIs - NOAELs		SIs - LOAELs		SIs - NOAELs		SIs - LOAELs		SIs - NOAELs		SIs - LOAELs		SIs - NOAELs		SIs - LOAELs		SIs - NOAELs	
	LOAELs	NOAELs	Average	95th	Average	95th	Average	95th	Average	95th	Average	95th	Average	95th	Average	95th	Average	95th	Average	95th	Average	95th
Arsenic	3.60	-	0.188	**1.016**	-	-	0.260	**1.305**	-	-	0.256	**1.220**	-	-	0.236	**1.173**	-	-	0.188	**1.017**	-	-
Cadmium	2.37	1.47	<0.001	<0.001	<0.001	0.001	0.009	0.022	0.015	0.036	0.009	0.022	0.015	0.035	0.008	0.020	0.013	0.032	<0.001	<0.001	<0.001	0.001
Cobalt	148.00	14.80	<0.001	0.002	0.007	0.019	<0.001	0.003	0.009	0.025	<0.001	0.002	0.009	0.025	<0.001	0.002	0.008	0.025	<0.001	0.002	0.007	0.019
Copper	27.00	24.10	0.072	0.132	0.080	0.148	0.072	0.132	0.080	0.148	0.072	0.132	0.080	0.148	0.072	0.132	0.080	0.148	0.072	0.132	0.080	0.148
Lead	11.80	6.51	0.009	0.037	0.016	0.066	0.009	0.040	0.017	0.072	0.009	0.040	0.017	0.072	0.009	0.037	0.017	0.067	0.009	0.037	0.016	0.066
Molybdenum	20.83	-	0.003	0.009	-	-	0.051	0.144	-	-	0.053	0.151	-	-	0.043	0.114	-	-	0.003	0.009	-	-
Nickel	10.70	14.60	0.031	0.095	0.022	0.069	0.032	0.098	0.023	0.071	0.032	0.099	0.023	0.072	0.031	0.097	0.023	0.071	0.031	0.095	0.022	0.069
Selenium	1.37	1.18	0.012	0.030	0.014	0.035	0.016	0.039	0.019	0.045	0.016	0.043	0.019	0.049	0.015	0.037	0.017	0.043	0.012	0.030	0.014	0.035
Uranium	-	16.00	-	-	<0.001	0.002	-	-	0.001	0.002	-	-	0.001	0.002	-	-	<0.001	0.002	-	-	<0.001	0.002
Zinc	62.70	-	0.098	0.251	-	-	0.098	0.251	-	-	0.098	0.251	-	-	0.098	0.251	-	-	0.098	0.251	-	-

Fraction of time in area: 1.0

JSL @ Sissons	Toxicity Benchmarks (mg/(kg d))		Base				Kiggavik Project Year 10 of Operation				Kiggavik Project Year 5 of Final Closure				Kiggavik Project Year 15 of Final Closure				Kiggavik Project Year 5 of Post Closure			
			SIs - LOAELs		SIs - NOAELs		SIs - LOAELs		SIs - NOAELs		SIs - LOAELs		SIs - NOAELs		SIs - LOAELs		SIs - NOAELs		SIs - LOAELs		SIs - NOAELs	
	LOAELs	NOAELs	Average	95th	Average	95th	Average	95th	Average	95th	Average	95th	Average	95th	Average	95th	Average	95th	Average	95th	Average	95th
Arsenic	3.60	-	0.203	**1.093**	-	-	0.234	**1.304**	-	-	0.220	**1.126**	-	-	0.206	**1.101**	-	-	0.203	**1.094**	-	-
Cadmium	2.37	1.47	<0.001	<0.001	<0.001	0.001	0.002	0.006	0.004	0.009	0.002	0.005	0.004	0.009	0.002	0.005	0.003	0.008	<0.001	<0.001	<0.001	0.001
Cobalt	148.00	14.80	<0.001	0.002	0.007	0.020	<0.001	0.002	0.007	0.020	<0.001	0.002	0.007	0.020	<0.001	0.002	0.007	0.020	<0.001	0.002	0.007	0.020
Copper	27.00	24.10	0.077	0.142	0.086	0.159	0.077	0.142	0.086	0.159	0.077	0.142	0.086	0.159	0.077	0.142	0.086	0.159	0.077	0.142	0.086	0.159
Lead	11.80	6.51	0.010	0.039	0.017	0.071	0.010	0.039	0.017	0.071	0.010	0.040	0.017	0.072	0.010	0.039	0.017	0.071	0.010	0.039	0.017	0.071
Molybdenum	20.83	-	0.004	0.010	-	-	0.025	0.071	-	-	0.018	0.049	-	-	0.009	0.026	-	-	0.004	0.010	-	-
Nickel	10.70	14.60	0.033	0.102	0.024	0.075	0.033	0.102	0.024	0.075	0.033	0.102	0.024	0.075	0.033	0.102	0.024	0.075	0.033	0.102	0.024	0.075
Selenium	1.37	1.18	0.013	0.032	0.015	0.038	0.014	0.035	0.016	0.041	0.014	0.036	0.016	0.041	0.014	0.034	0.016	0.039	0.013	0.032	0.015	0.038
Uranium	-	16.00	-	-	0.001	0.002	-	-	0.002	0.004	-	-	0.002	0.003	-	-	0.001	0.002	-	-	0.001	0.002
Zinc	62.70	-	0.106	0.270	-	-	0.106	0.270	-	-	0.106	0.270	-	-	0.106	0.270	-	-	0.106	0.270	-	-

Fraction of time in area: 1.0

Note: **BOLD SHADING** indicates a screening index exceedance of 1.0

Table 8.2-13 Screening Index Values for Non-Radionuclide Intakes by Falcon

LAA	Toxicity Benchmarks		Base				Kiggavik Project Year 10 of Operation				Kiggavik Project Year 5 of Final Closure				Kiggavik Project Year 15 of Final Closure				Kiggavik Project Year 5 of Post Closure			
	(mg/(kg d))		SIs - LOAELs		SIs - NOAELs		SIs - LOAELs		SIs - NOAELs		SIs - LOAELs		SIs - NOAELs		SIs - LOAELs		SIs - NOAELs		SIs - LOAELs		SIs - NOAELs	
	LOAELs	NOAELs	Average	95th	Average	95th	Average	95th	Average	95th	Average	95th	Average	95th	Average	95th	Average	95th	Average	95th	Average	95th
Arsenic	3.60	-	0.004	0.012	-	-	0.004	0.012	-	-	0.004	0.012	-	-	0.004	0.012	-	-	0.004	0.012	-	-
Cadmium	2.37	1.47	0.002	0.005	0.003	0.008	0.002	0.005	0.004	0.008	0.002	0.005	0.004	0.008	0.002	0.005	0.003	0.008	0.002	0.005	0.003	0.008
Cobalt	14.13	4.10	0.002	0.005	0.006	0.016	0.002	0.005	0.006	0.017	0.002	0.005	0.006	0.016	0.002	0.005	0.006	0.016	0.002	0.005	0.006	0.016
Copper	75.20	15.30	0.015	0.050	0.075	0.247	0.015	0.050	0.075	0.247	0.015	0.050	0.075	0.247	0.015	0.050	0.075	0.247	0.015	0.050	0.075	0.247
Lead	11.80	6.51	0.003	0.006	0.005	0.011	0.003	0.006	0.005	0.011	0.003	0.006	0.005	0.011	0.003	0.006	0.005	0.011	0.003	0.006	0.005	0.011
Molybdenum	20.83	-	0.001	0.003	-	-	0.003	0.010	-	-	0.003	0.010	-	-	0.003	0.011	-	-	0.001	0.003	-	-
Nickel	10.70	14.60	0.004	0.008	0.003	0.006	0.004	0.008	0.003	0.006	0.004	0.008	0.003	0.006	0.004	0.008	0.003	0.006	0.004	0.008	0.003	0.006
Selenium	0.68	0.36	0.404	**1.157**	0.763	**2.186**	0.414	**1.196**	0.783	**2.259**	0.416	**1.197**	0.785	**2.262**	0.412	**1.196**	0.778	**2.259**	0.404	**1.157**	0.763	**2.186**
Uranium	-	16.00	-	-	<0.001	<0.001	-	-	<0.001	<0.001	-	-	<0.001	<0.001	-	-	<0.001	<0.001	-	-	<0.001	<0.001
Zinc	62.70	-	0.093	0.274	-	-	0.093	0.274	-	-	0.094	0.274	-	-	0.094	0.274	-	-	0.094	0.274	-	-

Fraction of time in area: 0.33

RAA	Toxicity Benchmarks		Base				Kiggavik Project Year 10 of Operation				Kiggavik Project Year 5 of Final Closure				Kiggavik Project Year 15 of Final Closure				Kiggavik Project Year 5 of Post Closure			
	(mg/(kg d))		SIs - LOAELs		SIs - NOAELs		SIs - LOAELs		SIs - NOAELs		SIs - LOAELs		SIs - NOAELs		SIs - LOAELs		SIs - NOAELs		SIs - LOAELs		SIs - NOAELs	
	LOAELs	NOAELs	Average	95th	Average	95th	Average	95th	Average	95th	Average	95th	Average	95th	Average	95th	Average	95th	Average	95th	Average	95th
Arsenic	3.60	-	0.004	0.012	-	-	0.004	0.012	-	-	0.004	0.012	-	-	0.004	0.012	-	-	0.004	0.012	-	-
Cadmium	2.37	1.47	0.002	0.005	0.003	0.008	0.002	0.005	0.004	0.008	0.002	0.005	0.004	0.008	0.002	0.005	0.003	0.008	0.002	0.005	0.003	0.008
Cobalt	14.13	4.10	0.002	0.005	0.006	0.016	0.002	0.005	0.006	0.017	0.002	0.005	0.006	0.016	0.002	0.005	0.006	0.016	0.002	0.005	0.006	0.016
Copper	75.20	15.30	0.015	0.050	0.075	0.247	0.015	0.050	0.075	0.247	0.015	0.050	0.075	0.247	0.015	0.050	0.075	0.247	0.015	0.050	0.075	0.247
Lead	11.80	6.51	0.003	0.006	0.005	0.011	0.003	0.006	0.005	0.011	0.003	0.006	0.005	0.011	0.003	0.006	0.005	0.011	0.003	0.006	0.005	0.011
Molybdenum	20.83	-	0.001	0.003	-	-	0.003	0.010	-	-	0.003	0.010	-	-	0.003	0.011	-	-	0.001	0.003	-	-
Nickel	10.70	14.60	0.004	0.008	0.003	0.006	0.004	0.008	0.003	0.006	0.004	0.008	0.003	0.006	0.004	0.008	0.003	0.006	0.004	0.008	0.003	0.006
Selenium	0.68	0.36	0.404	**1.157**	0.763	**2.186**	0.414	**1.196**	0.783	**2.259**	0.416	**1.197**	0.785	**2.262**	0.412	**1.196**	0.778	**2.259**	0.404	**1.157**	0.763	**2.186**
Uranium	-	16.00	-	-	<0.001	<0.001	-	-	<0.001	<0.001	-	-	<0.001	<0.001	-	-	<0.001	<0.001	-	-	<0.001	<0.001
Zinc	62.70	-	0.093	0.274	-	-	0.093	0.274	-	-	0.093	0.274	-	-	0.094	0.274	-	-	0.094	0.274	-	-

Fraction of time in area: 0.33

Note: **BOLD SHADING** indicates a screening index exceedance of 1.0

Table 8.2-14 Screening Index Values for Non-Radionuclide Intakes by Lapland Longspur

Rock Lake Watershed	Toxicity Benchmarks (mg/(kg d))		Base				Kiggavik Project Year 10 of Operation				Kiggavik Project Year 5 of Final Closure				Kiggavik Project Year 15 of Final Closure				Kiggavik Project Year 5 of Post Closure			
			SIs - LOAELs		SIs - NOAELs		SIs - LOAELs		SIs - NOAELs		SIs - LOAELs		SIs - NOAELs		SIs - LOAELs		SIs - NOAELs		SIs - LOAELs		SIs - NOAELs	
	LOAELs	NOAELs	Average	95th	Average	95th	Average	95th	Average	95th	Average	95th	Average	95th	Average	95th	Average	95th	Average	95th	Average	95th
Arsenic	3.60	-	0.131	0.292	-	-	0.131	0.294	-	-	0.131	0.294	-	-	0.131	0.294	-	-	0.131	0.294	-	-
Cadmium	2.37	1.47	0.023	0.049	0.037	0.080	0.024	0.052	0.039	0.084	0.023	0.049	0.037	0.080	0.023	0.049	0.037	0.080	0.023	0.049	0.037	0.080
Cobalt	14.13	4.10	0.023	0.049	0.080	0.167	0.023	0.049	0.080	0.167	0.023	0.049	0.080	0.167	0.023	0.049	0.080	0.167	0.023	0.049	0.080	0.167
Copper	75.20	15.30	0.135	0.260	0.663	**1.278**	0.135	0.261	0.666	**1.285**	0.136	0.262	0.667	**1.286**	0.136	0.262	0.667	**1.286**	0.136	0.262	0.668	**1.286**
Lead	11.80	6.51	0.028	0.057	0.052	0.103	0.029	0.057	0.052	0.104	0.028	0.057	0.052	0.103	0.028	0.057	0.052	0.103	0.028	0.057	0.052	0.103
Molybdenum	20.83	-	0.013	0.037	-	-	0.013	0.037	-	-	0.013	0.037	-	-	0.013	0.037	-	-	0.013	0.037	-	-
Nickel	10.70	14.60	0.197	0.515	0.144	0.377	0.197	0.515	0.144	0.377	0.197	0.515	0.144	0.377	0.197	0.515	0.144	0.377	0.197	0.515	0.144	0.377
Selenium	0.68	0.36	0.095	0.227	0.179	0.429	0.095	0.228	0.180	0.431	0.095	0.228	0.180	0.431	0.095	0.228	0.180	0.431	0.095	0.228	0.180	0.431
Uranium	-	16.00	-	-	0.004	0.006	-	-	0.005	0.007	-	-	0.004	0.006	-	-	0.004	0.006	-	-	0.004	0.006
Zinc	62.70	-	**1.008**	**2.474**	-	-	**1.010**	**2.484**	-	-	**1.010**	**2.484**	-	-	**1.010**	**2.484**	-	-	**1.010**	**2.484**	-	-

Fraction of time in area: 1.0

JSL @ Kiggavik	Toxicity Benchmarks (mg/(kg d))		Base				Kiggavik Project Year 10 of Operation				Kiggavik Project Year 5 of Final Closure				Kiggavik Project Year 15 of Final Closure				Kiggavik Project Year 5 of Post Closure			
			SIs - LOAELs		SIs - NOAELs		SIs - LOAELs		SIs - NOAELs		SIs - LOAELs		SIs - NOAELs		SIs - LOAELs		SIs - NOAELs		SIs - LOAELs		SIs - NOAELs	
	LOAELs	NOAELs	Average	95th	Average	95th	Average	95th	Average	95th	Average	95th	Average	95th	Average	95th	Average	95th	Average	95th	Average	95th
Arsenic	3.60	-	0.130	0.288	-	-	0.154	0.332	-	-	0.154	0.362	-	-	0.148	0.354	-	-	0.130	0.288	-	-
Cadmium	2.37	1.47	0.023	0.049	0.037	0.080	0.038	0.077	0.061	0.124	0.038	0.076	0.061	0.122	0.036	0.073	0.057	0.117	0.023	0.049	0.037	0.080
Cobalt	14.13	4.10	0.024	0.050	0.081	0.171	0.026	0.058	0.091	0.200	0.026	0.059	0.091	0.202	0.026	0.054	0.088	0.187	0.024	0.050	0.081	0.171
Copper	75.20	15.30	0.134	0.259	0.658	**1.272**	0.134	0.259	0.659	**1.275**	0.134	0.260	0.660	**1.276**	0.134	0.260	0.661	**1.276**	0.135	0.260	0.661	**1.277**
Lead	11.80	6.51	0.029	0.057	0.052	0.103	0.029	0.058	0.052	0.106	0.029	0.057	0.052	0.103	0.029	0.057	0.052	0.103	0.029	0.057	0.052	0.103
Molybdenum	20.83	-	0.013	0.036	-	-	0.047	0.123	-	-	0.049	0.133	-	-	0.042	0.112	-	-	0.013	0.036	-	-
Nickel	10.70	14.60	0.196	0.515	0.144	0.377	0.198	0.515	0.145	0.378	0.198	0.516	0.145	0.378	0.197	0.515	0.144	0.377	0.196	0.515	0.144	0.377
Selenium	0.68	0.36	0.095	0.226	0.179	0.426	0.110	0.273	0.207	0.515	0.112	0.281	0.211	0.531	0.106	0.274	0.201	0.517	0.095	0.226	0.179	0.427
Uranium	-	16.00	-	-	0.004	0.006	-	-	0.005	0.007	-	-	0.004	0.006	-	-	0.004	0.006	-	-	0.004	0.006
Zinc	62.70	-	**1.008**	**2.478**	-	-	**1.008**	**2.478**	-	-	**1.008**	**2.478**	-	-	**1.008**	**2.478**	-	-	**1.008**	**2.478**	-	-

Fraction of time in area: 1.0

Table 8.2-14 (cont'd) Screening Index Values for Non-Radionuclide Intakes by Lapland Longspur

Kiggavik Camp Watershed	Toxicity Benchmarks (mg/(kg d))		Base				Kiggavik Project Year 10 of Operation				Kiggavik Project Year 5 of Final Closure				Kiggavik Project Year 15 of Final Closure				Kiggavik Project Year 5 of Post Closure			
			SIs - LOAELs		SIs - NOAELs		SIs - LOAELs		SIs - NOAELs		SIs - LOAELs		SIs - NOAELs		SIs - LOAELs		SIs - NOAELs		SIs - LOAELs		SIs - NOAELs	
	LOAELs	NOAELs	Average	95th	Average	95th	Average	95th	Average	95th	Average	95th	Average	95th	Average	95th	Average	95th	Average	95th	Average	95th
Arsenic	3.60	-	0.123	0.271	-	-	0.123	0.272	-	-	0.123	0.271	-	-	0.123	0.271	-	-	0.123	0.271	-	-
Cadmium	2.37	1.47	0.023	0.049	0.037	0.080	0.031	0.062	0.051	0.100	0.023	0.049	0.037	0.080	0.023	0.049	0.037	0.080	0.023	0.049	0.037	0.080
Cobalt	14.13	4.10	0.023	0.047	0.078	0.163	0.023	0.047	0.078	0.163	0.023	0.047	0.078	0.163	0.023	0.047	0.078	0.163	0.023	0.047	0.078	0.163
Copper	75.20	15.30	0.128	0.244	0.630	**1.201**	0.128	0.245	0.631	**1.206**	0.129	0.246	0.632	**1.210**	0.129	0.246	0.632	**1.210**	0.129	0.246	0.632	**1.211**
Lead	11.80	6.51	0.028	0.054	0.051	0.098	0.029	0.054	0.052	0.098	0.028	0.054	0.051	0.098	0.028	0.054	0.051	0.098	0.028	0.054	0.051	0.098
Molybdenum	20.83	-	0.013	0.036	-	-	0.013	0.036	-	-	0.013	0.036	-	-	0.013	0.036	-	-	0.013	0.036	-	-
Nickel	10.70	14.60	0.192	0.514	0.141	0.376	0.193	0.514	0.141	0.377	0.192	0.514	0.141	0.377	0.192	0.514	0.141	0.377	0.192	0.514	0.141	0.377
Selenium	0.68	0.36	0.090	0.212	0.170	0.400	0.090	0.212	0.170	0.400	0.090	0.212	0.170	0.400	0.090	0.212	0.170	0.400	0.090	0.212	0.170	0.400
Uranium	-	16.00	-	-	0.001	0.002	-	-	0.014	0.035	-	-	0.001	0.002	-	-	0.001	0.002	-	-	0.001	0.002
Zinc	62.70	-	0.986	**2.459**	-	-	0.987	**2.460**	-	-	0.987	**2.459**	-	-	0.987	**2.459**	-	-	0.987	**2.459**	-	-

Fraction of time in area: 1.0

JSL @ Sissons	Toxicity Benchmarks (mg/(kg d))		Base				Kiggavik Project Year 10 of Operation				Kiggavik Project Year 5 of Final Closure				Kiggavik Project Year 15 of Final Closure				Kiggavik Project Year 5 of Post Closure			
			SIs - LOAELs		SIs - NOAELs		SIs - LOAELs		SIs - NOAELs		SIs - LOAELs		SIs - NOAELs		SIs - LOAELs		SIs - NOAELs		SIs - LOAELs		SIs - NOAELs	
	LOAELs	NOAELs	Average	95th	Average	95th	Average	95th	Average	95th	Average	95th	Average	95th	Average	95th	Average	95th	Average	95th	Average	95th
Arsenic	3.60	-	0.134	0.298	-	-	0.151	0.345	-	-	0.142	0.337	-	-	0.136	0.309	-	-	0.134	0.298	-	-
Cadmium	2.37	1.47	0.023	0.049	0.037	0.080	0.030	0.060	0.049	0.097	0.028	0.058	0.045	0.093	0.027	0.057	0.044	0.092	0.023	0.049	0.037	0.080
Cobalt	14.13	4.10	0.024	0.051	0.083	0.177	0.024	0.052	0.084	0.178	0.024	0.051	0.084	0.177	0.024	0.051	0.083	0.177	0.024	0.051	0.083	0.177
Copper	75.20	15.30	0.137	0.263	0.674	**1.292**	0.137	0.264	0.675	**1.296**	0.137	0.264	0.676	**1.297**	0.138	0.264	0.676	**1.297**	0.138	0.264	0.676	**1.297**
Lead	11.80	6.51	0.029	0.058	0.052	0.106	0.029	0.059	0.053	0.106	0.029	0.058	0.053	0.106	0.029	0.058	0.053	0.106	0.029	0.058	0.052	0.106
Molybdenum	20.83	-	0.013	0.037	-	-	0.035	0.095	-	-	0.028	0.080	-	-	0.019	0.053	-	-	0.013	0.037	-	-
Nickel	10.70	14.60	0.198	0.518	0.145	0.380	0.199	0.518	0.146	0.380	0.199	0.519	0.146	0.380	0.198	0.518	0.145	0.380	0.198	0.518	0.145	0.380
Selenium	0.68	0.36	0.097	0.233	0.184	0.440	0.103	0.247	0.194	0.467	0.102	0.250	0.192	0.472	0.100	0.245	0.189	0.462	0.097	0.233	0.184	0.440
Uranium	-	16.00	-	-	0.004	0.006	-	-	0.009	0.014	-	-	0.006	0.009	-	-	0.004	0.006	-	-	0.004	0.006
Zinc	62.70	-	**1.019**	**2.523**	-	-	**1.019**	**2.524**	-	-	**1.020**	**2.524**	-	-	**1.020**	**2.524**	-	-	**1.020**	**2.524**	-	-

Fraction of time in area: 1.0

Note: **BOLD SHADING** indicates a screening index exceedance of 1.0

Rock ptarmigans were selected because they are consumed by humans. The ptarmigan is also a surrogate in the assessment for other terrestrial birds with similar diets, such as goose and grouse. Table 8.2-15 presents the results for ptarmigan living in the Rock Lake Watershed, Judge Sissons Lake in the vicinity of the Kiggavik WTP discharge (i.e., JSL-2), the Kiggavik Camp, and Judge Sissons Lake in the vicinity of the Sissons WTP discharge (i.e., JSL-8). The results show that all screening index values are below 1.0 in all areas, with the exception of zinc. Similar to the longspur, the zinc intakes by the ptarmigan exceed the LOAEL (there is no NOAEL benchmark available) at the 95th percentile value over the duration of the assessment at four assessment locations as well as baseline. This indicates that these are not Project effects, but rather due to baseline levels of zinc measured in the environment. Further, the exceedance of the LOAEL at a baseline level indicates that the benchmark may be overly conservative.

Table 8.2-16 presents the results for semipalmated sandpiper living 100% of the time in Judge Sissons Lake in the vicinity of the Kiggavik WTP discharge (i.e., JSL-2), and Judge Sissons Lake in the vicinity of the Sissons WTP discharge (i.e., JSL-8). The results show that all predicted screening index values are less than 1.0, with the exception of arsenic, copper, selenium, and zinc. For copper, selenium, and zinc, the 95th percentile predicted intakes exceed the NOAEL (for copper and selenium) and the LOAEL (for zinc, no NOAEL value is available) throughout the Project period as well as baseline. For copper, the average intakes also exceed the NOAEL benchmark. LOAEL benchmarks are not exceeded for copper and selenium. There is very little change in SI values over the assessment period, which indicates that the Project is not having a significant effect on the calculated intakes of copper, selenium, and zinc, and exceedances are due to baseline levels in the environment. For arsenic, the 95th percentile intakes slightly exceed the LOAEL benchmark (no NOAEL available for arsenic) during the operation phase and final closure (at Kiggavik WTP discharge only). Considering baseline conditions and the slight exceedances indicated for the sandpiper, adverse effects are not expected from Project discharges.

Table 8.2-15 Screening Index Values for Non-Radionuclide Intakes by Ptarmigan

Rock Lake Watershed	Toxicity Benchmarks (mg/(kg d))		Base				Kiggavik Project Year 10 of Operation				Kiggavik Project Year 5 of Final Closure				Kiggavik Project Year 15 of Final Closure				Kiggavik Project Year 5 of Post Closure			
			SIs - LOAELs		SIs - NOAELs		SIs - LOAELs		SIs - NOAELs		SIs - LOAELs		SIs - NOAELs		SIs - LOAELs		SIs - NOAELs		SIs - LOAELs		SIs - NOAELs	
	LOAELs	NOAELs	Average	95th	Average	95th	Average	95th	Average	95th	Average	95th	Average	95th	Average	95th	Average	95th	Average	95th	Average	95th
Arsenic	3.60	-	0.022	0.070	-	-	0.022	0.070	-	-	0.022	0.070	-	-	0.022	0.070	-	-	0.022	0.070	-	-
Cadmium	2.37	1.47	0.060	0.144	0.096	0.232	0.060	0.144	0.096	0.233	0.060	0.144	0.096	0.232	0.060	0.144	0.096	0.232	0.060	0.144	0.096	0.232
Cobalt	14.13	4.10	0.013	0.046	0.045	0.158	0.013	0.046	0.045	0.158	0.013	0.046	0.045	0.158	0.013	0.046	0.045	0.158	0.013	0.046	0.045	0.158
Copper	75.20	15.30	0.030	0.057	0.146	0.279	0.030	0.057	0.147	0.282	0.030	0.058	0.147	0.284	0.030	0.058	0.148	0.284	0.030	0.058	0.148	0.284
Lead	11.80	6.51	0.010	0.021	0.017	0.039	0.010	0.021	0.017	0.039	0.010	0.021	0.017	0.039	0.010	0.021	0.017	0.039	0.010	0.021	0.017	0.039
Molybdenum	20.83	-	0.006	0.024	-	-	0.006	0.024	-	-	0.006	0.024	-	-	0.006	0.024	-	-	0.006	0.024	-	-
Nickel	10.70	14.60	0.052	0.120	0.038	0.088	0.052	0.120	0.038	0.088	0.052	0.120	0.038	0.088	0.052	0.120	0.038	0.088	0.052	0.120	0.038	0.088
Selenium	0.68	0.36	0.012	0.027	0.023	0.051	0.012	0.027	0.023	0.051	0.012	0.027	0.023	0.051	0.012	0.027	0.023	0.051	0.012	0.027	0.023	0.051
Uranium	-	16.00	-	-	<0.001	<0.001	-	-	<0.001	<0.001	-	-	<0.001	<0.001	-	-	<0.001	<0.001	-	-	<0.001	<0.001
Zinc	62.70	-	0.792	**1.970**	-	-	0.792	**1.972**	-	-	0.792	**1.975**	-	-	0.792	**1.976**	-	-	0.792	**1.977**	-	-

Fraction of time in area: 1.0

JSL @ Kiggavik	Toxicity Benchmarks (mg/(kg d))		Base				Kiggavik Project Year 10 of Operation				Kiggavik Project Year 5 of Final Closure				Kiggavik Project Year 15 of Final Closure				Kiggavik Project Year 5 of Post Closure			
			SIs - LOAELs		SIs - NOAELs		SIs - LOAELs		SIs - NOAELs		SIs - LOAELs		SIs - NOAELs		SIs - LOAELs		SIs - NOAELs		SIs - LOAELs		SIs - NOAELs	
	LOAELs	NOAELs	Average	95th	Average	95th	Average	95th	Average	95th	Average	95th	Average	95th	Average	95th	Average	95th	Average	95th	Average	95th
Arsenic	3.60	-	0.022	0.070	-	-	0.023	0.071	-	-	0.023	0.072	-	-	0.023	0.072	-	-	0.022	0.070	-	-
Cadmium	2.37	1.47	0.060	0.144	0.096	0.232	0.061	0.145	0.098	0.234	0.061	0.145	0.098	0.234	0.060	0.145	0.097	0.234	0.060	0.144	0.096	0.232
Cobalt	14.13	4.10	0.013	0.046	0.046	0.158	0.013	0.046	0.046	0.159	0.013	0.046	0.046	0.159	0.013	0.046	0.046	0.159	0.013	0.046	0.046	0.158
Copper	75.20	15.30	0.030	0.057	0.146	0.279	0.030	0.057	0.146	0.281	0.030	0.058	0.147	0.283	0.030	0.058	0.147	0.284	0.030	0.058	0.147	0.284
Lead	11.80	6.51	0.010	0.021	0.017	0.039	0.010	0.022	0.017	0.039	0.010	0.021	0.017	0.039	0.010	0.021	0.017	0.039	0.010	0.021	0.017	0.039
Molybdenum	20.83	-	0.006	0.024	-	-	0.008	0.025	-	-	0.008	0.026	-	-	0.008	0.025	-	-	0.006	0.024	-	-
Nickel	10.70	14.60	0.052	0.120	0.038	0.088	0.052	0.120	0.038	0.088	0.052	0.120	0.038	0.088	0.052	0.120	0.038	0.088	0.052	0.120	0.038	0.088
Selenium	0.68	0.36	0.012	0.027	0.023	0.051	0.013	0.030	0.024	0.056	0.013	0.033	0.025	0.062	0.013	0.030	0.024	0.057	0.012	0.027	0.023	0.051
Uranium	-	16.00	-	-	<0.001	<0.001	-	-	<0.001	<0.001	-	-	<0.001	<0.001	-	-	<0.001	<0.001	-	-	<0.001	<0.001
Zinc	62.70	-	0.792	**1.970**	-	-	0.792	**1.972**	-	-	0.792	**1.975**	-	-	0.792	**1.976**	-	-	0.792	**1.977**	-	-

Fraction of time in area: 1.0

Table 8.2-15 Screening Index Values for Non-Radionuclide Intakes by Ptarmigan

Kiggavik Camp Watershed	Toxicity Benchmarks (mg/(kg d))		Base				Kiggavik Project Year 10 of Operation				Kiggavik Project Year 5 of Final Closure				Kiggavik Project Year 15 of Final Closure				Kiggavik Project Year 5 of Post Closure			
			SIs - LOAELs		SIs - NOAELs		SIs - LOAELs		SIs - NOAELs		SIs - LOAELs		SIs - NOAELs		SIs - LOAELs		SIs - NOAELs		SIs - LOAELs		SIs - NOAELs	
	LOAELs	NOAELs	Average	95th	Average	95th	Average	95th	Average	95th	Average	95th	Average	95th	Average	95th	Average	95th	Average	95th	Average	95th
Arsenic	3.60	-	0.022	0.070	-	-	0.022	0.070	-	-	0.022	0.070	-	-	0.022	0.070	-	-	0.022	0.070	-	-
Cadmium	2.37	1.47	0.060	0.144	0.096	0.232	0.060	0.146	0.097	0.235	0.060	0.144	0.096	0.233	0.060	0.144	0.096	0.232	0.060	0.144	0.096	0.232
Cobalt	14.13	4.10	0.013	0.046	0.045	0.158	0.013	0.046	0.045	0.158	0.013	0.046	0.045	0.158	0.013	0.046	0.045	0.158	0.013	0.046	0.045	0.158
Copper	75.20	15.30	0.029	0.057	0.144	0.278	0.029	0.057	0.145	0.281	0.030	0.057	0.146	0.283	0.030	0.058	0.146	0.283	0.030	0.058	0.146	0.283
Lead	11.80	6.51	0.010	0.021	0.017	0.039	0.010	0.021	0.017	0.039	0.010	0.021	0.017	0.039	0.010	0.021	0.017	0.039	0.010	0.021	0.017	0.039
Molybdenum	20.83	-	0.006	0.024	-	-	0.006	0.024	-	-	0.006	0.024	-	-	0.006	0.024	-	-	0.006	0.024	-	-
Nickel	10.70	14.60	0.052	0.119	0.038	0.088	0.052	0.119	0.038	0.088	0.052	0.119	0.038	0.088	0.052	0.119	0.038	0.088	0.052	0.119	0.038	0.088
Selenium	0.68	0.36	0.012	0.027	0.023	0.051	0.012	0.027	0.023	0.051	0.012	0.027	0.023	0.051	0.012	0.027	0.023	0.051	0.012	0.027	0.023	0.051
Uranium	-	16.00	-	-	<0.001	<0.001	-	-	<0.001	0.001	-	-	<0.001	<0.001	-	-	<0.001	<0.001	-	-	<0.001	<0.001
Zinc	62.70	-	0.791	**1.970**	-	-	0.791	**1.972**	-	-	0.791	**1.975**	-	-	0.791	**1.976**	-	-	0.791	**1.976**	-	-

Fraction of time in area: 1.0

JSL @ Sissons	Toxicity Benchmarks (mg/(kg d))		Base				Kiggavik Project Year 10 of Operation				Kiggavik Project Year 5 of Final Closure				Kiggavik Project Year 15 of Final Closure				Kiggavik Project Year 5 of Post Closure			
			SIs - LOAELs		SIs - NOAELs		SIs - LOAELs		SIs - NOAELs		SIs - LOAELs		SIs - NOAELs		SIs - LOAELs		SIs - NOAELs		SIs - LOAELs		SIs - NOAELs	
	LOAELs	NOAELs	Average	95th	Average	95th	Average	95th	Average	95th	Average	95th	Average	95th	Average	95th	Average	95th	Average	95th	Average	95th
Arsenic	3.60	-	0.023	0.071	-	-	0.023	0.071	-	-	0.023	0.071	-	-	0.023	0.071	-	-	0.023	0.071	-	-
Cadmium	2.37	1.47	0.060	0.144	0.096	0.232	0.060	0.145	0.097	0.234	0.060	0.145	0.097	0.233	0.060	0.144	0.097	0.233	0.060	0.144	0.096	0.232
Cobalt	14.13	4.10	0.013	0.046	0.046	0.158	0.013	0.046	0.046	0.158	0.013	0.046	0.046	0.158	0.013	0.046	0.046	0.158	0.013	0.046	0.046	0.158
Copper	75.20	15.30	0.030	0.057	0.146	0.280	0.030	0.057	0.147	0.282	0.030	0.058	0.148	0.284	0.030	0.058	0.148	0.284	0.030	0.058	0.148	0.284
Lead	11.80	6.51	0.010	0.022	0.017	0.039	0.010	0.022	0.017	0.039	0.010	0.022	0.017	0.039	0.010	0.022	0.017	0.039	0.010	0.022	0.017	0.039
Molybdenum	20.83	-	0.006	0.024	-	-	0.007	0.025	-	-	0.007	0.025	-	-	0.007	0.024	-	-	0.006	0.024	-	-
Nickel	10.70	14.60	0.053	0.120	0.038	0.088	0.053	0.120	0.038	0.088	0.053	0.120	0.038	0.088	0.053	0.120	0.038	0.088	0.053	0.120	0.038	0.088
Selenium	0.68	0.36	0.012	0.027	0.023	0.052	0.013	0.028	0.024	0.054	0.013	0.029	0.024	0.055	0.012	0.028	0.023	0.054	0.012	0.027	0.023	0.052
Uranium	-	16.00	-	-	<0.001	<0.001	-	-	<0.001	0.001	-	-	<0.001	<0.001	-	-	<0.001	<0.001	-	-	<0.001	<0.001
Zinc	62.70	-	0.792	**1.970**	-	-	0.793	**1.972**	-	-	0.793	**1.975**	-	-	0.793	**1.976**	-	-	0.793	**1.977**	-	-

Fraction of time in area: 1.0

Note: **BOLD SHADING** indicates a screening index exceedance of 1.0

Table 8.2-16 Screening Index Values for Non-Radionuclide Intakes by Sandpiper

JSL @ Kiggavik	Toxicity Benchmarks (mg/(kg d))		Base				Kiggavik Project Year 10 of Operation				Kiggavik Project Year 5 of Final Closure				Kiggavik Project Year 15 of Final Closure				Kiggavik Project Year 5 of Post Closure			
			SIs - LOAELs		SIs - NOAELs		SIs - LOAELs		SIs - NOAELs		SIs - LOAELs		SIs - NOAELs		SIs - LOAELs		SIs - NOAELs		SIs - LOAELs		SIs - NOAELs	
	LOAELs	NOAELs	Average	95th	Average	95th	Average	95th	Average	95th	Average	95th	Average	95th	Average	95th	Average	95th	Average	95th	Average	95th
Arsenic	3.60	-	0.339	0.857	-	-	0.443	**1.111**	-	-	0.442	**1.168**	-	-	0.419	**1.054**	-	-	0.342	0.863	-	-
Cadmium	2.37	1.47	0.008	0.011	0.012	0.017	0.068	0.176	0.109	0.284	0.071	0.186	0.114	0.301	0.061	0.166	0.099	0.267	0.008	0.010	0.012	0.017
Cobalt	148.00	14.80	0.050	0.129	0.172	0.445	0.062	0.172	0.215	0.592	0.063	0.171	0.218	0.589	0.060	0.149	0.208	0.513	0.051	0.131	0.177	0.452
Copper	27.00	24.10	0.244	0.432	**1.197**	**2.123**	0.244	0.432	**1.198**	**2.124**	0.244	0.432	**1.198**	**2.124**	0.244	0.432	**1.198**	**2.125**	0.244	0.432	**1.198**	**2.125**
Lead	11.80	6.51	0.045	0.108	0.082	0.196	0.046	0.116	0.083	0.211	0.046	0.122	0.084	0.222	0.046	0.109	0.083	0.197	0.045	0.107	0.082	0.195
Molybdenum	20.83	-	0.011	0.029	-	-	0.152	0.474	-	-	0.161	0.459	-	-	0.132	0.377	-	-	0.012	0.030	-	-
Nickel	10.70	14.60	0.183	0.561	0.134	0.411	0.190	0.590	0.139	0.432	0.191	0.579	0.140	0.424	0.188	0.580	0.138	0.425	0.183	0.563	0.134	0.413
Selenium	1.37	1.18	0.211	0.676	0.398	**1.276**	0.278	0.897	0.525	**1.694**	0.287	0.963	0.541	**1.818**	0.262	0.848	0.496	**1.601**	0.212	0.677	0.401	**1.278**
Uranium	-	16.00	-	-	0.014	0.020	-	-	0.015	0.022	-	-	0.015	0.022	-	-	0.014	0.020	-	-	0.014	0.020
Zinc	62.70	-	0.905	**3.026**	-	-	0.906	**3.026**	-	-	0.907	**3.026**	-	-	0.908	**3.029**	-	-	0.909	**3.032**	-	-

Fraction of time in area: 1.0

JSL @ Sissons	Toxicity Benchmarks (mg/(kg d))		Base				Kiggavik Project Year 10 of Operation				Kiggavik Project Year 5 of Final Closure				Kiggavik Project Year 15 of Final Closure				Kiggavik Project Year 5 of Post Closure			
			SIs - LOAELs		SIs - NOAELs		SIs - LOAELs		SIs - NOAELs		SIs - LOAELs		SIs - NOAELs		SIs - LOAELs		SIs - NOAELs		SIs - LOAELs		SIs - NOAELs	
	LOAELs	NOAELs	Average	95th	Average	95th	Average	95th	Average	95th	Average	95th	Average	95th	Average	95th	Average	95th	Average	95th	Average	95th
Arsenic	3.60	-	0.362	0.918	-	-	0.412	**1.050**	-	-	0.387	0.981	-	-	0.368	0.940	-	-	0.362	0.920	-	-
Cadmium	2.37	1.47	0.008	0.011	0.012	0.018	0.021	0.050	0.035	0.080	0.022	0.051	0.035	0.083	0.020	0.046	0.032	0.075	0.008	0.011	0.012	0.017
Cobalt	148.00	14.80	0.053	0.138	0.181	0.475	0.053	0.140	0.181	0.484	0.052	0.138	0.180	0.477	0.052	0.137	0.179	0.474	0.051	0.136	0.177	0.470
Copper	27.00	24.10	0.262	0.464	**1.286**	**2.281**	0.262	0.464	**1.286**	**2.282**	0.262	0.464	**1.287**	**2.283**	0.262	0.464	**1.287**	**2.283**	0.262	0.465	**1.287**	**2.283**
Lead	11.80	6.51	0.047	0.115	0.086	0.208	0.047	0.115	0.085	0.208	0.047	0.115	0.084	0.208	0.046	0.114	0.084	0.206	0.046	0.114	0.084	0.206
Molybdenum	20.83	-	0.011	0.031	-	-	0.073	0.217	-	-	0.055	0.168	-	-	0.029	0.083	-	-	0.012	0.031	-	-
Nickel	10.70	14.60	0.194	0.602	0.142	0.441	0.195	0.604	0.143	0.443	0.195	0.604	0.143	0.442	0.195	0.604	0.143	0.443	0.195	0.603	0.143	0.442
Selenium	1.37	1.18	0.226	0.727	0.427	**1.373**	0.244	0.792	0.460	**1.496**	0.241	0.768	0.454	**1.450**	0.236	0.742	0.446	**1.402**	0.228	0.728	0.430	**1.374**
Uranium	-	16.00	-	-	0.014	0.021	-	-	0.025	0.039	-	-	0.021	0.034	-	-	0.015	0.022	-	-	0.014	0.021
Zinc	62.70	-	0.971	**3.252**	-	-	0.971	**3.251**	-	-	0.972	**3.253**	-	-	0.973	**3.254**	-	-	0.973	**3.255**	-	-

Fraction of time in area: 1.0

Note: **BOLD SHADING** indicates a screening index exceedance of 1.0

8.2.2 Radiological Dose

The potential adverse effects of radionuclides on terrestrial ecological receptors were evaluated by comparing the predicted mean and 95th percentile dose estimates, which were derived using a RBE value of 10, to the selected benchmark of 2.7 mGy/d. Attachment H provides details of the dose calculation and a sample calculation. The exposure calculations consider their total exposure and thus include baseline plus Project impacts as well as background exposures to receptors while they are outside of the study area. Therefore, calculated screening index values are compared to a benchmark of 1.0.

A baseline gamma level of 40 nGy/h (or 0.04 μGy/h) was used to calculate external dose to ecological receptors. This value represents a typical value based on airborne gamma ray spectrometry for the Thelon River area, as presented by Carson et al. (2001).

The screening index values for the equivalent dose are provided in Table 8.2-17. All calculated screening index values are well below a benchmark value of 1.0, which indicates that there are no predicted negative impacts to terrestrial receptors. The largest screening index values (0.06 at the 95^{th} percentile level) were calculated for the ptarmigan and sandpiper. The SI values provided in the table show that the Project is expected to have a trivial contribution to the exposure of radioactivity to terrestrial biota.

Table 8.2-17 Results of Radiological Assessment for Terrestrial Receptors

Screening Index - Equivalent Dose	Baseline		Year 10 of Operation		Year 5 of Final Closure		Year 15 of Final Closure		Year 5 of Post Closure	
RBE 10, Benchmark 2.7 mGy/d	**Mean**	**95th**	**Mean**	**95th**	**Mean**	**95th**	**Mean**	**95th**	**Mean**	**95th**
Bear - LAA	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Caribou - LAA	<0.01	0.03	<0.01	0.03	<0.01	0.03	<0.01	0.03	<0.01	0.03
Caribou - RAA	<0.01	0.03	<0.01	0.03	<0.01	0.03	<0.01	0.03	<0.01	0.03
Falcon - LAA	0.01	0.04	0.01	0.04	0.01	0.04	0.01	0.04	0.01	0.04
Falcon - RAA	0.01	0.04	0.01	0.04	0.01	0.04	0.01	0.04	0.01	0.04
Fox - LAA	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Lemming - Rock Lake Watershed	<0.01	0.01	<0.01	0.01	<0.01	0.01	<0.01	0.01	<0.01	0.01
Lemming - JSL @ Kiggavik Discharge	<0.01	0.01	<0.01	0.01	<0.01	0.01	<0.01	0.01	<0.01	0.01
Lemming - Kiggavik Camp	<0.01	0.01	0.01	0.04	<0.01	0.01	<0.01	0.01	<0.01	0.01
Lemming - JSL @ Sissons Discharge	<0.01	0.01	<0.01	0.02	<0.01	0.01	<0.01	0.01	<0.01	0.01
Lapland Longspur - Rock Lake Watershed	<0.01	0.03	<0.01	0.03	<0.01	0.03	<0.01	0.03	<0.01	0.03
Lapland Longspur - JSL @ Kiggavik Discharge	<0.01	0.03	<0.01	0.03	<0.01	0.03	<0.01	0.03	<0.01	0.03

Table 8.2-17 Results of Radiological Assessment for Terrestrial Receptors

Screening Index - Equivalent Dose	Baseline		Year 10 of Operation		Year 5 of Final Closure		Year 15 of Final Closure		Year 5 of Post Closure	
RBE 10, Benchmark 2.7 mGy/d	**Mean**	**95th**	**Mean**	**95th**	**Mean**	**95th**	**Mean**	**95th**	**Mean**	**95th**
Lapland Longspur - Kiggavik Camp	<0.01	0.03	0.01	0.03	<0.01	0.03	<0.01	0.03	<0.01	0.03
Lapland Longspur - JSL @ Sissons Discharge	<0.01	0.03	<0.01	0.03	<0.01	0.03	<0.01	0.03	<0.01	0.03
Long-Tailed Duck - JSL @ Kiggavik Discharge	0.01	0.04	0.01	0.04	0.01	0.04	0.01	0.04	0.01	0.04
Long-Tailed Duck - JSL @ Sissons Discharge	0.01	0.04	0.01	0.04	0.01	0.04	0.01	0.04	0.01	0.04
Merganser - JSL @ Kiggavik Discharge	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Merganser - JSL @ Sissons Discharge	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Muskox - JSL @ Kiggavik Discharge	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Muskox - JSL @ Sissons Discharge	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Northern Pintail - JSL @ Kiggavik Discharge	<0.01	0.03	<0.01	0.03	<0.01	0.03	<0.01	0.03	<0.01	0.03
Northern Pintail - JSL @ Sissons Discharge	<0.01	0.03	<0.01	0.03	<0.01	0.03	<0.01	0.03	<0.01	0.03
Ptarmigan - Rock Lake Watershed	0.02	0.06	0.02	0.06	0.02	0.06	0.02	0.06	0.02	0.06
Ptarmigan - JSL @ Kiggavik Discharge	0.02	0.06	0.02	0.06	0.02	0.06	0.02	0.06	0.02	0.06
Ptarmigan - Kiggavik Camp	0.02	0.06	0.02	0.06	0.02	0.06	0.02	0.06	0.02	0.06
Ptarmigan - JSL @ Sissons Discharge	0.02	0.06	0.02	0.06	0.02	0.06	0.02	0.06	0.02	0.06
Sandpiper - JSL @ Kiggavik Discharge	0.02	0.06	0.02	0.06	0.02	0.06	0.02	0.06	0.02	0.06
Sandpiper - JSL @ Sissons Discharge	0.02	0.06	0.02	0.06	0.02	0.06	0.02	0.06	0.02	0.06
Shrew - Rock Lake Watershed	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Shrew - JSL @ Kiggavik Discharge	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Shrew - Kiggavik Camp	<0.01	<0.01	<0.01	0.02	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Shrew - JSL @ Sissons Discharge	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Squirrel - Rock Lake Watershed	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Squirrel - JSL @ Kiggavik Discharge	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Squirrel - Kiggavik Camp	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Squirrel - JSL @ Sissons Discharge	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Wolf - LAA	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Wolf - RAA	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Wolverine - LAA	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Wolverine - RAA	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01

Note: Results presented for a RBE of 10 and a benchmark value of 2.7 mGy/d.

9 Results for Human Health Risk Assessment

This section presents the predicted risk of adverse health effects to individuals (other than those classified as nuclear energy workers) who could conceivably be exposed to COPC released to the environment from the Kiggavik Project. An assessment of the exposure to COPC to workers is presented in Volume 8 of the EIS.

Atmospheric and aquatic emissions from the Kiggavik Project were used to predict doses and intakes to human receptors in the study area. As outlined in previous sections, the aquatic environment was explicitly modeled; water and sediment quality predictions were made for Judge Sissons Lake. Similarly, atmospheric emissions from dust re-suspension and radon releases from the site were included in the assessment as discussed in Section 3.

The water quality and pathways models are coupled and were run probabilistically to permit uncertainty in the input parameters to be explicitly accounted for in the model predictions. Results from air quality modelling (discussed separately in Appendix 4B Air Quality) were input to the pathways model. The magnitude of the uncertainties in the model parameters is reflected in the values assigned to the input parameter distributions discussed in prior sections and in the attachments. The pathways modeling results presented below are based on 200 trials, and unless noted otherwise, results are the arithmetic mean or expected value.

9.1 Exposure to NO_x, SO_2 and Dust

In Appendix 4B predicted air concentrations were compared to air quality standards. The standards used are from NWT which in turn adopted the Canadian National Ambient Air Quality Objectives (Government of Northwest Territories, 2011). The NAAQO's are developed through scientific assessment, derivation of reference levels, assessment of monitoring technologies, economic benefits and public/stakeholder consultations. Therefore, the ambient air quality objectives are not necessarily protective of health. In addition, there has been a substantial amount of study into the health effects to criteria air pollutants in recent times, before the NAAQOs were established. Therefore, in order to examine the effects of the predicted NO_2 air concentrations on human health it is necessary to compare to health-based criteria such as those provided by the World Health Organization (WHO). The maximum incremental concentrations of NO_2 and SO_2 are presented in Table 9.1-1 for the maximum bounding scenario. It should be noted that these maximum concentrations do not occur simultaneously as outlined in Appendix 4B. Also shown in the table are health-based criteria provided by the World Health Organization (WHO).

Table 9.1-1 Incremental Maximum Concentrations of NO_2 and SO_2 at Discrete Receptor Locations

Receptor Name	NO_2 (µg/m^3)			SO_2 (µg/m^3)	
	Incremental 1-hr Maximum	Frequency of Exceedances 1-hr Max (hours per year)	Incremental Annual Maximum	Incremental 1-hr Maximum	Incremental 24-hr Maximum
Accommodation Complex	**380.7**	117	13.6	41	1.03
Community of Baker Lake	3.8	n/a	0.04	0.16	
Judge Sissons Lake Cabin	36.5	n/a	0.80	2.7	
Health-Based Criteria (µg/m^3)	200	-	40	500	20

The use of the health-based 1-hr maximum incremental criteria for NO_2 of 200 µg/m^3 is protective of sensitive individuals (i.e., people with asthma) and therefore needs no built in safety factors. The annual guideline of 40 µg/m^3 is set to protect the public from gaseous effects of NO_2 (WHO 2005). In addition, there is epidemiological evidence in children with asthma indicating that bronchitic symptoms increase with increasing NO2 concentrations. Annual NO2 concentrations meet applicable criteria at the discrete receptors locations, including at the residential community of Baker Lake. Although only workers will be present on the site the occupational limits were not applied to the Accomodation Complex since people will be spending a significant amount of time at that location, more than generally accounted for in the derivation of time-weighted occupational limits. There are 1-hour NO2 concentrations above the criterion of 200 µg/m3 over the area surrounding both the Kiggavik and Sissons mine sites. Exceedances can be attributed to emissions of NOx from open pit mining activities, including diesel-powered mining equipment and blasting. At the Camp location, approximately 1% of the hours (117 hours out of 8760 hours over the year) exceed the health-based limit of 200 µg/m3. As mentioned above, the health-based limit is set to be protective of sensitive individuals such as asthmatics. It should be noted that the WHO indicates that concentrations in the range of 1880 µg/m^3 did not result in any adverse respiratory effects in healthy adults. NIOSH has a short-term occupational limit of 1800 µg/m^3 and since all people present at the Accomodation Complex are workers this value can be considered. Overall, it is unlikely that adults working at the Camp would experience any health issue related to short-term NO_2 exposure..

As can be seen in Table 9.1-1, 1- and 24-hour maximum concentrations of SO_2 are well within the limits of applicable health-based criteria.

The predicted incremental concentrations of dust (PM_{10} and $PM_{2.5}$) are presented in Table 9.1-2 for the maximum bounding scenario. Also shown in the table are health-based criteria for particulate. It is important to note that the maximum concentrations at each receptor typically occur during different meteorological conditions (i.e., different days) and do not occur simultaneously.

Table 9.1-2 Incremental Maximum 24-hr Concentrations of PM_{10} and $PM_{2.5}$ at Discrete Receptor Locations

Discrete Receptor Name	PM_{10} (µg/m^3)		$PM_{2.5}$ (µg/m^3)	
	Incremental 24-hr Maximum	**Frequency of Exceedances 24-hr Max (days per year)**	**24-hr 98th Percentile**	**Frequency of Exceedances 24-hr Max (days per year)**
Accommodation Complex	**115.2**	35	22.5	34
Community of Baker Lake	0.6	n/a	0.2	n/a
Judge Sissons Lake Cabin	11.1	n/a	2.0	n/a
Health-Based Criteria (µg/m^3)	**25**	-	**7**	-

As can be seen in the table, the modelling suggests the potential for particulate matter at the Accommodation Complex to exceed the health-based guidelines. No exceedances are expected at other receptor locations. Exceedances can be attributed to emissions of dust from open pit mining activities, including unpaved road dust generated on the in-pit ramps.

This current assessment does not attempt to predict $PM_{2.5}$-induced changes in mortality or morbidity rates at the camp because the concentration-response relationships are based on epidemiological studies on large cities with large populations (several hundred thousand people) and the robustness of these studies and applicability to the small number of people in the camp becomes increasingly less certain as the number of people decrease. Furthermore, there are a number of uncertainties inherent in the $PM_{2.5}$ concentration-response relationships developed from these epidemiological studies (U.S.EPA 2010).

The epidemiological literature suggests the following relationships between fine particulate matter and potential health effects:

- Older adults have a greater susceptibility for cardiovascular morbidity with PM exposure.
- Children are at an increased risk of PM-related respiratory effects relative to adults.
- Individuals with underlying cardiovascular and respiratory diseases are more susceptible to adverse effects from PM-exposure.
- Good nutritional status is reported to have protective effects against PM exposure.

Given the above discussion and the fact that the workers present at the camp would be healthy individuals with good nutritional status, the probability of adverse effects related to PM exposure is likely to be low.

Results did not account for application of routine mitigative control measures for blasting to ensure personnel at the accommodation complex will be minimally exposed to NO_2, PM_{10} and $PM_{2.5}$. Simple control measures such as monitoring weather conditions, notifying personnel, and relocating people before a blast can serve to eliminate exposure to the NO_2 and dust.

9.2 Non-Carcinogenic Effects

For many non-carcinogenic effects, protective biological mechanisms must be overcome before an adverse effect is manifested from exposure to the contaminant. This is known as a "threshold" concept. The potential for an effect is evaluated through a comparison to toxicity reference values (TRVs). However, it should be noted that exposure above a TRV does not mean that an effect will occur, but instead means that there is an increased risk of an adverse effect occurring.

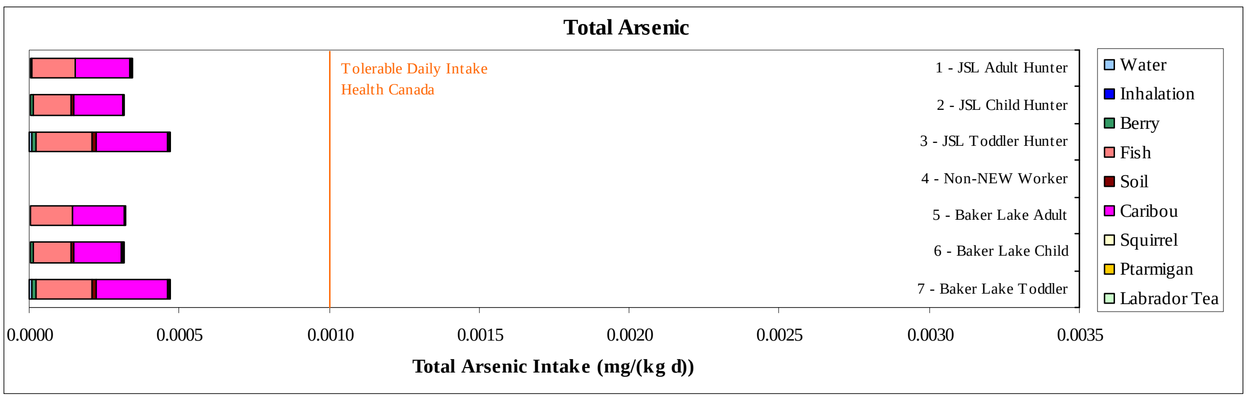
Doses occurring as a result of the Kiggavik Project are referred to as “incremental” (above background) exposures and include all of the exposure pathways assessed in the model. Exposures occurring as a result of other activities are referred to as “baseline” exposures. Both incremental and baseline exposure are required to estimate total intake, which is subsequently compared to toxicity benchmarks in the case of non-radionuclides.

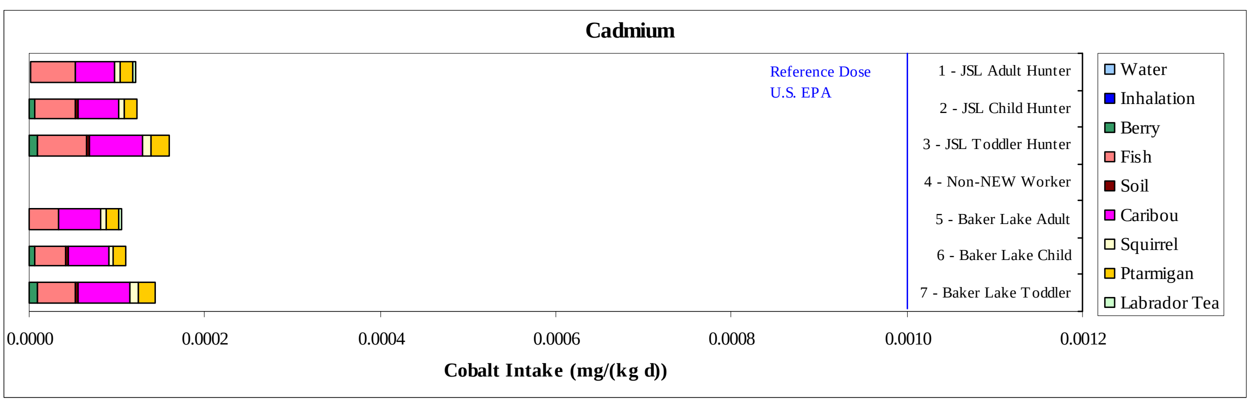
In this assessment, soil and inhalation exposures as well as water intakes and the majority of the diet (meat, fish, berries, and other traditional food consumption) over the year were evaluated; the dermal pathway (a relatively insignificant pathway for non-volatile chemicals); supermarket foods were not considered.

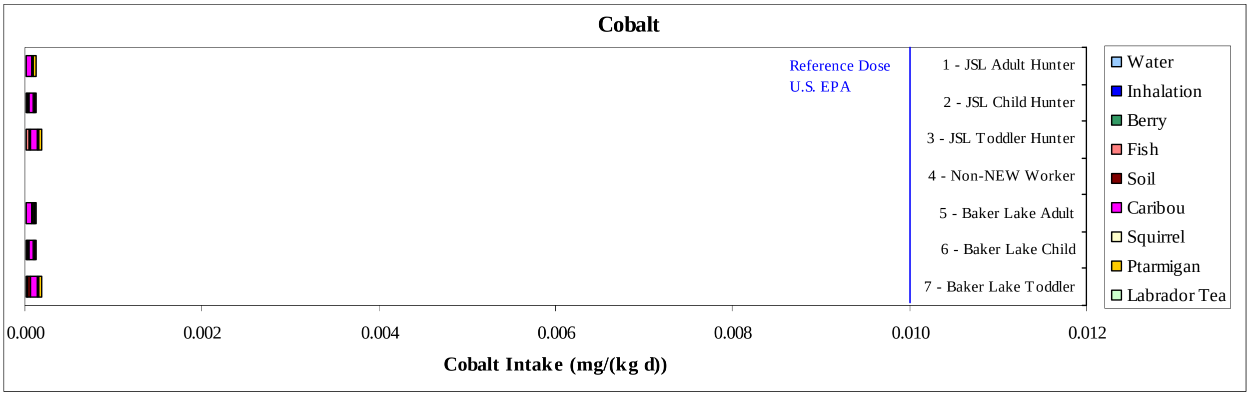
Exposures to non-radionuclides were evaluated as daily intakes. Estimated exposures to non-radionuclides for the adult and child human receptors were obtained from the INTAKE pathways model described in Section 2.10. The annual exposures were converted to a daily exposure (mg/(kg d)) by dividing by the body weight (70.7 kg for an adult and 32.9 kg for a child and 16.5 for a toddler) and the number of days in a year (365 d). These exposures were compared to the toxicity benchmarks, presented in Section 6.2.

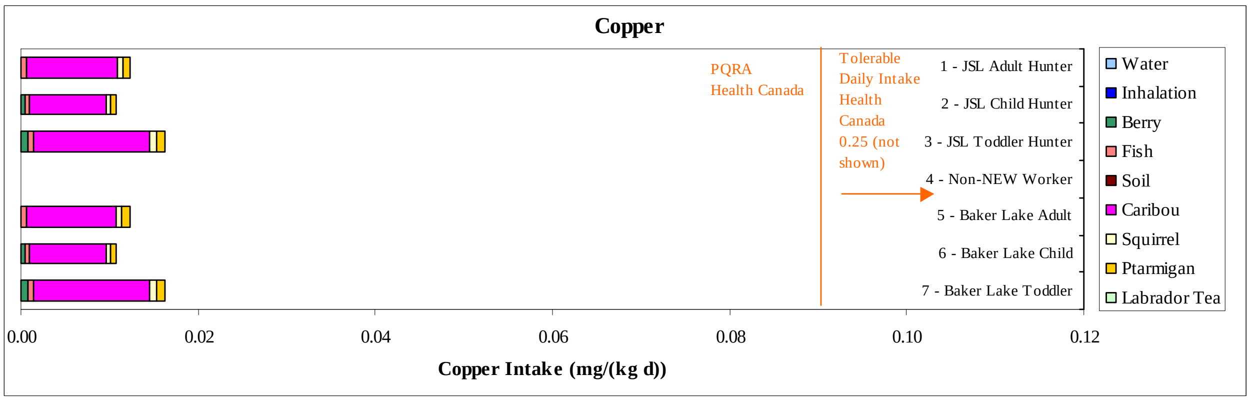
Detailed summaries of the contributions of each pathway to the total intakes are provided in Attachment F. Figure 9.2-1 presents a graphical summary of the predicted mean intakes for the maximum exposure during the operation period. The appropriate TRVs are also indicated in Figure 9.2-1 for comparison. The figure shows that the predicted intakes for all the human receptors are below the applicable TRVs for all non-carcinogenic COPC. Values provided by Health Canada were generally preferentially selected as TRVs for evaluation of the health impacts on human receptors. The Toxicology Evaluation Section of the Health Products and Food Branch of Health Canada has published TDIs for a number of trace elements found in foodstuff. These values were also considered for use in this assessment.

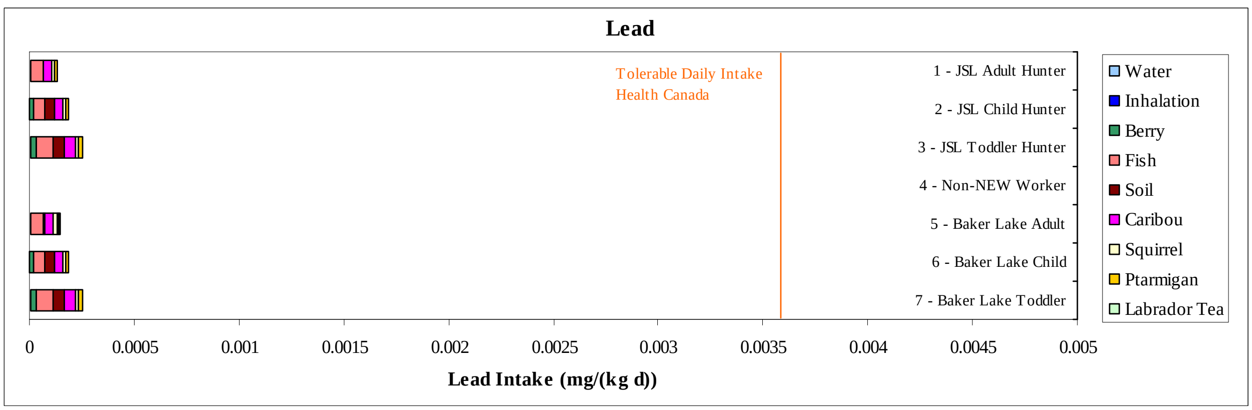
Figure 9.2-1 also indicates the most significant pathways for the total intake of each COPC. Fish and caribou ingestion are the biggest contributors for arsenic, cadmium, and selenium. Caribou, soil, berry, and ptarmigan ingestion are the most significant pathways for cobalt and molybdenum. Lead intake is mostly from soil, fish, and caribou ingestion. Berry and ptarmigan ingestion dominate the intake of nickel, and caribou ingestion is by far the most significant pathway for copper, uranium and zinc intakes.

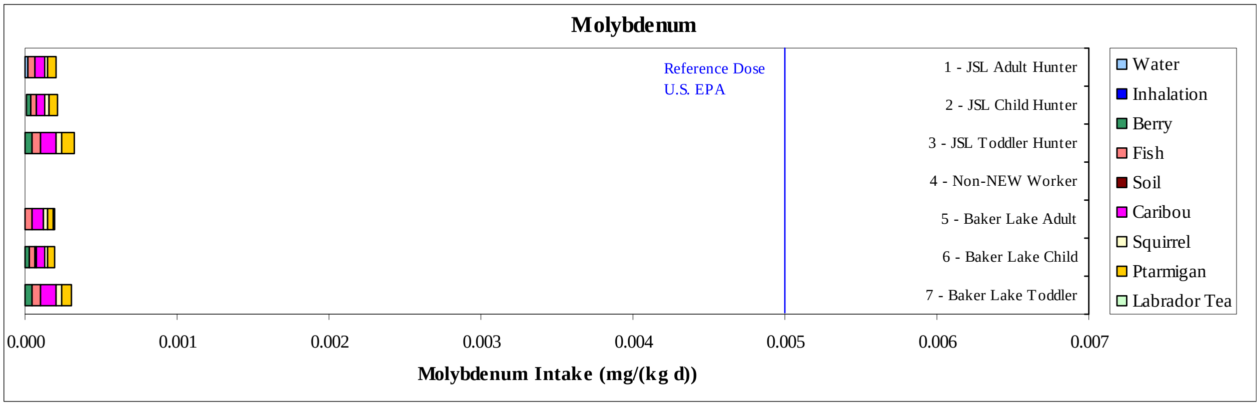


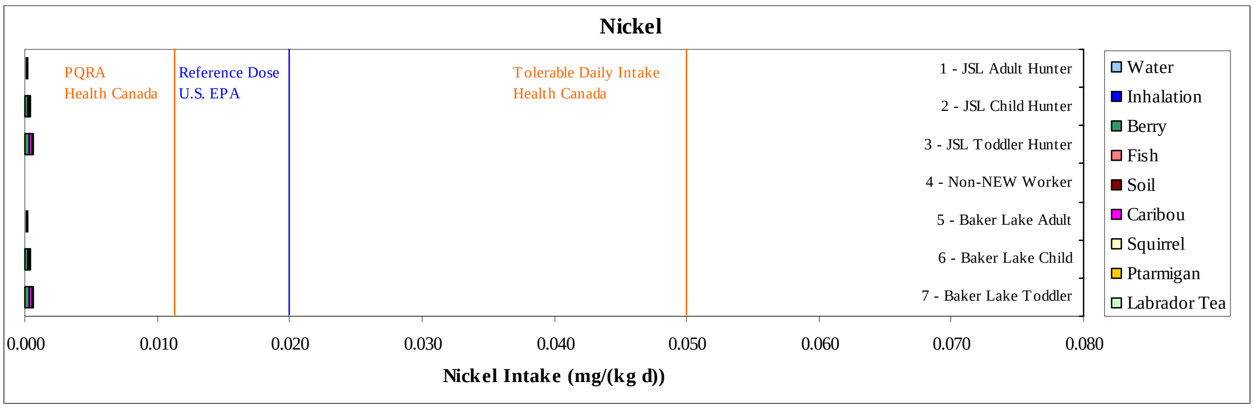


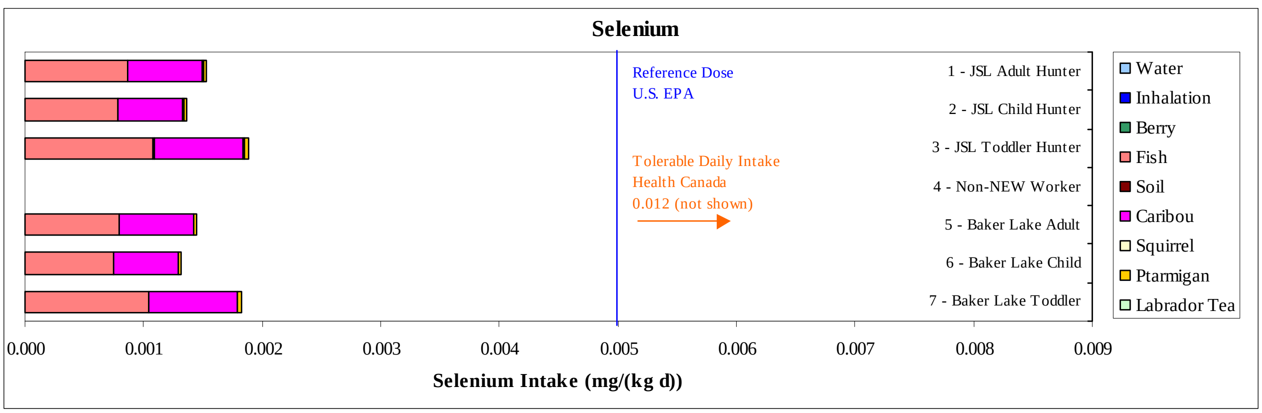

Cobalt
Reference Dose
U.S. EPA
1 - JSL Adult Hunter
2 - JSL Child Hunter
3 - JSL Toddler Hunter
4 - Non-NEW Worker
5 - Baker Lake Adult
6 - Baker Lake Child
7 - Baker Lake Toddler
Water
Inhalation
Berry
Fish
Soil
Caribou
Squirrel
Ptarmigan
Labrador Tea
0.000
0.002
0.004
0.006
0.008
0.010
0.012
Cobalt Intake (mg/(kg d))

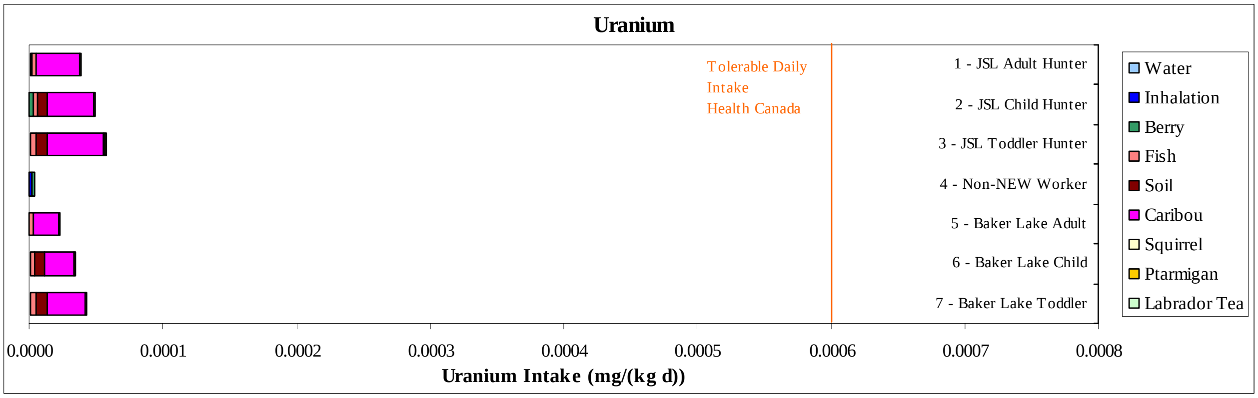

Copper
PQRA
Health Canada
Tolerable
Daily Intake
Health
Canada
0.25 (not
shown)
1 - JSL Adult Hunter
2 - JSL Child Hunter
3 - JSL Toddler Hunter
4 - Non-NEW Worker
5 - Baker Lake Adult
6 - Baker Lake Child
7 - Baker Lake Toddler
Water
Inhalation
Berry
Fish
Soil
Caribou
Squirrel
Ptarmigan
Labrador Tea
0.00
0.02
0.04
0.06
0.08
0.10
0.12
Copper Intake (mg/(kg d))


Lead
Tolerable Daily Intake
Health Canada
1 - JSL Adult Hunter
2 - JSL Child Hunter
3 - JSL Toddler Hunter
4 - Non-NEW Worker
5 - Baker Lake Adult
6 - Baker Lake Child
7 - Baker Lake Toddler
Water
Inhalation
Berry
Fish
Soil
Caribou
Squirrel
Ptarmigan
Labrador Tea
0
0.0005
0.001
0.0015
0.002
0.0025
0.003
0.0035
0.004
0.0045
0.005
Lead Intake (mg/(kg d))


Molybdenum
Reference Dose
U.S. EPA
1 - JSL Adult Hunter
2 - JSL Child Hunter
3 - JSL Toddler Hunter
4 - Non-NEW Worker
5 - Baker Lake Adult
6 - Baker Lake Child
7 - Baker Lake Toddler
Water
Inhalation
Berry
Fish
Soil
Caribou
Squirrel
Ptarmigan
Labrador Tea
0.000
0.001
0.002
0.003
0.004
0.005
0.006
0.007
Molybdenum Intake (mg/(kg d))


Nickel
PQRA
Health Canada
Reference Dose
U.S. EPA
Tolerable Daily Intake
Health Canada
1 - JSL Adult Hunter
2 - JSL Child Hunter
3 - JSL Toddler Hunter
4 - Non-NEW Worker
5 - Baker Lake Adult
6 - Baker Lake Child
7 - Baker Lake Toddler
Water
Inhalation
Berry
Fish
Soil
Caribou
Squirrel
Ptarmigan
Labrador Tea
0.000
0.010
0.020
0.030
0.040
0.050
0.060
0.070
0.080
Nickel Intake (mg/(kg d))


Selenium
Reference Dose
U.S. EPA
Tolerable Daily Intake
Health Canada
0.012 (not shown)
1 - JSL Adult Hunter
2 - JSL Child Hunter
3 - JSL Toddler Hunter
4 - Non-NEW Worker
5 - Baker Lake Adult
6 - Baker Lake Child
7 - Baker Lake Toddler
Water
Inhalation
Berry
Fish
Soil
Caribou
Squirrel
Ptarmigan
Labrador Tea
0.000
0.001
0.002
0.003
0.004
0.005
0.006
0.007
0.008
0.009
Selenium Intake (mg/(kg d))



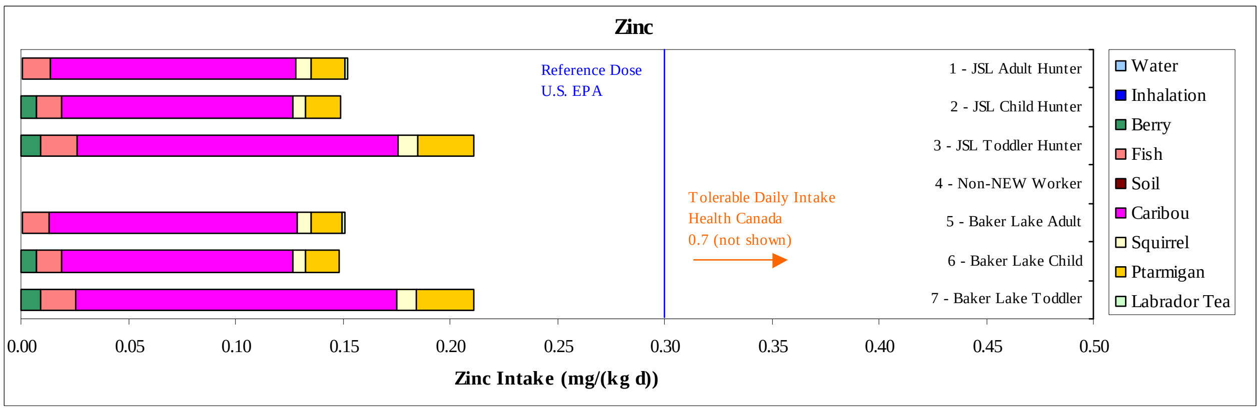


Figure 9.2-1 Predicted Maximum Mean Intakes of Non-Radionuclides by Pathway for Human Receptors

Table 9.2-1 provides a comparison on the mean intake of the toddler (the most exposed) to intakes that are generally expected for Canadian toddlers. It should be noted that the intakes for the Kiggavik Project and baseline do not account for all pathways of exposure as supermarket foods (e.g., milk, pasta) are not included. This table shows that the exposure to local toddlers is similar to typical Canadian exposure and below levels of concern. The intakes associated with baseline exposures from the model are also indicated in Table 9.2-1.

Table 9.2-1 Assessment of Exposure to Non-Radioactive COPC for Members of the Public (Toddler of Judge Sissons Hunter)

		Baseline[a]		Kiggavik Project + Baseline[a]		General Canadian	
	Health Benchmark (µg/(kg d))	Intake (µg/(kg d))	% Health Benchmark	Intake (µg/(kg d))	% Health Benchmark	Intake (µg/(kg d))	% Health Benchmark
Arsenic	1	0.47	47%	0.47	47%	0.66	66%
Cadmium	1	0.14	14%	0.16	16%	0.56	56%

	Health Benchmark (µg/(kg d))	Baseline[a]		Kiggavik Project + Baseline[a]		General Canadian	
		Intake (µg/(kg d))	% Health Benchmark	Intake (µg/(kg d))	% Health Benchmark	Intake (µg/(kg d))	% Health Benchmark
Cobalt	10	0.19	2%	0.19	2%	0.71	7.1%
Copper	90	16.3	18%	16.3	18%	56.8	63%
Lead	3.6	0.25	7%	0.25	7%	0.60	17%
Molybdenum	5	0.31	6%	0.32	6%	8.59	172%
Nickel	11	0.59	5%	0.59	5%	11.5	104%
Selenium	5	1.84	37%	1.88	38%	4.2	84%
Uranium	0.6	0.03	5%	0.05	10%	0.08	13%
Zinc	300	211	70%	211	70%	549	183%

Note:

a The intakes reflect the total exposure (baseline + Project emissions) for all routes of exposure included in the assessment. Other routes of exposure (e.g., supermarket foods such as milk, grains) have not been included.

There in some uncertainty present in the assessment with the use of TRVs, specifically the TRV for lead, which is no longer supported by Health Canada. However, the results presented for the non-carcinogenic effects assessment for humans indicates that there is very little, if any, increase above baseline intakes predicted for the assessment for most COPC. Therefore, changes to the TRVs considered in the assessment are unlikely to affect the conclusions of the assessment.

9.3 Carcinogenic Effects

For carcinogenic COPC (arsenic in this assessment), a risk is calculated by multiplying the estimated dose (in mg/(kg-d)) by the appropriate slope factor (in $(mg/(kg\text{-}d))^{-1}$). This is shown in equation (9.3-1). The estimate corresponds to an incremental risk of an individual developing cancer over a lifetime as a result of exposure. Risk is defined as follows:

$$Risk = (D_o \times SF_o) + (D_d \times SF_d) \quad (9.3\text{-}1)$$

where:

D_o = Dose due to oral (ingestion) exposure (mg/(kg-d));

D_d = Dose due to dermal exposure (mg/(kg-d));

SF_o = Slope Factor for oral exposure $(mg/(kg\text{-}d))^{-1}$;

SF_d = Slope Factor for dermal exposure $(mg/(kg\text{-}d))^{-1}$ (assumed equal to SF_o).

The doses or intakes for the different pathways of exposure are presented in Attachment F and the slope factors used in this assessment are presented in Section 6.2. The calculated risk is then compared to acceptable benchmarks. In this assessment, an incremental risk level of 1 x 10^{-5} (1 in 100,000) was used to assess carcinogenic effects. Health Canada considers this value to represent an “essentially negligible” risk (Appendix C: Essentially Negligible Cancer Risk for Contaminated Site Risk Assessment of Health Canada (2010) *Part 1: Guidance on Human Health Preliminary Quantitative Risk Assessment (PQRA), Version 2.0)*. In this case, two composite receptors are assessed: one composite resident receptor in the Baker Lake community and one Judge Sissons Lake hunter composite receptor. The composite receptors encompass the exposure of a toddler for 4 years, then as a child on the site for 10 years, and the exposure of this child as an adult for another 60 years. In simple terms, the assessment considers that each composite receptor is exposed throughout their lifetime from toddler to child to an adult.

Table 9.3-1 summarizes the mean predicted lifetime incremental risks from arsenic associated with the Project. The Judge Sissons Lake hunter composite receptor has a higher predicted incremental risk from arsenic than the Baker Lake composite receptor; however, both composite receptors have an incremental arsenic risk below the acceptable benchmark of 1 x 10^{-5} (1 in 100,000) which, as outlined by Health Canada, represents an “essentially negligible" risk.

Table 9.3-1 Predicted Lifetime Incremental Risk from Arsenic

	Average Lifetime Risk From Incremental Arsenic From Project Effects									
	Water	Inhalation	Berries	Fish	Soil	Caribou	Squirrel	Ptarmigan	L. Tea	Total
JSL Hunter Composite	$1.3x10^{-6}$	$4.3x10^{-10}$	$4.0x10^{-9}$	$5.8x10^{-8}$	$2.6x10^{-10}$	$4.5x10^{-7}$	$5.1x10^{-9}$	$3.5x10^{-7}$	$1.2x10^{-10}$	$2.2x10^{-6}$
Baker Lake Composite	$1.8x10^{-8}$	$1.6x10^{-10}$	$2.8x10^{-10}$	$1.7x10^{-6}$	$3.2x10^{-10}$	$2.0x10^{-7}$	$2.7x10^{-10}$	$1.4x10^{-10}$	$1.1x10^{-10}$	$1.9x10^{-6}$

	Breakdown of Average Lifetime Risk by Pathway								
	Water	Inhalation	Berries	Fish	Soil	Caribou	Squirrel	Ptarmigan	L. Tea
JSL Hunter Composite	59.8%	<0.1%	0.2%	2.7%	<0.1%	20.7%	0.2%	16.4%	<0.1%
Baker Lake Composite	0.9%	<0.1%	<0.1%	88.5%	<0.1%	10.5%	<0.1%	<0.1%	<0.1%

9.4 Radiation Dose Effects

Regardless of where people live or work, they are exposed to radiation from natural sources; this ranges from about 1,000 to 13,000 microsieverts per year (μSv/year) (UNSCEAR 2008, Annex B). People are exposed to radiation from natural sources, such as: cosmic rays; radionuclides in air, water and food; and gamma radiation from naturally occurring radioactive elements in the soil, rocks, and building materials used in homes. Table 9.4-1 lists exposure to radiation to some of the common sources of naturally occurring radiation for those living in Canada (AECB 1995). This information is also illustrated in Table 9.4-1. An additional source of radiation to some individuals is through diagnostic medical procedures.

Table 9.4-1 Typical Natural Sources of Radiation for Canadian Population

Natural Sources of Radiation	Average Annual Dose
Dose from cosmic radiation	300 μSv/year
Naturally-occurring radionuclides (uranium and thorium series and K-40) found in soil, rocks, sediments that transfer naturally to human food, water and air	350 μSv/year
Naturally-occurring radionuclides in soils, rocks, and building materials contributing to gamma radiation	350 μSv/year
Naturally-occurring radon gas and its radioactive decay products	1,000 μSv/year

Source: AECB (1995)

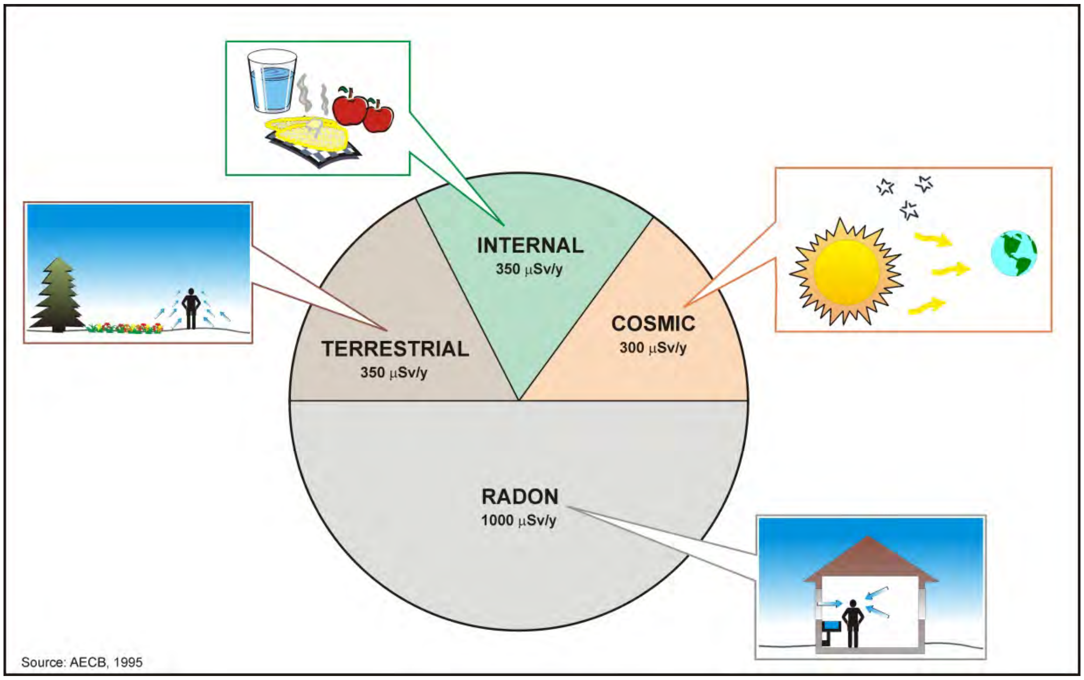


Figure 9.4-1 Typical Distribution of Annual Dose from Natural Radiation

The typical radiation dose for people living in the Project area may be different than that identified in Table 9.4-1 and Figure 9.4-1. Due to consumption of caribou that consume lichen, the internal dose is likely higher than that shown above. For example, ingestion of caribou in northern Canada has been shown to add 1,000 to 4,000 µSv/y, primarily due to the natural background levels of Po-210 (Thomas et al. 2001). Artificial radionuclides from fall-out can also contribute to the dose from ingestion of caribou, although this is expected to be a small factor. For example, Thomas and Gates (1999) estimated that Cs-137 could contribute to just over 10% of the total dose. Due to the lack of basements in houses in the far north, the dose from radon may be less than than the typical exposure estimates for radon provided above.

Annual incremental doses (i.e., above baseline) for the Project were evaluated for exposure to radionuclides. For exposure to radionuclides, the incremental dose from the Project was calculated for each receptor.

The incremental annual radiation dose resulting from the Project for the seven receptors is summarized in

Table 9.4-2. The highest predicted mean incremental dose is 98 μSv/year for the non-NEW worker. This is below the CNSC incremental dose limit of 1,000 μSv/year as well as the Health Canada dose constraint of 300 μSv/year.

Table 9.4-2 Summary of Incremental Annual Radiation Dose Related to Project Activities

Human Receptor	Maximum Mean Incremental Radiation Dose Related to Project Activities (µSv/year)	CNSC Recommended Allowable Incremental Dose for Protection of Members of Public
1 – JSL Adult Hunter	29	1,000 µSv/year
2 – JSL Child Hunter	50	
3 – JSL Toddler Hunter	59	
4 – Non-NEW Worker	98	
5 – Baker Lake Adult	15	
6 – Baker Lake Child	24	
7 – Baker Lake Toddler	29	

Figure 9.4-2 presents a graphical summary of the predicted average incremental dose to human receptors from radiation for the Project activities. The majority of the incremental radiation dose for all receptors except for the non-NEW worker is from caribou. This dose is primarily from Po-210. As discussed in Section 7.1.1, the assessment of Pb-210, and therefore Po-210, was based on uranium in dust and the ingrowth of Pb-210 from radon was not included. The inclusion of this additional source of Pb-210 and Po-210 would increase the estimated doses to these receptors; however, the dose would remain well below the CNSC recommended allowable dose for members of the public. The non-NEW worker receives most of his/her incremental dose from radon and inhalation. Figure 9.4-3 provides the predicted incremental radiation doses to human receptors considered in the assessment over the phases of the project.

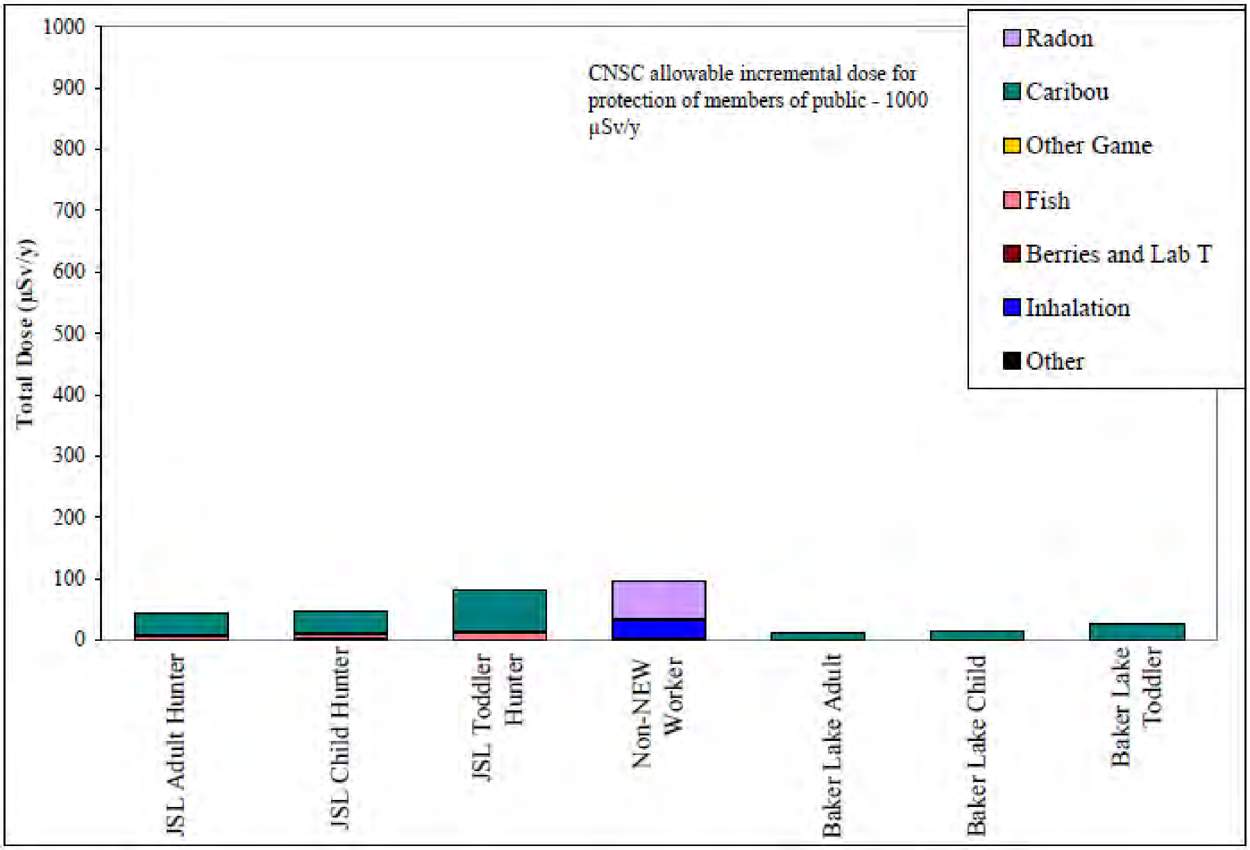
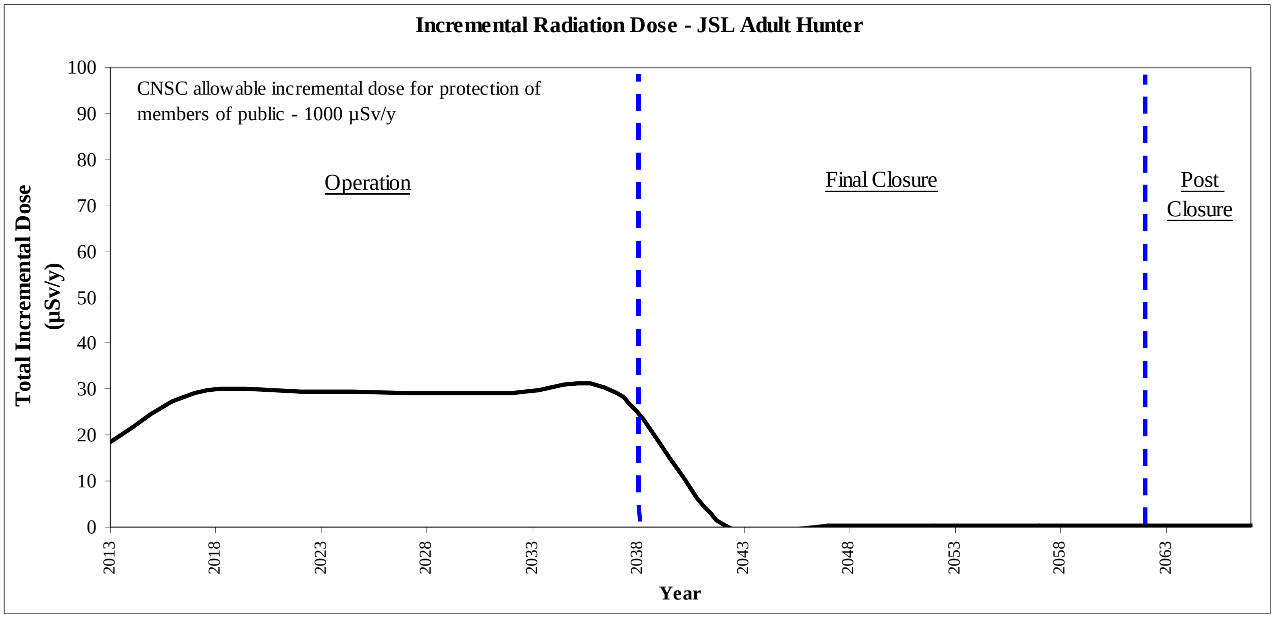
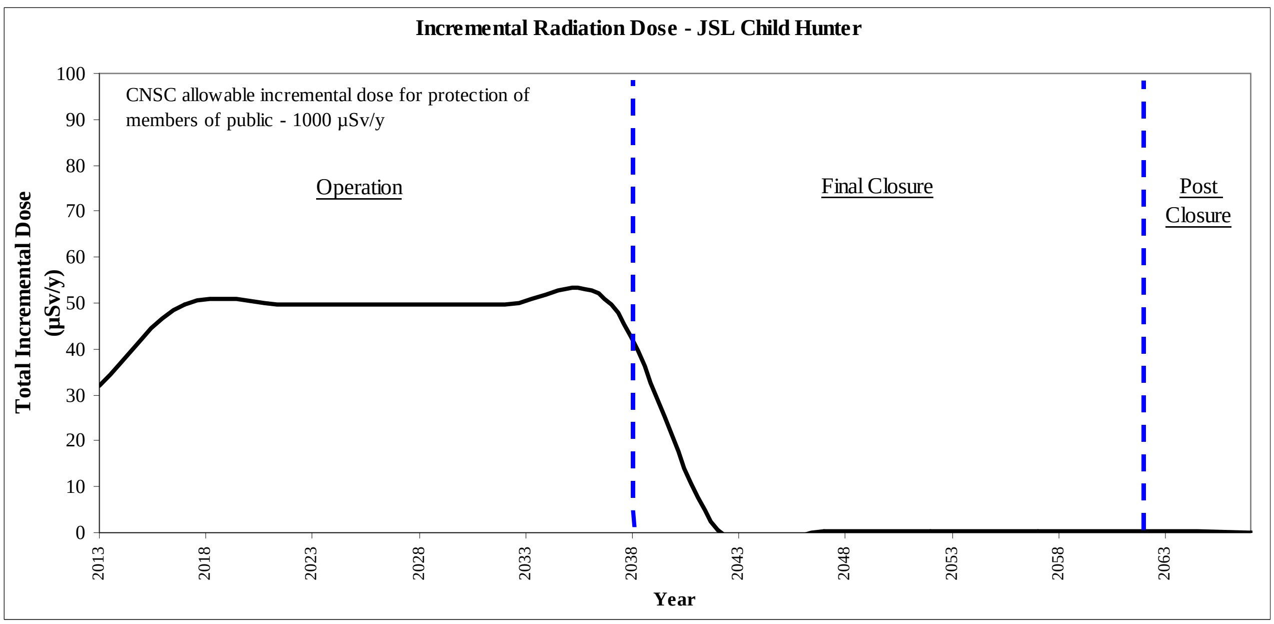
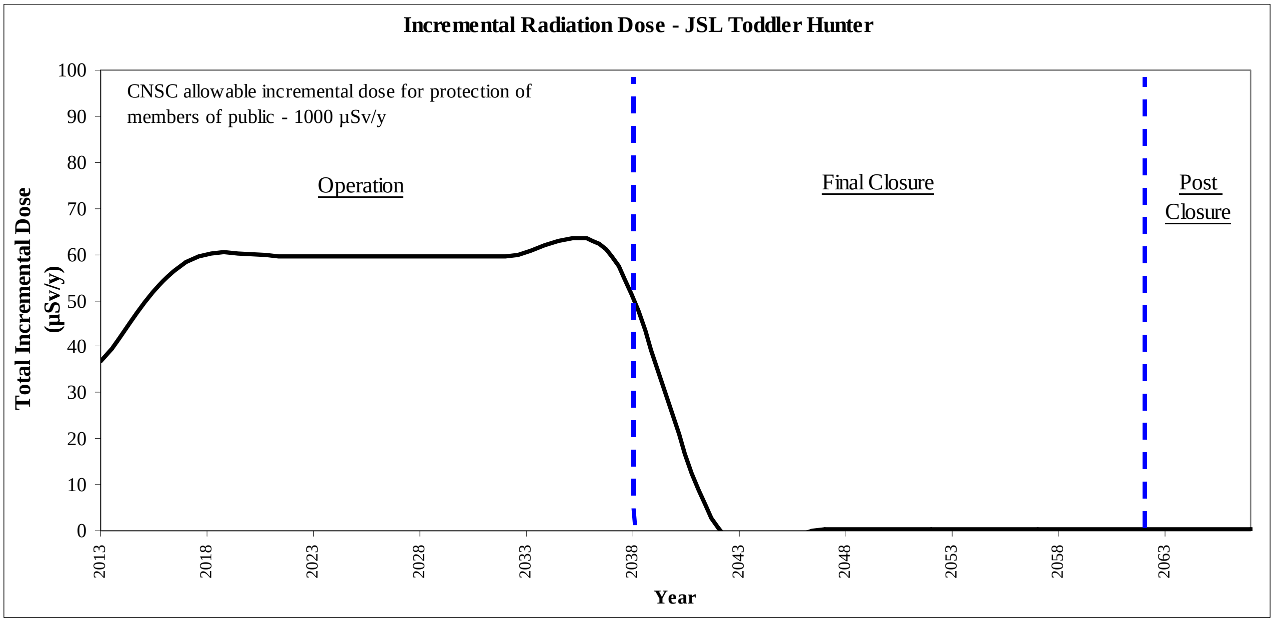
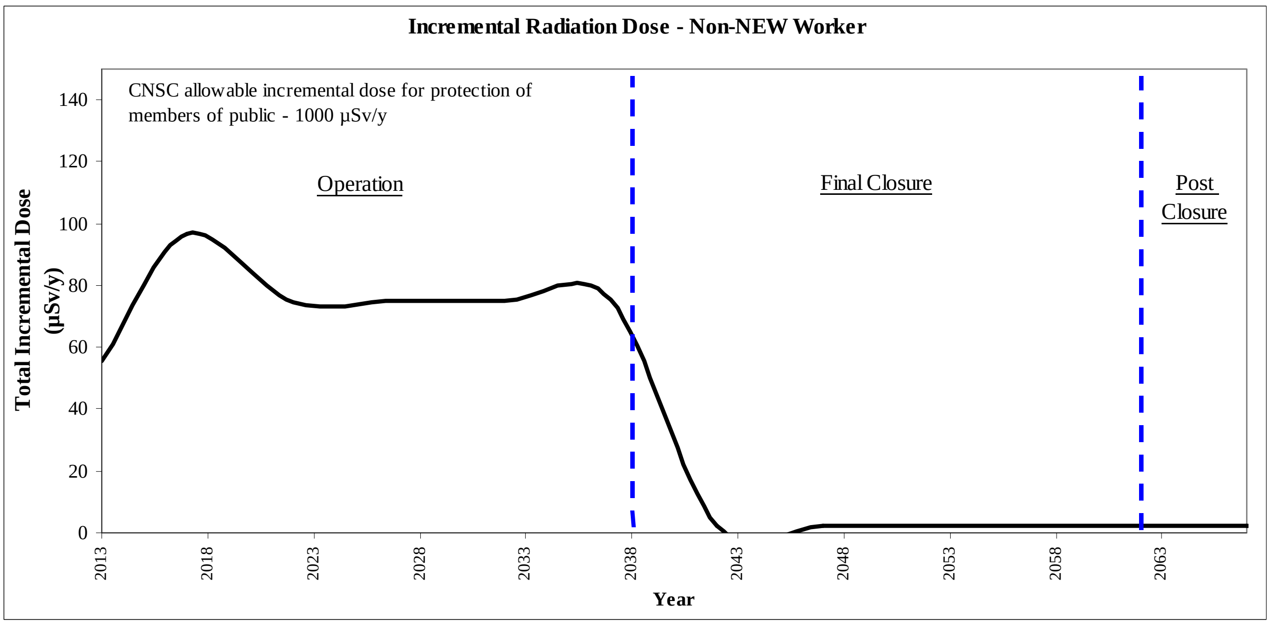


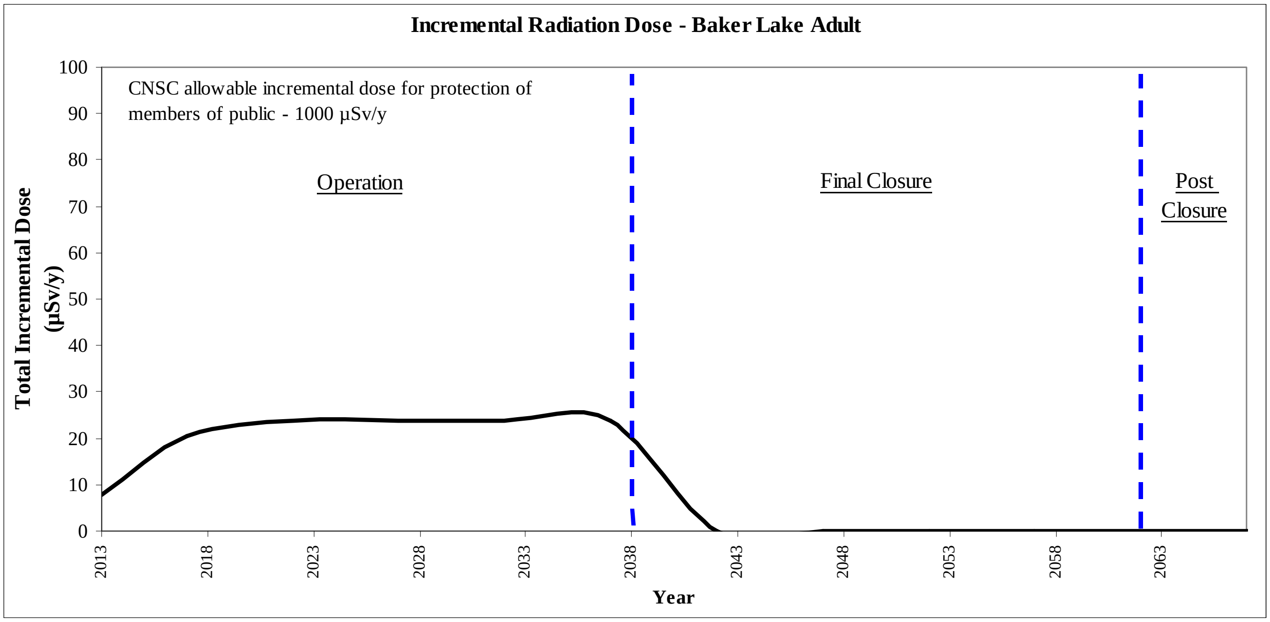
Figure 9.4-2 Breakdown of Incremental Radiation Dose from Kiggavik Project

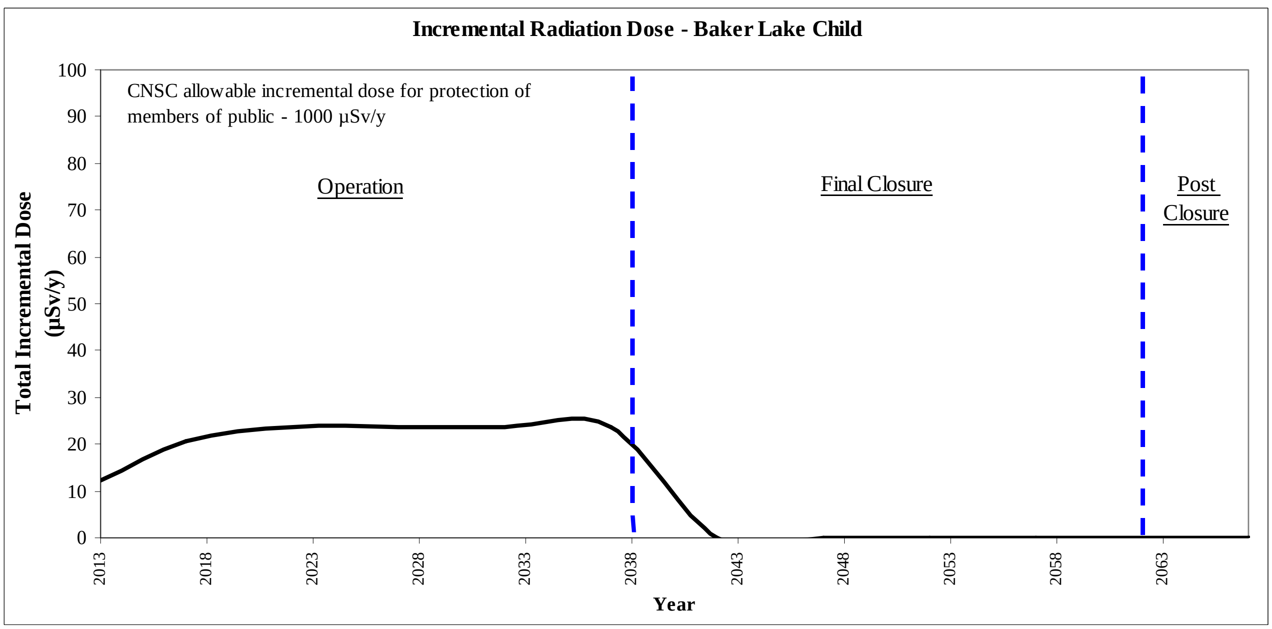

Incremental Radiation Dose - JSL Adult Hunter
CNSC allowable incremental dose for protection of members of public - 1000 µSv/y
Operation
Final Closure
Post Closure
Total Incremental Dose (µSv/y)
Year
100
90
80
70
60
50
40
30
20
10
0
2013
2018
2023
2028
2033
2038
2043
2048
2053
2058
2063


Incremental Radiation Dose - JSL Child Hunter
CNSC allowable incremental dose for protection of members of public - 1000 µSv/y
Operation
Final Closure
Post Closure
Total Incremental Dose (µSv/y)
Year
100
90
80
70
60
50
40
30
20
10
0
2013
2018
2023
2028
2033
2038
2043
2048
2053
2058
2063


Incremental Radiation Dose - JSL Toddler Hunter
CNSC allowable incremental dose for protection of members of public - 1000 µSv/y
Operation
Final Closure
Post Closure
Total Incremental Dose (µSv/y)
Year
0
10
20
30
40
50
60
70
80
90
100
2013
2018
2023
2028
2033
2038
2043
2048
2053
2058
2063


Incremental Radiation Dose - Non-NEW Worker
CNSC allowable incremental dose for protection of members of public - 1000 µSv/y
Operation
Final Closure
Post Closure
Total Incremental Dose (µSv/y)
Year
0
20
40
60
80
100
120
140
2013
2018
2023
2028
2033
2038
2043
2048
2053
2058
2063


Incremental Radiation Dose - Baker Lake Adult
CNSC allowable incremental dose for protection of members of public - 1000 µSv/y
Operation
Final Closure
Post Closure
Total Incremental Dose (µSv/y)
100
90
80
70
60
50
40
30
20
10
0
2013
2018
2023
2028
2033
2038
2043
2048
2053
2058
2063
Year


Incremental Radiation Dose - Baker Lake Child
CNSC allowable incremental dose for protection of members of public - 1000 µSv/y
Operation
Final Closure
Post Closure
Total Incremental Dose (µSv/y)
100
90
80
70
60
50
40
30
20
10
0
2013
2018
2023
2028
2033
2038
2043
2048
2053
2058
2063
Year

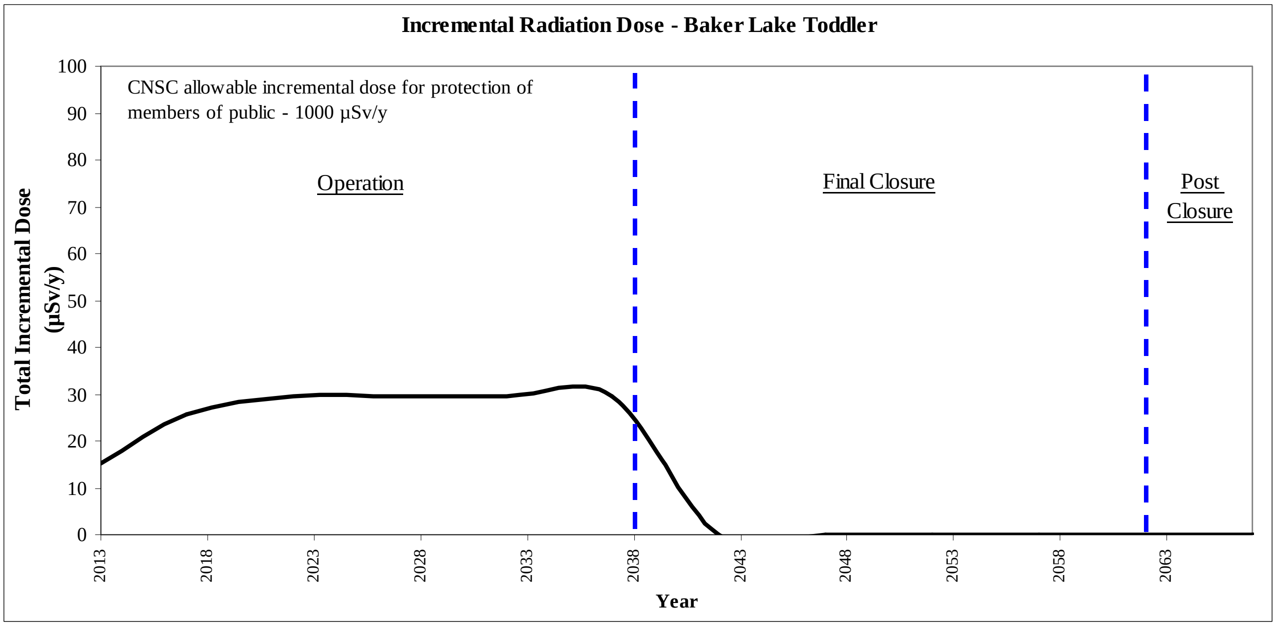


Figure 9.4-3 Incremental Radiation Dose over Time from Kiggavik Project

The estimated dose for the non-NEW receptor provided inTable 9.4-2 and shown in Figure 9.4-2 addresses the exposure while at the Kiggavik camp. However, it is likely that this individual resides in the Baker Lake community the remaining fifty percent of their time. The total dose for the non-NEW could therefore be taken to be 106 µSv/y (i.e., 98 µSv/y for a non-NEW while at the campsite + 0.5*15 µSv/y the dose while an adult resident at Baker Lake). This dose is still well below the CNSC allowable dose for members of the public and the Health Canada dose constraint.

10 Summary and Conclusions

The purpose of the assessment was to determine the level of effect on the local environment (including people) for constituents of potential concern (COPC) attributable to the Kiggavik Project.

The study included four major components as follows:

- Atmospheric dispersion modelling which provides estimates of COPC in air due to the various activities associated with the Project (detailed in Appendix 4B);
- Aquatic environment assessment in which potential changes in water and sediment quality due to releases from the Water Treatment Plants at the Kiggivik site are predicted (results are shown in Section 7.2and 7.3 of this document);
- Ecological risk assessment (ERA) where changes in COPC levels in the environment are examined to determine if there are any potential effects on biota (results are provided in Section 7.5 for vegetation and Section 8 for aquatic biota and wildlife); and,
- Human health risk assessment (HHRA) where the potential for effects on people due to emissions of COPC from the Project that reside in the area and consume local foods is examined (Section 9).

The COPC identified for the risk assessment included: uranium and the uranium-238 decay series (thorium-230, lead-210, radium-226, and polonium-210), arsenic, cadmium, cobalt, copper, lead, molybdenum, nickel, selenium, and zinc, as well as the standard water quality constituents ammonia, chloride, hardness, sulphate, and total dissolved solids (TDS).

The assessment was completed within a probabilistic framework to characterize the variability and uncertainty in the input parameters, such as measured site concentrations, literature-based transfer factors, and receptor characteristics. The results of the probabilistic assessment are probability distributions of the estimated risks from exposure to each COPC, which illustrates the variability and uncertainty in the estimated risks and provides a basis for quantifying the likelihood of exceedances. The variabilities in input parameters were represented by distribution functions and were selected to cover the potential range of values, but also remain conservative. Therefore, the expected values (represented in this assessment by the arithmetic mean values) are the most likely results, yet remain conservatively biased. The upper-bound values (represented by the 95^{th} percentile values) define the range of results and in the case where these upper-bound values are below the selected benchmarks, it can be confidently stated that effects are not expected.

For the ecological risk assessment, a range of ecological receptors were examined from different trophic levels in the aquatic and terrestrial environments. The results of the ERA showed that:

- For the COPC with water quality guidelines available, such as thorium-230, lead-210, radium-226, polonium-210, arsenic, cobalt, lead, molybdenum, nickel, un-ionized ammonia, chloride, and sulphate,, predicted water concentrations were below the guidelines in all segments of Judge Sissons Lake. Predicted water quality for copper and zinc does exceed the WQG in two shallow segments of the lake but this is due to natural fluctuations that occur during winter and is not influenced by the Project. For cadmium, predicted concentrations in water exceed the Canadian Water Quality Guideline (CWQG) at all points of the assessment in most segments of Judge Sissons Lake. Consideration of estimated seasonal variation in hardness shows that expected cadmium concentrations are below the calculated hardness-specific criteria. It was shown that effluent discharge does affect cadmium concentrations in Judge Sissons Lake. For selenium, there are slight exceedances of the applicable WQG during the operation phase in two segments of Judge Sissons Lake.

- Downstream of Judge Sissons Lake, predicted incremental downstream water concentrations are well below the CWQG for all COPC.

- Generally, the sediment is not influenced by the effluent contribution to water; however, there are some minor changes in sediment quality near the effluent discharge locations predicted for uranium, arsenic, cadmium, and molybdenum. For the COPC with sediment quality guidelines, predicted sediment concentrations of all COPC were below the guidelines in all segments of Judge Sissons Lake, with the exception of arsenic, copper, and nickel. For arsenic, baseline concentrations in sediment exceed the CCME Interim Sediment Quality Guideline (ISQG); however, maximum 95th percentile concentrations in several Judge Sissons Lake segments are also predicted to exceed the Thompson et al. (2005) lowest effect level (LEL). For copper, the LEL is exceeded, but not the CCME ISQG. The elevated nickel is associated with baseline and the Project is not expected to have a measureable effect on sediment. The predicted arsenic, copper, and nickel concentrations in sediment are well below the severe effects level (SEL) and probable effect level (PEL) indicating that there will not be effects to sediment-dwelling organisms as a result of the Project.

- All predicted soil concentrations are below the available soil quality guidelines in all phases of the assessment (operation, final closure, post-closure). There is very little change in soil concentrations predicted as a result of the Project.

- All predicted vegetation (browse and forage) concentrations are below the minimum benchmarks that are available in the literature which indicate potential effects to vegetation, with the exception of predicted cobalt, copper and zinc concentrations. These elevated concentrations are generally characteristic of background concentrations; since the Project is not expected to result in a measurable change in the vegetation concentration, no effects are expected. It is noted that there are a lack of benchmarks with which to determine potential effects on lichen. Based on comparison to baseline and information from other sites wide-spread effects are not expected but it could not be determined whether there would be an effect on lichen at locations close to the site due to metal accumulation.

- In general, the Project does not result in exceedances of benchmarks for aquatic receptors. However, some minor exceedances were identified for cadmium, copper, zinc, and sulphate. For copper and zinc, the exceedance relates to baseline conditions and the Project has no discernable effect on the conditions in Judge Sisson Lake, thus no effect is expected. For cadmium and sulphate there is the potential for the Project to affect zooplankton; however the exceedences are minor and the spatial extent limited.

- For terrestrial ecological receptors, it is unlikely that there will be effects due to the Project as their exposure is expected to be similar to current baseline conditions.

For the human health assessment, a number of receptors, which represent hypothetical individuals (toddler, child, adult), were considered. It was assumed that these individuals undertake activities on the landscape that are typical of the people of the region. Activities included the gathering of berries, trapping, hunting, and fishing for up to 1.5 months per year and to gather sufficient supply of these food items from the site to last for a 6 month period. The results of the HHRA showed that:

- Predicted SO_2 concentrations do not exceed health-based limits. Predicted NO_2 concentrations do not exceed health-based limits, with the exception of annual NO_2 concentrations at the proposed Kiggavik Camp location, where approximately 1% of the hours exceed the health-based limit of 200 $\mu g/m^3$. Exposure to fine particulate matter was also identified as a potential issue only at the Kiggavik Camp location. Based on the low frequency of exceedences, the conservative nature of the benchmark and that only working adults would be exposed, negligible health effects are expected;

- There are no effects predicted at the expected (mean) level of exposure for all non-carcinogenic COPC;

- The risk levels calculated for arsenic for both the Judge Sissons Lake hunter composite receptor and the Baker Lake composite receptor are below the acceptable benchmark of 1×10^{-5} (1 in 100,000) for incremental arsenic risk;

- The incremental radiation dose for all receptors were below the CNSC recommended incremental dose limit of 1,000 μSv/year and the Health Canada dose constraint of 300 μSv/year, and well within the range of variability of radiation dose from natural sources.

A summary table of the conclusions of the risk assessment is provided in Table 9.4-1. From the table it can be seen that while there may be the potential for an effect on sensitive species of zooplankton in certain areas of Judge Sissons Lake due to the exposure to cadmium and sulphate, it is not expected that this will result in population-level effects. No other aquatic biota are expected to be affected. Terrestrial biota are not expected to be affected by emissions from the project. Human receptors that reside at Baker Lake and may use the area for hunting are not anticipated to experience adverse effects at the expected level of exposure. Workers at the site, not directly involved in mining operations (e.g., a cook) are also not expected to experience any adverse effects from exposure to radioactivity or non-radiological COPC. Although determined to be unlikely, there is the possibility of short-term discomfort for people with asthma respect to exposure to NO_2.

Table 9.4-1 Summary of Risk Assessment Conclusions

<table>
<tr><th></th><th colspan="3">Judge Sissons Lake</th></tr>
<tr><td>Aquatic Receptors</td><td colspan="3">Due to exposure to cadmium it is possible that in certain segments of the lake there are exceedances of the generic water qualtiy criteria in the winter. This could affect the more sensitive zooplankton species. However considering the minor exceedance of the benchmark and the limited spatial extent of the impact and that the period of concern is during the winter, no significant changes are expected. Water quality in the shallowest segment of Judge Sissons Lake may exceed the generic water quality guideline for selenium but further consideration of effects in aquatic biota did not indicate a potential concern. No other combinations of receptors and COPC were identified as an issue.</td></tr>
<tr><td>Benthic Organisms</td><td colspan="3">No likely adverse effects from project</td></tr>
<tr><th></th><th>Rock Lake Watershed</th><th>Judge Sissons Lake</th><th>Kiggavik Camp</th></tr>
<tr><td>Terrestrial Vegetation</td><td>No likely adverse effects from project</td><td>No likely adverse effects from project</td><td>The potential for effects on lichen cannot be determined. However, it is not expected that population-level effects would be experienced.</td></tr>
<tr><td>Terrestrial Biota</td><td>No likely adverse effects from project</td><td>No likely adverse effects from project</td><td>No likely adverse effects from project</td></tr>
<tr><th></th><th>Hunter</th><th>Non-NEW Worker</th><th>Baker Lake</th></tr>
<tr><td rowspan="2">Human Health</td><td rowspan="2">No likely adverse effects for consumption of berries, medicinal teas, wild game and fish from the LAA</td><td>No likely adverse effects for exposure to COPC (metals and radioactivity) from consumption of berries and exposure from radon and through inhalation for a worker at the camp</td><td rowspan="2">No likely adverse effects for consumption of berries, medicinal teas, wild game and fish from the RAA</td></tr>
<tr><td>Although determined to be unlikely, there is a possibility of effects to workers at the accomodation camp due to NO_2 and dust.</td></tr>
</table>

Note:

Potential adverse effect – based on ecological risks to several species and SI values >10 times benchmarks or a human health effect.

No adverse effect – based on SI values all <10 times benchmarks.

Acceptable – based on no exceedances of benchmarks and consideration of baseline.

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Attachment A Lakeview Model

A.1 Model Description

To assess the fate of radioactive and non-radioactive constituents in the surface waters and sediments of lakes and rivers, a proprietary computer code called LAKEVIEW has been developed by SENES Consultants Limited. LAKEVIEW is a module of the overall INTAKE Pathways model developed by SENES to assess exposures and risks to ecological species and humans of constituents released to the aquatic and atmospheric environments. The module may be run in either a deterministic or a probabilistic manner. The code has been applied on several occasions on Beaverlodge Lake, Hatchet Lake and Wollaston Lake in northern Saskatchewan to assess the impact of uranium mining operations within the watersheds on metal and radionuclide levels in several of the lake embayments (SENES 1989, 1993a, 1993b, 1995a, 1995b, 1995c, 1995d, 1996, 2000, 2001a, 2003, 2005, 2006, 2007, 2008a, 2008b, 2008c, 2008d). The LAKEVIEW model has also been applied on mining projects at other locations, for example, to simulate the effects of arsenic input to Back Bay and Yellowknife Bay on Great Slave Lake (SENES 2001b, 2006). Using parametric sensitivity analysis, the LAKEVIEW model was applied recently to rank major contaminant sources and to evaluate contaminated sediment loads in the Fulton Creek watershed on Beaverlodge Lake in northern Saskatchewan (SENES 2008c; Manolopoulos *et al.,* 2008). For application in the arctic, the program has been modified by including solid (ice) and liquid phase speciation of contaminants and has been applied to assess the potential impact of treated mine water discharge to Judge Sissons Lake in the Kiggavik mining region, Nunavut (SENES, 2008d).

The following table (Table 1.1-1) provides a summary of sites where LAKEVIEW has been applied. These sites represent a large range of systems (e.g. rivers, wetlands, small lakes, mid-sized lakes, large lakes along with exchange with large bays) for many different contaminants. At several of these sites, the LAKEVIEW dispersion model has been applied numerous times; in some cases, to assess the effects of expanding the life of the operations and, in other cases, to assess the effects of decommissioning components of the sites.

Table 1.1- 1 Summary of Sites Modelled with LAKEVIEW

Site	Province / Territory	Description	Client	COPC	Comment
Giant Mine	Northwest Territories	Former gold mine	Indian and Northern Affairs Canada (INAC)	Arsenic	Modelling of water and sediment quality in Back Bay and Yellowknife Bay, Great Slave Lake, to assess the effects of remediation options. Pathways analysis and ecological and human health risk assessments
McClean Lake Operation	Saskatchewan	Operating uranium mine and mill	AREVA Resources Canada Inc. (formerly Cogema)	Radionuclides, arsenic, cobalt, copper, lead, molybdenum, nickel, selenium, uranium, zinc, general water quality parameters	Modelling of effects of effluent discharge to Sink/Vulture Treated Effluent Management System and on water and sediment quality in the Collins Creek watershed ; pathways analysis; ecological and human health risk assessments
Midwest Project	Saskatchewan	Proposed uranium mine	Midwest Joint Venture and AREVA Resources Canada Inc.	Radionuclides, arsenic, cobalt, copper, lead, molybdenum, nickel, selenium, uranium, zinc, general water quality parameters	Modelling of effects on water and sediment quality in the Smith Creek and Collins Creek watersheds; pathways analysis and human health and ecological risk assessments.
Rabbit Lake Operation	Saskatchewan	Operating uranium mine and mill	Cameco Corporation	Radionuclides, arsenic, cobalt, copper, lead, manganese, molybdenum, nickel, selenium, uranium, general water quality parameters	Modelling of effluent discharge to Horseshoe Creek watershed; groundwater and surface water contributions to Link Lake watershed on resulting water and sediment quality the watersheds and adjacent bays on Wollaston Lake; pathways analysis; ecological and human health risk assessments

Table 1.1- 1 Summary of Sites Modelled with LAKEVIEW

Site	Province / Territory	Description	Client	COPC	Comment
Rabbit Lake Operation – Collins Bay Facilities	Saskatchewan	Decommissioning of three uranium mine open pits and a waste rock pile e	Cameco Corporation	Radionuclides, arsenic, nickel, uranium, sulphate	Modified to incorporate processes in the pits, and breach/non-breach scenario interactions with Collins Bay (Wollaston Lake); resulting water and sediment quality; pathways analysis; ecological and human health risk assessments
Cigar Lake	Saskatchewan	Uranium mine under development	Cameco Corporation	Radionuclides, arsenic, cobalt, copper, lead, molybdenum, nickel, selenium, uranium, zinc, general water quality parameters	Seru Bay/Waterbury Lake dispersion analysis, including ice cover effects, of treated effluent discharge on water and sediment quality. Model results input to pathways analysis and ecological and human health risk assessments.
Beaverlodge	Saskatchewan	Decommissioned uranium mine	Cameco Corporation	Radionuclides, selenium, uranium and total dissolved solids	Evaluation of remedial options on water and sediment quality in the Ace Creek and Fulton Creek watersheds, as well as in Beaverlodge Lake. Pathways analysis of risks to aquatic and terrestrial species and to human health.
Cluff Lake	Saskatchewan	Former uranium mine (operating and decommissioning phases)	AREVA Resources Canada Inc. (formerly Cogema)	Radionuclides, arsenic, cobalt, copper, lead, molybdenum, nickel, selenium, uranium, zinc, general water quality parameters	Evaluation of impacts of new open pit mining development and post-closure impacts on water and sediment quality in the Cluff Creek and Island Creek watersheds; pathways modeling and assessment of residual risks to aquatic and terrestrial species and people in the study area.
Tundra Mine	Northwest Territories	Former gold mine	INAC	Arsenic	Modelling of the effects of a range of treated effluent discharge options on water and sediment quality in the Whale Tail Lake watershed; and, assessment of ecological and human health risks.

Table 1.1- 1 Summary of Sites Modelled with LAKEVIEW

Site	Province / Territory	Description	Client	COPC	Comment
Colomac Mine	Northwest Territories	Former gold mine	INAC	Ammonia, arsenic, copper, cyanate, cyanide, lead, nickel, nitrate, nitrite, phosphate, selenium, silver, thiocyanate, zinc	Modelling of effects of cyanide compound degradation/oxidation on byproduct concentrations taking into pH and temperature and of effluent discharge effects on metal levels in water and sediments in Indin River sub-watershed
Port Hope Harbour	Ontario	Adjacent to uranium conversion facility	Cameco Corporation	Arsenic, uranium, zinc	Investigate the impact of different remediation alternatives. Coupled with a detailed hydrodynamic model of the harbour.
Fishing Lake	Saskatchewan	Flood water management	Canada North Environmental Services (for Saskatchewan Watershed Authority)	Sulphate and total dissolved solids	Evaluation of water quality in the Assiniboine River downstream of Fishing Lake under various flood relief scenarios

The important processes incorporated into the LAKEVIEW model include horizontal (lateral) and vertical transport of dissolved species, chemical and biochemical reactions, settling of particulate matter, and sediment exchange. Chemical reactions comprise both equilibrium and dynamic processes. Equilibrium processes are reactions for which the time scale is at least two orders of magnitude less than the time scale of the modelling. These may be metal-ligand interactions, adsorption to solids, colloidal chemistry, etc. (Stumm and Morgan 1981; Stumm 1992), which are necessary to estimate constituent ion balances and pH. Equilibrium modelling algorithms such as MINTEQL (Schecker and McAvoy 1994) and PHREEQC (Parkhurst and Appelo, 2005) are well suited to establish these tasks. However, these programs are rather cumbersome (too slow and detailed) for probabilistic model applications and a simplified equilibrium modelling approach developed by Scharer *et al.* (1994) is employed in LAKEVIEW.

The transport of contaminants in and out of the sediments is governed by both equilibrium and dynamic processes. An important equilibrium process is speciation resulting from the adsorption of dissolved species to solids. These solids may be organic or inorganic in nature. Dynamic processes comprise oxidative and reductive chemical reactions and consumption of nutrients by aquatic microbiota and macrobiota. An important, and often modeled, dynamic process is the uptake of dissolved oxygen in the water column and benthos underlying the water column. Often the time scale of these reactions is such that steady state approximation is possible on either an annual or monthly time scale. For example, the oxygen re-aeration and consumption rates in a water column may be calculated and be assumed to be constant for a period of one month, say in July, resulting in constant (steady state) concentration of oxygen for that particular month. These steady state approximations greatly reduce the complexity of the calculations.

The movement of various chemical species in the sediment exchange zone is particularly important. Sediments may be a significant source of inorganic substances such as toxic metal ions, nutrient chemicals (phosphate, for example), and recalcitrant organic compounds. Since the solubility of most metal ions is considerably higher under aerobic than anaerobic conditions, most exchange occurs from the oxidized zone of sediments (Davé *et al.* 1997). A portion of the sedimented material may be re-introduced into the water column by diffusive processes; the remaining part becomes buried by the continual deposition of fresh settling mater.

A.1.1 Lake Dispersion Model

A.1.1.1 Control Volume Concept

A very common approach to water quality modelling is the control volume concept. The control volume is defined as a homogeneous volume segment of water with clearly defined boundaries and the water constituent concentrations are either constant or vary continuously in a linear manner within the segment. The control volume segment may be hydraulically connected with one or more other segments forming a network. Control volume models with assumed constant concentrations are known as compartment or box models (Schnoor 1996). Key elements of the control volume models include volume, surface area, areas of exchange zones with adjacent control volumes, data on hydraulic inputs and outputs, information on transport, and reaction kinetics.

In the LAKEVIEW model, a lake is divided into one of more segments. Each segment consists of at least two zones: surface water and sediment. As an optional feature of the model, surface water is allowed to stratify into three layers during the summer months: the upper layer known as the epilimnion, a transition layer (metalimnion) and the bottom layer called the hypolimnion. Taking into account the horizontal aspect of mass transfer between the two or more segments and the vertical aspect between the epilimnion, the hypolimnion and the underlying sediment, the advective and dispersive processes in each segment are modelled by differential equations for the water column and for the sediment. An additional equation is used to simulate chemical constituent behaviour during thermal stratification. The volume change in stratified lake is subject to the following constraint:

$$\frac{dV_T}{dt} = \frac{dV_j}{dt} + \frac{dV_k}{dt} = 0 \qquad (1.2\text{-}1)$$

where:

V_T = the total lake volume (m^3)

V_j = volume of the epilimnion (m^3)

V_k = volume of the hypolimnion (m^3)

According to equation (1.2-1), the total lake volume is assumed to be constant. The rate of volume change is calculated explicitly for the hypolimnion (V_k) as follows:

$$\frac{dV_k}{dt} = Q_p - cV_k \qquad (1.2\text{-}2)$$

where:

Q_p = seasonal polishing pond discharge ($m^3\ yr^{-1}$)

V_k = volume of the hypolimnion (m^3)

c = characteristic time constant (0.69 yr^{-1})

The characteristic time constant in equation (1.2-2) is found by parameter estimation using the seasonal variability of the height of the thermocline as the criterion. The rate of change of the epilimnetic volume is found by employing equation (1.2-1). The rate of contaminant mass change in the stratified layers is calculated using the chain rule. For example, the mass differential for the epilimnion is given by:

$$\frac{d(V_j C_j)}{dt} = V_j \frac{dC_j}{dt} + C_j \frac{dV_j}{dt} \qquad (1.2\text{-}3)$$

where:

V_j = volume of the epilimnion (m^3)

C_j = concentration of a contaminant in the epilimnion ($g\ m^{-3}$)

A similar equation was written for the hypolimnion. The mass differential given by equation (1.2-3) is equal to the mass input and output for a particular zone. The overall mass balance for the epilimnion is:

$$\frac{d(V_j C_{i,j})}{dt} = W_j(t) - Q_j(C_{i,j} - C_{i,j-1}) + E_{j-1}A_{j-1}(C_{i,j-1} - C_{i,j})$$
$$- E_j A_j (C_{i,j} - C_{i,j+1}) + E_k A_k (C_{i,k} - C_{i,j}) - S_j(K_{ds} C_{i,j})\sigma_j A_k + V_j\left(\frac{dC_{i,j}}{dt}\right)_{RX} \quad (1.2\text{-}4)$$

where:

$C_{i,j}$ = concentration of the 'i^th' species in the hypolimnion of segment "j" (g m^{-3})

W_i = waste load (time dependent) to the epilimnion of segment "j" (g yr^{-1})

V_j = volume of hypolimnion in segment "j" (m^3)

Q_i = outflow from segment "j" (m^3 yr^{-1})

E_j, E_{j-1} = lateral mass transfer (i.e. dispersion) coefficient between adjacent segments (m yr^{-1})

A_j = contact area between segments (m^2)

E_k = mass transfer coefficient across the thermocline (m yr^{-1})

A_k = contact area between epilimnion and hypolimnion at the thermocline (m^2)

C_k = concentration of constituent in the hypolimnion below segment "j" (g m^{-3})

S_j = solids settling velocity (m yr^{-1})

σ_j = total suspended solids concentration (g m^{-3})

K_{ds} = solid/liquid distribution in settling solids (m^3 g^{-1})

$(dC_{i,j}/dt)_{Rx}$ = reaction rate in the epilimnion (yr^{-1})

A nominal step size of one month (Δt = 1 month) is often used for computational purposes. The model allows time step sizes of up to one year. The internal step size for computing is considerably smaller. As shown in equation (1.2-4), dispersion is a two way process, while sedimentation is a one way process. Sedimentation transport is based on adsorption equilibrium with solid surfaces and settling to the bottom of the water column. The numerator in the sedimentation transport term is known as the sedimentation flux for a particular chemical. The solids settling velocity is the gravitational settling velocity in water and may be calculated from a modified Stokes law equation (Thibodeaux 1996) using median settling particle size and density. In lakes, the net settling velocity generally ranges between 10 and 100 m/year. In addition to settling inorganic particles, the settling flux resulting from sedimenting phytoplankton is also considered. Parameter estimates for dispersive transport are derived in the following section.

The differential equation for the hypolimnion was developed in an analogous manner:

$$\frac{d(V_k C_{i,k})}{dt} = W_k(t) - S_k(K_{ds}C_{i,k})\sigma_k A_k + K_l A_s (C_{i,s} - C_{i,k}) + E_k A_k (C_{i,k} - C_{i,j}) + V_k \left(\frac{dC_{i,k}}{dt}\right)_{RX} \quad (1.2\text{-}5)$$

where:

$C_{i,k}$ = concentration of the "i^th^" species in the hypolimnion (g m^{-3})

$C_{i,s}$ = concentration of the "i" species in the sediment pore water (g m^{-3})

K_l = mass transfer coefficient between sediment and the water column (m yr^{-1})

A_s = interfacial area between the sediment and the water column (m^2)

W_k = contaminant load to the hypolimnion (kg yr^{-1})

$(dC_{i,k}/dt)_{RX}$ = reaction rate of the "i^{th}" species in the hypolimnion (yr^{-1})

Equation (1.2-5) is employed only if the time scale of the simulation is one month or less. The concentration terms $C_{i,j}$ in equation (1.2-4) and $C_{i,k}$ in equation (1.2-5) refer to concentrations at the midpoint of a given segment. In small lakes, often a single segment designation suffices. In case of multiple segments in a large lake or water body, the distances between adjacent segments should be equally spaced for best accuracy.

A.1.1.2 Sediment Transport

Transport in and out of the exchange zone of sediments involves particulate settling of adsorbed constituents, dispersive exchange between sediment porewater and the hypolimnion and "sinking out" of the sediments from the active zone by burial. The differential equation is given as follows:

$$\Psi = ((1-\varepsilon)\ \rho_{sed}\ K_d + \varepsilon)\ z A_b$$

$$\Psi \frac{dC_{i,S}}{dt} = K_l (C_{i,k} - C_{i,s}) A_b + S_k (K_{ds} C_{i,k}) \sigma_k A_b + R_X A_b - k_b \Psi C_{i,s} \qquad (1.2\text{-}6)$$

where

ρ_{sed}	=	density of sediment (g m^{-3})
z	=	the thickness of the sediment exchange zone (m)
ε	=	porosity of sediment
R_X	=	reaction rate in the sediment (g m^{-2} yr^{-1})
k_b	=	burial rate constant (yr^{-1})
A_b	=	sediment surface area (m^2)

For sediments, the "retardation factor", Ψ is first calculated. Using this factor, the differential equation given by equation (1.2-6) is applied and solved simultaneously with the equations for surface water. Equation (1.2-6) is the mass balance for the exchange zone of the sediment. The thickness of the zone (Z_j) was assumed to be equal to the oxidized (i.e. oxygenated) microzone. This zone is either estimated from the sedimental oxygen demand flux or inputted directly. The estimated thickness of the sediment exchange zone may range from less than 1 cm to 15 cm, depending on the oxygen demand. Often, the zone thickness is a calibrated value that is entered as such as a model input. Both the epilimnion and the seasonal hypolimnion are assumed to be in contact with the sediment. In addition to transport, the sediment model includes redox reaction kinetics that contributes to the mobility of a given constituent. The redox reactions and the burial ($R_X A_b$ and $k_b \Psi C_{i,s}$) terms in equation (1.2-6) are generally expressed as first order kinetic phenomena. The oxidation rate, of course is constrained to the sediment surface area in contact with the oxygen-rich water column. The approach used in developing the above equations and estimating the parameter is known as the well established and proven Thomann's (1972) "finite section" method. In the current version of LAKEVIEW the mass balances can result in up to 20 differential equations that are solved simultaneously.

Normally the most important sediment transport mechanism is the dispersive transport in and out of the water column (the first term, $K_l (C_{i,k} - C_{i,s}) A_b$, on the right side of equation (1.2-6)). Decades of research and experimental observations support this simple, but elegant mathematical expression for interphase (sediment to water column) transport (Thibodeaux, 2005; Thibodeaux and MacKay, 2003). The concept derives from the Fickian law of diffusion, but the value of the mass transfer coefficient, K_l, is often higher than the value expected for molecular diffusion. As shown by the equation, the flux is a positive vector if the net transport is from the water column to the sediment. In modeling chemical transport to and from the sediments, K_l is often a calibrated parameter (Manolopoulos *et al*., 2008).

Contaminant levels in the sediment are differentiated in LAKEVIEW into exchangeable and non-exchangeable fractions. This differentiation is usually accomplished on the basis of Tessier's extraction data (Mossop and Davidson, 2003). The non-exchangeable fraction comprises contaminants embedded in insoluble minerals or present as sparsely soluble pure solids. This non-exchangeable fraction may undergo chemical oxidation/reduction to convert to an exchangeable state or "sink out" from the transport zone. A minimum residual (background) concentration is defined for each constituent. The exchangeable fraction includes adsorbed (K_d-dependent) components, components forming solid solution with soluble host minerals, and pure soluble minerals. Solid solution is a homogeneous solid phase having either a trace element interstitially in the host crystal structure (Ra-226 in barite, for example) or a chemically similar species replacing the host component in the crystal matrix.

The mass transfer coefficient between the exchangeable sediment component and the water column, K_l, is either a calibrated value or calculated from the physical properties of the sediment. The sediment porewater concentration term, $C_{i,s}$, is a key parameter that is evaluated in specific subroutines in every time step. To perform the necessary calculations, first the pH-dependent carbonate/bicarbonate equilibrium is established as a function of the CO_2 partial pressure in the sediment porewater. Then the ionic strength is calculated by taking into account either the major ions in solution or the TDS values. The ionic strength, in turn, is used to calculate the activity coefficients of the various ions and their ligands using the Davies equation. Using the activity coefficients and the appropriate equilibrium expressions, dissolved ion speciation is performed and the total solute concentration is compared to adsorption-based (K_D-based) equilibrium. Unless simultaneous porewater/solid phase concentration data are available, the K_D value is either calibrated or calculated for each sediment type. These calculations take into account published clay, quartz, and organics- based K_D values.

The controlling mechanism (solubility versus adsorption) is established for each key constituent in every time step using established thermodynamic stability (minimum free energy) criteria. The constituent concentrations in the porewater of the sediment exchange zone are calculated for each lake segment in each time step and are used to calculate the sediment transport flux as outlined in Section A.1.3 (Computational Procedure).

A.1.1.3 Dispersive/Diffusive Parameters

Prior to solving the differential equations outlined above, the nominal parameter values for the various exchange processes and their stochastic distributions need to be established (Duever and Reilly 1990). Particularly, the dispersive parameter estimates require close analysis. It has been shown in numerous studies that the turbulent dispersion coefficient in lakes is scale dependent. This is due to the increasingly large eddies coming into play as two points are further and further apart (Csanady 1973). The scale dependence of horizontal dispersion derived and computed by several methods has been summarized by Thibodeaux (1996) and is presented in Figure 1.2-1. In the open waters of larger lakes and in oceans, the horizontal dispersion is generally governed by the 4/3 power law (Okubo, 1971; Thibodeaux 1996; Stacey *et al.,* 2000), thus the dispersion coefficient is given by the following expression:

$$E = 10^{-4} l^{4/3} \qquad (1.2\text{-}7)$$

where:

E = dispersion coefficient between two points estimated "l" distance apart ($m^2\ s^{-1}$)

l = distance (m)

The coefficient for equation (1.2-7) (i.e. 10^{-4}), which was derived by SENES, represents the mid-value of the range shown in Figure 1.2-1. Equation (1.2-7) refers to the applicable dispersion between two points. The expression seems to apply from point-to-point scale of one meter to point-to-point scale in excess of one hundred kilometers. It is well known, however, that the coefficient of dispersion does not remain constant for a region, but varies from a distance 0 to a distance X between two points within connected regions. Thus, to calculate the expected dispersion between two hydraulically connected segments an averaging of the dispersion is necessary. In the LAKEVIEW model, the line average dispersion coefficient between the midpoints of connected segments is calculated by integral averaging:

$$\overline{E} = \frac{10^{-4} \int_0^l l^{4/3}\, \mathrm{d}l}{l} = \frac{4}{7} \times 10^{-4} \times l^{4/3} \qquad (1.2\text{-}8)$$

where:

$\bar{l}$ = scale (line) averaged turbulent dispersion coefficient ($m^2\ s^{-1}$)

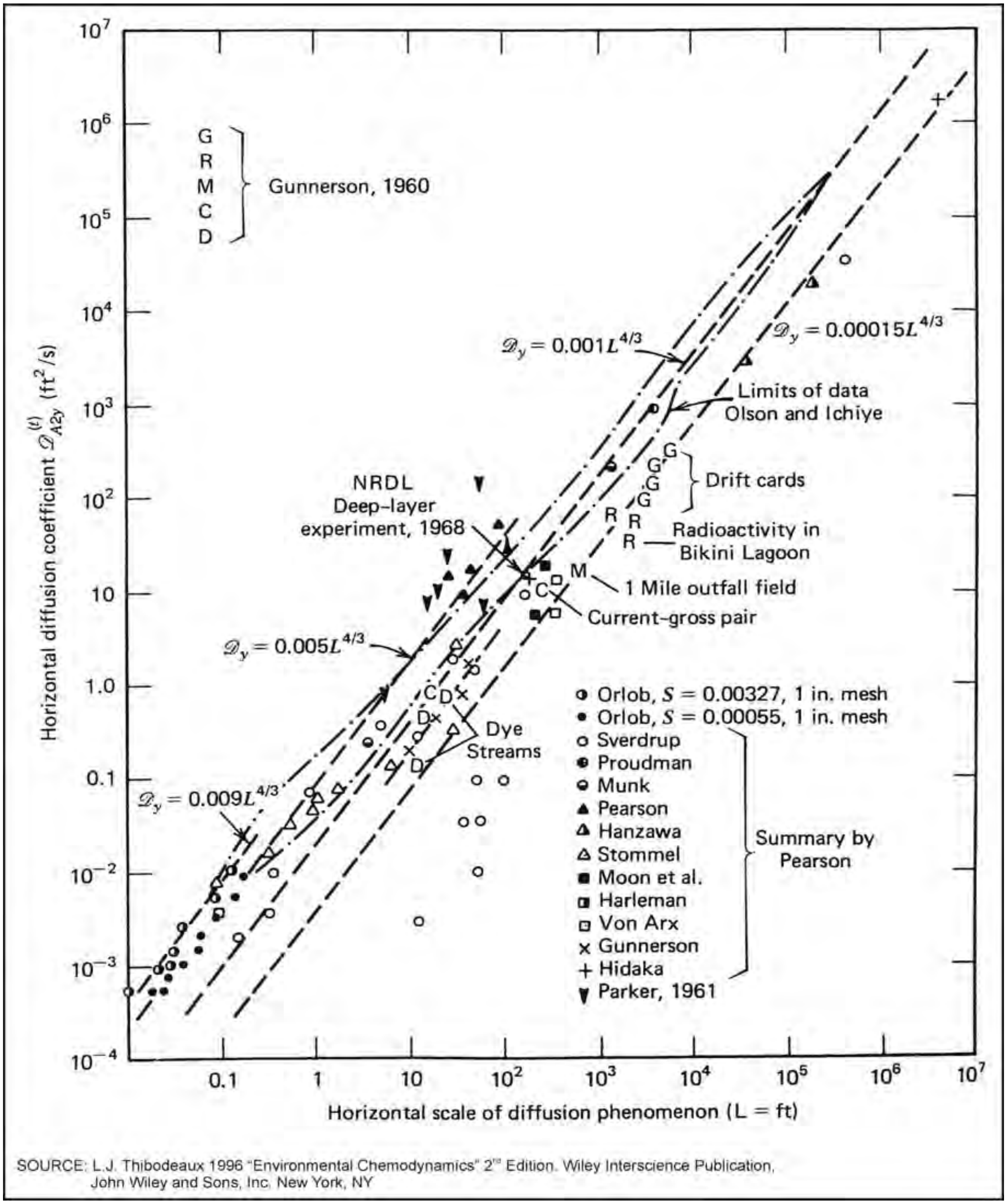


Figure 1.2-1 Plot of Horizontal Dispersion Coefficients

The units of $\overline{E}$ in equation (1.2-8) are given in ($m^2\ s^{-1}$), however, it is easily scaled to more convenient computational units ($m^2\ yr^{-1}$, for example). Although the use of the 4/3 power law dependence of the dispersion coefficient with distance is conventional in large lakes and oceans, Stocker and Imberger (2003) argued that the range of eddies implied by the 4/3 power law may not develop in confined bays or small lakes. Experimental observations in small lakes indicate that the power value may be somewhat less, ranging from 1.1 to 1.25. In Figure 1.2-2, the turbulent dispersion coefficient is compared with the dispersion models of Lawrence *et al.* (1995), Okubo (1968) and Kullenberg *et al.* (1973). It is evident that the predicted values of the various dispersion models are comparable at distances less than 3000 m. The lower values of the Kullenberg *et al*. model is probably due to data taken in the thermocline and the hypolimnion.

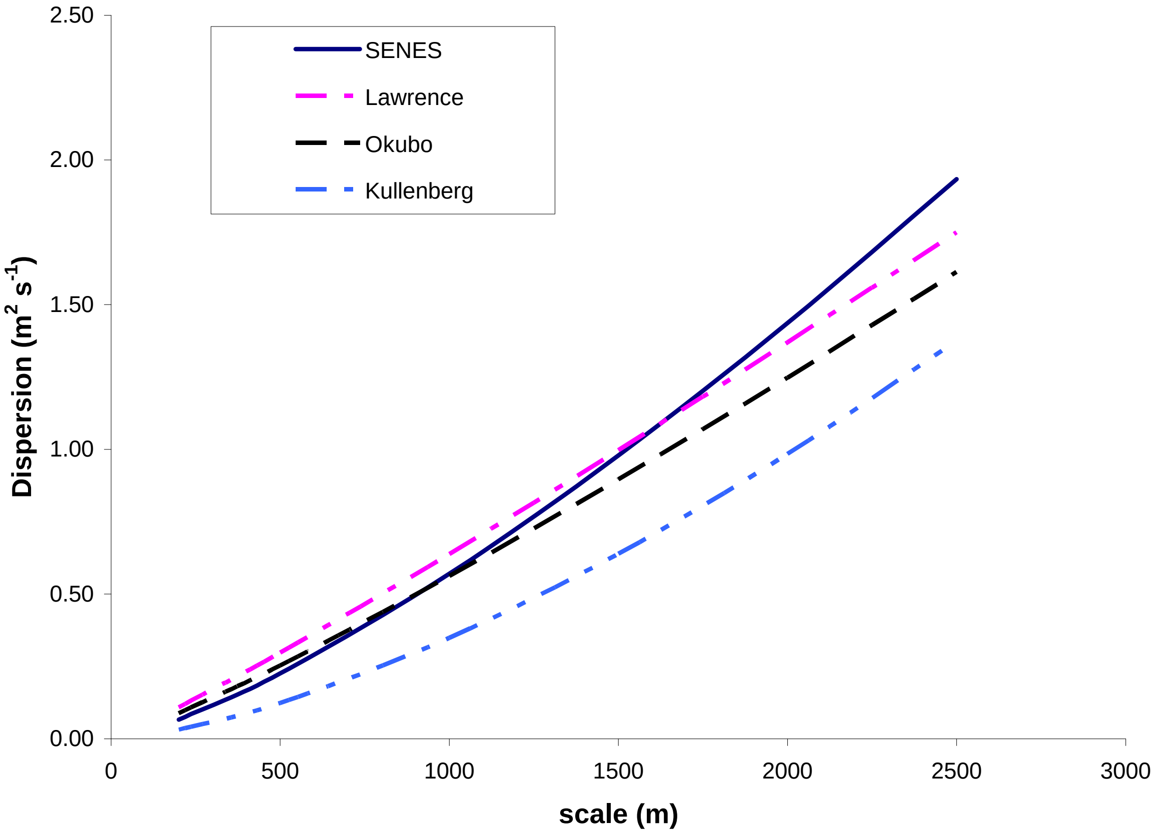


Figure 1.2- 1 Comparison of Horizontal Dispersion Models

An important modelling criterion is the assessment of the relative significance of the dispersion with respect to other transport processes. To appraise this relative significance, Schnoor (1996) suggests that the Nusselt number (Nu) be evaluated for a particular water body as follows:

$$\mathrm{Nu} = \frac{Q_o\, l}{A\, \overline{E}} \qquad (1.2\text{-}9)$$

where:

Q_o = outflow from the control volume ($m^3\ yr^{-1}$)

A = an average cross-sectional area (depth x width) in the direction of outflow (m^2)

l = distance between the midpoints of hydraulically connected segments (m)

$\overline{E}$ = characteristic turbulent dispersion coefficient between hydraulically connected segments ($m^2\ yr^{-1}$).

Dispersion becomes important for Nusselt numbers less then unity. It can be easily shown that dispersion dominance is a characteristic feature of pollutant transport from embayments to midlake in most mid to large sized lakes. Once the average dispersion coefficient is obtained, the volumetric (bulk average) dispersion coefficient for a control volume can be evaluated as follows (Chapra and Rechow 1983):

$$E' = \frac{\overline{E}\, A_c}{l} \qquad (1.2\text{-}10)$$

where:

E' = volumetric dispersion coefficient ($m^3\ yr^{-1}$)

$\overline{E}$ = scale average diffusion coefficient between two connected segments ($m^2\ yr^{-1}$)

A_c = cross-sectional area (depth x width) between two connected segments (m^2)

l = distance between the midpoints of two connected segments (m).

It is the dispersion gradient ($\overline{E}$/l) that is employed in the differential equations (1.2-4) and (1.2-5). The value calculated as outlined above is the nominal value. For probabilistic calculations, the probability density function for the volumetric dispersion coefficient is assumed to be distributed symmetrically (i.e. mean and the median being the same) about the nominal value.

Although the two processes are structurally similar (see equation (1.2-6), a different methodology is applied for calculating the diffusive exchange between the sediment and the overlying water column.

The scale of the transport parameters differs by several orders of magnitude. Lateral transport is orders of magnitude greater than molecular diffusion, while the vertical transport parameter is the same order of magnitude as molecular diffusion for a given dissolved species in water. First, the effective molecular diffusion coefficient (D_e) is evaluated by the following equation (Dulien 1979):

$$D_e = \frac{\varepsilon D_m}{\tau} \qquad (1.2\text{-}11)$$

where:

D_m = the molecular diffusion coefficient for a given dissolved species in water ($m^2 yr^{-1}$)

ε = porosity of the sediment

τ = tortuosity

The minimum value of the tortuosity determined from Einstein's relationship is 1.417 in unconsolidated porous media (Cussler 1984) while the maximum realistic value in sediments is about 4.5. In the LAKEVIEW model, a tortuosity factor of 3.14 (i.e. π) is usually employed as a mid-range estimate.

The estimation of the effective diffusion coefficient for dissolved oxygen transport in the sediment is particularly important. Since most metal ions and their stable counterions are more soluble in oxidative environments, the thickness of the sediment exchange zone needs to be established. Conceptually, this zone is equivalent to the boundary layer concept of Thibodeaux (1996). For zero order or near zero order (i.e. hyperbolic reaction rate expressions with a relatively low half saturation constant) reactions with respect to dissolved oxygen, the thickness of the oxygenated zone can be established from the benthic oxygen demand, the effective diffusion coefficient, and the oxygen concentration at the outer limit of the viscous sublayer above the sediment surface (Scharer *et al*. 1991) as described by the following equation:

$$Z_j = 2 \frac{D_e C_{O_2}}{J_{O_2}} \qquad (1.2\text{-}12)$$

where:

Z_j = thickness of the exchange zone (m)

D_e = effective diffusion coefficient of oxygen ($m^2 yr^{-1}$)

C_{O_2} = concentration of oxygen at the water sediment interface ($g\ m^{-3}$)

J_{O_2} = benthic oxygen demand ($g^2\ m^{-2}\ y^{-1}$)

The numerical factor of 2 in equation (1.2-12) is due to a parabolic oxygen profile resulting from constant effective diffusivity and zero order oxygen consumption in the exchange (reactive) zone. The oxygen concentration reaches zero at the lower limit of the reactive zone. The benthic oxygen demand ranges from 7.4 $g(O_2)\ m^{-2}\ yr^{-1}$ for inorganic reactive tailings under a water cover (Davé *et al.* 1997) to 24 $g(O_2)\ m^{-2}\ yr^{-1}$ in oligotrophic lakes (Wetzel 1975). Combining these values with an effective oxygen diffusion coefficient of $3.85 \times 10^{-2}\ m^2\ yr^{-1}$ and a dissolved oxygen concentration of 12 $g(O_2)\ m^{-3}$ at the interface yields a sediment exchange zone thickness (Z_j in equation (1.2-6) and in equation (1.2-12)) of 3.85 cm for oligotrophic lakes to 12.5 cm in reactive tailings deposits. The experimentally observed oxidative zone in reactive tailings was approximately 10 cm (Davé *et al.* 1997). In mesotrophic to eutrophic lakes where the benthic oxygen demand may range up to greater than 100 $g(O_2)\ m^{-2}\ yr^{-1}$ in eutrophic systems, the boundary layer thickness is in the order of 1 cm or less resulting in much higher mass transfer rates from the boundary layer (Schnoor 1996).

In the LAKEVIEW model, linear adsorption models are used as the dissolved concentration of the individual species are expected to be 10^{-3} mol/L or less. The mass transfer coefficient in equation (1.2-6) takes into account the effective diffusion coefficient (D) for a given species, the thickness of the exchange zone (Z_j), the porosity of the exchange zone (ε), the solid-liquid distribution coefficient (K_d), and the density of the sediment in the exchange zone (ρ) as follows:

$$K_s = \frac{D\ \varepsilon}{Z_j\left[\varepsilon + (1 - \varepsilon)\ K_d\ \rho\right]} \qquad (1.2\text{-}13)$$

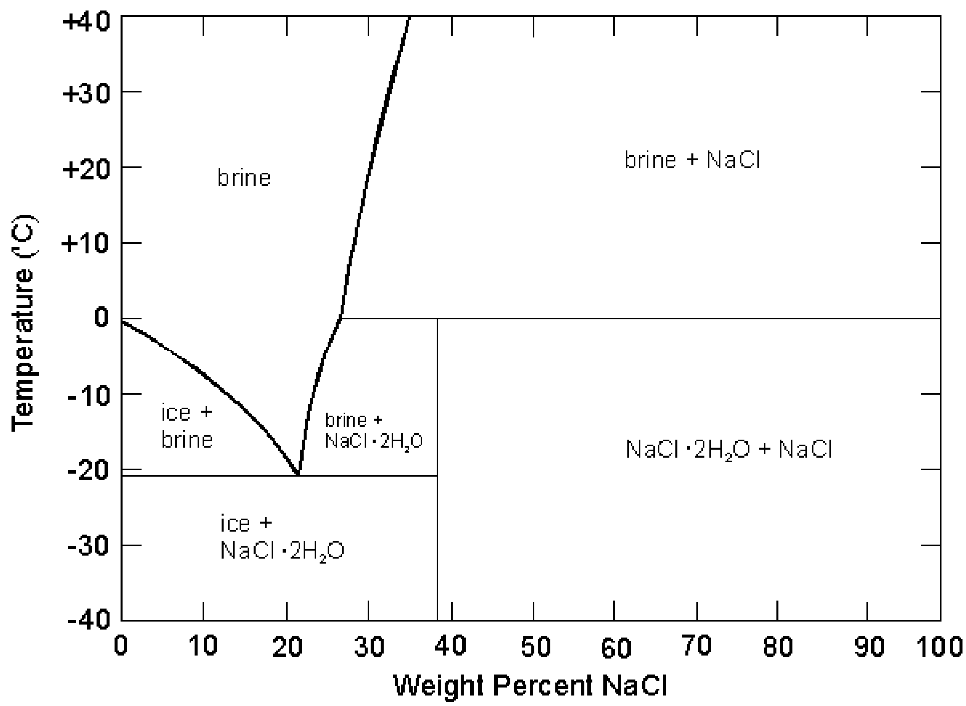
where:

K_s	=	mass transfer coefficient in the sediment ($m\ yr^{-1}$)
ε	=	porosity of sediment
D	=	diffusion coefficient ($m^2\ yr^{-1}$)
ρ	=	solids density ($g\ m^{-3}$)
K_d	=	solid-liquid distribution coefficient ($m^3\ g^{-1}$)
Z_j	=	thickness of the exchange zone (m)

Molecular diffusion coefficients, hence, effective diffusion coefficients are evaluated as a function of temperature (4 °C in deep water bodies).

A.1.1.4 Ice Cover

For four months or more lakes are covered with ice in most of Canada. The thickness of ice varies, but it may reach 2 m or more in Northern arctic lakes. If the of ice volume is significant with respect to the total lake volume, then the concentration effect due to ice formation is significant and distribution of solutes between the solid phase (ice) and the liquid phase (water) needs to be evaluated. In general, the concentration of solutes due to ice formation reaches a maximum level in the liquid in late winter. The distribution of a solute between the solid (ice) and liquid (water) phases can be estimated from appropriate phase diagrams. The phase diagram for salt in sea water is presented in Figure 1.2-3. Sodium chloride forms a near ideal liquid solution. At initial concentrations that are normally observed in lakes and oceans, the cooling of saline solution results in essentially pure ice formation and an ideal stoichiometric concentration of the salt in the liquid solution. This concentration effect continues until a eutectic concentration of 279.6 g/L salt is reached at -21.1 °C. The density of the liquid is 1.2 g/L at this point. At temperatures below the eutectic point, the saline solution solidifies as a eutectic mixture. However, in deeper lakes the eutectic point is never reached, therefore a liquid phase below the ice cover is maintained. Phase diagrams, for inorganic solutes other than salt (NaCl) is rare, therefore Figure 1.2-3 has been used to model the solid/liquid distribution of all dissolved constituents.



(Adapted from C. Clarke, 2004)

Figure 1.2- 2 Solid/Liquid Phase Diagram for NaCl

Horizontal dispersion is affected by ice cover. It seems that horizontal transport processes shielded from wind effects by ice cover are simpler to measure than in open water (Coleman and Armstrong, 1983). It has been shown that under ice cover dispersion depends on lake size (Bengtsson, 1986, 1996). In small lakes horizontal dispersion under ice was found to be two orders of magnitude less (i.e. nearly insignificant) than in open water. In larger lakes, however, seiche induced currents and thermal effects due to sunlight on bare ice cover are significant and the dispersion coefficients are almost as high as those normally observed under ice-free conditions (Bengtsson, 1986). In fact, the dispersion under ice cover is comparable to horizontal dispersion in the hypolimnion of larger lakes (Umlauf and Lemmin, 2005). From data reported by Coleman and Armstrong (1983) and Bengtsson (1986) the horizontal dispersion coefficient was estimated to be:

$$E = 3.8x10^{-5} l^{n} \qquad (1.2\text{-}14)$$

where:

E = dispersion coefficient between two points estimated "l" distance apart (m^2/s)

L = distance (m)

n = exponent with value between 1.1 and 1.5

For a unit distance and n = 4/3, the value of the dispersion coefficient is approximately 1/3 of the value found in open water. The cross sectional mass transfer area, A_C (see equation 1.2-10), is re-evaluated taking into account the transport area occupied by ice. Usually ice formation is assumed to take place in two months (November and December) and ice break-up in one month. The period of ice cover depends on location.

The dispersion coefficient is applicable for a time scale of 1 month or less. For larger time scales, a geometric mean of the summer and winter cross sectional transfer areas (A_C in equation 1.2-10) and a calibrated horizontal dispersion coefficient are applied for taking into account ice formation. Horizontal dispersion calibration entails normal monthly model simulations with periodic ice cover under stationary state conditions are reached. The monthly values are then averaged and the horizontal dispersion coefficient on the annual scale is calibrated to give the same yearly steady state concentration than the monthly mean.

A.1.2 Computational Procedure

In each segment of the LAKEVIEW model, the change of water quality is formulated as ordinary differential equations such as equation (1.2-4) to equation (1.2-6). Ordinary finite difference solutions of the differential equations resulted in numerical dispersion, particularly at very low retention times (i.e. retention times less than the integration interval, Δt). Consequently, the equations were solved by asymptotic integration (Kodakova, 2000; Shkil and Samusenko, 2000) as indicated below. These differential equations have the following structure:

$$\frac{dC_i}{dt} = \{\omega_i\} + \{a_{i,j}\} x \{C_i\} \qquad (1.3\text{-}1)$$

where:

C_i = dependent variable (concentrations) (g m^{-3})

t = independent variable (time) (yr)

ω_i = mass loading (time dependent) (g yr^{-1})

$a_{i,j}$ = constants

{ } = matrix (vector) designation

The left-hand side of equation (1.3-1) is an n x 1 vector of the differentials. The term $\{\omega_i\}$ is a time dependent vector of the normalized mass loadings to each segment. The term $\{a_{i,j}\}$ designates an n x n sparse matrix of inverse time constants, while $\{C_i\}$ is the local concentration vector. It can be shown, that the series of equations may be solved analytically in the following format (Wiley 1960):

$$\{C_{i,t+\Delta t}\} = \overline{C_i} + \left[\left(C_{i,t} - \overline{C_i}\right) \sum_{k=1}^{n} \alpha_k \exp(-\lambda_k \Delta t)\right] \qquad (1.3\text{-}2)$$

and $$\sum \alpha_k = 1$$

where:

$C_{i,t}$ = concentration in the 'i^th' segment at time t (g m^{-3})

$C_{i,t+\Delta t}$ = concentration in the 'i^th' segment at t+Δt (g m^{-3})

$\overline{C_i}$ = theoretical "steady state" concentration in the 'i^th' segment (g m^{-3})

α_k = partitioning coefficient

λ_k = eigen values

{ } = matrix elements

In equation (1.3-2), $\overline{C_i}$ represents a theoretical steady state concentration provided the external mass load, ω_i, remains invariant between t = t and t = ∞. This concentration, however, is never reached in practice, since the load varies continually. Thus, the numerical values of $\overline{C_i}$ were derived annually from the following equality:

$$\{a_{i,j}\} x \{C_i\} + \{\omega_i\} = 0 \qquad (1.3\text{-}3)$$

Next, the matrix is symmetrised and the eigenvalues of the matrix, $\{a_{i,j}\}$, are obtained by Jacobi's methods. The elements of the eigenvector are often approximately equal to the elements of the main diagonal of the $\{a_{i,j}\}$ matrix:

$$\lambda_1 = a_{11} ; \lambda_2 = a_{22} ; \lambda_3 = a_{33} ; \lambda_n = a_{n,n} \qquad (1.3\text{-}4)$$

Matrix solutions for second and higher order are also available. Second order solutions were used for evaluating sediment to water column exchanges. The eigenvalues, of course, were independent of the load. They depend only on the local exchange parameters and the particular contaminant species. The entire computational procedure is iterative. The time interval of integration (one day, one month, or one year – depending on the purpose) is partitioned into successively smaller sub-time steps until the integral converges to a constant (within 0.5%) value.

Once the liquid phase concentration of each constituent is established, the solids phase concentration change in the sediment reactive zone is calculated by flux balance. Any uptake of a constituent is considered as exchangeable fraction. However, the constituent may undergo chemical transformation (e.g. reduction of soluble "selenium" as selenate to insoluble "selenium" as selenide, for example) to a non-exchangeable state. Both the exchangeable and the non-exchangeable solid phase fractions undergo burial due to the deposition of fresh inert material. The average life span of solids in a 5 cm reactive zone is 20 to 85 years.

A.1.3 Parameter Estimation

Data based environmental modeling often requires parameter estimates by some statistical methods. Parameter estimation from data is an important task to be undertaken prior to predictive simulations. However, parameters are not known precisely at the onset of modeling but must be estimated from available data. This is particularly cumbersome if the parameters are embedded in differential equations in water quality models. Several regression techniques, both linear and non-linear, are available to estimate parameter values for algebraic expressions. However, many of these techniques break down if the parameters are defined on the differential level, while observations need to be compared with predictions after some integration is performed. Markov Chain Monte Carlo (MCMC) methods such as the Metropolis-Hastings algorithm have been found to be powerful tools, especially when some prior knowledge about the parameters is available (Gilks *et al*., 1996; Gamerman and Lopez, 2006). This method is applicable to any set of observations that conform to a

Markov chain. The algorithm has been employed to solve difficult, non-linear parameter estimation problems arising in various disciplines (Siddhartha and Greenberg, 1995; Berg, 2004; Biglari *et al*., 2006; Manolopoulos *et al.*, 2008). It involves one parameter at a time sampling and iteration to find the posterior parameter distribution.

Let us assume that $y_1, y_2, y_3 \ldots y_{n-1}, y_n$ are independent observations that have been collected in a temporal or physical space. These observations are said to form a Markov chain if the following conditional probability is obeyed:

$$P(y_n | y_1, y_2, \ldots y_{n-2}, y_{n-1}) = P(y_n | y_{n-1}) \qquad (1.4\text{-}1)$$

Thus the probability of obtaining the current observation (i.e. observation "n") is conditional on only the previous (i.e. penultimate) observation ("n-1"). A number of data sets resulting from natural processes such as growth, death, reaction products, etc., are in fact Markov chain observations. Generally, water quality observations from lakes and rivers also obey this requirement, since any prediction at some time $t + \Delta t$ is conditional upon the current observation at time t. For this reason, the Metropolis-Hastings algorithm is fully incorporated into the LAKEVIEW program.

If one wishes to develop a model to represent water quality observations (see equations (1.2-4), (1.2-5), (1.2-6) and (1.2-9)), these models will contain a set of parameters θ (i.e. θ_1, θ_2, θ_3 etc.) that needs to be estimated given the set of observations, y. The Bayesian inference of model parameters θ given the observed data involves the joint posterior probability distribution conditional on the data $P(\theta \mid y)$. According to Bayes' theorem, the joint probability of θ given y is:

$$P(\theta \mid y) \propto P(\theta)\, P(y \mid \theta) \qquad (1.4\text{-}2)$$

where:

$P(\theta)$	=	prior distribution of the parameters
$P(y \mid \theta)$	=	likelihood function conditional on θ.

The Metropolis-Hastings algorithm for parameter estimation can be summarized as follows (Gilks *et al*. 1996):

1. Assign prior probability distribution $J(\theta_n \mid \theta_{n-1})$ for each parameter to be estimated.
2. Obtain $\theta_{(0)}$ as the initial realization of the parameter vector.

3. Sample the proposed distribution $J(\theta_n \mid \theta_{n-1})$ to obtain parameter value θ^*.
4. Calculate the decision variable (r).

$$r = \frac{P(\theta^* \mid y) / J(\theta^* \mid \theta_{n-1})}{P(\theta_{n-1} \mid y) / J(\theta_{n-1} \mid \theta^*)} \tag{1.4-3}$$

set $\theta_n = \theta^*$ with probability min (r, 1)

$\theta_n = \theta_{n-1}$ otherwise

Continue obtaining realizations of θ_n for n = 1, 2, 3, N until $P(\theta_n \mid y)$ converges to $P(\theta \mid y)$.

In the LAKEVIEW model, each parameter to be estimated is assigned a triangular *a priori* distribution, $J(\theta_n|\theta_{n-1})$, containing the maximum, mean (most likely) and the minimum possible values. The mean value is established either by graphical means or "eyeballing" the experimental data. The obvious advantage of choosing a symmetric prior distribution such as the triangular distribution is that $J(\theta^*|\theta_{n-1}) = J(\theta_{n-1}|\theta^*)$. Consequently "*r*" reduces to:

$$r = \frac{P(\theta^* \mid y)}{P(\theta_{n-1} \mid y)} \tag{1.4-4}$$

The parameter distribution space is sampled and a given parameter value is assigned by a Monte Carlo draw. Using the sampled value, the predicted concentrations are computed by integrating the differential equations. The predictions are then compared with measurements by calculating the normalized sum of squares between the observations and predictions. In LAKEVIEW, the normalized squared differences are calculated between predictions and observations for surface water and/or porewater. The parameter sampling procedure is repeated a number of times. Both the new parameter and its value are chosen by random draw using the Monte Carlo technique.

The objective of the parameter estimation is to minimize the sum of squared differences between predicted and observed dependent variables. A "benchmark" conditional model probability is calculated after substituting the expected parameter values $\theta_{mean} = E(\theta_{li})$ into the differential equations and integrating to give the predicted dependent variable $y(\theta_{mean},t)$:

$$p(y|\theta_{mean}) \propto exp - \frac{\Sigma[y|(\theta_{mean}, t_k) - y(t_k)]^2}{2\, n_t\, \sigma^2} \qquad (1.4\text{-}5)$$

where:

$p(y|\theta_{,mean})$	=	conditional “baseline” model probability
$y(\theta_{mean},t_k)$	=	model prediction using expected parameter values at time t_k
$y(t_k)$	=	observation taken at time t_k
n_t	=	total number of observations
σ^2	=	variance

Using Bayesian inference, the posterior probability is given by:

$$P(\theta_{mean} \mid y) \propto p(\theta_{mean}) \times p(y|\theta_{mean}) \qquad (1.4\text{-}6)$$

where:

$P(\theta_{mean} \mid y)$ = "benchmark" predictive model probability for a given set of observations, y_k

$p(\theta_{,mean})$ = the probability of selecting parameter set $\theta_{,mean}$

It is evident that minimizing the sum of squared differences between predictions and observations implies maximizing the probability $P(\theta_{mean} \mid y)$. The posterior probability is re-calculated after each parameter selection.

The sampling space consists of *n* trials and a maximum of *m* iterations per trial. This leads to a maximum of *n* x *m* parameter selection. The number of trials (the value of “*n*”) should be at least 100 resulting in a set (θ_1, θ_2, θ_3 etc.) of 100 parameter estimates. The number of iterations is based on the number of parameters to be estimated. As a rule of thumb, the number of draws should be about 10 for each parameter. Thus, the total number of iterations per trial, *m*, should be about tenfold the number of parameters to be estimated.

The first trial commences with the calculation of the benchmark (or baseline probability) with the expected parameter values, $E(\theta_i)$-s. Then the selection of the parameter, say parameter "i" and its value (θ_i) is performed by random draw as described above. Model probability with the selected value, θ_i is given as:

$$P(\theta_i | y) = p(\theta i | \delta_i, \theta) \times p(y | \theta_i, \theta) \quad (1.4\text{-}7)$$

where:

$$p(y|\theta_i, \theta) \propto exp - \frac{\Sigma[y|(\theta_i, \theta, t_k) - y(t_k)]^2}{2\, n_t\, \sigma^2} \quad (1.4\text{-}8)$$

where:

θ_I = most recently drawn parameter value

It should be noted that the Metropolis-Hastings algorithm is quite flexible and the posterior probability function (equation (1.4-5)) can also be defined as:

$$p(y|\theta_i, \theta) \propto exp - \frac{\Sigma\left[\ln \frac{y|(\theta_i, \theta, t_k)}{y(t_k)}\right]^2}{2\, n_t\, \sigma^2} \quad (1.4\text{-}9)$$

If the probability min{r, 1} for equation (1.4-4) is satisfied with respect to the benchmark value in trial 1, then $P(\theta_i| y)$ becomes a "first" estimate of a "global probability maximum", $P(\theta^g |y)$.

In practice, the variance, σ^2, is not known. An estimate of σ^2 is obtained from the “previous best” $p(y|\theta_i, \theta)$ value that resulted in the acceptance of θ_i in a following manner:

$$\sigma^2 \approx s^2 = \frac{\Sigma[y|(\theta_i, \theta, t_k) - y(t_k)]^2}{n_t} \quad (1.4\text{-}10)$$

It can be shown that the estimated model variance σ^2 is X^2 distributed.

After storing the accepted parameter values, the parameters are reset to their expectations (E(θ)) and a new trial begins. Alternatively, the selected parameter values are replaced and the draw may continue until the number of trials, n_t is exceeded. At this point the parameters are also reset to E(θ)-s and a new trial begins. In subsequent trials, if the probability $P(\theta_i| y)$ is greater than the benchmark probability, but less than the current global probability, then the drawn parameter θ_i is retained and is used in subsequent iterations within the trial as a starter value. If, however, the probability $P(\theta_l \mid y)$ is less than the benchmark probability then θ_i is replaced by previous estimate. An accelerated search technique allows the parameters corresponding to interim $P(\theta \ |y)$ to become the benchmark parameters (new $E(\theta_i)$-s by centering the triangular distribution on the best current estimate of θ^g) after a certain number of unsuccessful trials (i.e. trials in which the number of iterations exceeds "m"). This is performed once after a number of "training" trials (1/3 of the total number of trials). In this case, the "bins" for storing the accepted θ-s is established after the initial number of "training" trials. If needed, the triangular parameter range (i.e. θ_{max} and θ_{min}) is adjusted to maintain symmetry. This adjustment becomes necessary whenever the current best parameter value approaches but cannot be less than zero.

A difficult problem remains the need to estimate the marginal posterior density for the parameter set θ:

$$P(\theta|\ y(t_k)\} = \int p\{\theta|\ \sigma,\delta,\ y(t_k))\ d\delta \qquad (1.4\text{-}11)$$

It is well known that the posterior density for θ possesses a multivariate normal distribution, but the performance of the integration analytically is far too difficult (Min 1998). An acceptable empirical solution is to save the set of θ-s after the training trials. The argument is that, if the maximum trial number "*n*" is chosen large enough, then the parameters have converged (or nearly so) to their best estimate by try nxm-*l* so the variance may be calculated empirically as follows:

$$\sigma_i^2 = \frac{\sum_l (\theta_{i,j} - \theta_{i,mean})^2}{\ell - 1} \qquad (1.4\text{-}12)$$

where:

σ_i^2 = variance of parameter "i"

$\theta_{i,j}$ = the parameter value of type "i" in the j th data set (η-k <= j <=η)

$\theta_{i,mean}$ = the average value of parameter "i"

ℓ = total number accepted of parameter sets in nxm-*l to "nxm"* number of tries

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ANNEX A: WATERSHED INPUT PARAMETERS

Table A-1 Watershed Input Parameters

Location	Lake / Wetland / River	Cumulative Drainage Area (m^2)	Mean Depth (m)	Volume (m^3)	Surface Area (m^2)	Length (m)
1. Pointer Lake	Lake	1.6×10^7		5.6×10^6	3.7×10^6	9000
2. Rock Lake	Lake	1.9×10^7		1.0×10^3	2.9×10^5	500
3. JSL-1	Lake	1.88×10^8	2.6	6.7×10^6	2.6×10^6	1000
4. JSL-2	Lake	1.94×10^8	5.6	1.4×10^7	2.5×10^6	1000
5. JSL-3	Lake	2.09×10^8	6.3	5.3×10^7	8.4×10^6	2000
6. JSL-7	Lake	8.42×10^7	1.1	6.3×10^6	5.6×10^6	3000
7. JSL-8	Lake	1.68×10^8	2.1	1.5×10^7	7.2×10^6	3000
8. JSL-6	Lake	2.73×10^8	3.3	1.6×10^8	4.8×10^7	3000
9. JSL-5	Lake	4.64×10^8	5.2	4.4×10^7	8.5×10^6	3000
10. JSL-4	Lake	7.04×10^8	8.8	1.5×10^8	1.7×10^7	3000

Table A-2 Water and Sedminent Input Parameters

Location	Suspended Solids (g/m^3)	Settling Velocity (m/yr)	Sediment Porosity (-)	Sediment Exchangeable Zone (m)	Sediment Oxygen Demand (g/m^2-d)	Kl (m/yr)
1. Pointer Lake	1	48	0.94	0.05	0.05	2.4
2. Rock Lake	1	48	0.94	0.05	0.05	2.4
3. JSL-1	1	48	0.94	0.035	0.05	2.4
4. JSL-2	1	48	0.94	0.065	0.05	2.4
5. JSL-3	1	48	0.94	0.04	0.05	2.4
6. JSL-7	1	48	0.94	0.06	0.05	2.4
7. JSL-8	1	48	0.94	0.04	0.05	2.4
8. JSL-6	1	48	0.94	0.028	0.05	2.4
9. JSL-5	1	48	0.94	0.05	0.05	2.4
10. JSL-4	1	48	0.94	0.04	0.05	2.4

Table A-3 Horizontal Dispersion Input Parameters

Adjoining Segments	Distance Between Segment Midpoints (m)	Cross-Sectional Area – Summer (m^2)	Cross-Sectional Area – Winter (m^2)
3. JSL-1 and 4. JSL-2	850	9,000	5,200
4. JSL-2 and 5. JSL-3	1,600	18,000	13,000
5. JSL-3 and 10. JSL-4	2,300	39,000	29,000
6. JSL-7 and 7. JSL-8	1,900	1,000	0
7. JSL-8 and 9. JSL-5	3,500	1,700	378
6. JSL-7 and 8. JSL-6	2,100	260	0
8. JSL-6 and 9. JSL-5	2,700	16,000	11,000
9. JSL-5 and 10. JSL-4	2,700	22,000	18,000

Table A-4 COPC Specfic Input Parameters

COPC	Reaction Rate Constant – Disappearance in Sediment (-)	Exchangeable Fraction in Sediment (-)[b]	$Kd_{sediment}$[a] (m^3/g)[b]	Background Water Concentration (g/m^3 or Bq/m^3)	Background Sediment Concentration[c] (g/g or Bq/g)
Uranium	$3.6x10^{-2}$	0.46	$7.5x10^{-3}$	$1.0x10^{-4}$	$1.5x10^{-6}$
Thorium-230	$3.6x10^{-2}$	0.1	$7.5x10^{-4}$	6.0	0.036
Lead-210	$3.6x10^{-2}$	0.4	$6.7x10^{-3}$	11.0	0.042
Radium-226	$3.6x10^{-2}$	0.334	$2.1x10^{-3}$	4.0	0.026
Polonium-210	$3.6x10^{-2}$	0.4	$6.7x10^{-3}$	5.0	0.054
Arsenic	$3.6x10^{-2}$	0.174	$5.5x10^{-3}$	$2.0x10^{-4}$	$6.6x10^{-6}$
Cadmium	$3.6x10^{-2}$	0.1	$3.0x10^{-4}$	$1.5x10^{-6}$	$1.5x10^{-7}$
Cobalt	$3.6x10^{-2}$	0.309	$4.1x10^{-2}$	$6.5x10^{-5}$	$3.9x10^{-6}$
Copper	$3.6x10^{-2}$	0.166	$4.1x10^{-3}$	$8.0x10^{-4}$	$1.8x10^{-5}$

Table A-4 COPC Specfic Input Parameters					
COPC	**Reaction Rate Constant – Disappearance in Sediment (-)**	**Exchangeable Fraction in Sediment (-)[b]**	**$Kd_{sediment}$[a] (m^3/g)[b]**	**Background Water Concentration (g/m^3 or Bq/m^3)**	**Background Sediment Concentration [c] (g/g or Bq/g)**
Lead	3.6×10^{-2}	0.235	1.5×10^{-2}	1.0×10^{-4}	7.8×10^{-6}
Molybdenum	3.6×10^{-2}	0.150	1.5×10^{-3}	1.0×10^{-4}	1.1×10^{-6}
Nickel	3.6×10^{-2}	0.157	4.6×10^{-3}	6.0×10^{-4}	1.9×10^{-5}
Selenium	3.6×10^{-2}	0.243	1.0×10^{-3}	1.0×10^{-4}	2.7×10^{-7}
Zinc	3.6×10^{-2}	0.459	6.3×10^{-3}	4.0×10^{-3}	3.8×10^{-5}
Ammonia	3.6×10^{-2}	-	-	4.0×10^{-2}	-
Chloride	-	-	-	0.6	-
Sulphate	-	-	-	0.6	-
TDS	-	-	-	24.6	-
Calcium	-	-	-	2.8	-

Note: Initial water and sediment concentrations vary by waterbody and are determined based on measured data and the calibration process.
a – Kd_{water} were calculated in the model as using a relationship factor between Kd_{water} and Kd_{sed} (normal distribution with an average of 3, standard deviation of 1, minimum of 1, and maximum of 5).
b – geometric mean values; lognormal distributions were applied in the model to capture uncertainty.
c – represents non-exchangeable sediment concentration only (exchangeable background sediment calculated internally in the model based on background water and Kd_{water}

Attachment B Caribou Data Comparison

This attachment provides a summary of the measured caribou data collected from Baker Lake with a comparison to caribou data from other herds across the north.

B.1 Caribou Data from Baker Lake

Twenty-seven caribou samples (comprised of various numbers of muscle, bone, kidney and liver) from Baker Lake were analyzed for metals and radionuclide concentrations. A summary of the data by tissue type is provided in Tables B.1-1 through B.1-4 for muscle, bone, kidney, and liver, respectively.

Table B.1-1 Summary of Baker Lake Caribou Data Muscle

Muscle											
Parameter	**Units**	**N**	**N<MDL**	**Min**	**Median**	**95th percentile**	**Max**	**Average**	**St. Dev**	**Geomean**	**GSD**
Aluminum	µg/g ww	23	1	0.005	0.73	1.89	2.9	0.72	0.71	0.38	4.19
Antimony	µg/g ww	23	22	0.01	0.01	0.01	0.22	0.02	0.04	0.01	1.91
Arsenic	µg/g ww	23	1	0.005	0.04	0.05	0.06	0.03	0.01	0.03	1.78
Barium	µg/g ww	23	0	0.05	0.12	0.57	0.62	0.17	0.15	0.13	1.93
Beryllium	µg/g ww	23	23	0.001	0.001	0.001	0.001	0.001	0.0	0.001	1.00
Boron	µg/g ww	23	22	0.1	0.1	0.1	0.5	0.12	0.08	0.11	1.40
Cadmium	µg/g ww	23	2	0.001	0.006	0.02	0.07	0.01	0.01	0.01	2.49
Chromium	µg/g ww	23	20	0.05	0.05	0.1	0.1	0.06	0.02	0.06	1.31
Cobalt	µg/g ww	23	0	0.002	0.006	0.018	0.021	0.01	0.005	0.01	1.86
Copper	µg/g ww	23	0	0.74	2.1	4.03	4.2	2.4	0.81	2.2	1.44
Iron	µg/g ww	23	0	22	40	73.9	87	42.74	15.6	40.6	1.38
Lead	µg/g ww	23	0	0.002	0.014	0.038	0.049	0.02	0.01	0.01	2.50
Manganese	µg/g ww	23	0	0.19	0.31	0.60	0.74	0.36	0.14	0.34	1.41
Mercury	µg/g ww	0	-	-	-	-	-	-	-	-	-
Molybdenum	µg/g ww	23	13	0.01	0.01	0.07	0.46	0.05	0.09	0.02	2.83
Nickel	µg/g ww	23	7	0.005	0.02	0.088	0.16	0.03	0.04	0.02	2.95
Selenium	µg/g ww	23	0	0.1	0.18	0.21	0.22	0.17	0.02	0.17	1.17
Silver	µg/g ww	23	22	0.001	0.001	0.001	0.002	0.001	0.0	0.001	1.16
Strontium	µg/g ww	23	0	0.03	0.07	0.27	0.34	0.10	0.08	0.08	1.88
Thallium	µg/g ww	23	23	0.005	0.005	0.005	0.005	0.01	0.0	0.01	1.00
Tin	µg/g ww	23	20	0.005	0.005	0.02	0.03	0.01	0.01	0.01	1.70
Titanium	µg/g ww	23	0	0.06	0.64	0.82	0.93	0.47	0.33	0.30	3.03
Uranium	µg/g ww	23	8	0.0005	0.002	0.03	0.17	0.01	0.04	0.00	5.22
Vanadium	µg/g ww	23	23	0.01	0.01	0.01	0.01	0.01	0.0	0.01	1.00

Table B.1-1 Summary of Baker Lake Caribou Data Muscle

Zinc	µg/g ww	23	0	18	41	61.8	62	40.4	14.2	37.8	1.48
Moisture	%	14	0	72.5	74.5	75.7	75.9	74.4	0.89	74.4	1.01
Lead-210	Bq/g ww	23	14	0.0005	0.0005	0.004	0.007	0.001	0.002	0.001	2.26
Polonium-210	Bq/g ww	23	0	0.0042	0.026	0.039	0.046	0.027	0.008	0.025	1.58
Radium-226	Bq/g ww	23	6	0.000025	0.0001	0.0002	0.00035	0.00011	0.00008	0.00009	2.06
Thorium-230	Bq/g ww	23	22	0.000035	0.00005	0.0001	0.0005	0.00008	0.00009	0.00006	1.70
Thorium-232	Bq/g ww	23	22	0.000035	0.00005	0.00028	0.0005	0.00008	0.00011	0.00006	1.86
Source: AREVA (2010)											

Table B.1-2 Sumary of Baker Lake Caribou Data Bone

Bone											
Parameter	**Units**	**N**	**N<MDL**	**Min**	**Median**	**95th percentile**	**Max**	**Average**	**St. Dev**	**Geomean**	**GSD**
Aluminum	µg/g ww	24	1	0.01	1.8	4.9	5.4	2.13	1.34	1.55	3.31
Antimony	µg/g ww	24	24	0.025	0.025	0.025	0.025	0.03	0.0	0.03	1.00
Arsenic	µg/g ww	24	24	0.01	0.01	0.01	0.01	0.01	0.0	0.01	1.00
Barium	µg/g ww	24	0	42	352	438.4	440	336.3	90.24	313.9	1.60
Beryllium	µg/g ww	24	24	0.005	0.005	0.005	0.005	0.01	0.0	0.01	1.00
Boron	µg/g ww	24	24	0.25	0.25	0.25	0.25	0.25	0.0	0.25	1.00
Cadmium	µg/g ww	24	24	0.005	0.005	0.005	0.005	0.01	0.0	0.01	1.00
Chromium	µg/g ww	24	24	0.1	0.1	0.1	0.1	0.10	0.0	0.10	1.00
Cobalt	µg/g ww	24	1	0.005	0.04	0.06	0.07	0.04	0.01	0.04	1.67
Copper	µg/g ww	24	1	0.01	0.12	0.19	0.22	0.12	0.05	0.10	1.89
Iron	µg/g ww	24	0	0.47	7	10	11	6.9	2.35	6.1	1.85
Lead	µg/g ww	24	0	0.3	2.4	4.9	5.8	2.6	1.3	2.3	1.81
Manganese	µg/g ww	24	0	0.08	1.05	1.3	1.3	1.00	0.26	0.92	1.73
Mercury	µg/g ww	0	-	-	-	-	-	-	-	-	-
Molybdenum	µg/g ww	24	11	0.025	0.05	0.28	0.33	0.09	0.09	0.06	2.45
Nickel	µg/g ww	24	1	0.01	0.16	0.21	0.24	0.16	0.04	0.15	1.81
Selenium	µg/g ww	24	8	0.01	0.02	0.05	0.05	0.02	0.01	0.02	1.82
Silver	µg/g ww	24	24	0.005	0.005	0.005	0.005	0.01	0.0	0.01	1.00
Strontium	µg/g ww	24	0	29	225	278.8	287	212.5	59.9	197.9	1.60
Thallium	µg/g ww	24	24	0.01	0.01	0.01	0.01	0.01	0.0	0.01	1.00
Tin	µg/g ww	24	24	0.01	0.01	0.01	0.01	0.01	0.0	0.01	1.00
Titanium	µg/g ww	24	0	0.04	0.64	0.85	1.4	0.64	0.22	0.58	1.83
Uranium	µg/g ww	24	12	0.005	0.0075	0.049	0.65	0.04	0.13	0.01	3.10
Vanadium	µg/g ww	24	24	0.025	0.025	0.025	0.025	0.03	0.0	0.03	1.00
Zinc	µg/g ww	24	0	10	98	128.5	140	98.9	24.1	92.4	1.64
Moisture	%	14	0	15.1	18.4	27.1	30.5	19.6	4.6	19.1	1.24
Lead-210	Bq/g ww	24	0	0.49	0.93	1.59	2	1.00	0.36	0.94	1.41
Polonium-210	Bq/g ww	24	0	0.32	0.595	1.17	1.3	0.65	0.25	0.61	1.44
Radium-226	Bq/g ww	24	0	0.016	0.053	0.083	0.087	0.05	0.02	0.05	1.51
Thorium-230	Bq/g ww	24	23	0.0015	0.002	0.0025	0.004	0.0020	0.0005	0.0019	1.25
Thorium-232	Bq/g ww	24	23	0.0015	0.002	0.0025	0.004	0.0020	0.0005	0.0019	1.25

Table B.1-3 Summary of Baker Lake Caribou Data Kidney

Kidney											
Parameter	**Units**	**N**	**N<MDL**	**Min**	**Median**	**95th percentile**	**Max**	**Average**	**St. Dev**	**Geomean**	**GSD**
Aluminum	µg/g ww	15	0	0.11	0.34	0.92	1.4	0.45	0.33	0.37	1.92
Antimony	µg/g ww	15	14	0.01	0.01	0.019	0.04	0.01	0.01	0.01	1.43
Arsenic	µg/g ww	15	0	0.01	0.02	0.03	0.03	0.02	0.01	0.02	1.38
Barium	µg/g ww	15	0	0.37	0.76	1.6	2.8	0.85	0.58	0.74	1.67
Beryllium	µg/g ww	15	15	0.001	0.001	0.001	0.001	0.001	0.0	0.001	1.00
Boron	µg/g ww	15	14	0.1	0.1	0.43	1.2	0.17	0.28	0.12	1.90
Cadmium	µg/g ww	15	0	0.6	3.1	5.6	5.8	3.17	1.53	2.74	1.86
Chromium	µg/g ww	15	14	0.05	0.05	0.065	0.1	0.05	0.01	0.05	1.20
Cobalt	µg/g ww	15	0	0.029	0.042	0.068	0.076	0.05	0.01	0.04	1.37
Copper	µg/g ww	15	0	3.1	4.6	5.7	6.4	4.54	0.79	4.48	1.19
Iron	µg/g ww	15	0	25	46	68	68	45.9	12.1	44.5	1.31
Lead	µg/g ww	15	0	0.11	0.14	0.18	0.2	0.14	0.02	0.14	1.18
Manganese	µg/g ww	15	0	1.2	1.8	2.3	2.3	1.86	0.30	1.84	1.19
Mercury	µg/g ww	0	-	-	-	-	-	-	-	-	-
Molybdenum	µg/g ww	15	0	0.03	0.13	0.16	0.17	0.12	0.04	0.11	1.53
Nickel	µg/g ww	15	4	0.005	0.02	0.073	0.08	0.02	0.02	0.02	2.52
Selenium	µg/g ww	15	0	0.76	1.1	1.26	1.4	1.09	0.16	1.08	1.17
Silver	µg/g ww	15	14	0.001	0.001	0.0055	0.016	0.002	0.004	0.001	2.05
Strontium	µg/g ww	15	0	0.08	0.14	0.74	1.4	0.25	0.33	0.17	2.06
Thallium	µg/g ww	15	13	0.005	0.005	0.01	0.01	0.01	0.002	0.01	1.28
Tin	µg/g ww	15	13	0.005	0.005	0.02	0.02	0.01	0.01	0.01	1.63
Titanium	µg/g ww	15	0	0.08	0.68	1.05	1.2	0.55	0.45	0.32	3.38
Uranium	µg/g ww	15	6	0.0005	0.001	0.013	0.021	0.004	0.01	0.002	3.71
Vanadium	µg/g ww	15	15	0.01	0.01	0.01	0.01	0.01	0.0	0.01	1.00
Zinc	µg/g ww	15	0	20	22	27.3	28	22.6	2.4	22.5	1.11
Moisture	%	8	0	77.7	78.3	79.8	80.4	78.5	0.84	78.5	1.01
Lead-210	Bq/g ww	15	0	0.04	0.07	0.12	0.12	0.07	0.03	0.07	1.47
Polonium-210	Bq/g ww	15	0	0.18	0.36	0.47	0.51	0.34	0.09	0.33	1.32
Radium-226	Bq/g ww	15	11	0.0003	0.001	0.003	0.004	0.0010	0.0011	0.0007	2.33
Thorium-230	Bq/g ww	15	15	0.0005	0.0005	0.002	0.002	0.0012	0.0008	0.0010	2.05
Thorium-232	Bq/g ww	15	15	0.0005	0.0005	0.002	0.002	0.0012	0.0008	0.0010	2.05

Table B.1-4 Summary of Baker Lake Caribou Data - Liver

Liver											
Parameter	**Units**	**N**	**N<MDL**	**Min**	**Median**	**95th percentile**	**Max**	**Average**	**St. Dev**	**Geomean**	**GSD**
Aluminum	µg/g ww	14	0	0.14	0.40	0.93	1.2	0.47	0.27	0.40	1.76
Antimony	µg/g ww	14	14	0.01	0.01	0.01	0.01	0.01	0.0	0.01	1.00
Arsenic	µg/g ww	14	0	0.01	0.02	0.02	0.02	0.02	0.005	0.02	1.41
Barium	µg/g ww	14	0	0.12	0.36	0.49	0.52	0.35	0.12	0.32	1.52
Beryllium	µg/g ww	14	14	0.001	0.001	0.001	0.001	0.001	0.0	0.001	1.00
Boron	µg/g ww	14	14	0.1	0.1	0.1	0.1	0.10	0.0	0.10	1.00
Cadmium	µg/g ww	14	0	0.15	0.62	0.84	0.87	0.58	0.21	0.53	1.62
Chromium	µg/g ww	14	13	0.05	0.05	0.10	0.2	0.06	0.04	0.06	1.45
Cobalt	µg/g ww	14	0	0.069	0.084	0.09	0.095	0.08	0.01	0.08	1.12
Copper	µg/g ww	14	0	9.6	29	39.1	41	25.4	10.1	23.2	1.61
Iron	µg/g ww	14	0	160	435	824	980	468.6	247.4	406.1	1.78
Lead	µg/g ww	14	0	0.21	0.44	0.65	0.86	0.42	0.17	0.39	1.48
Manganese	µg/g ww	14	0	3	3.7	4.2	4.5	3.64	0.40	3.61	1.12
Mercury	µg/g ww	0	-	-	-	-	-	-	-	-	-
Molybdenum	µg/g ww	14	0	0.33	0.60	0.73	0.74	0.57	0.12	0.56	1.25
Nickel	µg/g ww	14	7	0.005	0.008	0.31	0.61	0.07	0.16	0.02	4.80
Selenium	µg/g ww	14	0	0.33	0.435	0.54	0.57	0.44	0.07	0.43	1.17
Silver	µg/g ww	14	0	0.043	0.09	0.26	0.38	0.13	0.09	0.11	1.79
Strontium	µg/g ww	14	0	0.03	0.06	0.13	0.14	0.07	0.03	0.06	1.64
Thallium	µg/g ww	14	14	0.005	0.005	0.005	0.005	0.01	0.0	0.01	1.00
Tin	µg/g ww	14	14	0.005	0.005	0.005	0.005	0.01	0.0	0.01	1.00
Titanium	µg/g ww	14	0	0.11	1.1	1.3	1.3	0.81	0.53	0.55	2.95
Uranium	µg/g ww	14	6	0.0005	0.001	0.014	0.017	0.004	0.01	0.001	3.70
Vanadium	µg/g ww	14	14	0.01	0.01	0.01	0.01	0.01	0.0	0.01	1.00
Zinc	µg/g ww	14	0	18	21.5	28.7	30	22.8	3.79	22.51	1.17
Moisture	%	9	0	70.2	71.2	74.0	75.2	71.7	1.51	71.63	1.02
Lead-210	Bq/g ww	14	0	0.075	0.19	0.30	0.36	0.19	0.08	0.18	1.51
Polonium-210	Bq/g ww	14	0	0.27	0.44	0.58	0.68	0.45	0.10	0.43	1.26
Radium-226	Bq/g ww	14	8	0.000035	0.0003	0.00087	0.001	0.0003	0.0003	0.0003	2.23
Thorium-230	Bq/g ww	14	12	0.00005	0.0005	0.014	0.04	0.0032	0.011	0.0004	5.34
Thorium-232	Bq/g ww	14	14	0.00005	0.0005	0.002	0.005	0.0007	0.0013	0.0003	3.79

B.2 Caribou Data from Other Herds

AECOM/Gartner Lee (2005) provided analytical data on 10 caribou (collected between 2004 and 2007) that were captured in the study area of the Faro Mine Complex Site (Yukon). Dry weight concentrations were reported by the laboratory and were converted to fresh weight based on the reported sample moisture content. These data are presented in Tables B.2-1 through B.2-3 for muscle, kidney, and liver.

Table B.2-1 Summary of Faro Mine Complex Caribou Data - Muscle

Muscle											
Parameter	**Units**	**N**	**N<MDL**	**Min**	**Median**	**95th percentile**	**Max**	**Average**	**St. Dev.**	**Geomean**	**GSD**
Antimony	mg/kg (ww)	10	9	0.001	0.001	0.004	0.006	0.002	0.002	0.002	1.6
Arsenic	mg/kg (ww)	10	2	0.001	0.010	0.036	0.048	0.01	0.01	0.01	3.2
Beryllium	mg/kg (ww)	10	10	0.001	0.001	0.002	0.002	0.001	0.0	0.001	1.0
Boron	mg/kg (ww)	10	1	0.08	0.34	0.52	0.59	0.34	0.13	0.31	1.8
Cadmium	mg/kg (ww)	10	2	0.001	0.008	0.021	0.024	0.009	0.007	0.007	2.6
Chromium	mg/kg (ww)	10	6	0.03	0.029	0.15	0.17	0.06	0.05	0.05	2.0
Cobalt	mg/kg (ww)	10	1	0.002	0.01	0.12	0.13	0.03	0.05	0.01	4.3
Copper	mg/kg (ww)	10	0	1.3	2.3	2.9	3.0	2.2	0.52	2.1	1.3
Lead	mg/kg (ww)	10	0	0.008	0.012	0.024	0.027	0.014	0.006	0.013	1.5
Manganese	mg/kg (ww)	10	0	0.17	0.25	0.75	0.85	0.34	0.22	0.30	1.7
Nickel	mg/kg (ww)	10	9	0.006	0.007	0.01	0.02	0.01	0.00	0.01	1.2
Selenium	mg/kg (ww)	10	0	0.05	0.18	0.8	1.2	0.26	0.33	0.18	2.3
Silver	mg/kg (ww)	10	0	0.008	0.03	0.08	0.10	0.03	0.03	0.03	2.3
Strontium	mg/kg (ww)	10	0	0.03	0.05	0.12	0.14	0.06	0.03	0.05	1.5
Tin	mg/kg (ww)	10	3	0.001	0.006	0.11	0.18	0.023	0.055	0.006	4.6
Vanadium	mg/kg (ww)	10	6	0.007	0.007	0.040	0.044	0.015	0.014	0.012	2.1
Zinc	mg/kg (ww)	10	0	42.2	55.6	71.6	73.7	54.9	11.9	53.8	1.3
Source: AECOM/Gartner Lee (2005)											

Table B.2-2Summary of Faro Mine Complex Caribou Data - Kidney

Kidney											
Parameter	**Units**	**N**	**N<MDL**	**Min**	**Median**	**95th percentile**	**Max**	**Average**	**St. Dev.**	**Geomean**	**GSD**
Antimony	mg/kg (ww)	11	11	0.001	0.0011	0.0012	0.0012	0.0011	0.0	0.0011	1.0
Arsenic	mg/kg (ww)	11	0	0.009	0.016	0.043	0.051	0.02	0.01	0.02	1.7
Beryllium	mg/kg (ww)	11	11	0.001	0.0011	0.0012	0.0012	0.0011	0.0	0.0011	1.0
Boron	mg/kg (ww)	11	1	0.05	0.27	0.36	0.36	0.26	0.09	0.23	1.7
Cadmium	mg/kg (ww)	11	0	1.2	9.5	20.4	20.9	10.0	6.5	7.7	2.3
Chromium	mg/kg (ww)	11	3	0.02	0.05	0.13	0.15	0.06	0.04	0.05	1.9
Cobalt	mg/kg (ww)	11	0	0.002	0.05	0.09	0.10	0.06	0.03	0.04	2.8
Copper	mg/kg (ww)	11	0	4.3	5.2	5.4	5.4	5.0	0.36	5.0	1.1
Lead	mg/kg (ww)	11	0	0.23	0.61	1.1	1.3	0.60	0.32	0.54	1.7
Manganese	mg/kg (ww)	11	0	1.2	1.5	2.0	2.0	1.6	0.25	1.6	1.1
Nickel	mg/kg (ww)	11	6	0.005	0.006	0.03	0.05	0.01	0.01	0.01	2.3
Selenium	mg/kg (ww)	11	0	0.14	0.82	1.2	1.2	0.81	0.34	0.70	2.0
Silver	mg/kg (ww)	11	0	0.010	0.02	0.34	0.39	0.09	0.13	0.04	3.9
Strontium	mg/kg (ww)	11	0	0.03	0.13	0.18	0.19	0.12	0.04	0.11	1.7
Tin	mg/kg (ww)	11	6	0.001	0.0012	0.011	0.015	0.004	0.004	0.002	2.6
Vanadium	mg/kg (ww)	11	2	0.006	0.017	0.041	0.045	0.019	0.012	0.016	1.9
Zinc	mg/kg (ww)	11	0	17.8	24.0	29.0	29.8	24.4	4.0	24.0	1.2

Source: AECOM/Gartner Lee (2005)

Table B.2-3 Summary of Faro Mine Complex Caribou Data - Liver

Liver											
Parameter	**Units**	**N**	**N<MDL**	**Min**	**Median**	**95th percentile**	**Max**	**Average**	**St. Dev.**	**Geomean**	**GSD**
Antimony	mg/kg (ww)	11	10	0.002	0.002	0.004	0.006	0.002	0.001	0.002	1.5
Arsenic	mg/kg (ww)	11	2	0.002	0.0128	0.027	0.035	0.01	0.01	0.01	2.7
Beryllium	mg/kg (ww)	11	11	0.002	0.002	0.002	0.002	0.002	0.0	0.002	1.0
Boron	mg/kg (ww)	11	0	0.19	0.35	0.51	0.59	0.35	0.11	0.34	1.3
Cadmium	mg/kg (ww)	11	0	0.30	1.5	2.8	3.2	1.5	0.82	1.3	1.9
Chromium	mg/kg (ww)	11	7	0.03	0.033	0.16	0.22	0.06	0.06	0.05	1.9
Cobalt	mg/kg (ww)	11	1	0.002	0.09	0.13	0.13	0.09	0.04	0.06	3.5
Copper	mg/kg (ww)	11	0	6.3	15.1	30.2	34.2	16.6	8.48	14.7	1.7
Lead	mg/kg (ww)	11	0	0.13	0.41	0.68	0.77	0.41	0.17	0.38	1.6
Manganese	mg/kg (ww)	11	0	2.9	4.4	5.0	5.0	4.3	0.60	4.2	1.2
Nickel	mg/kg (ww)	11	7	0.008	0.008	0.04	0.05	0.02	0.01	0.01	2.0
Selenium	mg/kg (ww)	11	0	0.17	0.39	1.0	1.6	0.47	0.39	0.39	1.8
Silver	mg/kg (ww)	11	0	0.30	0.52	0.88	1.0	0.54	0.21	0.51	1.5
Strontium	mg/kg (ww)	11	0	0.04	0.06	0.12	0.17	0.07	0.04	0.06	1.5
Tin	mg/kg (ww)	11	5	0.002	0.003	0.029	0.043	0.008	0.012	0.004	3.0
Vanadium	mg/kg (ww)	11	6	0.008	0.008	0.036	0.044	0.017	0.012	0.014	1.9
Zinc	mg/kg (ww)	11	0	13.5	23.8	29.5	31.2	23.4	5.1	22.8	1.3
Source: AECOM/Gartner Lee (2005)											

Concentrations for caribou at background locations were represented by data collected from other Yukon locations. The caribou samples were provided by the community and the Northern Contaminants Program and the data were summarized by EDI (2007). Dry weight concentrations were reported by the laboratory and were converted to fresh weight based on the reported sample moisture content. Table B.2-4 provides the summary statistics for caribou muscle.

Table B.2-4 Summary of Yukon Background Caribou Data - Muscle

Muscle											
Parameter	**Units**	**N**	**N<MDL**	**Min**	**Median**	**95th percentile**	**Max**	**Average**	**St. Dev.**	**Geomean**	**GSD**
Antimony	mg/kg (ww)	2	0	0.001	0.001	0.001	0.001	0.001	0	0.001	1.0
Arsenic	mg/kg (ww)	2	0	0.003	0.007	0.011	0.011	0.007	0.006	0.005	2.8
Beryllium	mg/kg (ww)	2	1	<0.0001	0.0005	0.001	0.001	0.0005	0.0007	0.0003	2.7
Cadmium	mg/kg (ww)	2	0	0.03	0.031	0.036	0.04	0.03	0.007	0.03	1.1
Chromium	mg/kg (ww)	2	0	0.10	0.12	0.13	0.14	0.12	0.02	0.12	1.1
Cobalt	mg/kg (ww)	2	0	0.003	0.004	0.004	0.005	0.004	0.0008	0.004	1.1
Copper	mg/kg (ww)	2	0	3.4	3.6	3.7	3.7	3.6	0.18	3.6	1.0
Lead	mg/kg (ww)	2	0	0.002	0.002	0.002	0.002	0.002	0	0.002	1.9
Manganese	mg/kg (ww)	2	0	0.35	0.41	0.45	0.46	0.41	0.07	0.40	1.1
Nickel	mg/kg (ww)	2	0	0.06	0.067	0.074	0.08	0.07	0.01	0.07	1.1
Selenium	mg/kg (ww)	2	0	0.04	0.055	0.069	0.07	0.06	0.02	0.05	2.2
Silver	mg/kg (ww)	2	0	0.022	0.030	0.036	0.037	0.03	0.01	0.03	1.2
Strontium	mg/kg (ww)	2	0	0.033	0.042	0.049	0.05	0.04	0.01	0.04	1.1
Tin	mg/kg (ww)	2	1	<0.01	0.09	0.17	0.18	0.09	0.12	0.06	7.4
Vanadium	mg/kg (ww)	2	1	<0.001	0.001	0.001	0.001	0.0008	0.0004	0.0007	1.3
Zinc	mg/kg (ww)	2	0	24.4	26.3	28.0	28.2	26.3	2.7	26.2	1.2
Source: EDI (2007)											

EDI (2007) summarized caribou samples provided by the community and the Northern Contaminants Program for the Mt. Nansen Mine area. Dry weight concentrations were reported by the laboratory and are converted to fresh weight based on the reported sample moisture content. The data are summarized in Table B.2-5.

Table B.2-5 Summary of Mt. Nansen Mine Caribou Data - Muscle

Muscle											
Parameter	**Units**	**N**	**N<MDL**	**Min**	**Median**	**95th percentile**	**Max**	**Average**	**St. Dev.**	**Geomean**	**GSD**
Aluminum	mg/kg (ww)	2	0	0.013	0.043	0.070	0.073	0.043	0.043	0.03	3.5
Antimony	mg/kg (ww)	2	0	0.00025	0.00026	0.00027	0.00027	0.00026	0.00001	0.0003	1.1
Arsenic	mg/kg (ww)	2	0	0.001	0.002	0.003	0.003	0.002	0.002	0.002	2.6
Barium	mg/kg (ww)	2	0	0.005	0.007	0.009	0.009	0.007	0.003	0.007	1.6
Beryllium	mg/kg (ww)	2	1	0.00001	0.0001	0.00026	0.00027	0.00014	0.0002	0.0001	8.8
Cadmium	mg/kg (ww)	2	0	0.006	0.008	0.010	0.010	0.008	0.002	0.008	1.3
Chromium	mg/kg (ww)	2	0	0.026	0.031	0.036	0.037	0.031	0.008	0.03	1.3
Cobalt	mg/kg (ww)	2	0	0.0008	0.0010	0.0012	0.0012	0.0010	0.0003	0.0010	1.3
Copper	mg/kg (ww)	2	0	0.9	0.94	1.0	1.0	0.9	0.10	0.93	1.1
Iron	mg/kg (ww)	2	0	9.5	10.4	11.3	11.4	10.4	1.3	10.4	1.1
Lead	mg/kg (ww)	2	0	0.0005	0.001	0.0005	0.0005	0.0005	0.00003	0.001	1.1
Manganese	mg/kg (ww)	2	0	0.10	0.11	0.11	0.12	0.11	0.013	0.11	1.1
Mercury	mg/kg (ww)	2	0	0.0008	0.001	0.0012	0.0013	0.0010	0.0003	0.001	1.4
Molybdenum	mg/kg (ww)	2	0	0.006	0.008	0.010	0.010	0.008	0.003	0.007	1.5
Nickel	mg/kg (ww)	2	0	0.015	0.018	0.020	0.020	0.018	0.004	0.017	1.3
Potassium	mg/kg (ww)	2	0	836	919	993	1001	919	117	915	1.1
Selenium	mg/kg (ww)	2	0	0.011	0.014	0.017	0.018	0.014	0.005	0.014	1.4
Silver	mg/kg (ww)	2	2	0.00001	0.00001	0.00001	0.00001	0.00001	0.000001	0.00001	1.1
Strontium	mg/kg (ww)	2	0	0.008	0.011	0.013	0.014	0.011	0.004	0.011	1.4
Thallium	mg/kg (ww)	2	0	0.00014	0.00014	0.00015	0.00015	0.00014	0.00001	0.00014	1.1
Tin	mg/kg (ww)	2	1	0.001	0.023	0.043	0.045	0.023	0.031	0.008	11.9
Uranium	mg/kg (ww)	2	2	0.00001	0.00001	0.00001	0.00001	0.00001	0.000001	0.00001	1.1
Vanadium	mg/kg (ww)	2	1	0.00013	0.00020	0.00026	0.00027	0.00020	0.00010	0.00019	1.7
Zinc	mg/kg (ww)	2	0	6.64	6.87	7.08	7.10	6.87	0.33	6.87	1.0
Source: EDI (2007)											

B.3 Comparison of Average Caribou Data - Muscle

Table B.3-1 provides a summary of the average concentrations from the various caribou muscle data sets presented above.

Table B.3-1 Summary of Average Caribou Concentrations - Muscle

		Average Muscle Concentration			
Parameter	**Units**	**Baker Lake**	**Faro Mine**	**Yukon BG**	**Mt. Nansen Mine**
Aluminum	µg/g ww	0.72	-	-	0.04
Antimony	µg/g ww	0.02	0.002	0.001	0.0003
Arsenic	µg/g ww	0.03	0.01	0.007	0.002
Barium	µg/g ww	0.17	-	-	0.007
Beryllium	µg/g ww	0.001	0.001	0.0005	0.00014
Boron	µg/g ww	0.12	0.34	-	-
Cadmium	µg/g ww	0.01	0.009	0.03	0.008
Chromium	µg/g ww	0.06	0.06	0.12	0.031
Cobalt	µg/g ww	0.01	0.03	0.004	0.001
Copper	µg/g ww	2.4	2.2	3.6	0.9
Iron	µg/g ww	42.7	-	-	10.4
Lead	µg/g ww	0.02	0.014	0.002	0.0005
Manganese	µg/g ww	0.36	0.34	0.41	0.11
Mercury	µg/g ww	-	-	-	0.0010
Molybdenum	µg/g ww	0.05	-	-	0.008
Nickel	µg/g ww	0.03	0.01	0.07	0.018
Potassium	µg/g ww	-	-	-	919
Selenium	µg/g ww	0.17	0.26	0.06	0.014
Silver	µg/g ww	0.001	0.03	0.03	0.00001
Strontium	µg/g ww	0.10	0.06	0.04	0.011
Thallium	µg/g ww	0.01	-	-	0.00014
Tin	µg/g ww	0.01	0.023	0.09	0.023
Titanium	µg/g ww	0.47	-	-	-
Uranium	µg/g ww	0.01	-	-	0.00001
Vanadium	µg/g ww	0.01	0.015	0.0008	0.0002
Zinc	µg/g ww	40.4	54.9	26.3	6.9
Lead-210	Bq/g ww	0.001	-	-	-
Polonium-210	Bq/g ww	0.027	-	-	-
Radium-226	Bq/g ww	0.00011	-	-	-
Thorium-230	Bq/g ww	0.00008	-	-	-
Thorium-232	Bq/g ww	0.00008	-	-	-

B.4 Comparison of Geometric Mean Caribou Data - Muscle

Table B.4-1 provides a summary of the geometric mean concentrations from the various caribou muscle data sets presented above.

Table B.4-1 Summary of Geometric Mean Caribou Concentrations - Muscle

Geometric Mean Muscle Concentration					
Parameter	**Units**	**Baker Lake**	**Faro Mine**	**Yukon BG**	**Mt. Nansen Mine**
Aluminum	µg/g ww	0.38	-	-	0.03
Antimony	µg/g ww	0.01	0.002	0.001	0.0003
Arsenic	µg/g ww	0.03	0.01	0.005	0.002
Barium	µg/g ww	0.13	-	-	0.007
Beryllium	µg/g ww	0.001	0.001	0.0003	0.0001
Boron	µg/g ww	0.11	0.31	-	-
Cadmium	µg/g ww	0.01	0.007	0.03	0.008
Chromium	µg/g ww	0.06	0.05	0.12	0.03
Cobalt	µg/g ww	0.01	0.01	0.004	0.0010
Copper	µg/g ww	2.2	2.1	3.6	0.93
Iron	µg/g ww	40.6	-	-	10.4
Lead	µg/g ww	0.01	0.013	0.002	0.001
Manganese	µg/g ww	0.34	0.30	0.40	0.11
Mercury	µg/g ww	-	-	-	0.001
Molybdenum	µg/g ww	0.02	-	-	0.007
Nickel	µg/g ww	0.02	0.01	0.07	0.017
Potassium	µg/g ww	-	-	-	915
Selenium	µg/g ww	0.17	0.18	0.05	0.014
Silver	µg/g ww	0.001	0.03	0.03	0.00001
Strontium	µg/g ww	0.08	0.05	0.04	0.011
Thallium	µg/g ww	0.01	-	-	0.00014
Tin	µg/g ww	0.01	0.006	0.06	0.008
Titanium	µg/g ww	0.30	-	-	-
Uranium	µg/g ww	0.00	-	-	0.00001
Vanadium	µg/g ww	0.01	0.012	0.0007	0.00019
Zinc	µg/g ww	37.8	53.8	26.2	6.9
Lead-210	Bq/g ww	0.001	-	-	-
Polonium-210	Bq/g ww	0.025	-	-	-
Radium-226	Bq/g ww	0.00009	-	-	-
Thorium-230	Bq/g ww	0.00006	-	-	-
Thorium-232	Bq/g ww	0.00006	-	-	-

B.5 References

AREVA (AREVA Resources Canada Inc.). 2010. *Kiggavik Project: Environmental Impact Statement.* Terrestrial Environment.

Environmental Dynamics Inc. (EDI) 2007. *Mount Nansen Terrestrial and Aquatic Effects Study 2005-2006*. Prepared for Government of Yukon. June.

Gartner Lee Limited 2005. *Anvil Range Mine Complex – Terrestrial Effects Study: Investigation into Metal Concentrations in Vegetation, Wildlife and Soils*. Prepared for Deloitte & Touche Inc. Draft for Discussion. April.

Attachment C Effluent Characteristics

C.1 Option 2 Discharge Scenario

The Option 2 discharge scenario considers Kiggavik WTP and Sissons WTP discharge locations at segment JSL-2. Tables C.1-1 and C.1-2 summarize the water quality distributions assumed to characterize the Kiggavik WTP and Sissons WTP for this discharge scenario. Figures C.1-1 and C.1-2 present the assumed monthly flows for the Option 2 discharge scenario (under the extended scenario). The predicted monthly flows were provided by AREVA and these values were assumed to be the mode of a triangular distribution, with the minimum and maximum represented by +/- 33%.

Table C.1-1 Effluent Concentration Distributions for Kiggavik WTP Discharge – Option 2

COPC	Lognormal Distribution Descriptors (mg/L or Bq/L)			
	Geometric Mean (GM)[a]	Geometric Standard Deviation (GSD)[b]	Minimum (-3 GSD)	Maximum (+3 GSD)
Uranium	0.002	2.24	0.0002	0.02
Thorium-230	0.011	2.05	0.0013	0.10
Lead-210	0.052	1.54	0.014	0.19
Radium-226	0.008	2.53	0.0005	0.13
Polonium-210	0.007	2.10	0.0007	0.06
Arsenic	0.021	1.76	0.004	0.11
Cadmium	0.007	1.44	0.0023	0.02
Cobalt	0.007	2.12	0.0007	0.07
Copper	0.002	2.41	0.0001	0.02
Lead	0.002	2.63	0.0001	0.04
Molybdenum	0.2	1.75	0.038	1.1
Nickel	0.02	1.57	0.005	0.08
Selenium	0.01	1.28	0.0047	0.02
Zinc	0.003	2.06	0.0003	0.03
Ammonia	17.3	1.36	6.9	44
Calcium	470	1.29	219	1010
Chloride	237	1.49	71	792
Sulphate	2199	1.29	1027	4708
TDS[c]	3115	1.31	1373	7068

Table C.1-1 Effluent Concentration Distributions for Kiggavik WTP Discharge – Option 2

COPC	Lognormal Distribution Descriptors (mg/L or Bq/L)			
	Geometric Mean (GM)[a]	Geometric Standard Deviation (GSD)[b]	Minimum (-3 GSD)	Maximum (+3 GSD)

Note: a - GM from predicted Kiggavik WTP data, if not specified. Kiggavik WTP values provided by AREVA were assumed to be geometric mean values for the distributions.

b – GSDs preferentially selected from Key Lake data (4/2009-9/2010) for uranium, radium-226, arsenic, copper, molybdenum, nickel, selenium, and ammonia. GSDs from McClean (2011) for the JEB WTP (future quality) were used in the absence of other data for thorium-230, lead-210, polonium-210, cadmium, cobalt, lead, zinc, chloride, sulphate, and TDS.

c – TDS calculated as the sum of the anions and cations (as available).

Table C.1-2 Effluent Concentration Distributions for Sissons WTP Discharge – Option 2

COPC	Lognormal Distribution Descriptors (mg/L or Bq/L)			
	Geometric Mean (GM)[a]	Geometric Standard Deviation (GSD)[b]	Minimum (-3 GSD)	Maximum (+3 GSD)
Uranium	0.034	2.24	0.003	0.38
Thorium-230	0.19	2.05	0.022	1.64
Lead-210	0.59	1.54	0.16	2.17
Radium-226	0.10	2.53	0.006	1.62
Polonium-210	0.17	2.10	0.018	1.58
Arsenic	0.018	1.76	0.003	0.10
Cadmium	0.0001	1.44	0.00004	0.0004
Cobalt	0.0003	2.12	0.00003	0.003
Copper	0.001	2.41	0.00007	0.014
Lead	0.0005	2.63	0.00003	0.009
Molybdenum	0.085	1.75	0.016	0.46
Nickel	0.001	1.57	0.0003	0.005
Selenium	0.004	1.28	0.002	0.008
Zinc	0.014	2.06	0.002	0.12
Ammonia	3.1	1.36	1.24	7.86
Calcium	336	1.29	157	721
Chloride	846.6	1.49	254	2825
Sulphate	167.0	1.29	78	357
TDS[c]	1528	1.31	673	3466

Table C.1-2 Effluent Concentration Distributions for Sissons WTP Discharge – Option 2				
COPC	Lognormal Distribution Descriptors (mg/L or Bq/L)			
	Geometric Mean (GM)[a]	Geometric Standard Deviation (GSD)[b]	Minimum (-3 GSD)	Maximum (+3 GSD)
Note: a - GM from predicted Kiggavik WTP data, if not specified. Kiggavik WTP values provided by AREVA were assumed to be geometric mean values for the distributions. b – GSDs preferentially selected from Key Lake data (4/2009-9/2010) for uranium, radium-226, arsenic, copper, molybdenum, nickel, selenium, and ammonia. GSDs from McClean (2011) for the JEB WTP (future quality) were used in the absence of other data for thorium-230, lead-210, polonium-210, cadmium, cobalt, lead, zinc, chloride, sulphate, and TDS. c – TDS calculated as the sum of the anions and cations (as available).				

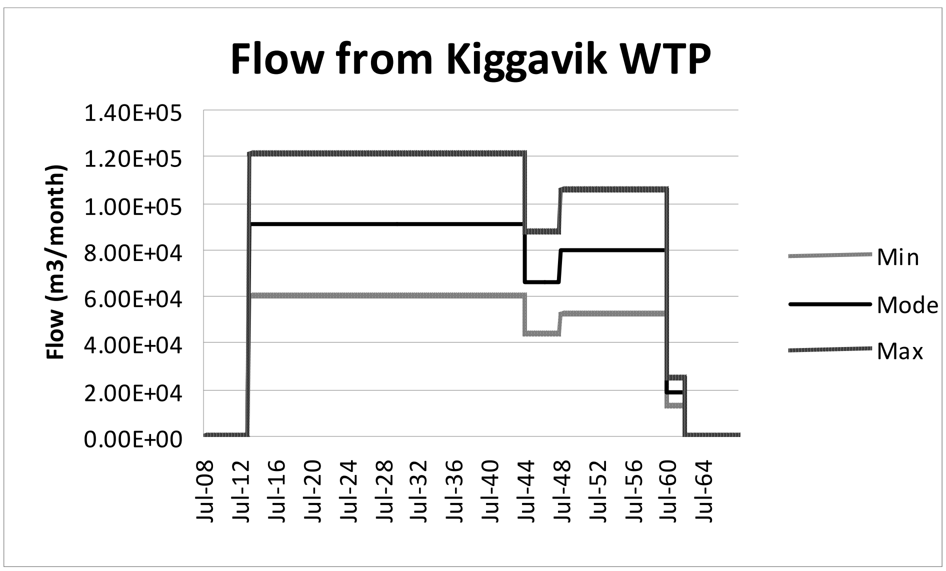

Figure C.1-1 Assumed Flow Distributions for the Kiggavik WTP

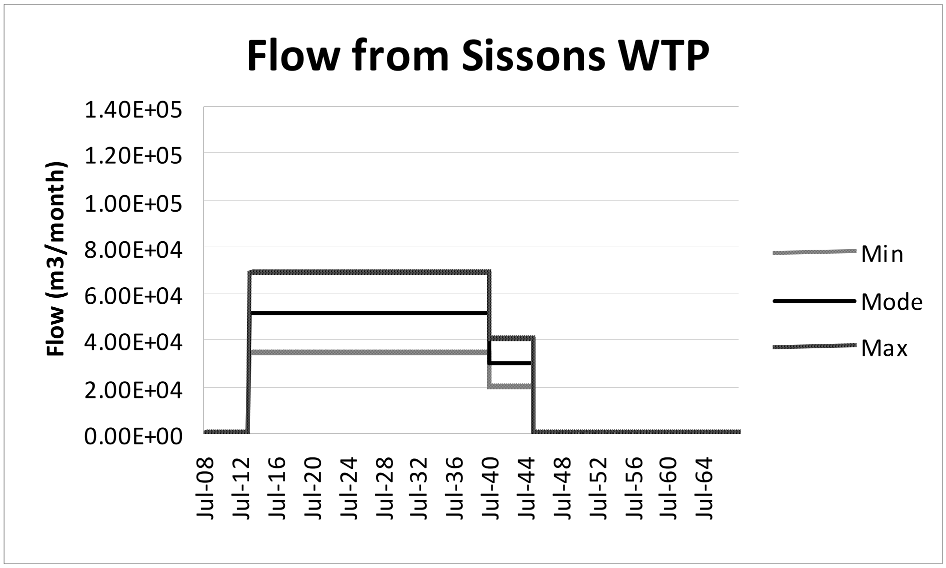

Figure C.1-2 Assumed Flow Distributions for the Sissons WTP

C.2 Option 3 Discharge Scenario

The Option 3 discharge scenario considers one expanded Kiggavik WTP for the treatment of both Kiggavik and Sissons wastewater. The expanded Kiggavik WTP discharges to segment JSL-2. Table C.2-1 summarizes the water quality distributions assumed to characterize the expanded Kiggavik WTP for this discharge scenario. Figure C.2-1 presents the assumed monthly flows for the Option 3 discharge scenario (under the extended scenario). The predicted monthly flows were provided by AREVA and these values were assumed to be the mode of a triangular distribution, with the minimum and maximum represented by +/- 33%.

Table C.2-1 Effluent Concentration Distributions for Expanded Kiggavik WTP Discharge – Option 3

COPC	Lognormal Distribution Descriptors (mg/L or Bq/L)			
	Geometric Mean (GM)[a]	Geometric Standard Deviation (GSD)[b]	Minimum (-3 GSD)	Maximum (+3 GSD)
Uranium	0.0275	2.24	0.0025	0.3
Thorium-230	0.1	2.05	0.012	0.9
Lead-210	0.325	1.54	0.089	1.2
Radium-226	0.0099	2.53	0.0006	0.16
Polonium-210	0.086	2.10	0.009	0.79
Arsenic	0.026	1.76	0.005	0.14

Table C.2-1	**Effluent Concentration Distributions for Expanded Kiggavik WTP Discharge – Option 3**			
COPC	**Lognormal Distribution Descriptors (mg/L or Bq/L)**			
	Geometric Mean (GM)[a]	**Geometric Standard Deviation (GSD)[b]**	**Minimum (-3 GSD)**	**Maximum (+3 GSD)**
Cadmium	0.007	1.44	0.0022	0.02
Cobalt	0.009	2.12	0.0009	0.08
Copper	0.004	2.41	0.0003	0.06
Lead	0.004	2.63	0.0002	0.08
Molybdenum	0.2	1.75	0.037	1.1
Nickel	0.02	1.57	0.005	0.08
Selenium	0.009	1.28	0.0047	0.02
Zinc	0.007	2.06	0.0008	0.06
Ammonia	17.3	1.36	6.9	44
Calcium	556	1.29	259	1190
Chloride	627	1.49	190	2080
Sulphate	2199	1.29	1020	4720
TDS[c]	4330	1.31	1920	9730

Note: a - GM from predicted Kiggavik WTP data, if not specified. Kiggavik WTP values provided by AREVA were assumed to be geometric mean values for the distributions.

b – GSDs preferentially selected from Key Lake data (4/2009-9/2010) for uranium, radium-226, arsenic, copper, molybdenum, nickel, selenium, and ammonia. GSDs from McClean (2011) for the JEB WTP (future quality) were used in the absence of other data for thorium-230, lead-210, polonium-210, cadmium, cobalt, lead, zinc, chloride, sulphate, and TDS.

c – TDS calculated as the sum of the anions and cations (as available).

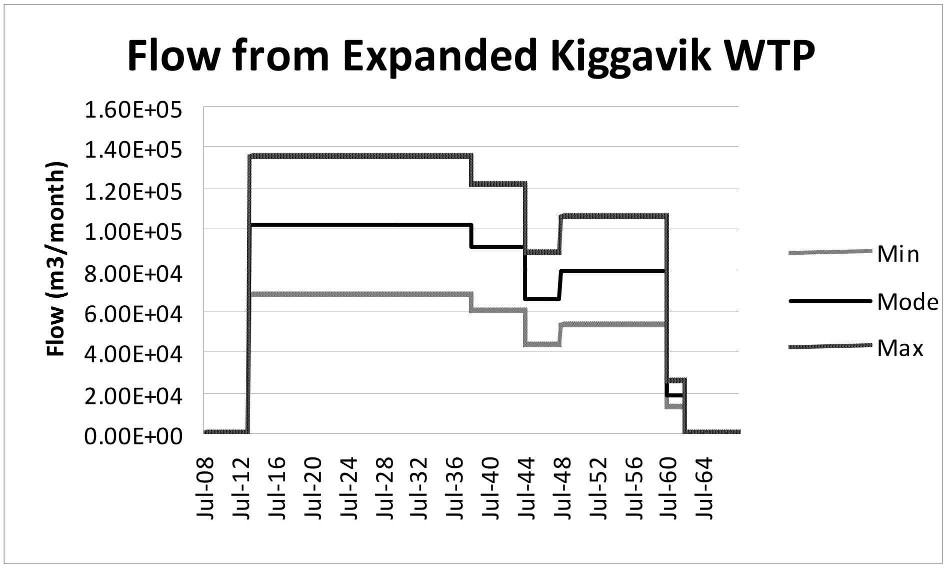

Figure C.2-1 Assumed Flow Distributions for the Expanded Kiggavik WTP

C.3 Closure Scenarios

Four closure scenarios for the Kiggavik effluent were considered for the assessment:

- Base Case: for the Project Scenario only, East Zone and Centre Zone consolidation and decommissioning completed during the operational period, Main Zone TMF partially full at the end of the operational period
  - o 14-years for Main Zone Consolidation (Kiggavik closure complete June 2043)
  - o 22-years for Main Zone Consolidation (Kiggavik closure complete June 2050)

- Bounding Case: for the Extended Scenario only, the three TMFs are filled with tailings and no consolidation has occurred prior to the decommissioning period
  - o 14-years for Main Zone Consolidation (Kiggavik closure complete June 2055)
  - o 22-years for Main Zone Consolidation (Kiggavik closure complete June 2062)

Table C.3-1 summarizes the closure scenarios for the Base Case 14-years for Main Zone Consolidation and 22-years for Main Zone Consolidation.

Table C.3-1 Treated Effluent Discharge Assumptions – Decommissioning and Post-Decommissioning Base Case

Year Post-Operations	Kiggavik (14 year MZ consolidation)		
	Expected Treated Effluent Discharge (m3/day)	Percentage Chemical WTP Effluent (%)	Percentage RO permeate (%)
1	3,482	60	40
2	3,482	60	40
3	3,482	60	40
4	3,041	60	40
5	3,041	60	40
6	3,041	60	40
7	2,821	100	0
8	2,821	100	0
9	2,821	100	0
10	2,821	100	0
11	2,821	100	0
12	2,821	100	0
13	2,821	100	0
14	2,821	100	0
15	621	100	0
16	621	100	0
17	621	100	0
Year Post-Operations	**Kiggavik (22 year MZ consolidation)**		
	Expected Treated Effluent Discharge (m3/day)	**Percentage Chemical WTP Effluent (%)**	**Percentage RO permeate (%)**
1	2,782	100	0
2	2,782	100	0
3	2,782	100	0
4	2,341	100	0
5	2,341	100	0
6	2,341	100	0
7	2,121	100	0
8	2,121	100	0
9	2,121	100	0
10	2,121	100	0

Table C.3-1 Treated Effluent Discharge Assumptions – Decommissioning and Post-Decommissioning Base Case

Year Post-Operations	Kiggavik (14 year MZ consolidation)		
	Expected Treated Effluent Discharge (m3/day)	Percentage Chemical WTP Effluent (%)	Percentage RO permeate (%)
11	2,121	100	0
12	2,121	100	0
13	2,121	100	0
14	2,121	100	0
15	2,121	100	0
16	2,121	100	0
17	2,121	100	0
18	1,621	100	0
19	1,621	100	0
20	1,621	100	0
21	1,621	100	0
22	1,621	100	0
23	621	100	0
24	621	100	0

Table C.3-2 summarizes the closure scenarios for the Bounding Case 14-years for Main Zone Consolidation and 22-years for Main Zone Consolidation.

Table C.3-2 Treated Effluent Discharge Assumptions – Decommissioning and Post-Decommissioning Bounding Case

Year Post-Operations	Kiggavik (14 year MZ consolidation)		
	Expected Treated Effluent Discharge (m3/day)	Percentage Chemical WTP Effluent (%)	Percentage RO permeate (%)
1	5,000	60	40
2	5,000	60	40
3	5,000	60	40
4	5,000	60	40
5	5,000	60	40
6	5,000	60	40
7	5,000	60	40
8	5,000	60	40

Table C.3-2 Treated Effluent Discharge Assumptions – Decommissioning and Post-Decommissioning Bounding Case

Year Post-Operations	Kiggavik (14 year MZ consolidation)		
	Expected Treated Effluent Discharge (m3/day)	Percentage Chemical WTP Effluent (%)	Percentage RO permeate (%)
9	5,000	60	40
10	5,000	60	40
11	5,000	60	40
12	5,000	60	40
13	5,000	60	40
14	5,000	60	40
15	1,621	100	0
16	621	100	0
17	621	100	0
Year Post-Operations	**Kiggavik (22 year MZ consolidation)**		
	Expected Treated Effluent Discharge (m3/day)	**Percentage Chemical WTP Effluent (%)**	**Percentage RO permeate (%)**
1	5,000	60	40
2	5,000	60	40
3	5,000	60	40
4	5,000	60	40
5	5,000	60	40
6	5,000	60	40
7	3,621	60	40
8	3,621	60	40
9	3,621	60	40
10	3,621	60	40
11	2,621	100	0
12	2,621	100	0
13	2,621	100	0
14	2,621	100	0
15	2,621	100	0
16	2,621	100	0
17	2,621	100	0
18	2,621	100	0
19	2,621	100	0

Table C.3-2 Treated Effluent Discharge Assumptions – Decommissioning and Post-Decommissioning Bounding Case

Year Post-Operations	Kiggavik (14 year MZ consolidation)		
	Expected Treated Effluent Discharge (m3/day)	Percentage Chemical WTP Effluent (%)	Percentage RO permeate (%)
20	2,621	100	0
21	2,621	100	0
22	2,621	100	0
23	621	100	0
24	621	100	0

Table C.3-3 summarizes the closure scenario for the Sissons WTP.

Table C.3-3 Treated Effluent Discharge Assumptions – Decommissioning and Post-Decommissioning Sissons WTP

Year Post-Operations	Sissons		
	Expected Treated Effluent Discharge (m3/day)	Percentage Chemical WTP Effluent (%)	Percentage RO permeate (%)
1	1700	100	0
2	1700	100	0
3	1000	100	0
4	1000	100	0
5	1000	100	0
6	1000	100	0
7	1000	100	0

Attachment D Ecological Receptor Characteristics

Caribou

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).

Mass 55 to 318 kg, subspecies inhabiting the more southerly latitudes are larger than their northern cousins (Shefferly and Joly 2000).

Weight 270000 grams (NatureServe 2007).

Weights of adult bulls average 159-182 kg. Mature females average 80-120 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. They can traverse more than 5,000 kilometres in a year, with extensive migrations in spring and fall (Shefferly and Joly 2000).

Tundra caribou may travel extensively in summer in attempt to avoid bothersome insects (NatureServe 2007)

It was assumed that the caribou spends 100% of its time in the study area; although most herds are migratory, there have been observances of non-migratory herds in the area.

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 and browse in the summer (75% lichen, 11% summer forage, 11% browse and 3% soil (as discussed below)).

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 1.35×10^5 g the FI is 3874 g dw/d, or 6457 g ww/d (moisture content of 40%, based on diet composed mainly of lichen as discussed below). This wet weight value is taken as the mode of a triangular distribution with maximum and minimum values of +/- 30%.

Soil Ingestion:

No specific information is available; therefore the general value for all mammals of 5% based on the information provided by Beyer *et al.* (1994) was used.

Based on a dry weight consumption rate of 3874 g/d this corresponds to approximately 194 g/d, or 3% of the wet weight FI of 6457 g ww/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. This value is taken as the mode of a triangular distribution with maximum and minimum values of +/- 50%.

Summary Table:

Exposure Characteristics		
Body Weight (kg)	135	ADF&G 1999
Food Intake Rate (g ww/d)	TRI(4520, 6457, 8394)	U.S. EPA 1993 (allometric scaling)
Soil Ingestion Rate (g dw/d)	194	Beyer *et al.* 1994
Water Intake Rate (L/d)	TRI(4.1, 8.2, 12.3)	U.S. EPA 1993 (allometric scaling)
Fraction of time in area	Varies by scenario	Assumed
Fractional Composition of Diet		
Soil	0.03	Fraction of wet weight diet (Beyer *et al.* 1994)
Summer Forage	0.11	Based on CWS 2005, NatureServe 2007, Shefferly and Joly 2000
Browse	0.11	
Lichen	0.75	

Note: TRI = triangular distribution (minimum, mode, maximum)

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.

Lemming

The lemming is a mouse-like rodent which lives in treeless areas in Northern Canada. The true lemming is the brown lemming (*Lemmus sibiricus*), and along with the collared lemming (*Dicrostonyx. torquatus*) are the two predominant lemming species in the mainland tundra west of Hudson Bay. The collared lemming has colonized the Queen Elizabeth Islands to the northern tip of Ellesmere Island. The lemming is the smallest of the mammals of the high Arctic and is an important food for ermines, arctic foxes, Snowy Owls, Gyrfalcons and jaegers. It has roughly four years of cycles of drastically fluctuating populations and therefore controls the rhythm of life on the tundra (CWS 2010, NatureServe 2009).

Size:

The brown lemming is the largest of the various lemming species and weighs from 40 to 112 g, with an average weight of 78 g (ADF&G 1994).

The closely related Neararctic collared lemming (*D. groenlandicus)* weighs from 30 to 112 g (Poloskey 200), with various average weights reported: a little over 40 g (ADF&G 1994); 112 g (NatureServe 2009); or 71 g (Poloskey 2000).

Adult collared lemmings are approximately 150 mm in total length (CWS 2010).

Weight varies from year to year, ranging from 55 g to 115 g for the brown lemming. Collared lemmings are a similar size (CWS 2010).

Based on the above information a typical adult lemming is expected to weigh 70 g (ADF&G 1994, Poloskey 2000, CWS 2010).

Home Range:

Lemmings are not migrant creatures and, in general, home ranges are quite small; however, some species will travel several kilometres from their natal area. Roads, especially divided highways, are major barriers to their dispersal (NatureServe 2009).

Feeding Habits:

Collared lemmings consume mostly plants, including willow buds, cranberries, flowers, grasses and twigs. Brown lemmings prefer sedges, arctic cotton and certain mosses. In the winter, the segregation in diets between collared and brown lemmings tends to break down as collared lemmings seek out snow shelter in lower ground areas, thereby consuming more sedges and mosses. Although the morphology of the teeth suggests that they consume insects, this has not been observed in the wild (Poloskey 2000, ADF&G 1994, CWS 2010).

Based on the available information the lemming is assumed to consume primarily forage with some lichen and small amounts of berries (75% forage, 15% lichen, 8.5% berries and 1.5% soil (as discussed below)).

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 70 g the FI is 7.7 g dw/d, or 26 g ww/d (moisture content of 70% based on diet composed mainly of terrestrial vegetation as discussed below). The wet weight value is taken as the mode of a triangular distribution with maximum and minimum values of +/- 30%.

Soil Ingestion:

No specific information is available; therefore the general value for all mammals of 5% based on the information provided by Beyer *et al.* (1994) was used.

Based on a dry weight consumption rate of 7.7 g/d this corresponds to approximately 0.39 g/d, or 1.5% of the wet weight FI of 26 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 0.071 kg the WI is 0.01 L/d. This value is taken as the mode of a triangular distribution with maximum and minimum values of +/- 50%.

Summary Table:

Exposure Characteristics		
Body Weight (g)	71	ADF&G 1994, Poloskey 2000, CWS 2010
Food Intake Rate (g ww/d)	TRI(18, 26, 33)	U.S. EPA 1993 (allometric scaling)
Soil Ingestion Rate (g dw/d)	0.39	Beyer *et al.* 1994
Water Intake Rate (L/d)	TRI(0.005, 0.009, 0.014)	U.S. EPA 1993 (allometric scaling)
Fraction of time in area	1	Assumed
Fractional Composition of Diet		
Soil	0.015	Fraction of wet weight diet (Beyer *et al.* 1994)
Berries	0.085	Based on Poloskey 2000, ADF&G 1994, CWS 2010
Forage	0.75	
Lichen	0.15	

Note: TRI = triangular distribution (minimum, mode, maximum)

References:

Alaska Department of Fish & Game (ADF&G) 1994. *Wildlife Notebook Series: Lemmings*. Accessed July 22 2010 at: http://www.adfg.state.ak.us/pubs/notebook/smgame/lemmings.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) 2010. *Hinterland Who's Who. Mammal Fact Sheet: Lemmings.* Available at: http://www.hww.ca/hww2.asp?id=91&cid=8

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

Muskox

The muskox (*Ovibos moschatus*) is an arctic mammal of the Bovidae family. It resembles the bison: humped shoulders and a long black coat accentuate the shortness of its legs and is generally found in the low-lying coastal and inland plains or river valleys of the Arctic, where shrubs are most abundant (CWS 1990).

Size:

The few weights of wild muskoxen available indicate that adult bulls weigh 270 to 315 kg and cows about 90 kg or less (CWS 1990).

405000 grams (NatureServe 2008).

180 to 400 kg; avg. 285 kg (Elder 2005).

Based on the above information, a typical muskox is expected to weigh 300 kg (CWS 1990, Elder 2005).

Home Range:

Relatively sedentary; seasonal movements between winter and summer ranges do not exceed 80 km and are probably often less than 50 km (NatureServe 2008).

Feeding Habits:

On the mainland, muskoxen feed extensively on the shrubby willows that follow the river courses. On the arctic islands they feed in the wet meadows. When snow covers the ground, the muskoxen must dig craters through the snow to find the willows, grasses, and sedges that form the major part of their diet (CWS 1990). The muskox eats mainly sedges, grasses, and willows in summer, primarily sedges or woody plants in winter (NatureServe 2008).

Based on the available information, the muskox is assumed to consume primarily browse with some forage during the summer (90% browse, 8.5% forage and 1.5% soil (as discussed below)).

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 300 kg the FI is 7.5 kg dw/d or 25 kg ww/d (moisture content of 70% based on a diet of mainly terrestrial vegetation as discussed below). The wet weight value is taken as the mode of a triangular distribution with maximum and minimum values of +/- 30%.

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 FI of 7.5 kg/d this corresponds to approximately 373 g/d, or 1.5% of the wet weight FI of 25 kg/d.

The arctic wolf is the only wild predator of muskoxen (CWS 1990).

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 300 kg the WI is 17 L/d, which is taken as the mode of a triangular distribution with maximum and minimum values of +/- 50%.

Summary Table:

Exposure Characteristics		
Body Weight (kg)	300	CWS 1990, Elder 2005
Food Intake Rate (kg ww/d)	TRI(17, 25, 32)	U.S. EPA 1993 (allometric scaling)
Soil Ingestion Rate (g dw/d)	373	Beyer *et al.* 1994
Water Intake Rate (L/d)	TRI(8.4, 17, 25)	U.S. EPA 1993 (allometric scaling)
Fraction of time in area	0.1	Assumed
Fractional Composition of Diet		
Soil	0.015	Fraction of wet weight diet (Beyer *et al.* 1994)
Summer forage	0.085	NatureServe 2008
Browse	0.9	CWS 1991

Note: TRI = triangular distribution (minimum, mode, maximum)

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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Elder, S., Mammology and L. Olson. 2005. "Ovibos moschatus" (On-line), Animal Diversity Web. Accessed April 07, 2008 at http://animaldiversity.ummz.umich.edu/site/accounts/information/Ovibos_moschatus.html.

NatureServe. 2008. NatureServe Explorer: An online encyclopedia of life. Version 7.0. NatureServe, Arlington, Virginia. Available http://www.natureserve.org/explorer. 1 February (Accessed: April 7, 2008).

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

Rock Ptarmigan

Ptarmigans are hardy members of the grouse family that spend most of their lives on the ground at or above the treeline. The Rock Ptarmigan (*Lagopus muta*) is a typical bird of the arctic tundra. It prefers high elevations and barren areas. 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).

Ptarmigans weigh from 450 to 800 g (CWS 1994, for Willow Ptarmigan).

Based on the above information a typical ptarmigan is expected to weigh approximately 620 g (0.62 kg) (NatureServe 2007, Cornell 2003, CWS 1994).

Home Range:

Mainly permanent resident but somewhat migratory (NatureServe 2007).

Note: Home range for a female grouse is from 0.16 km^2 to 0.40 km^2; home range for a male grouse is from 0.04 km^2 to 0.20 km^2 (North Carolina State University 1995)

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 ingest terrestrial vegetation and insects (80% browse, 10% berries, 7% insects and 3% soil (as discussed below).

Food Consumption Rate:

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

Based on a body weight of 620 g the FI is 43 g dw/d, or 142 g ww/d (moisture content of 70% based on a diet of mainly terrestrial vegetation as discussed below). The wet weight value is taken as the mode of a triangular distribution with maximum and minimum values of+/- 30%.

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 FI of 43 g/d this corresponds to approximately 4.2 g/d, or 3% of the wet weight FI of 142 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. This value is taken as the mode of a triangular distribution with maximum and minimum values of +/- 50%.

Arctic Climate:

Food intake rate for arctic breeding birds were increased by 50% to reflect increased energy requirements in the arctic. A similar 50% increase in soil ingestion, concurrent with the increased food ingestion rate, was made. Water intake rates were not adjusted, since allometric equations are largely based on birds in warmer climates, which are likely to have to consume more water.

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Summary Table:

Exposure Characteristics		
Body Weight (kg)	0.62	NatureServe 2007, Cornell 2003
Food Intake Rate (g ww/d)	TRI(149, 213, 278)	U.S. EPA 1993 (allometric scaling), increased by 50% to account for arctic environment
Soil Ingestion Rate (g dw)/d)	6.4	Beyer *et al.* 1994, increased by 50% to account for arctic environment
Water Intake Rate (L/d)	TRI(0.02, 0.04, 0.06)	U.S. EPA 1993 (allometric scaling)
Fraction of Time in Area	1	Assumed (mainly resident)
Fractional Composition of Diet		
Soil	0.03	Fraction of wet weight diet (Beyer *et al.* 1994)
Insects	0.07	Based on information from CWS 1994, NatureServe 2007, Cornell 2003, Weeden 1994
Browse	0.8	
Berries	0.1	

Note: TRI = triangular distribution (minimum, mode, maximum)

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) 1994. *Hinterland Who's Who. Bird Fact Sheet: Ptarmigan.* Available at http://www.ffdp.ca/hww2.asp?id=64

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

NatureServe. 2007. NatureServe Explorer: An online encyclopedia of life. Version 6.2. NatureServe, Arlington, Virginia. Available http://www.natureserve.org/explorer. 8 June (Accessed: November 27, 2007).

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

Weeden, R.B. 1994. ADF&G Wildlife Notebook Series – Ptarmigan. Alaska Department of Fish & Game. Available at: http://www.adfg.state.ak.us/pubs/notebook/bird/ptarmiga.php

Masked Shrew

The masked shrew or common shrew (*Sorex cinereus)* is found in Alaska and most of Canada. The majority of the shrew's activities occur at night (Lee 2001).

Size:

Weighs 4g (NatureServe 2011)

Weighs 2.5 to 4g (Lee 2001)

Weighs 3 to 6 g (U.S. EPA. 1993)

Based on the above information the average weight of a masked shrew is expected to be 4 g (NatureServe 2011).

Home Range:

The average home range of a masked shrew is 0.6 hectares. The masked shrew lives in a wide range of habitats (open areas, forest and brush) where moister environments are more favourable. The masked shrew may also inhabitat areas that have been disturbed by either fires or logging (Lee 2001, U.S. EPA. 1993).

Feeding Habits:

The masked shrew diet varies based on the geography of the habitat. It is a carnivore, which primarily feeds on insects. The masked shrew also consumes seeds and fungi (Lee 2001, U.S. EPA. 1993).

Based on the available information the masked shrew is assumed to consume insects (90%) and terrestrial vegetation (10%).

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 4 g the FI is 0.73g dw/d or 3.67 g ww/d (moisture content of 80%).

Specific food consumption rates were not available for the masked shrew thus the average food consumption rate for the short-tailed shrew (0.55 g ww/d per body weight) was applied as both species of shrews have a similar diet. With a body weight of 4g for the masked shrew this corresponds to an intake rate of 2.2 g ww/d, which is 0.44 g dw/d with a moisture content of 80%.

Soil Ingestion:

No information was available for the masked shrew. Beyer et. al (1994) provided values for two possible surrogates: 2.7% to 7.7% for prairie dogs, and 2.4% for the meadow vole. The average prairie dog value of 5.2% used in lieu of specific information, as the prairie dog value is higher. Based on a dry weight FI of 0.44 g/d this corresponds to approximately 0.02 g ww/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 0.004 kg the WI is 0.0007 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 0.004 kg the IR is 0.007 m^3/d

Summary Table:

Exposure Characteristics		
Body Weight (kg)	0.004	NatureServe 2011, Lee 2001, U.S. EPA 1993
Food Intake Rate (g ww/d)	2.2	U.S. EPA 1993 (using the average food consumption rate for the short-tailed shrew (0.55 g ww/d per body weight))
Soil Ingestion Rate: (g/d) Fraction of ww diet:	0.02 0.01	Beyer *et al.* 1994
Water Intake Rate (L/d)	0.0007	U.S. EPA 1993 (allometric scaling)
Inhalation rate (m^3/d)	0.007	U.S. EPA 1993 (allometric scaling)
Fraction of time in area	1	Assumed
Fractional Composition of Diet		
Insects	0.9	Lee 2001, U.S. EPA. 1993
Terrestrial vegetation	0.1	

References:

Lee, W. 2001. "Sorex cinereus" (On-line), Animal Diversity Web. Accessed June 06, 2011 http://animaldiversity.ummz.umich.edu/site/accounts/information/Sorex_cinereus.html.

NatureServe. 2011. NatureServe Explorer: An online encyclopedia of life. Version 6.2. NatureServe, Arlington, Virginia. Available http://www.natureserve.org/explorer. (Accessed June 6, 2011).

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

Arctic Ground Squirrel

The arctic ground squirrel (*Sper mophilus parryii*), a.k.a gopher or sik sik, is a species of ground squirrel native to the Arctic. It inhabits tundra and forest clearings from eastern Siberia to Hudson Bay (Environment Yukon 2007).

Size:

900 g in weight (Environment Yukon 2007)

Weight: 791 grams (NatureServe 2008).

Based on the above information, a typical arctic ground squirrel is expected to weigh 800 g (Environment Yukon 2007, NatureServe 2008).

Home Range:

Recorded home ranges for most species are very small, in the order of 0.1 to 0.6 hectares but occasionally up to 4 hectares (NatureServe 2008).

Feeding Habits:

Eats stems and leaves, seeds, fruits, and roots of grasses, sedges, and other green plants, as well as woody plants and mushrooms (NatureServe 2008).

This rodent is primarily herbivorous, favouring such foods as grasses, sedges, mushrooms, bog rushes, bilberries, willows, roots, stalks, leaves, flowers, and seeds (Brensike 2000).

Based on the available information, the sik sik is assumed to consume terrestrial vegetation (50% forage, 48.5% berries and 1.5% soil (as discussed below)).

Predators of *Spermophilus parryii* include the grizzly bear, foxes, wolves, ermine, and various types of birds (Brensike 2000).

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 800 g, the FI is 57 g dw/d, or 191 g ww/d (moisture content of 70% based on a diet composed mainly of terrestrial plants as discussed below). The wet weight value is taken as the mode of a triangular distribution with maximum and minimum values of +/- 30%.

Soil Ingestion:

Beyer *et al.* (1994) provides values of 2.7 and 7.7% for prairie dogs; an average of 5.4% was used.

Based on a dry weight FI of 57 g/d this corresponds to approximately 3 g/d, or 1.5% of the wet weight FI of 191 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 800 g the WI is 0.1 L/d. This value is taken as the mode of a triangular distribution with maximum and minimum values of +/- 50%.

Summary Table:

Exposure Characteristics		
Body Weight (kg)	0.8	Environment Yukon 2007, NatureServe 2008
Food Intake Rate (g ww/d)	TRI(133, 191, 248)	U.S. EPA 1993 (allometric scaling)
Soil Ingestion Rate (g dw/d)	3	Beyer *et al*. 1994
Water Intake Rate (L/d)	TRI(0.04, 0.08, 0.12)	U.S. EPA 1993 (allometric scaling)
Fraction of time in area	1	Assumed (Small home range)
Fractional Composition of Diet		
Soil	0.015	Fraction of wet weight diet (Beyer *et al.*1994)
Forage	0.5	NatureServe 2008
Berry	0.485	

Note: TRI = triangular distribution (minimum, mode, maximum)

References:

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

Brensike, J. 2000. "Spermophilus parryii" (On-line), Animal Diversity Web. Accessed April 08, 2008 at http://animaldiversity.ummz.umich.edu/site/accounts/information/Spermophilus_parryii.html.

Environment Yukon. 2007. Available at http://www.environmentyukon.gov.yk.ca/wildlifebiodiversity/mammals/agsquirrel.php.

NatureServe. 2008. NatureServe Explorer: An online encyclopedia of life. Version 7.0. NatureServe, Arlington, Virginia. Available http://www.natureserve.org/explorer. 1 February (Accessed: April 7, 2008).

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

Red-Breasted Merganser

The Red-Breasted Merganser (*Mergus serrator*) is large diving duck. Red-breasted mergansers live in large lakes, rivers, and oceans, and prefer salt water more than the other two species of merganser (Cornell 2003). Nests are typically in the ground, under a boulder, or in a shrub. Mergansers are diving predators who locate their prey by sight, and therefore tend to feed in clear waters, less than 4 m deep. The long bill has toothy projections along its edges that help the duck hold onto its fish prey (Cornell 2003, Becker and Fraser 2006).

Size:

Red-breasted mergansers are 800 to 1350 g (Cornell 2003).

Based on the above information a typical red-breasted merganser is expected to weigh approximately 1.0 kg, or 1000 g (Cornell 2003).

Home Range:

Nesting sites are usually separated from one another, but mergansers have also been known to nest in close proximity in some cases. Territorial behaviour is minimal. Individuals feed over a large range, seeking medium to large bodies of clear water (Becker and Fraser 2006).

Feeding Habits:

Mergansers are skilled diving predators, eating mainly fish. Clear water is preferred for feeding because the birds hunt primarily by sight. When fish are scarce, mergansers will substitute other small aquatic prey such as insects, mollusks, crustaceans, frogs, and other invertebrates (Becker and Fraser 2006, NatureServe 2008, Cornell 2003).

Based on the available information the merganser, the principal source of food is fish. The diet is assumed to comprise equal quantities of pelagic and benthic fish.

Food Consumption Rate:

Daily food consumption rate for the red-breasted merganser is 0.235 kg ww/d (CCME 1997).

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

Based on a body weight of 1000 g the FI is 58 g dw/d, or 290 g ww/d (moisture content of 80% based on a diet comprising mainly aquatic species as discussed below). The wet weight value is taken as the mode of a triangular distribution with maximum and minimum values of +/- 30%.

Sediment Ingestion:

Data on sediment ingestion by merganser were not found in the open literature. However, Beyer *et al.* (1994) provides a value of 2% for the ring-necked duck and the blue winged teal. Since the merganser is piscivorous and would not ingest significant amounts of sediment, this value was considered appropriate.

Based on a dry weight FI of 58 g/d this corresponds to approximately 1.2 g/d, which represents 0.4% of the wet weight FI of 290 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 1.00 kg the WI is 0.06 L/d. This value is taken as the mode of a triangular distribution with maximum and minimum values of +/- 50%.

Arctic Climate:

Food intake rate for arctic breeding birds were increased by 50% to reflect increased energy requirements in the arctic. A similar 50% increase in soil ingestion, concurrent with the increased food ingestion rate, was made. Water intake rates were not adjusted, since allometric equations are largely based on birds in warmer climates, which are likely to have to consume more water.

Summary Table:

Exposure Characteristics		
Body Weight (kg)	1.0	Cornell 2003
Food Intake Rate (g (ww)/d)	TRI(305, 435, 566)	U.S. EPA 1993 (allometric scaling), increased by 50% to account for arctic environment
Sediment Ingestion Rate (g dw/d)	1.7	Beyer *et al.* 1994, increased by 50% to account for arctic environment
Water Intake Rate (L/d)	TRI(0.03, 0.06, 0.09)	U.S. EPA 1993 (allometric scaling)
Fraction of time in area	1	Migratory, but assumed for calculations
Fractional Composition of Diet		

Sediment	0.004	Fraction of wet weight diet (Beyer *et al.* 1994)
Fish	0.996	Based on information from Becker and Fraser 2006, NatureServe 2008, Cornell 2003

Note: TRI = triangular distribution (minimum, mode, maximum)

References:

Becker, R. and A. Fraser. 2006. "Mergus merganser" (On-line), Animal Diversity Web. Accessed January 11, 2008 at http://animaldiversity.ummz.umich.edu/site/accounts/information/Mergus_merganser.html.

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

Canadian Council of Ministers of the Environment (CCME) 1997. *Protocol for the Derivation of Canadian Tissue Residue Guidelines for the Protection of Wildlife that Consume Aquatic Biota.* Provided in the Canadian Environmental Quality Guidelines.

Cornell 2003. *All About Birds. Bird Guide.* Cornell Lab of Ornithology. Accessed January 11, 2008 http://www.birds.cornell.edu/AllAboutBirds/BirdGuide/

NatureServe. 2007. NatureServe Explorer: An online encyclopedia of life. Version 6.2. NatureServe, Arlington, Virginia. Available http://www.natureserve.org/explorer. 8 June (Accessed: January 11, 2008).

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

Long-Tailed Duck

The Long-Tailed Duck (*Clangula hyemalis*), formerly known as the Oldsquaw, breeds in the Arctic and is distinctive among ducks in plumage, molt sequences, foraging behavior, and vocalizations (Cornell 2003). The nests of the long-tailed duck are on the ground, along the edge of water (Cornell 2003).

Size:

Weight: 500-1100 g (Cornell 2003).

Based on the above information, a typical long-tailed duck is expected to weigh 0.8 kg (Cornell 2003).

Home Range:

Long-tailed ducks breed in Arctic ponds, streams, and wetlands (Cornell 2003) and migrates to coastal areas in the winter. As a species, these ducks have a large geographic range and population size.

Feeding Habits:

Long-tailed ducks feed mainly on benthic invertebrates (molluscs and crustaceans) and aquatic insects, fish and plants in summer (Cornell 2003, NatureServe 2008, SAS 2005). They may dive very deep to obtain food (NatureServe 2008). Robertson and Savard (2002) report that long-tailed ducks on breeding grounds feed on larval and adult insects, crustaceans, fish roe and vegetable matter, with predominantly aquatic invertebrates.

Based on the available information the duck is assumed to consume benthic invertebrates (90%, of which 0.7% is sediment), aquatic vegetation (5%), and fish (5%).

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 800 g the FI is 50 g dw/d, or 251 g ww/d (moisture content of 80% based on a diet comprising mainly aquatic species as discussed below). The wet weight value is taken as the mode of a triangular distribution with maximum and minimum values of+/- 30%.

Sediment Ingestion:

Data on sediment ingestion by the long-tailed duck were not found in the open literature. However, Beyer *et al.* (1994) provides a value of 3.3% for the mallard duck. This value was considered appropriate for the long-tailed duck.

Based on a dry weight FI of 50 g/d this corresponds to approximately 1.7 g/d, which represents 0.7% of the wet weight FI of 251 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 800 g the WI is 0.05 L/d. This value is taken as the mode of a triangular distribution with maximum and minimum values of+/- 50%.

Arctic Climate:

Food intake rate for arctic breeding birds were increased by 50% to reflect increased energy requirements in the arctic. A similar 50% increase in soil ingestion, concurrent with the increased food ingestion rate, was made. Water intake rates were not adjusted, since allometric equations are largely based on birds in warmer climates, which are likely to have to consume more water.

Summary Table:

Exposure Characteristics		
Body Weight (kg)	0.8	Cornell 2003
Food Intake Rate (g ww/d)	TRI(264, 377, 490)	U.S. EPA 1993 (allometric scaling), increased by 50% to account for arctic environment
Sediment Ingestion Rate (g dw/d)	2.6	Beyer *et al*. 1994, increased by 50% to account for arctic environment
Water Intake Rate (L/d)	TRI(0.025, 0.05, 0.075)	U.S. EPA 1993 (allometric scaling)
Fraction of time in area	1	Migratory, but assumed for calculations
Fractional Composition of Diet		
Sediment	0.007	Fraction of wet weight diet (Beyer *et al.* 1994)
Benthic invertebrates	0.893	Robertson and Savard (2002)
Aquatic vegetation	0.05	
Fish	0.05	

Note: TRI = triangular distribution (minimum, mode, maximum)

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 January 14, 2011 http://www.birds.cornell.edu/AllAboutBirds/BirdGuide/

NatureServe. 2008. NatureServe Explorer: An online encyclopedia of life [web application]. Version 7.0. NatureServe, Arlington, Virginia. Available http://www.natureserve.org/explorer. (Accessed: April 10, 2008).

Robertson, Gregory J. and Jean-Pierre L. Savard. 2002. Long-tailed Duck (Clangula hyemalis), The Birds of North America Online (A. Poole, Ed.). Ithaca: Cornell Lab of Ornithology; Retrieved from the Birds of North America Online: http://bna.birds.cornell.edu/bna/species/651

Seattle Audubon Society (SAS). 2005. *Bird Web*. http://birdweb.org/birdweb/bird_details.aspx?id=87. Accessed January 14, 2011.

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

Lapland Longspur

The Lapland Longspur (*Calcarius lapponicus*) is a common songbird on the Arctic tundra (Cornell 2003). The longspur is a ground forager and breeds in the Arctic tundra in grassy tussocks or scrub (Cornell 2003). These sparrow-like birds are known for forming large flocks.

Size:

Weight: 23-33 g (Cornell 2003).

Based on the above information, a typical longspur is expected to weigh 0.030 kg (Cornell 2003).

Home Range:

Lapland longspur breed in Arctic tundra in grassy tussocks or scrub (Cornell 2003) and migrate to prairie, pastures and coastal areas in the winter (SAS 2005).

Feeding Habits:

Lapland longspur feed mainly on seeds and insects (Cornell 2003, SAS 2005). During the summer, insects are about 50% of the diet (SAS 2005).

Based on the available information the longspur is assumed to consume insects (50%) and seeds (50%, of which 3% is soil).

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 30 g the FI is 6 g dw/d, or 20 g ww/d (moisture content of 70% based on a diet comprising mainly terrestrial species as discussed below). The wet weight value is taken as the mode of a triangular distribution with maximum and minimum values of+/- 30%.

Hussell and Montgomerie (2002) state that Lapland Longspur consume 3,000 -10,000 seeds and insects per day during the breeding season, and an additional 3000 insects/day during chick rearing to feed young. Assuming an intake rate of approximately 6500 items and the breakdown of 75% seeds, 10% immature arthropods, and 15% adult arthropods based on Custer and Pitelka (1978), an approximate intake rate of 30 g ww/d can be derived.

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 FI of 6 g/d this corresponds to approximately 0.6 g/d, or 3% of the wet weight FI of 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 30 g the WI is 0.006 L/d. This value is taken as the mode of a triangular distribution with maximum and minimum values of+/- 50%.

Arctic Climate:

Food intake rate for arctic breeding birds were increased by 50% to reflect increased energy requirements in the arctic. A similar 50% increase in soil ingestion, concurrent with the increased food ingestion rate, was made. Water intake rates were not adjusted, since allometric equations are largely based on birds in warmer climates, which are likely to have to consume more water. The 50% increase to the ingestion rate is consistent with the information presented by Hussell and Montgomerie (2002).

Summary Table:

Exposure Characteristics		
Body Weight (kg)	0.03	Cornell 2003
Food Intake Rate (g ww/d)	TRI(21, 30, 39)	U.S. EPA 1993 (allometric scaling), increased by 50% to account for arctic environment
Soil Ingestion Rate (g dw/d)	0.9	Beyer *et al*. 1994, increased by 50% to account for arctic environment
Water Intake Rate (L/d)	TRI(0.003, 0.006, 0.009)	U.S. EPA 1993 (allometric scaling)
Fraction of time in area	1	Migratory, but assumed for calculations
Fractional Composition of Diet		
Soil	0.03	Fraction of wet weight diet (Beyer *et al.* 1994)
Insects	0.5	SAS 2005 and Cornell 2003
Seeds	0.47	

Note: TRI = triangular distribution (minimum, mode, maximum)

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 January 14, 2011 http://www.birds.cornell.edu/AllAboutBirds/BirdGuide/

Custer, T.W., and F. A. Pitelka. 1978. Seasonal Trends in the Diet of Lapland Longspur Near Barrow, Alaska. Condor, 80: 295-301.

Hussell, David J. and Robert Montgomerie. 2002. Lapland Longspur (Calcarius lapponicus), The Birds of North America Online (A. Poole, Ed.). Ithaca: Cornell Lab of Ornithology; Retrieved from the Birds of North America Online: http://bna.birds.cornell.edu/bna/species/656

Seattle Audubon Society (SAS) 2005. *Bird Web*. http://birdweb.org/birdweb/bird_details.aspx?id=87. Accessed January 14, 2011.

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

Northern Pintail

The Northern Pintail (*Anus acuta*) is a medium sized dabbling duck (Cornell 2003). The pintail nests in shallow wetlands amidst prairie grasslands or Arctic tundra (Cornell 2003). These birds are among the earliest nesting birds in North America (Cornell 2003).

Size:

Weight: 500-1450 g (Cornell 2003).

Based on the above information, a typical longspur is expected to weigh 1.0 kg (Cornell 2003).

Home Range:

Northern pintail breed in Arctic tundra and are an early fall migrant to wintering areas in the southern areas of North America (Cornell 2003).

Feeding Habits:

Northern pintail feed mainly on aquatic vegetation (Cornell 2003, SAS 2005). Insects are also a part of the northern pintail diet (Robinson 2002). Invertebrates are important to hens during prelaying and laying periods, with about 29% invertebrate diet for birds nesting in Alaska (Austin and Miller (1995).

Based on the available information the pintail is assumed to consume insects (25%) and aquatic vegetation (75%, of which 0.66% is sediment).

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 1000 g the FI is 58 g dw/d, or 290 g ww/d (moisture content of 80% based on a diet comprising mainly aquatic species). The wet weight value is taken as the mode of a triangular distribution with maximum and minimum values of+/- 30%.

Soil Ingestion:

Beyer *et al.* (1994) provides a value of 3.3% for a mallard duck and this value was used in lieu of species specific data.

Based on a dry weight FI of 58 g/d this corresponds to approximately 1.9 g/d, or 0.66% of the wet weight FI of 290 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 1 kg the WI is 0.06 L/d. This value is taken as the mode of a triangular distribution with maximum and minimum values of+/- 50%.

Arctic Climate:

Food intake rate for arctic breeding birds were increased by 50% to reflect increased energy requirements in the arctic. A similar 50% increase in soil ingestion, concurrent with the increased food ingestion rate, was made. Water intake rates were not adjusted, since allometric equations are largely based on birds in warmer climates, which are likely to have to consume more water.

Summary Table:

Exposure Characteristics		
Body Weight (kg)	1.0	Cornell 2003
Food Intake Rate (g ww/d)	TRI(305, 435, 566)	U.S. EPA 1993 (allometric scaling), increased by 50% to account for arctic environment
Sediment Ingestion Rate (g dw/d)	2.9	Beyer *et al*. 1994, increased by 50% to account for arctic environment
Water Intake Rate (L/d)	TRI(0.03, 0.06, 0.09)	U.S. EPA 1993 (allometric scaling)
Fraction of time in area	1	Migratory, but assumed for calculations
Fractional Composition of Diet		
Sediment	0.0066	Fraction of wet weight diet (Beyer *et al.* 1994)
Insects	0.25	Cornell 2003, Robinson 2002, Austin and Miller 1995
Aquatic vegetation	0.7434	

Note: TRI = triangular distribution (minimum, mode, maximum)

References:

Austin, Jane E. and Michael R. Miller. 1995. Northern Pintail (Anas acuta), The Birds of North America Online (A. Poole, Ed.). Ithaca: Cornell Lab of Ornithology; Retrieved from the Birds of North America Online: http://bna.birds.cornell.edu/bna/species/163

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 January 14, 2011 http://www.birds.cornell.edu/AllAboutBirds/BirdGuide/

Robinson, J. 2002. "Anas acuta" (On-line), Animal Diversity Web. Accessed February 07, 2011 http://animaldiversity.ummz.umich.edu/site/accounts/information/Anas_acuta.html

Shorebirds (Semipalmated Sandpiper)

Shorebirds comprise a diverse group of species, including the plovers, oystercatchers, avocets, stilts, turnstones, sandpipers, yellowlegs, snipes, godwits, curlews, and phalaropes (CWS 2001). The areas frequented by shorebirds include wetlands, estuaries, and coastlines. Shorebirds generally forage on sandy beaches and mudflats and feed almost exclusively on small invertebrates, either by probing into or gleaning from the substrate. Sandpipers, specifically the Semipalmated Sandpiper (possibly the most abundant shorebird), was selected as the representative species. These birds breed on open tundra, generally near water (CWS 1991, Cornell 2003).

Size:

About 30 grams (CWS 1991)

Weight: 28 grams (NatureServe 2008).

Weight: 21-32 g (Cornell 2003)

Based on the above information, typical shorebird is expected to weigh 30 g (CWS 1991 and NatureServe 2008).

Home Range:

Average territory size 1 ha on breeding grounds in Manitoba (NatureServe 2008). The territory size of the spotted sandpiper is 0.25 ha (U.S. EPA 1993).

Feeding Habits:

On the tundra, many feed on surface insects. On migration, they feed on invertebrates such as polychaete worms, bivalves such as *Macoma balthica* and mud shrimp or *Corophium volutator* (CWS 2001).

Semipalmated Sandpipers feed on insects and tiny, mostly shrimplike, water animals that collectively are called aquatic invertebrates. (CWS 1991)

Feeds primarily on aquatic insects; also eats mollusks, worms, and crustaceans (NatureServe 2008).

Shorebirds feed almost exclusively on small invertebrates, either by probing into or gleaning from the substrate (U.S. EPA 1993).

During breeding season, Semipalmated Sandpipers switch from a diet of predominantly insect larvae to adult insects and chironomid larvae (Hicklin and Gratto-Trevor (2010). For the purposes of the model, there is no distinction between aquatic and terrestrial insects; they are all assessed in their larval stage and assumed to be equivalent to benthic invertebrates.

Based on the available information the sandpiper is assumed to consume benthic invertebrates (CWS 2001 and NatureServe 2008).

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 30 g the FI is 5.9 g dw/d, or 30 g ww/d (moisture content of 80% based on diet comprising mainly aquatic species as discussed below). The wet weight value is taken as the mode of a triangular distribution with maximum and minimum values of+/- 30%.

Sediment Ingestion:

Beyer *et al*. (1994) provides values for the stilt sandpiper (17%), semipalmated sandpiper (30%), least sandpiper (7.3%) and western sandpiper (18%). The 30% value for the semipalmated sandpiper was used.

Based on a dry weight FI of 5.9 g/d this corresponds to approximately 1.8 g/d, which represents 6% of the wet weight FI of 30 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 30 g the WI is 0.006 L/d. This value is taken as the mode of a triangular distribution with maximum and minimum values of +/- 50%.

Arctic Climate:

Food intake rate for arctic breeding birds were increased by 50% to reflect increased energy requirements in the arctic. A similar 50% increase in soil ingestion, concurrent with the increased food ingestion rate, was made. Water intake rates were not adjusted, since allometric equations are largely based on birds in warmer climates, which are likely to have to consume more water.

Summary Table:

Exposure Characteristics		
Body Weight (kg)	0.03	CWS 1991, NatureServe 2008
Food Intake Rate (g ww/d)	TRI(30, 45, 60)	U.S. EPA 1993 (allometric scaling), increased by 50% to account for arctic environment
Soil Ingestion Rate (g dw/d)	2.7	Beyer *et al*. 1994, increased by 50% to account for arctic environment
Water Intake Rate (L/d)	TRI(0.003, 0.006, 0.008)	U.S. EPA 1993 (allometric scaling)
Fraction of time in area	1	Migratory, but assumed for calculations
Fractional Composition of Diet		
Sediment	0.06	Fraction of wet weight diet (Beyer *et al.* 1994)
Benthic invertebrates	0.94	CWS 1991 and NatureServe 2008

Note: TRI = triangular distribution (minimum, mode, maximum)

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) 2001. Hinterland Who's Who. Shorebirds. Available at: http://www.hww.ca/hww2.asp?id=75

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

Grizzly Bear

Brown bears (*Ursus arctos*) found inland and in northern habitats are often called “grizzlies”.

The grizzly is the second largest North American land carnivore. Historically, it ranged across the western half of North America, approximately to the eastern boundary of Manitoba. As human populations have grown, the grizzly’s range has gradually shrunk and is now limited to northwestern North America (CWS 1990).

Size:

Bear weights vary depending on the time of year. At this time most mature males weigh between 500 and 900 pounds (180-410 kg) (ADF&G 2003).

Although grizzly bears have been known to weigh as much as 500 kg. An average male weighs 250 to 350 kg and the female about half that (CWS 1990).

Based on the above information, a typical grizzly bear is expected to weigh 300 kg (CWS 1990).

Home Range:

The home range for a female bear can range between 2.6 km^2 to 40 km^2; the home range for a male bear can range from 21 km^2 to 155 km^2 (American Bear Association 2003).

It is a solitary animal whose home range may be as large as 1,800 km^2 for males (CWS 1990).

Feeding Habits:

Common foods include berries, grasses, sedges, horsetails, cow parsnips, fish, ground squirrels, and roots of many kinds of plants (ADF&G 2003).

Plants make up 80 to 90 percent of its diet. Grizzlies prey on mammals and migrating salmon, where they are available, but on the whole rely on vegetation for food. For a brief time in spring, grizzly bears are significant predators of caribou. Grizzly bears that live on the arctic tundra feed heavily on arctic ground squirrels in late summer. However, berries are the most important item in the bears’ diet (CWS 1990).

Based on the above information, the grizzly bear is assumed to eat browse (30%), berries (40%), fish (18.5%), caribou (5%), squirrels (5%) and soil (1.5%, as discussed above).

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 300,000 g the FI is 7.5 kg dw/d or 25 kg ww/d (moisture content of 70% based on dietary characteristics as described below). The wet weight value is taken as the mode of a triangular distribution with maximum and minimum values of +/- 30%.

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 FI of 7.5 kg/d this corresponds to approximately 373 g/d of soil. This accounts for 1.5% of the wet weight FI of 25 kg/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 300 kg the WI is 17 L/d. This value is taken as the mode of a triangular distribution with maximum and minimum values of +/- 50%.

Summary Table:

Exposure Characteristics		
Body Weight (kg)	300	CWS 1990
Food Intake Rate (kg ww/d)	TRI(17, 25, 32)	U.S. EPA 1993 (allometric scaling)
Soil Ingestion Rate (g dw/d)	373	Beyer *et al.* 1994
Water Intake Rate (L/d)	TRI(8.4, 17, 25)	U.S. EPA 1993 (allometric scaling)
Fraction of time in area	0.5	Assumed
Fractional Composition of Diet		
Soil	0.015	Fraction of wet weight diet (Beyer *et al.* 1994)
Browse	0.3	ADF&G (2003) and CWS (1999)
Berries	0.4	
Fish	0.185	
Caribou	0.05	
Arctic Ground Squirrel	0.05	

Note: TRI = triangular distribution (minimum, mode, maximum)

References:

Alaska Department of Fish & Game (ADF&G) 2003. Wildlife Notebook Series: Brown Bear. Accessed on June 24, 2008 at http://www.adfg.state.ak.us/pubs/notebook/biggame/brnbear.php

American Bear Association (ABA). 2003. The American Bear Association, Vince Shute Wildlife Sanctuary. Internet: http://www.americanbear.org/Habitat%20-%20Home%20Range.htm. Accessed on June 10, 2003.

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Canadian Wildlife Service (CWS) 1990. *Hinterland Who's Who. Mammal Fact Sheet: Grizzly.* Accessed on June 24, 2008 at http://www.hww.ca/hww2.asp?id=90

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

Falcon

The Peregrine Falcon (*Falco peregrinus*) is found in Nunavut. It is a sturdy crow-sized falcon and has a small head, firm compact plumage, and long pointed wings; adaptations that allow it to fly at great speed. Powerful and fast-flying, the Peregrine Falcon hunts medium-sized birds, dropping down on them from high above in a spectacular stoop. They nest on cliff faces and crevices (CWS 1990, Cornell 2003).

Size:

Adult females weigh about 910 g while males weigh about 570 g (CWS 1990).

Weight: 530-1600 g (Cornell 2003).

Weight: 1500 grams (NatureServe 2008)

Mass: 907 g (average) (Dewey and Potter 2002)

Based on the above information, a typical Peregrine Falcon is expected to weigh 900 g (CWS 1990, Cornell 2003, Dewey and Potter 2002).

Home Range:

Home ranges have been estimated from 177 to 1508 km^2 (White 2002).

Home ranges in Great Britain varied from 44-65 km^2, and averaged km^2. In Utah, home range radii varied from 0.3 to 29.8 kilometers, average 12.2 km (NatureServe 2008)

Feeding Habits:

At Rankin Inlet, on the west shore of Hudson Bay, Peregrines eat mostly lemmings and shorebirds (CWS 1990).

The peregrine falcon feeds primarily on birds (medium-size passerines up to small waterfowl). Rarely or locally, small mammals (e.g., bats, lemmings), lizards, fishes, and insects (by young birds) may be eaten (NatureServe 2008).

Peregrine falcons prey almost exclusively on birds, which make up 77 to 99% of prey items. The most important set of prey, by biomass, is Columbidae (doves, pigeons) as well as shorebirds, waterfowl, ptarmigan, grouse, and relatives, and smaller songbirds. They will also eat small reptiles and mammals. Most frequent mammal prey include bats, rodents, squirrels, and rats. (Dewey and Potter 2002).

Based on the available information the Peregrine Falcon is assumed to consume birds (90%), small mammals (10%) and soil (1.5%, as discussed below).

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 900 g the FI is 54 g dw/d or 181 g ww/d (moisture content of 70%). The wet weight value is taken as the mode of a triangular distribution with maximum and minimum values of +/- 50%.

Soil Ingestion:

There is no specific information available on soil ingestion by falcons. The estimated % soil/sediment in diet (dry weight) for birds (other than shorebirds) is 5% (Beyer *et al*. 1994). This value was used in lieu of species specific data.

Based on a dry weight consumption rate of 54 g/d this corresponds to approximately 2.7 g/d, which represents 1.5% of the wet weight FI of 181 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 900 g the WI is 0.05 L/d. This value is taken as the mode of a triangular distribution with maximum and minimum values of +/- 50%.

Arctic Climate:

Food intake rate for arctic breeding birds were increased by 50% to reflect increased energy requirements in the arctic. A similar 50% increase in soil ingestion, concurrent with the increased food ingestion rate, was made. Water intake rates were not adjusted, since allometric equations are largely based on birds in warmer climates, which are likely to have to consume more water.

Summary Table:

Exposure Characteristics		
Body Weight (kg)	0.9	CWS 1990, Cornell 2003
Food Intake Rate (g ww/d)	TRI(191, 272, 353)	U.S. EPA 1993 (allometric scaling), increased by 50% to account for arctic environment
Soil Ingestion Rate (g dw/d)	4.1	Beyer *et al*. 1994, increased by 50% to account for arctic environment
Water Intake Rate (L/d)	TRI(0.03, 0.05, 0.08)	U.S. EPA 1993 (allometric scaling)
Fraction of time in area	0.33	Assumed
Fractional Composition of Diet		
Soil	0.015	Fraction of wet weight diet (Beyer *et al.* 1994)
Small mammals: Lemming Arctic Ground Squirrel	 0.05 0.05	CWS 1990, Dewey and Potter 2002 and NatureServe 2008
Birds: Merganser Sandpiper Ptarmigan	 0.295 0.295 0.295	

Note: TRI = triangular distribution (minimum, mode, maximum)

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. Peregrine Falcon. Available at: http://www.hww.ca/hww2.asp?id=95

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Gray Wolf

The gray wolf (*Canis lupus*) is a social animal and has a highly organized social structure centring 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 (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 km^2, and is defended against intruders (Dewey and Smith 2002).

Wolves have a territory of 100 to 2500 km^2 (Resources Inventory Committee 1998).

Feeding Habits:

Gray wolves are carnivores. Wolves' chief preys 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 caribou and muskox in equal proportion.

Food Consumption Rate:

The gray wolf in northeastern Alberta eats 5.5 kg/d (Fuller and Keith 1980).

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

Based on a body weight of 43,000 g the FI is approximately 1.5 kg dw/d, or 5 kg ww/d (moisture content of 70% based on dietary characteristics as discussed below). For assessment purposes, the FI was taken to be 5.5 kg (ww)/d (Fuller and Keith 1980) (corresponding to a dry weight FI of 1.65 kg/d), which agrees well with the allometric estimate. This value is taken as the mode of a triangular distribution with maximum and minimum values of +/- 30%.

Soil Ingestion:

Beyer *et al*. (1994) provides a value of 2.8% for the red fox; this value was considered appropriate for the wolf. This is a conservative assumption as the wolves hunt larger prey and would therefore ingest less soil. Based on a dry weight consumption rate of 1.65 kg/d this corresponds to approximately 46 g/d, which represents 0.8% of the wet weight FI of 5.5 kg/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. This value is taken as the mode of a triangular distribution with maximum and minimum values of +/- 50%.

Summary Table:

Exposure Characteristics		
Body Weight (kg)	43	Schmidt and Gilbert 1978
Food Intake Rate (kg ww/d)	TRI(3.9, 5.5, 7.2)	Fuller and Keith 1980
Soil Ingestion Rate (g dw/d)	46	Beyer *et al.* 1994
Water Intake Rate (L/d)	TRI(1.5, 2.9, 4.4)	U.S. EPA 1993 (allometric scaling)
Fraction of time in area	0.5-1	Assumed
Fractional Composition of Diet		
Soil	0.008	Fraction of wet weight diet (Beyer *et al.* 1994)
Caribou	0.496	Based on information from CWS 1993, NatureServe 2007, Dewey and Smith 2002
Muskox	0.496	

Note: TRI = triangular distribution (minimum, mode, maximum)

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) 1993. Hinterland Who's Who. Mammal Fact Sheet: Wolf. Available at: http://www.ffdp.ca/hww2.asp?id=107

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

Arctic Fox

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 4-8 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)

Weighs 4000 grams (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)

The home range is much larger in winter than in summer. Based on a few radiotelemetry studies, the adult home range is around 10-20 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. In the 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%), birds (25%) and soil (0.8%, as discussed below).

Food Consumption Rate:

Specific information for the arctic fox not available in U.S. EPA (1993), however a food consumption rate of 0.069 g ww/d per g body weight is provided for a red fox (weight of 4.5 kg). With a body weight of 4,000 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 4,000 g the FI is 215 g dw/d, or 716 g ww/d (moisture content of 70% based on dietary characteristics as described below). To be conservative, the allometric value was selected over the lower value derived from the red fox ingestion rate. The wet weight value is taken as the mode of a triangular distribution with maximum and minimum values of +/- 30%.

Soil Ingestion:

Beyer *et al.* (1994) provides a value of 2.8% for the red fox, which was considered appropriate for the arctic fox.

Based on a dry weight FI of 215 g/d this corresponds to approximately 6 g/d, which represents 0.8% of the wet weight FI of 716 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. This value is taken as the mode of a triangular distribution with maximum and minimum values of +/- 50%.

Summary Table:

Exposure Characteristics		
Body Weight (kg)	4	NatureServe 2007
Food Intake Rate (g ww/d)	TRI(501, 716, 931)	U.S. EPA 1993 (allometric scaling)
Soil Ingestion Rate (g dw/d)	2.3	Beyer *et al.* 1994
Water Intake Rate (L/d)	TRI(0.2, 0.3, 0.5)	U.S. EPA 1993 (allometric scaling)
Fraction of time in area	1	Assumed
Fractional Composition of Diet		
Soil	0.008	Fraction of wet weight diet (Beyer *et al.* 1994)
Small mammals: Lemming Arctic Ground Squirrel Shrew	 0.247 0.247 0.247	Based on information from CWS 1993, NatureServe 2007, Middlebrook 1999
Birds: Ptarmigan Merganser	 0.125 0.125	

Note: TRI = triangular distribution (minimum, mode, maximum)

References:

Alaska Department of Fish & Game (ADF&G) 1994. Wildlife Notebook Series: Arctic Fox. Accessed September 19, 2007 at: http://www.adfg.state.ak.us/pubs/notebook/furbear/arcfox.php

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

Wolverine

The wolverine (*Gulo gulo*) is known by a variety of descriptive names, such as the skunk-bear. It is generally found in remote areas, far away from humans and development. However, specific characteristics of the wilderness that make a habitat desirable for a wolverine are not yet known. The wolverine was formerly distributed throughout the taiga and boreal regions of North America, but the range has receded substationally from most of the eastern United States and Canada. Wolverines require dens so that the female may give birth and raise her kits. In tundra regions, these dens consist of a complex of snow tunnels associated with boulders or rocks. Although the wolverine belongs to the weasel family, it is built more like a small bear than a weasel. (CWS 2001, ADF&G)

Size:

Approximately the size of a medium-sized dog; males weight 12 to 18 kg, while females weight 8 to 12 kg (CWS 2001)

Male has a mass of 7 to 32 kg (average 15 kg), while females are approximately 30% less in mass (5 to 22 kg, average 10.5 kg) (NatureServe 2009)

Males weight 11 to 18 kg, while females weigh 6-12 kg (ADF&G 1994)

Based on the above information a typical wolverine is expected to weigh 13 kg, as the average of all reported ranges above (CWS 2001, NatureServe 2009, ADF&G 1994).

Home Range:

Wolverines travel extensively in search of food and males tend to have larger home ranges than do females, while females without kits have larger home ranges than females with kits. The home range size and use changes seasonally. Male home range sizes tend to be between 500 and 700 km^2 (200 to 260 square miles), while females have an upper home range size of 300 km^2 (115 square miles) (ADF&G 1994).

The male may range up to 1,000 km^2, while the female with young will generally only range from 73 to 416 km^2 (NatureServe 2009).

The home range of an adult wolverine extends from less than 100 km^2 for females to over 1,000 km^2 for males (CWS 2001).

Feeding Habits:

The wolverine is an opportunistic carnivore and is more of a scavenger than a hunter, depending on carrion from large mammal kills by other carnivores such as wolves. In absence of other food, the wolverine will revisit old kills to consume frozen bones and pelts to kill the animals for it. Some individuals can become good hunters and will kill young and adult caribou or moose in poor physical condition or in heavy snow. Wolverines, especially females with kits, will rely on birds and small and medium-sized mammals such as marmots, ground squirrels and snowshoes hares. (CWS 2001, NatureServe 2009)

Based on the available information the fox is assumed to consume small mammals (70%), birds (15%), large mammals (13.5%) and soil (1.5%, as discussed below).

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 13,000 g the FI is 566 g dw/d or 1886 g ww/d (moisture content of 70% based on dietary characteristics as described below). The wet weight value is taken as the mode of a triangular distribution with maximum and minimum values of +/- 30%.

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 FI of 566 g/d this corresponds to approximately 28 g dw/d, which represents 1.5% of the wet weight FI of 1886 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 13 kg the WI is 1.0 L/d. This value is taken as the mode of a triangular distribution with maximum and minimum values of +/- 50%.

Summary Table:

Exposure Characteristics		
Body Weight (kg)	13	CWS 2001, NatureServe 2009, ADF&G 1994
Food Intake Rate (g ww/d)	TRI(1320, 1886, 2452)	U.S. EPA 1993 (allometric scaling)
Soil Ingestion Rate (g dw/d)	28	Beyer *et al.* 1994
Water Intake Rate (L/d)	TRI(0.5, 1, 1.5)	U.S. EPA 1993 (allometric scaling)
Fraction of time in area	0.5-1	Assumed
Fractional Composition of Diet		
Soil	0.015	Fraction of wet weight diet (Beyer *et al.* 1994)
Small mammals: Lemming Arctic Ground Squirrel	 0.35 0.35	Based on information from CWS 2001, NatureServe 2009
Birds (ptarmigan)	0.15	
Large mammals Caribou Muskox	 0.0675 0.0675	

Note: TRI = triangular distribution (minimum, mode, maximum)

References:

Alaska Department of Fish & Game (ADF&G) 1994. *Wildlife Notebook Series: Wolverine*. Accessed July 22 2010 at: http://www.adfg.state.ak.us/pubs/notebook/furbear/wolverin.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) 2001. *Hinterland Who's Who. Mammal Fact Sheet: Wolverine.* Available at: http://www.hww.ca/hww2.asp?cid=8&id=108

NatureServe. 2009. NatureServe Explorer: An online encyclopedia of life. Version 7.1. NatureServe, Arlington, Virginia. Available http://www.natureserve.org/explorer. 2 February (Accessed: July 21 2010).

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

Attachment E Measured Concentration Comparison

E.1 Fish Concentrations

Predicted average fish concentrations are summarized in Table E.1-1 with the measured average and geometric mean fish concentrations. Site-specific fish transfer factors were calculated and pooled with transfer factor data from other sites.

Table E.1-1 Comparison of Measured Fish Concentrations with Model Predicted Values

Constituent	Units	Fish Concentrations		
		Measured		Model Predicted Avg
		Avg	GM	
Uranium	ug/g ww	0.007	0.001	0.002
Thorium-230	Bq/g ww	0.0004	0.0002	0.0003
Lead-210	Bq/g ww	0.0027	0.0010	0.0011
Radium-226	Bq/g ww	0.0002	0.0001	0.0004
Polonium-210	Bq/g ww	0.0004	0.0003	0.0022
Arsenic	ug/g ww	0.03	0.02	0.08
Cadmium	ug/g ww	0.0012	0.0011	0.02
Cobalt	ug/g ww	0.006	0.005	0.006
Copper	ug/g ww	0.32	0.29	0.26
Lead	ug/g ww	0.003	0.002	0.038
Molybdenum	ug/g ww	0.010	0.010	0.021
Nickel	ug/g ww	0.020	0.014	0.016
Selenium	ug/g ww	0.28	0.27	0.43
Zinc	ug/g ww	6.4	6.0	6.8

Notes:
Avg = average.
GM = geometric mean; GSD = geometric standard deviation.
ug/g = micrograms per gram; Bq/g = Bequerels per gram; ww = wet weight basis

Source for measured data: AREVA (2011), data from 2007, 2008, and 2009; data reported as less than the method detection limit was treated as equal to ½ the method detection limit. For shoots and roots combined.

E.2 Aquatic Vegetation Concentrations

Predicted average aquatic vegetation concentrations are summarized in Table E.2-1 with the measured average and geometric mean aquatic vegetation concentrations. All thorium-230 concentrations were reported as below detection limit in the measured data.

Table E.2-1 Comparison of Measured Aquatic Vegetation Concentrations with Model Predicted Values

Constituent	Units	Aquatic Vegetation Concentrations		
		Measured		Model Predicted Avg
		Avg [a]	GM [a]	
Uranium	ug/g ww	0.032	0.009	0.01
Thorium-230	Bq/g ww	0.0002	0.0001	0.0042
Lead-210	Bq/g ww	0.017	0.012	0.009
Radium-226	Bq/g ww	0.002	0.001	0.001
Polonium-210	Bq/g ww	0.012	0.009	0.011
Arsenic	ug/g ww	1.1	0.16	2.0
Cadmium	ug/g ww	0.030	0.013	0.00
Cobalt	ug/g ww	0.21	0.07	0.17
Copper	ug/g ww	1.5	1.2	1.8
Lead	ug/g ww	0.25	0.07	0.2
Molybdenum	ug/g ww	0.18	0.14	0.17
Nickel	ug/g ww	0.40	0.26	0.6
Selenium	ug/g ww	0.011	0.008	0.02
Zinc	ug/g ww	6.3	6.0	6.4

Notes:
Avg = average.

GM = geometric mean; GSD = geometric standard deviation.
ug/g = micrograms per gram; Bq/g = Bequerels per gram; ww = wet weight basis
a = converted from dry weight basis (dw) using an assumed moisture content of 76%

Source for measured data: AREVA (2011), data from 2007, 2008, and 2009; data reported as less than the method detection limit was treated as equal to ½ the method detection limit. For shoots and roots combined.

E.3 Benthic Invertebrate and Insect Concentrations

Predicted average benthic invertebrate concentrations are summarized in Table E.3-1 with the measured average and geometric mean insect concentrations from the site. Benthic invertebrate transfer factors were taken from the McClean Lake site and adjusted based on a comparison with site-specific benthic invertebrate concentrations. Insect concentrations were not used for calibration.

Table E.3-1 Comparison of Measured Insect and Benthic Invertebrate Concentrations with Model Predicted Values

Constituent	Units	Insect/Benthic Invertebrate Concentrations				
		Measured Insect		Measured Benthos		Model Predicted Avg
		Avg	GM	Avg	GM	
Uranium	ug/g ww	0.03	0.02	0.09	0.09	0.08
Thorium-230	Bq/g ww	0.045 [a]	0.045 [a]	0.003	0.003	0.001
Lead-210	Bq/g ww	0.011 [a]	0.011 [a]	0.009	0.008	0.004
Radium-226	Bq/g ww	0.009 [a]	0.009 [a]	0.002	0.002	0.006
Polonium-210	Bq/g ww	0.015 [a]	0.015 [a]	0.045	0.039	0.012
Arsenic	ug/g ww	0.042	0.038	0.73	0.58	0.78
Cadmium	ug/g ww	1.1	1.1	0.15	0.10	1.0
Cobalt	ug/g ww	0.08	0.07	0.39	0.36	0.40
Copper	ug/g ww	27.9	27.7	12.4	7.8	13.3
Lead	ug/g ww	0.43	0.35	0.24	0.21	0.24
Molybdenum	ug/g ww	0.76	0.74	0.17	0.17	0.15
Nickel	ug/g ww	0.97	0.69	1.10	1.06	1.20
Selenium	ug/g ww	0.70	0.69	0.18	0.16	0.10
Zinc	ug/g ww	278	204	16.3	15.2	40

Notes:
Avg = average.
GM = geometric mean; GSD = geometric standard deviation.
ug/g = micrograms per gram; Bq/g = Bequerels per gram; ww = wet weight basis
a = converted from dry weight basis (dw) using an assumed moisture content of 70% (Gray and Bradley, 2005)

Source for measured data: AREVA (2011), data from 2007, 2008, and 2009; data reported as less than the method detection limit was treated as equal to ½ the method detection limit. Benthic invertebrates were collected in 2013 for analysis.

E.4 Terrestrial Vegetation Concentrations

Predicted average browse concentrations are summarized in Table E.4-1 with the measured average and geometric mean browse concentrations from the site. Only one sample concentration was reported above the detection limit for arsenic in browse (0.13 ug/g ww) and the model predicted average concentration matches this value. Only four samples (out of 18) for molybdenum were reported above the detection limit and the 95th percentile concentration of the measured data was 0.52 ug/g ww.

Table E.4-1 Comparison of Measured Browse Concentrations with Model Predicted Values

Constituent	Units	Browse Concentrations		
		Measured		Model Predicted Avg
		Avg	GM	
Uranium	ug/g ww	0.005	0.005	0.001
Thorium-230	Bq/g ww	0.0003 [a]	0.0002 [a]	0.0003
Lead-210	Bq/g ww	0.05 [a]	0.05 [a]	0.04
Radium-226	Bq/g ww	0.002 [a]	0.002 [a]	0.0014
Polonium-210	Bq/g ww	0.04 [a]	0.04 [a]	0.04
Arsenic	ug/g ww	0.03	0.03	0.18
Cadmium	ug/g ww	1.2	0.62	0.47
Cobalt	ug/g ww	0.42	0.30	0.55
Copper	ug/g ww	6.8	6.5	6.3
Lead	ug/g ww	0.11	0.09	0.23
Molybdenum	ug/g ww	0.12	0.08	0.41
Nickel	ug/g ww	1.8	1.6	1.6
Selenium	ug/g ww	0.025	0.025	0.01
Zinc	ug/g ww	132	104	159

Notes:
Avg = average.
GM = geometric mean; GSD = geometric standard deviation.
ug/g = micrograms per gram; Bq/g = Bequerels per gram; ww = wet weight basis
a = converted from dry weight basis (dw) using an assumed moisture content of 53%

Source for measured data: AREVA (2010), data from 2007, 2008, and 2009 for willow, bog birch, and blueberry vegetation; data reported as less than the method detection limit was treated as equal to ½ the method detection limit.

Predicted average forage concentrations are summarized in Table E.4-2 with the measured average and geometric mean forage concentrations from the site.

Table E.4-2 Comparison of Measured Forage Concentrations with Model Predicted Values

Constituent	Units	Forage Concentrations		
		Measured		Model Predicted Avg
		Avg	GM	
Uranium	ug/g ww	0.4	0.02	0.08
Thorium-230	Bq/g ww	0.003 [a]	0.001 [a]	0.007
Lead-210	Bq/g ww	0.10 [a]	0.08 [a]	0.14
Radium-226	Bq/g ww	0.005 [a]	0.002 [a]	0.008
Polonium-210	Bq/g ww	0.08 [a]	0.06 [a]	0.07
Arsenic	ug/g ww	0.05	0.03	0.06
Cadmium	ug/g ww	0.05	0.04	0.09
Cobalt	ug/g ww	0.16	0.09	0.19
Copper	ug/g ww	2.2	2.0	2.9
Lead	ug/g ww	0.23	0.14	0.41
Molybdenum	ug/g ww	0.57	0.29	0.70
Nickel	ug/g ww	1.1	0.74	1.3
Selenium	ug/g ww	0.18	0.13	0.19
Zinc	ug/g ww	22.2	18.0	19.4

Notes:
Avg = average.
GM = geometric mean; GSD = geometric standard deviation.
ug/g = micrograms per gram; Bq/g = Bequerels per gram; ww = wet weight basis
a = converted from dry weight basis (dw) using an assumed moisture content of 53%

Source for measured data: AREVA (2010), data from 2007, 2008, and 2009 for Carex sp. and sedge; data reported as less than the method detection limit was treated as equal to ½ the method detection limit.

Predicted average berry concentrations are summarized in Table E.4-3 with the measured average and geometric mean berry concentrations from the site. Only one sample concentration was reported above the detection limit for arsenic in berry (0.026 ug/g ww) and the model predicted average concentration matches this value. All selenium concentrations were reported as less than the detection limit, so the measured data does not provide any information for comparison.

Table E.4-3 Comparison of Measured Berry Concentrations with Model Predicted Values

Constituent	Units	Berry Concentrations		
		Measured		Model Predicted Avg
		Avg	GM	
Uranium	ug/g ww	0.002	0.001	0.002
Thorium-230	Bq/g ww	0.0002 [a]	0.0002 [a]	0.0012
Lead-210	Bq/g ww	0.0017 [a]	0.0009 [a]	0.0019
Radium-226	Bq/g ww	0.0002 [a]	0.00012 [a]	0.0002
Polonium-210	Bq/g ww	0.0009 [a]	0.0008 [a]	0.0010
Arsenic	ug/g ww	0.009	0.007	0.03
Cadmium	ug/g ww	0.04	0.01	0.02
Cobalt	ug/g ww	0.02	0.01	0.04
Copper	ug/g ww	1.3	0.92	1.5
Lead	ug/g ww	0.012	0.011	0.05
Molybdenum	ug/g ww	0.09	0.04	0.08
Nickel	ug/g ww	0.49	0.27	0.62
Selenium	ug/g ww	0.09	0.08	0.004
Zinc	ug/g ww	17.0	11.0	18.7

Notes:
Avg = average.

GM = geometric mean; GSD = geometric standard deviation.
ug/g = micrograms per gram; Bq/g = Bequerels per gram; ww = wet weight basis
a = converted from dry weight basis (dw) using an assumed moisture content of 87%

Source for measured data: AREVA (2010), data from 2007, 2008, and 2009 for blueberry and other berries; data reported as less than the method detection limit was treated as equal to ½ the method detection limit.

Predicted average lichen concentrations are summarized in Table E.4-4 with the measured average and geometric mean lichen concentrations from the site.

Table E.4-4 Comparison of Measured Lichen Concentrations with Model Predicted Values

Constituent	Units	Lichen Concentrations		
		Measured		Model Predicted Avg
		Avg	GM	
Uranium	ug/g ww	0.05	0.02	0.03
Thorium-230	Bq/g ww	0.002 [a]	0.001 [a]	0.001
Lead-210	Bq/g ww	0.31 [a]	0.30 [a]	0.37
Radium-226	Bq/g ww	0.003 [a]	0.002 [a]	0.001
Polonium-210	Bq/g ww	0.28 [a]	0.27 [a]	0.61
Arsenic	ug/g ww	0.08	0.07	0.24
Cadmium	ug/g ww	0.11	0.10	0.28
Cobalt	ug/g ww	0.18	0.11	0.58
Copper	ug/g ww	1.9	1.7	2.5
Lead	ug/g ww	0.61	0.49	0.48
Molybdenum	ug/g ww	0.23	0.11	0.09
Nickel	ug/g ww	1.1	0.76	1.3
Selenium	ug/g ww	0.27	0.18	0.25
Zinc	ug/g ww	26.2	24.7	24.4

Notes:
Avg = average.
GM = geometric mean; GSD = geometric standard deviation.
ug/g = micrograms per gram; Bq/g = Bequerels per gram; ww = wet weight basis
a = converted from dry weight basis (dw) using an assumed moisture content of 34%

Source for measured data: AREVA (2010), data from 2007, 2008, and 2009; data reported as less than the method detection limit was treated as equal to ½ the method detection limit. Sample Kig4-3 collected in 2008 was removed as an outlier from the database and was not included in the summary statistics.

E.5 Terrestrial Animal Concentrations

Predicted average Lapland longspur concentrations are summarized in Table E.5-1 with the measured average and geometric mean sparrow concentrations from the site.

Table E.5-1 Comparison of Measured Sparrow Concentrations with Model Predicted Values

Constituent	Units	Sparrow Concentrations		
		Measured		Model Predicted Avg [a]
		Avg	GM	
Uranium	ug/g ww	0.001	0.001	0.005
Thorium-230	Bq/g ww	0.001	0.001	0.0010
Lead-210	Bq/g ww	0.044	0.037	0.063
Radium-226	Bq/g ww	0.002	0.002	0.003
Polonium-210	Bq/g ww	0.015	0.013	0.021
Arsenic	ug/g ww	0.010	0.010	0.042
Cadmium	ug/g ww	0.013	0.011	0.009
Cobalt	ug/g ww	0.022	0.020	0.067
Copper	ug/g ww	2.5	2.5	6.8
Lead	ug/g ww	0.023	0.023	0.076
Molybdenum	ug/g ww	0.10	0.09	0.179
Nickel	ug/g ww	0.11	0.10	0.198
Selenium	ug/g ww	0.24	0.20	0.388
Zinc	ug/g ww	22.0	21.5	34.4

Notes:
Avg = average.
GM = geometric mean; GSD = geometric standard deviation.
ug/g = micrograms per gram; Bq/g = Bequerels per gram; ww = wet weight basis
a = model results for Lapland Longspur (similar to sparrow)

Source for measured data: AREVA (2010), data from 2007, 2008, and 2009; data reported as less than the method detection limit was treated as equal to ½ the method detection limit.

Predicted average lemming concentrations are summarized in Table E.5-2 with the measured average and geometric mean lemming concentrations from the site.

Table E.5-2 Comparison of Measured Lemming Concentrations with Model Predicted Values

Constituent	Units	Lemming Concentrations		
		Measured		Model Predicted Avg [a]
		Avg	GM	
Uranium	ug/g ww	0.05	0.003	0.003
Thorium-230	Bq/g ww	0.001	0.001	0.001
Lead-210	Bq/g ww	0.07	0.05	0.05
Radium-226	Bq/g ww	0.037	0.001	0.003
Polonium-210	Bq/g ww	0.010	0.006	0.007
Arsenic	ug/g ww	0.02	0.02	0.027
Cadmium	ug/g ww	0.06	0.04	0.034
Cobalt	ug/g ww	0.10	0.08	0.10
Copper	ug/g ww	2.3	2.3	2.6
Lead	ug/g ww	0.07	0.05	0.06
Molybdenum	ug/g ww	0.27	0.12	0.10
Nickel	ug/g ww	0.20	0.18	0.18
Selenium	ug/g ww	0.06	0.05	0.04
Zinc	ug/g ww	27.7	27.1	19.8

Notes:
Avg = average.
GM = geometric mean; GSD = geometric standard deviation.
ug/g = micrograms per gram; Bq/g = Bequerels per gram; ww = wet weight basis
a = model results for lemming

Source for measured data: AREVA (2010), data from 2007, 2008, and 2009; data reported as less than the method detection limit was treated as equal to ½ the method detection limit.

Predicted average caribou concentrations are summarized in Table E.5-3 with the measured average and geometric mean caribou concentrations from the site.

Table E.5-3 Comparison of Measured Caribou Concentrations with Model Predicted Values

Constituent	Units	Caribou Concentrations		
		Measured		Model Predicted Avg [a]
		Avg	GM	
Uranium	ug/g ww	0.013	0.003	0.003
Thorium-230	Bq/g ww	0.0001	0.0001	0.000034
Lead-210	Bq/g ww	0.001	0.001	0.001
Radium-226	Bq/g ww	0.00011	0.00009	0.00004
Polonium-210	Bq/g ww	0.027	0.025	0.031
Arsenic	ug/g ww	0.035	0.031	0.048
Cadmium	ug/g ww	0.010	0.007	0.012
Cobalt	ug/g ww	0.008	0.006	0.016
Copper	ug/g ww	2.4	2.2	2.4
Lead	ug/g ww	0.016	0.012	0.010
Molybdenum	ug/g ww	0.05	0.02	0.02
Nickel	ug/g ww	0.032	0.019	0.025
Selenium	ug/g ww	0.17	0.17	0.15
Zinc	ug/g ww	40.4	37.7	30.4

Notes:
Avg = average.
GM = geometric mean; GSD = geometric standard deviation.
ug/g = micrograms per gram; Bq/g = Bequerels per gram; ww = wet weight basis
a = model results for caribou

Source for measured data: AREVA (2010), data from 2009; data reported as less than the method detection limit was treated as equal to ½ the method detection limit.

Predicted average muskox concentrations are summarized in Table E.5-4 with the measured muskox (one sample) concentrations from the site.

Table E.5-4 Comparison of Measured Muskox Concentrations with Model Predicted Values

Constituent	Units	Muskox Concentrations	
		Measured	
		Value	Model Predicted Avg [a]
Uranium	ug/g ww	0.03	0.002
Thorium-230	Bq/g ww	<0.0001	0.0001
Lead-210	Bq/g ww	0.002	0.0002
Radium-226	Bq/g ww	<0.00005	0.0001
Polonium-210	Bq/g ww	0.0087	0.0069
Arsenic	ug/g ww	0.02	0.08
Cadmium	ug/g ww	<0.002	0.028
Cobalt	ug/g ww	0.003	0.024
Copper	ug/g ww	1.2	11.5
Lead	ug/g ww	0.099	0.011
Molybdenum	ug/g ww	<0.02	0.13
Nickel	ug/g ww	0.01	0.06
Selenium	ug/g ww	0.11	0.05
Zinc	ug/g ww	40	273

Notes: Measured results based on one sample.
Avg = average.

ug/g = micrograms per gram; Bq/g = Bequerels per gram; ww = wet weight basis
a = model results for muskox

Source for measured data: AREVA, data from muskox belly meat harvested in May 2011 around km 90 of the Meadowbank All Weather Private Access Road

Attachment F Predicted Intakes

F.1 Ecological Receptors

Table F.1-1 summarizes the predicted intakes for ecological receptors for non-radiological constituents. Attachment I summarizes the predicted intakes for ecological receptors for radiological constituents.

F.2 Human Receptors

Table F.2-1 summarizes the predicted intakes for human receptors for non-radiological constituents for the maximum year of exposure. Table F.2-2 summarizes the predicted doses for human receptors for radiological constituents.

Attachment G Toxicity Benchmark Background

G.1 Introduction

This appendix provides all the background information that was used in the selection of the toxicity reference values (TRVs) for non-radionuclide and radionuclide COPC for the Project. The appendix describes the selection of the ecological TRVs including radiological biological Effectiveness (RBE) factors as well as reference dose limits for radiological COPC. TRVs that are protective of human health are also described.

G.2 Aquatic Organisms

G.2.1 General

The U.S. EPA ECOTOXicology database (ECOTOX) was used for selection of TRVs for aquatic biota. This database reports toxicity data for a wide range of aquatic species as well as laboratory and field studies. For most chemicals, ECOTOX includes toxicity data in literature from 1972 to the present. All data were quality assured according to EPA's criteria, and the system was updated quarterly (U.S. EPA 2000).

For the purpose of this review, the following principles were applied in the data selection:

- Endpoints involving growth, reproduction and survival were considered to be relevant to persistence of aquatic populations;
- Only freshwater toxicity studies were considered;
- Records without test duration, endpoint and exposure concentration were eliminated;
- Chronic toxicity data were preferred in the selection. When chronic data were not sufficient (minimum of 2), acute data were considered and converted to chronic values;
- Chronic EC_{20} concentrations were preferred. If not reported, other endpoints were considered and adjusted to an estimated EC_{20} value (Table G.2-1).
- If a selected TRV was lower than the CCME Guideline for Protection of Aquatic Life (CCME 1999), then the latter was used.

Table G.2-1 Procedure for Adjusting Test Endpoints to Chronic EC_{20}

Test Endpoint	Adjustment to Chronic EC_{20} [a]
EC_{10}	Chronic or acute EC_{10} multiplied by 2
EC_{25}	Chronic EC_{25} multiplied by 4/5
EC_{30}	Chronic EC_{30} multiplied by 2/3
EC_{50}	Chronic or acute EC_{50} multiplied by 2/5
IC_{10}	IC10 is treated as EC_{10}; multiplied by 2
IC_{20}	Treated as EC_{20}; no adjustment
IC_{50}	IC_{50} is treated as EC_{50}; multiplied by 2/5
LC_{10}	Chronic LC_{10} multiplied by 5/4; acute LC_{10} multiplied by 5/10
LC_{50}	Chronic LC_{50} divided by 4; acute LC_{50} divided by 10
LD_{50}	LD_{50} is treated as LC_{50}; Chronic LC_{50} divided by 4 to get chronic EC_{20}
MATC [b]	Treated as EC_{50}; multiplied by 2/5
NR [c]	Treated as EC_{20} but suspect

Note:

a-Acute data was only used in the absence of acceptable chronic data
b-MATC records were only included in the derivation of the TRV in the absence of other acceptable EC, LC or IC data; if two or more chronic MATC records were available, they were used in preference of acute data

c-NR records were only included in the derivation of the absence of other acceptable chronic or acute data

TRVs derived for aquatic biota included six taxonomic categories: forage fish, predator fish, zooplankton, benthic invertebrates, phytoplankton, and aquatic plants. If more than 20 chronic EC_{20} values were available in each taxonomic group, a 5^{th} percentile of the EC_{20} distribution was used as a recommended TRV; if there were less than 20 chronic EC_{20} values, the lowest EC_{20} was used as a recommended TRV for the taxonomic category.

The lowest chronic EC_{20} or 5^{th} percentile of chronic EC_{20} values derived from the above process were compared with widely used TRVs in ecological risk assessment as recommended by Suter & Tsao (1996), U.S. EPA, CCME or other government guideline documents. The more appropriate values were selected as the recommended TRVs for each taxonomic category in this review.

Basis for Adjustments to EC_{20}

The adjustment from acute LC_{50} to chronic EC_{20} (a 1/10 factor) was used by EC/HC (2003) based on review of aquatic toxicity literature for uranium. The adjustment from chronic LC_{50} to chronic EC_{20} (a ¼ factor) was based on an assumed linear chronic dose-response with zero response at EC_0 and 50% response at the EC_{50} concentration.

There is considerable uncertainty around these generic factors when applied to a particular chemical. For example, acute chronic ratios (ACRs) for metals (used in U.S. EPA water quality criteria) range from 2 to 51, as compared to our generic value of 10. Suter & Tsao (1996) examined the relationships between acute LC_{50}s and chronic values and found that the more toxic chemicals tend to have smaller ACRs. Dose-response curves are typically not linear, as assumed, but the simple linear assumption is conservative when adjusting to a lower response level, such as EC_{50} to EC_{20}.

G.2.2 Arsenic

The TRVs for arsenic are all chronic adjusted EC_{20} values and were selected based on information obtained from the U.S. EPA ECOTOX database. The data in the ECOTOX database pertained mainly to EC_{50}, LC_{50} and NOEC and LOEC values, the latter two of which were not included in the derivation of the TRVs. All toxicity values were adjusted to chronic EC_{20} values according to the guidelines outlined in Table G.2-1. If there were fewer than 20 toxicity values, then the minimum adjusted EC_{20} value was selected as the TRV, as was the case for aquatic plants, zooplankton and forage fish. For benthic invertebrates and predator fish, more than 20 records were found suitable for derivation of both of the TRVs and so the TRVs were selected as the 5^{th} percentile of the adjusted chronic EC_{20} values. The selected TRVs are summarized in Table G.2-2 from which it can be seen that benthic invertebrates and forage fish are the most sensitive to arsenic exposure while predator fish are the least sensitive.

Table G.2-2 Recommended Chronic Arsenic TRVs for Aquatic Biota

Taxonomic Group	TRV (µg/L)	# of Estimated Chronic EC_{20} Values	Rationale
Forage fish	123	2	Lowest estimated chronic EC_{20}
Predator fish	630	50	5th percentile of estimated chronic EC_{20}
Aquatic plants	252	8	Lowest estimated chronic EC_{20}
Zooplankton	340	6	Lowest estimated chronic EC_{20}
Benthic invertebrates	122	27	5^{th} percentile of estimated chronic EC_{20}

G.2.3 Cadmium

The TRVs for cadmium are all chronic adjusted EC_{20} values and were selected based on information obtained from the U.S. EPA ECOTOX database. The selected TRVs are summarized in Table G.2-3.

Table G.2-3 Recommended Chronic Cadmium TRVs for Aquatic Biota

Taxonomic Group	TRV (µg/L)	Reference	Rationale
Forage fish	7.3		
Predator fish	0.6		
Aquatic plants	16	Naumann et al 2007	from U.S. EPA ECOTOX database; EC10 7-d; used as TRV
Zooplankton	0.23		
Benthic invertebrates	0.5		

G.2.4 Cobalt

The TRVs for cobalt are all adjusted chronic EC_{20} values and were selected based on information obtained from the U.S. EPA ECOTOX database. The data in the ECOTOX database pertained mainly to EC_{50}, LC_{50} and NOEC and LOEC values, the latter two of which were not included in the derivation of the TRVs. All toxicity values were adjusted to chronic EC_{20} values according to the guidelines outlined in Table G.2-4. If there were fewer than 20 toxicity values, then the minimum adjusted EC_{20} value was selected as the TRV. This was true for all aquatic biota for cobalt. The selected TRVs are summarized in Table , from which it can be seen that zooplankton and benthic invertebrates are the most sensitive to cobalt exposure while forage fish are the least sensitive.

Table G.2-4 Recommended Chronic Cobalt TRVs for Aquatic Biota

Taxonomic Group	TRV (µg/L)	# of Estimated Chronic EC_{20} Values	Rationale
Forage fish	203	2	Lowest estimated chronic EC_{20}
Predator fish	118	50	Lowest estimated chronic EC_{20}
Aquatic plants	54.3	8	Lowest estimated chronic EC_{20}
Zooplankton	4.8	6	Lowest estimated chronic EC_{20}
Benthic invertebrates	4	27	Lowest estimated chronic EC_{20}

G.2.5 Copper

The TRVs for copper for three of the five aquatic biotas are adjusted chronic EC_{20} values and were selected based on information obtained from the U.S. EPA ECOTOX database. The data in the ECOTOX database pertained mainly to EC_{50}, LC_{50} and NOEC and LOEC values, the latter two of which were not included in the derivation of the TRVs. These toxicity values were adjusted to chronic EC_{20} values according to the guidelines outlined in Table G.2-1. If there were fewer than 20 toxicity values, the minimum adjusted EC_{20} value was selected as the TRV. However, if there were more than 20 acceptable records then the 5th percentile value of the adjusted chronic EC_{20} data was used, as was the case for aquatic plants, forage fish and predator fish. In the case of two of the aquatic biota (i.e. zooplankton and benthic invertebrates), the derived TRVs were lower than the existing CCME guideline values (CCME 1999) and so the CCME values were selected as the TRVs. The selected TRVs are summarized in Table G.2-5, from which it can be seen that zooplankton, benthic invertebrates, forage fish and predator fish are the most sensitive to copper exposure, while aquatic plants are the least sensitive. It should be noted that although the toxicity of copper is affected by water hardness, the values presented here have not been hardness-adjusted.

Table G.2-5 Recommended Chronic Copper TRVs for Aquatic Biota

Taxonomic Group	TRV (µg/L)	# of Estimated Chronic EC_{20} Values	Rationale
Forage fish	6	237	5th percentile of estimated chronic EC_{20}
Predator fish	4	89	5th percentile of estimated chronic EC_{20}
Aquatic plants	38	28	5th percentile of estimated chronic EC_{20}
Zooplankton	4	117	Previously used value based on CCME (1999)
Benthic invertebrates	4	264	Previously used value based on CCME (1999)
Note: Values have not been adjusted for water hardness			

G.2.6 Lead

The TRVs for lead for four of the five aquatic biotas are adjusted chronic EC_{20} values and were selected based on information obtained from the U.S. EPA ECOTOX database. The data in the ECOTOX database pertained mainly to EC_{50}, LC_{50} and NOEC and LOEC values, the latter two of which were not included in the derivation of the TRVs. All toxicity values were adjusted to chronic EC_{20} values according to the guidelines outlined in Table G.2-1. If there were fewer than 20 toxicity values, then the minimum adjusted EC_{20} value was selected as the TRV. However, if there were more than 20 acceptable records then the 5th percentile value of the adjusted chronic EC_{20} data was used. The derived TRV for benthic invertebrates was lower than the existing CCME guideline value (CCME 1999), and so the CCME value was selected as the TRV. The selected TRVs are summarized in Table G.2-6, from which it can be seen that benthic invertebrates are the most sensitive to lead exposure while aquatic plants are the least sensitive. It should be noted that although the toxicity of lead is affected by water hardness, the values presented here have not been hardness-adjusted.

Table G.2-6 Recommended Chronic Lead TRVs for Aquatic Biota

Taxonomic Group	TRV (µg/L)	# of Estimated Chronic EC_{20} Values	Rationale
Forage fish	132	3	Lowest estimated chronic EC_{20}
Predator fish	14.2	25	5th percentile of estimated chronic EC_{20}
Aquatic plants	439	9	Lowest estimated chronic EC_{20}
Zooplankton	40	5	Lowest estimated chronic EC_{20}
Benthic invertebrates	1 [a]	12	CCME guideline (1999)

Note: Values have not been adjusted for water hardness

a - CCME guideline values (1999) are as follows: 1 µg/L for water hardness of 0-60 mg/L; 2 µg/L for water hardness of 60-120 mg/L; 4 µg/L for water hardness of 120-180 mg/L; and 7 µg/L for water hardness greater than 180 mg/L

G.2.7 Molybdenum

The TRVs for molybdenum for four of the five aquatic biotas are adjusted chronic EC_{20} values and were selected based on information obtained from the U.S. EPA ECOTOX database. The data in the ECOTOX database pertained mainly to EC_{50}, LC_{50} and NOEC and LOEC values, the latter two of which were not included in the derivation of the TRVs. All toxicity values were adjusted to chronic EC_{20} values according to the guidelines outlined in Table G.2-1. If there were fewer than 20 toxicity values, then the minimum adjusted EC_{20} value was selected as the TRV. For aquatic plants, only one study was available by Den Dooren De Jong (1965). The selected TRVs are summarized in Table G.2-7, from which it can be seen that predator fish are the most sensitive to molybdenum exposure while forage fish and aquatic plants are the least sensitive.

Table G.2-7 Recommended Chronic Molybdenum TRVs for Aquatic Biota

Taxonomic Group	TRV (µg/L)	# of Estimated Chronic EC_{20} Values	Rationale
Forage fish	5000	5	Lowest estimated chronic EC_{20}
Predator fish	183	3	Lowest estimated chronic EC_{20}
Aquatic plants	15000	-	LOEC, Den Dooren De Jong (1965)
Zooplankton	233	4	Lowest estimated chronic EC_{20}
Benthic invertebrates	250	2	Lowest estimated chronic EC_{20}

G.2.8 Nickel

The TRVs for nickel are all adjusted chronic EC_{20} values and were selected based on information obtained from the U.S. EPA ECOTOX database. The data in the ECOTOX database pertained mainly to EC_{50}, LC_{50} and NOEC and LOEC values, the latter two of which were not included in the derivation of the TRVs. All toxicity values were adjusted to chronic EC_{20} values according to the guidelines outlined in Table G.2-1. If there were fewer than 20 toxicity values, the minimum adjusted EC_{20} value was selected as the TRV, as was the case for all aquatic biota except for benthic invertebrates. For benthic invertebrates, more than 20 records were found suitable for derivation of the TRV and so the TRV was selected as the 5th percentile of the adjusted chronic EC_{20} values. The selected TRVs are summarized in Table G.2-8, from which it can be seen that zooplankton are the most sensitive to nickel exposure while forage fish are the least sensitive. It should be noted that although the toxicity of nickel is affected by water hardness, the values presented here have not been hardness-adjusted.

Table G.2-8 Recommended Chronic Nickel TRVs for Aquatic Biota

Taxonomic Group	TRV (µg/L)	# of Estimated Chronic EC_{20} Values	Rationale
Forage fish	535	3	Lowest estimated chronic EC_{20}
Predator fish	62	17	Lowest estimated chronic EC_{20}
Aquatic plants	84	10	Lowest estimated chronic EC_{20}
Zooplankton	38	12	Lowest estimated chronic EC_{20}
Benthic invertebrates	53.5	47	5th percentile of estimated chronic EC_{20}
Note: Values have not been adjusted for water hardness			

G.2.9 Selenium

The TRVs for selenium are all adjusted chronic EC_{20} values and were selected based on information obtained from the U.S. EPA ECOTOX database. The data in the ECOTOX database pertained mainly to EC_{50}, LC_{50} and NOEC and LOEC values, the latter two of which were not included in the derivation of the TRVs. All toxicity values were adjusted to chronic EC_{20} values according to the guidelines outlined in Table G.2-1. If there were fewer than 20 toxicity values, the minimum adjusted EC_{20} value was selected as the TRV, but if there were more than 20 records the TRV was selected as the 5th percentile of the adjusted chronic EC_{20} values. The selected TRVs are summarized in Table G.2-9.

For forage and predator fish, the TRV is a whole body fish concentration and the following paragraphs discuss the development of the number.

Hamilton (2003) provides a detailed review of tissue-based selenium concentrations for freshwater fish. Hamilton presents a list of selenium concentrations in tissues that have been associated with toxic effects in fish. The concentrations range from a low value of 2 µg/g dw (dry weight basis) associated with blood changes in rainbow trout to a maximum of about 16 µg/g dw in fathead minnows and bluegill sunfish associated with reproductive failure. Based on the information provided in the Hamilton paper, it has been suggested that a whole body selenium threshold of 4 µg/g dw in fish is an appropriate value to use. However, Hamilton (2004) used low values (from studies such as Hunn *et al*. 1987 and Hamilton *et al*. 1990) to derive the whole body selenium threshold. These values were rejected by the U.S. EPA (2004) in deriving a final chronic value for selenium. Therefore, Hamilton's whole body selenium threshold value of 4 µg/g dw is not considered in this review.

The B.C. guideline for selenium is based on a proposed whole body toxicity threshold (EC_{10}) of 6 µg/g dw for Chinook salmon based on the 60-day exposure data by Brix *et al*. (2004) combined with Hamilton *et al*. (1990) (Nagpal and Howell 2001). They assumed 80% moisture content to develop a safe level for selenium on a wet weight (ww) basis of 1.2 µg Se/g ww (i.e. 6 µg Se/g dw). In this review, the EC_{20} is selected as the preferred endpoint for the TRV, so the B.C. guideline value based on EC_{10} for selenium is not recommended.

Muscatello *et al*. (2006) reported whole body Se EC_{20}s of 15.56 and 17.72 µg/g (dw), converted from fish egg and muscle concentrations respectively, which caused total fry deformities of northern pike (*Esox lucius*) exposed to uranium mining effluent. Further studies (Muscatello *et al*. 2008, Muscatello and Janz 2009) suggested that Se concentrations were elevated in aquatic biota by biomagnification factors of 1.5 to 6 between low and higher trophic levels downstream of uranium mining and milling operations. Fish tissue concentrations exceeded a 3 to 11 µg/g (dw) dietary toxicity threshold when water and sediment concentrations of Se were as low as 0.43 µg/L and 0.54 µg/g (dw), respectively. However, no adverse effects on the studied fish were identified in these more recent studies (Muscatello *et al.* 2008, Muscatello and Janz 2009).

A final chronic value (FCV) of 7.91 µg/g dw was recommended by the U.S. EPA in its 2004 Draft Aquatic Life Ambient Water Quality Criteria for Selenium, which is based on Lemly's (1993) study with juvenile bluegill sunfish (*Lepomis macrochirus*). Significantly elevated mortality (40%) was reported after exposure to the combination of low-level waterborne and dietary selenium for 180 days with temperatures decreasing from 20°C to 4°C.

The U.S. EPA conducted further studies of selenium effects on juvenile bluegill sunfish at reduced temperatures (McIntyre *et al*. 2008). That study suggested that the toxicity of selenium to juvenile bluegill was approximately 1.9 times less than that observed in the Lemly (1993) study. With similar test conditions, an EC_{20} of 10.16 µg/g dw was reported for the survival of juvenile bluegill sunfish with the exposure temperature decreased from 20°C to near 4°C, while an EC_{20} of 14.02 µg/g dw was reported for the survival of juvenile bluegill sunfish with the exposure temperature decreased from 20°C to 9°C. The results of the U.S. EPA (McIntyre *et al*. 2008) study are consistent with the results of Muscatello *et al.* (2006) for larval northern pike.

Therefore, the EC_{20} of 10.16 µg/g dw from U.S. EPA (McIntyre *et al.* 2008) based on survival of juvenile bluegill sunfish exposed to a combination of low-level waterborne and dietary selenium and declining temperature is considered protective of forage fish, and is recommended as the TRV for forage and predator fish.

Table G.2-9 Recommended Chronic Selenium TRVs for Aquatic Biota

Taxonomic Group	TRV (µg/L)	# of Estimated Chronic EC_{20} Values	Rationale
Forage fish	10.2	-	McIntyre *et al*. 2008
Predator fish	10.2	-	McIntyre *et al*. 2008
Aquatic plants	680	7	Lowest estimated chronic EC_{20}
Zooplankton	10	-	LOEC, Crane *et al*. 1992
Benthic invertebrates	10	-	LOEC, Crane *et al*. 1992

G.2.10 Uranium

There was limited data available in the ECOTOX database pertaining to the effects of uranium exposure on aquatic biota. Data were instead obtained from two reports which investigated the toxicity of uranium to aquatic biota in Northern Saskatchewan (VST 2004, Liber *et al.* 2007). From these reports, data was obtained for 12 organisms, 10 of which were tested under chronic exposure, 2 of which were tested under acute exposure and 1 of which was tested under both conditions. Acute exposure was defined as 72 hours (algae species) or 96 hours (fish species), while chronic exposure varied from 6 to 31 days. Details on the experimental methodologies are provided in the afore-mentioned reports (VST 2004, Liber *et al.* 2007).

The TRVs for uranium were all derived from chronic studies from two literature sources (VST 2004, Liber *et al.* 2007). The results are summarized in Table G.2-10 for a water hardness of 60 mg/L $CaCO_3$.

Table G.2-10 Recommended Chronic Uranium TRVs for Aquatic Biota

Taxonomic Group	TRV (µg/L)	Hardness (mg/L $CaCO_3$)	Rationale
Forage fish	550	60	Lowest estimated chronic EC_{20}
Predator fish	1500	60	Lowest estimated chronic EC_{20}
Aquatic plants	5500	60	Geometric mean of 2 EC_{25} values
Zooplankton	60	60	Lowest estimated chronic EC_{20}
Benthic invertebrates	270	60	Lowest estimated chronic EC_{20}

G.2.11 Zinc

The TRVs for zinc for two of the five aquatic biotas are adjusted chronic EC_{20} values and were selected based on information obtained from the U.S. EPA ECOTOX database. The data in the ECOTOX database pertained mainly to EC_{50}, LC_{50} and NOEC and LOEC values, the latter two of which were not included in the derivation of the TRVs. All toxicity values were adjusted to chronic EC_{20} values according to the guidelines outlined in Table G.2-1. If there were fewer than 20 toxicity values, the minimum adjusted EC_{20} value was selected as the TRV, as was the case for forage fish and aquatic plants. The derived TRVs for predator fish, zooplankton and benthic invertebrates were lower than the existing CCME guideline values (CCME 1999), and so the CCME values were selected as the TRVs. The selected TRVs are summarized in Table G.2-11, from which it can be seen that aquatic plants are less sensitive to zinc exposure than are the other four aquatic biota. It should be noted that although the toxicity of zinc is affected by water hardness, the values presented here have not been hardness-adjusted.

Table G.2-11 Recommended Chronic Zinc TRVs for Aquatic Biota

Taxonomic Group	TRVs (µg/L)	# of Estimated Chronic EC_{20} Values	Rationale
Forage fish	35	15	Lowest estimated chronic EC_{20}
Predator fish	30	39	CCME guideline (1999)
Aquatic plants	116	7	Lowest estimated chronic EC_{20}
Zooplankton	30	9	CCME guideline (1999)
Benthic invertebrates	30	14	CCME guideline (1999)
Note: Values have not been adjusted for water hardness			

G.2.12 Un-ionized Ammonia

The TRVs for un-ionized ammonia are from the Environment Canada/Health Canada Priorirty Substance List Assessment document for Ammonia in the Aquatic Environment, as summarized in Table G.2-12.

Table G.2-11 Recommended Chronic Un-Ionized Ammonia TRVs for Aquatic Biota

Taxonomic Group	TRVs (µg/L)	Reference	Rationale
Forage fish	173	EC/HC PSL2 (2001)	EC_{20} study provided in PSL2 – reduction in growth or reproductive success
Predator fish	90	EC/HC PSL2 (2001)	EC_{20} study provided in PSL2 – reduction in growth or reproductive success
Aquatic plants	-		No data available
Zooplankton	160	EC/HC PSL2 (2001)	Acute LC_{50} reported as geometric mean of 12 studies; derived TRV using a factor of 10 based on an empirical relationship between an acute LC_{50} and an EC_{20}
Benthic invertebrates	120	EC/HC PSL2 (2001)	Acute LC_{50}; lowest value for invertebrate species; derived TRV using a factor of 10 based on an empirical relationship between an acute LC_{50} and an EC_{20}

G.2.13 Chloride

The TRVs for chloride are summarized in Table G.2-13.

Table G.2-13 Recommended Chronic Chloride TRVs for Aquatic Biota

Taxonomic Group	TRVs (mg/L)	Reference	Rationale
Forage fish	220	Beak 1999	LC_{50} from chronic test (>7 days). Derived EC_{20} using a factor of 4 based on an empirical relationship between a chronic LC_{50} and EC_{50}
Predator fish	360	Beak 1999	LC_{50} from chronic test (>7 days). Derived EC_{20} using a factor of 4 based on an empirical relationship between a chronic LC_{50} and EC_{50}
Aquatic plants	1260	Buckley et al. 1996	EC_{50} on growth from chronic test (>7 days). Derived EC_{20} by linear extrapolation
Zooplankton	290	Degreave et al. 1985	EC_{50} for brood size from chronic test (>7 days). Derived EC_{20} by linear extrapolation
Benthic invertebrates	143	U.S. EPA ECOTOX	5^{th} percentile of estimated chronic EC20

G.3 Terrestrial Wildlife

G.3.1 General

The U.S. EPA has developed a set of risk-based ecological soil screening levels (Eco-SSLs) for a number of chemicals that are of ecological concern at contaminated sites. The databases were developed and the Eco-SSLs derived in order to limit the need for the U.S. EPA and other risk assessors to perform repetitious toxicity data literature searches and evaluations for the same contaminants at every site. The derivation process and data gathering was a group effort involving federal, state, consulting, industry and academic participants.

There were four steps involved in the derivation of the Eco-SSLs. These were: i) conduct literature searches; ii) screen identified literature with exclusion and acceptability criteria; iii) extract, evaluate, and score results for applicability in deriving the Eco-SSL; and iv) derive the value.

The acceptability criteria that were used for the literature data for wildlife involved ensuring that the studies were related to the oral route of exposure and that at least two exposures (control and contaminant) were reported in the studies. The endpoints that were selected were behavioural, biochemical, growth, mortality, pathology, population, physiology, and reproduction. In addition, the studies needed to be chronic in duration (i.e. greater than 3 days exposure duration). The scoring was based on the various endpoints and was based on: the source of the data; the chemical form; measurement or no measurement in substrate; ability to calculate a dose; bounded vs. unbounded NOAEL/LOAEL (no/lowest observable adverse effects level); and, route of exposure, endpoint type, duration of exposure, statistical power and adherence to test guidelines. Only studies that scored greater than 65% were used to derive a TRV. The TRV was generally equal to the geometric mean of the NOAEL values for growth and reproduction or the highest bounded NOAEL below the lowest bounded LOAEL for growth and reproduction.

Since the data used in the development of the Eco-SSLs underwent a rigorous screening process, it was felt that these data were appropriate to use in the derivation of NOAEL and LOAEL TRVs for this project.

In the derivation of the TRVs, a number of guiding principles were followed as outlined below:

- Studies were selected from the database where both NOAELs and LOAELs were reported as well as studies with only LOAELs. Studies that only reported NOAELs were not considered in the derivation of TRVs.
- TRVs were calculated as the geometric mean of the selected data for several species for both avian and mammalian wildlife. These species will serve as surrogates for various wildlife species that are similar in size and diet.

- NOAEL and LOAEL TRVs for each surrogate species were calculated as the geometric means of the NOAEL data for the NOAEL TRVs and LOAEL data for the LOAEL TRVs, pooling growth and reproduction endpoints.
- A NOAEL TRV was only provided if there was an associated LOAEL TRV for the species; if only LOAEL data were available then only a LOAEL TRV was provided.

G.3.2 Avian Species

G.3.2.1 Arsenic

The data for growth and reproduction for avian species were obtained from the data presented in the Eco-SSL document for arsenic exposure (U.S. EPA 2005a). The data were based on only five studies with chickens and ducks; these species served as the surrogates for avian wildlife. The geometric means of the presented LOAEL data were calculated to derive the TRVs for each surrogate species. None of the studies presented in the Eco-SSL document for avian exposure to arsenic reported both LOAEL and NOAEL data and, as such, no NOAEL TRVs were calculated. The geometric means of the LOAELs for chickens and ducks are presented in Table G.3-1. In this assessment, the duck was used as the surrogate species for waterfowl. No appropriate surrogate species was available for the eagle and so the lowest LOAEL of 3.6 mg/kg-d for the chicken was used as a conservative TRV for the eagle.

Table G.3-1 Recommended Chronic Arsenic TRVs for Avian Species

Species	TRV (mg/kg-d)			
	NOAEL	# of data	LOAEL	# of data
Mallard duck (Anas platyrhynchos)	-	-	5.1	2
Chicken (Gallus domesticus)	-	-	3.6	1

G.3.2.2 Cobalt

There were two species of birds represented in the Eco-SSL database with growth and reproduction endpoints, and with LOAEL only or LOAELs and NOAELs reported for exposure to cobalt (U.S. EPA 2005b). The geometric means of the NOAELs and LOAELs were calculated for the chicken and the duck, the results of which are presented in Table G.3-2. The geometric means of the NOAELs were 4.09 and 14.8 mg/kg-d for the chicken and duck, respectively while the geometric means of the LOAELs were 14.1 mg/kg-d and 148 mg/kg-d for the chicken and duck, respectively. In this assessment, the duck was used as the surrogate species for waterfowl based on the same family, and similar size and diet. No appropriate surrogate species was available for the eagle and so the lowest NOAEL and LOAEL values of 4.09 mg/kg-d and 14.1 mg/kg-d, respectively, were used as conservative TRVs for the eagle.

Table G.3-2 Recommended Chronic Cobalt TRVS for Avian species

Species	TRV (mg/kg-d)			
	NOAEL	# of data	LOAEL	# of data
Chicken (Gallus domesticus)	4.09	3	14.13	8
Duck (Anas sp.)	14.8	1	148	1

G.3.2.3 Copper

The data for growth and reproduction for avian species were obtained from the data presented in the Eco-SSL document for copper exposure (U.S. EPA 2007a). The data were based on studies with chickens, ducks and turkeys; these species served as the surrogates for avian wildlife. The geometric means calculated from the presented LOAEL and NOAEL data were selected to serve as the TRVs for each of the three species and are presented in Table G.3-3. In this assessment, the duck was used as the surrogate species for waterfowl based on the same family and similar size and diet. No appropriate surrogate species was available for the eagle and so the lowest NOAEL and LOAEL values of 15.3 mg/kg-d and 27 mg/kg-d, respectively, were used as conservative TRVs for the eagle.

Table G.3-3 Recommended Chronic Copper TRVs for Avian Species

Species	TRV (mg/kg-d)			
	NOAEL	# of data	LOAEL	# of data
Chicken (Gallus domesticus)	19.9	54	34.9	78
Mallard duck (Anas platyrhynchos)	24.1	2	75.2	3
Turkey (Meleagris gallopavo)	15.3	5	27	9

G.3.2.4 Lead

There were three species of birds represented in the Eco-SSL database with growth and reproduction endpoints for exposure to lead, and with LOAEL only or LOAEL plus NOAEL values reported (U.S. EPA 2005c). The geometric means of the NOAEL and LOAEL data were calculated for each species and are presented in Table G.3-4 for the chicken, Japanese quail and ringed turtle dove. In this assessment, since none of the test species is suitable as a surrogate for waterfowl or the eagle, the lowest LOAEL of 11.8 mg/kg-d was used as a conservative avian TRV for lead.

Table G.3-4 Recommended Chronic Lead TRVs for Avian Species

Species	TRV (mg/kg-d)			
	NOAEL	# of data	LOAEL	# of data

Chicken (Gallus domesticus)	6.51	5	67.3	17
Japanese quail (Coturnix japonica)	6.83	9	27.68	14
Ringed turtle dove (Streptopelia risoria)	-	-	11.8	1

G.3.2.5 Molybdenum

There were two species of birds obtained from references with growth and reproduction endpoints, and with LOAEL data reported. Geometric means of the LOAEL data were calculated for both the chicken and the turkey, the results of which are presented in Table G.3-5. No NOAEL data was available and so no NOAEL TRVs were calculated. In this assessment, since none of the test species are suitable as a surrogate for waterfowl or the eagle, the lowest LOAEL of 20.83 mg/kg-d was used as a conservative avian TRV for molybdenum.

Table G.3-5 Recommended Chronic Molybdenum TRVs for Avian Species

Species	TRV (mg/kg-d)			
	NOAEL	# of data	LOAEL	# of data
Chicken (Gallus domesticus)	-	-	38.6	3
Turkey (Meleagris gallopavo)	-	-	20.83	1

G.3.2.6 Nickel

There were two species of birds represented in the Eco-SSL database with growth and reproduction endpoints for nickel exposure, and with LOAEL only or LOAEL plus NOAEL data reported (U.S. EPA 2007b). Geometric means of the NOAEL and LOAEL data were calculated for each species, the results of which are presented in Table G.3-6 for the chicken and duck. In this assessment, since none of the test species is suitable as a surrogate for waterfowl or the eagle, the lowest NOAEL and LOAEL values of 14.6 mg/kg-d and 10.7 mg/kg-d, respectively, were used as conservative avian TRVs for nickel.

Table G.3-6 Recommended Chronic Nickel TRVS for Avian species

Species	TRV (mg/kg-d)			
	NOAEL	**# of data**	**LOAEL**	**# of data**
Chicken (Gallus domesticus)	14.6	4	19.9	8
Mallard duck (Meleagris gallopavo)	-	-	10.7	1

G.3.2.7 Selenium

There were five species of birds represented in the Eco-SSL database with growth and reproduction endpoints for selenium exposure, and with LOAEL only or LOAEL plus NOAEL data reported (U.S. EPA 2007c). Geometric means of the NOAEL and LOAEL data were calculated for all five species, the results of which are presented in Table G.3-7. In this assessment, the duck was used as the surrogate species for waterfowl based on same family and similar size and diet, and the black-crowned night heron was used as the surrogate species for the eagle.

Table G.3-7 Recommended Chronic Selenium TRVS for Avian species

Species	TRV (mg/kg-d)			
	NOAEL	**# of data**	**LOAEL**	**# of data**
Black-crowned night heron (N*ycticorax nycticorax*)	-	-	0.68	1
Chicken (*Gallus domesticus*)	0.36	12	0.59	32
Mallard duck (*Anas platyrhynchos*)	1.18	10	1.37	20
Japanese quail (*Coturnix japonica*)	-	-	0.75	6
Owl (*Otus asio*)	-	-	4.49	1

G.3.2.8 Uranium

Previous risk assessments have used TRVs for avian exposure to uranium derived from the data of Sample *et al.* (1996) as shown in Table G.3-8. The Sample *et al.* data were based on a study by Haseltine and Sileo (1983) related to mortality, body weight, and liver and kidney effects in ducks. Sample *et al.* derived a NOAEL of 16 mg/kg/day, but no LOAEL, from the study. However, it should be noted that depleted metallic uranium is not readily available and thus this TRV may not be a true representation of uranium toxicity. In this assessment, the duck was used as the surrogate species for waterfowl and the eagle.

Table G.3-8 Recommended Chronic Uranium TRvs for Avian species

Species	TRV (mg/kg-d)			
	NOAEL	# of data	LOAEL	# of data
Black duck (*Anas rubripes*)	16	1	-	-

G.3.2.9 Zinc

The data for growth and reproduction for avian species were obtained from the data presented in the Eco-SSL document for zinc exposure (U.S. EPA 2007d). The data were based predominantly on studies with chickens, with some studies with Japanese quails, mallard ducks and turkeys; these four species served as the surrogates for avian wildlife. The geometric means of the LOAEL and NOAEL data were selected to serve as the TRVs, calculated for each surrogate species from the presented LOAEL and NOAEL data. The values are presented in Table G.3-9. In this assessment, the duck was used as the surrogate species for waterfowl and the eagle.

Table G.3-9 Recommended Chronic Zinc TRVs for Avian species

Species	TRV (mg/kg-d)			
	NOAEL	# of data	LOAEL	# of data
Chicken (Gallus domesticus)	90.1	24	179	47
Mallard duck (Anas platyrhynchos)	-	-	62.7	2
Japanese quail (Coturnix japonica)	61.3	2	123	2
Turkey (Meleagris gallopavo)	148	1	297	1

G.3.3 Mammals

G.3.3.1 Arsenic

The data for growth and reproduction for mammalian species were obtained from the Eco-SSL document for arsenic exposure (U.S. EPA 2005a).The data were based on studies with dogs, goats, guinea pigs, mice, pigs, rabbits and rats; these species served as the surrogates for mammalian wildlife. The geometric means of the LOAEL and NOAEL data were selected to serve as the TRVs, calculated for each surrogate species from the presented LOAEL and NOAEL data. For mice and rats the geometric means of the NOAEL values were larger than the geometric means of the LOAEL values due to the larger data set for the LOAEL values. Therefore, for these two species, the LOAEL was derived only from the studies that presented both LOAEL and NOAEL values. The geometric means are provided in Table G.3-10. In this assessment, the rat LOAEL and NOAEL served as the surrogate TRVs for the muskrat and beaver, while the dog LOAEL and NOAEL served as the surrogate TRVs for the fox and mink. For the moose and caribou, the goat LOAEL was used as the surrogate TRV.

Table G.3-10 Recommended Chronic Arsenic TRVs for Mammalian Species

Species	TRV (mg/kg-d)			
	NOAEL	# of data	LOAEL	# of data
Dog (Canus familiaris)	1.5	2	3.1	2
Goat (Capra hircus)	-	-	14.4	2
Guinea pig (Cavia porcellus)	-	-	0.8	1
Mouse (Mus musculus)	7.6	3	20.7	9
Pig (Sus scrofa)	-	-	9.4	1
Rabbit (Oryctolagus cuniculus)	0.8	1	3	1
Rat (Rattus norvegicus)	8.1	4	14.2	10

G.3.3.2 Cobalt

There were three mammalian species represented in the Eco-SSL database with growth or reproduction endpoints for cobalt exposure, and with LOAEL only or LOAEL plus NOAEL data reported (U.S. EPA 2005b). The geometric means are provided in Table G.3-11. In this assessment, the rat LOAEL and NOAEL served as the surrogate TRVs for the beaver, fox, mink and muskrat, while the pig LOAEL served as the surrogate TRV for the moose and caribou.

Table G.3-11 Recommended Chronic Cobalt TRVs for Mammalian Species

Species	TRV (mg/kg-d)			
	NOAEL	# of data	LOAEL	# of data
Mouse (Mus musculus)	19.00	1	27.94	6
Pig (Sus scrofa)	-	-	20.20	1
Rat (Rattus norvegicus)	5.22	2	13.39	7

G.3.3.3 Copper

The data for growth and reproduction were obtained from the data presented in the Eco-SSL document for copper exposure (U.S. EPA 2007a). The data were based on studies with goats, minks, mice, pigs, rabbits, rats and sheep; these species served as the surrogates for mammalian wildlife. The geometric means of the LOAEL and NOAEL data are presented in Table G.3-12. In this assessment, the rat LOAEL and NOAEL served as the surrogate TRVs for the muskrat and beaver, the mink LOAEL and NOAEL served as the surrogate TRVs for the mink and fox, and the goat LOAEL served as the surrogate TRV for the moose and caribou.

Table G.3-12 Recommended Chronic Copper TRVs for Mammalian Species

Species	TRV (mg/kg-d)			
	NOAEL	# of data	LOAEL	# of data
Goat (Capra hircus)	-	-	1.5	1
Mink (Neovison vison)	5.9	2	11.5	2
Mouse (Mus musculus)	442	8	917	8
Pig (Sus scrofa)	9.8	3	12.8	6
Rabbit (Oryctolagus cuniculus)	27.7	1	45.7	1
Rat (Rattus norvegicus)	100	8	194	17
Sheep (Ovis aries)	-	-	3	1

G.3.3.4 Lead

There were eight mammalian species represented in the Eco-SSL database with growth or reproduction endpoints for lead exposure, and with LOAEL only or LOAEL plus NOAEL values reported (U.S. EPA 2005c). The geometric means are presented in Table G.3-13 for cattle, cotton rats, dogs, shrews, mice, pigs, rabbits and rats. In this assessment, the rat (common) LOAEL and NOAEL served as the surrogate TRVs for the muskrat and beaver, the dog LOAEL served as the surrogate TRV for the mink and fox, and the cattle LOAEL served as the surrogate TRV for the moose and caribou.

Table G.3-13 Recommended Chronic Lead TRVs for Mammalian Species

Species	TRV (mg/kg-d)			
	NOAEL	# of data	LOAEL	# of data
Cattle (Bos taurus)	-	-	15	1
Cotton rat (Sigmodon hispidus)	12.4	1	170	1
Dog (Canis familiaris)	-	-	50	1
Shrew (Sorex araneus)	-	-	61.5	1
Mouse (Mus musculus)	193	8	234	30
Pig (Sus scrofa)	-	-	173	1
Rabbit (Oryctolagus cuniculus)	10.7	1	50.4	1
Rat (Rattus norvegicus)	25.5	33	188	92

G.3.3.5 Molybdenum

There were five mammalian species from references with growth or reproduction endpoints, and with LOAEL only or LOAEL plus NOAEL values reported. The geometric means are presented in Table

G.3-14 for mice, Holstein calves, rabbits, rats (common) and Holtzman rats. For the LOAEL, the common rat served as the surrogate species for the muskrat, mink, beaver and fox, and the Holstein calf served as the surrogate species for the moose and caribou. No species served as surrogates for NOAELs.

Table G.3-14

Recommended Chronic Molybdenum TRVs for Mammalian Species

Table G.3-14 Recommended Chronic Molybdenum TRVs for Mammalian Species

Species	TRV (mg/kg-d)			
	NOAEL	# of data	LOAEL	# of data
Mouse (Mus musculus)	0.26	1	2.6	1
Holstein calf	-	-	4.1	1
Rabbit (Oryctolagus cuniculus)	-	-	30	1
Rat (Rattus norvegicus)	-	-	1.9	1
Holtzman rat	-	-	7.5	1

G.3.3.6 Nickel

The data for growth and reproduction were obtained from the data presented in the Eco-SSL document for nickel exposure (U.S. EPA 2007b). The data were based on studies with cattle, dogs, meadow voles, mice and rats. The geometric means of the LOAEL and NOAEL data are presented in Table G.3-15. In this assessment, the rat served as the surrogate species for the muskrat and beaver, the dog served as the surrogate species for the mink and fox, and the cattle served as the surrogate species for the moose and caribou.

Table G.3-15 Recommended Chronic Nickel TRVs for Mammalian Species

Species	TRV (mg/kg-d)			
	NOAEL	# of data	LOAEL	# of data
Cattle (Bos Taurus)	3.4	2	9.8	2
Dog (Canis familiaris)	45	1	112	1
Meadow vole (Microtus pennsylvanicus)	29.4	1	309	1
Mouse (Mus musculus)	17.8	5	33.2	9
Rat (Rattus norvegicus)	6.2	7	11.6	14

G.3.3.7 Selenium

There were seven mammalian species represented in the Eco-SSL database with growth or reproduction endpoints for selenium exposure, and with LOAEL only or LOAEL plus NOAEL values reported (U.S. EPA 2007c). The geometric means are presented in Table G.3-16 for cattle, dogs, hamsters, mice, pigs, pronghorns and rats. In this assessment, the rat served as the surrogate species for the muskrat and beaver for both the NOAEL and LOAEL, the dog LOAEL served as the surrogate TRV for the mink and fox, and the cattle served as the surrogate species for the moose and caribou for both the NOAEL and the LOAEL.

Table G.3-16 Recommended Chronic Selenium TRVs for Mammalian Species

Species	TRV (mg/kg-d)			
	NOAEL	**# of data**	**LOAEL**	**# of data**
Cattle (*Bos aurus*)	0.17	1	0.33	1
Dog (*Canis familiaris*)	-	-	0.21	1
Hamster (*Mesocricetus auratus*)	0.54	5	0.77	7
Mouse (*Mus musculus*)	0.93	14	1.53	23
Pig (*Sus scrofa*)	0.17	9	0.33	21
Pronghorn (*Antilocapra americana*)	-	-	0.49	1
Rat (*Rattus norvegicus*)	0.33	23	0.63	69

G.3.3.8 Uranium

Previous risk assessments have used TRVs for mammalian exposure to uranium derived from the data of Sample *et al.* (1996) as shown in Table G.3-17. The Sample *et al.* data for mammalian species were based on a study by Paternain *et al.* (1989) related to reproduction in mice. Sample derived a NOAEL of 3.07 mg/kg/day and a LOAEL of 6.13 mg/kg/day from the study. However, the TRV quoted by Sample et al. (1996) contains a small unit conversion error. Instead of 6.13 mg /kg/d for the LOAEL as reported, the value should be 5.6 mg /kg/d. The lowest dose in the Paternain et al. study was 2.8 mg/kg/d which is considered to be the NOAEL. Total implantations differed between treatment and control at this dose only, but there was no dose response in this endpoint, and all parameters of reproductive success were unimpaired at this dose level. For this reason the lowest dose (2.8 mg/kg/d) is considered to be a NOAEL. These values were used in this risk assessment for all mammalian species.

Table G.3-17 Recommended Chronic Uranium TRVs for Mammalian Species

Species	TRV mg/kg-d)			
	NOAEL	# of data	LOAEL	# of data
Mouse (Mus musculus)	2.8	1	5.6	1

G.3.3.9 Zinc

The data for growth and reproduction for mammalian species were obtained from the data presented in the Eco-SSL document for zinc exposure (U.S. EPA 2007d). The data were based on studies with cattle, mice, pigs, rats and sheep. The geometric means of the LOAEL and NOAEL data were calculated for each surrogate species from the presented LOAEL and NOAEL data and are summarized in Table G.3-18. In this assessment, the rat served as the surrogate species for the muskrat and beaver, the cattle served as the surrogate species for the moose and caribou, while the lowest LOAEL of 34.9 mg/kg-d for the sheep served as the surrogate TRV for the mink and fox.

Table G.3-18 Recommended Chronic Zinc TRVs for Mammalian Species

Species	TRV (mg/kg-d)			
	NOAEL	# of data	LOAEL	# of data
Cattle (*Bos aurus*)	37.9	1	75.9	1
Mouse (*Mus musculus*)	585	5	4395	5
Pig (*Sus scrofa*)	15.4	3	90	4
Rat (*Rattus norvegicus*)	215	17	249	3
Sheep (*Ovis aries*)	-	-	34.9	2

G.4 Surrogate Species Summary

To assess the risk of adverse effects for avian and mammalian species, data was obtained from the U.S. EPA's risk-based ecological soil screening levels (Eco-SSLs). Only studies that scored greater than 65% based on the U.S. EPA's scoring system were used to derive a TRV in this assessment. The TRV was generally equal to the geometric mean of the NOAEL values for growth and reproduction or the highest bounded NOAEL below the lowest bounded LOAEL for growth and reproduction.

TRVs were calculated from the selected data for several species of avian and mammalian wildlife, such as mallard ducks, chickens, cattle, pigs, rats, dogs, etc. These species served as surrogates for the species considered in this assessment. When possible, a surrogate species was selected based on taxonomy (i.e. same or similar order or family), diet (i.e. carnivorous vs. herbivorous), or physical characteristics (i.e. similar size). In general, for mammalian species, the rat served as the surrogate species for the beaver and muskrat, the dog served as the surrogate species for the mink and fox, and the goat served as the surrogate species for the caribou and moose. For avian species, in general the mallard duck served as the surrogate for waterfowl and the chicken served as the surrogate species for the eagle. When no appropriate surrogate species could be identified, then the most sensitive test species (i.e. lowest LOAEL or NOAEL) was selected as the surrogate species.

The avian and mammalian NOAEL and LOAEL values selected as TRVs selected for use in this assessment are summarized in Table G.4-1. A summary of the surrogate species and the rationale for their selection is also provided.

Table G.4-1 Summary of Chronic TRVs and Surrogate Species Rationale

COPC	Test Species	TRV [1] NOAEL mg/kg/d	TRV [1] LOAEL mg/kg/d	Taxonomy of test species: Order; Family	Diet of test species	Surrogate for these VECs	Rationale	Default to most sensitive test species[2]
As	**Mammal**							
	Dog (Canus familiaris)	1.5	3.1	Carnivora; Canidae	Carnivore	Mink, Fox	same Order, similar diet	
	Goat (Capra hircus)	-	14.4	Artiodactyla; Bovidae	Herbivore	Caribou, Moose	same Order, similar diet	
	Rat (Rattus norvegicus)	8.1	14.2	Rodentia; Muridae	Omnivore	Beaver, Muskrat	same Order or Family	
	Bird							
	Mallard duck (Anas platyrhynchos)	-	5.1	Anseriformes; Anatidae	Herbivore, some invertebrates	Waterfowl	same Family, similae size and diet	
	Chicken (Gallus domesticus)	-	3.6	Galliformes; Phasianidae	Herbivore, some invertebrates		same Family, similar size and diet	Eagle
Co	**Mammal**							
	Pig (Sus scrofa)	-	20.20	Artiodactyla; Suidae	Omnivore	Caribou, Moose	Same Order	
	Rat (Rattus norvegicus)	5.22	13.39	Rodentia; Muridae	Omnivore	Beaver, Muskrat	same Order or Family	Mink, Wolf
	Bird							
	Chicken (Gallus domesticus)	4.09	14.13	Galliformes; Phasianidae	Herbivore, some invertebrates		same Family, similar size and diet	Eagle
	Mallard duck (Anas platyrhynchos)	14.8	148	Anseriformes; Anatidae	Herbivore, some invertebrates	Waterfowl	same Family, similar size and diet	
Cu	**Mammal**							
	Goat (Capra hircus)	-	1.50	Artiodactyla; Bovidae	Herbivore	Caribou, Moose	same Order, similar diet	
	Mink (Neovison vison)	5.90	11.50	Carnivora; Mustelidae	Carnivore	Mink, Fox	same Genus (mink) or Order, similar diet	
	Rat (Rattus norvegicus)	100.00	194.00	Rodentia; Muridae	Omnivore	Beaver, Muskrat	same Order or Family	
	Bird							
	Mallard duck (Anas platyrhynchos)	24.1	75.2	Anseriformes; Anatidae	Herbivore, some invertebrates	Waterfowl	same Family, similar size and diet	
	Turkey (Meleagris gallopavo)	15.3	27	Galliformes; Phasianidae	Herbivore, some invertebrates			Eagle

Table G.4-1 Summary of Chronic TRVs and Surrogate Species Rationale

COPC	Test Species	TRV [1] NOAEL mg/kg/d	TRV [1] LOAEL mg/kg/d	Taxonomy of test species: Order; Family	Diet of test species	Surrogate for these VECs	Rationale	Default to most sensitive test species[2]
Pb	**Mammal**							
	Cattle (*Bos taurus*)	-	15	Artiodactyla; Bovidae	Herbivore	Caribou, Moose	same Order, similar diet	
	Dog (*Canis familiaris*)	-	50	Carnivora; Canidae	Carnivore	Mink, Fox	same Order, similar diet	
	Rat (*Rattus norvegicus*)	25.50	188	Rodentia; Muridae	Omnivore	Beaver, Muskrat	same Order or Family	
	Bird							
	Ringed turtle dove (*Streptopelia risoria*)	-	11.8	Columbiformes; Columbidae	Herbivore, rarely invertebrates			Waterfowl, Eagle
Mo	**Mammal**							
	Cow (Bos taurus)	-	4.1	Artiodactyla; Bovidae	Herbivore	Caribou, Moose	same Order, similar diet	
	Rat (Rattus norvegicus)	-	1.90	Rodentia; Muridae	Omnivore	Beaver, Muskrat	same Order or Family	Mink, Fox
	Bird							
	Turkey (Meleagris gallopavo)	-	20.83	Galliformes; Phasianidae	Herbivore, some invertebrates			Waterfowl
Ni	**Mammal**							
	Cattle (Bos taurus)	3.4	9.80	Artiodactyla; Bovidae	Herbivore	Caribou, Moose	same Order, similar diet	
	Dog (Canis familiaris)	45	112	Carnivora; Canidae	Carnivore	Mink, Fox	same Order, similar diet	
	Rat (Rattus norvegicus)	6.2	11.60	Rodentia; Muridae	Omnivore	Beaver, Muskrat	same Order or Family	
	Bird							
	Mallard duck (Anas platyrhynchos)	-	10.70	Anseriformes; Anatidae	Herbivore, some invertebrates	Waterfowl	same Family, similar size and diet	Eagle
Se	**Mammal**							
	Cattle (*Bos taurus*)	0.17	0.33	Artiodactyla; Bovidae	Herbivore	Moose, Caribou	same Order, similar diet	
	Dog (*Canis familiaris*)	-	0.21	Carnivora; Canidae	Carnivore	Mink, Fox	same Order, similar diet	
	Rat (*Rattus norvegicus*)	0.33	0.63	Rodentia; Muridae	Omnivore	Beaver, Muskrat	same Order or Family	

Table G.4-1 Summary of Chronic TRVs and Surrogate Species Rationale

COPC	Test Species	TRV [1]		Choice of a Surrogate Test Species for Typical VECs				
		NOAEL mg/kg/d	LOAEL mg/kg/d	Taxonomy of test species: Order; Family	Diet of test species	Surrogate for these VECs	Rationale	Default to most sensitive test species[2]
Se	**Bird**							
	Black-crowned night-heron (*Nycticorax nycticorax*)	-	0.68	Ciconiiformes ; Ardeidae	Carnivore, small vertebrates and invertebrates	Eagle	same Order, similar diet	
	Mallard duck (*Anas platyrhynchos*)	1.18	1.37	Anseriformes; Anatidae	Herbivore, some invertebrates	Waterfowl	same Family, similar size and diet	
U	**Mammal**							
	Mouse (Mus musculus)	2.8	5.6	Rodentia; Muridae	Omnivore	Beaver, Muskrat	same Order or Family	Mink, Fox, Caribou, Moose
	Bird							
	Black duck (*Anas rubripes*)	16		Anseriformes; Anatidae	Herbivore, some invertebrates	Waterfowl	same Family, similar size and diet	Eagle
Zn	**Mammal**							
	Cattle (Bos taurus)	37.9	75.9	Artiodactyla; Bovidae	Herbivore	Caribou, Moose	same Order, similar diet	
	Rat (Rattus norvegicus)	215	249	Rodentia; Muridae	Omnivore	Beaver, Muskrat	same Order or Family	
	Sheep (Ovis aries)	-	34.9	Artiodactyla; Bovidae	Herbivore			Mink, Fox
	Bird							
	Mallard duck (Anas platyrhynchos)		62.7	Anseriformes; Anatidae	Herbivore, some invertebrates	Waterfowl	same Family, similar size and diet	Eagle

Note: Taxonomy from IT IS (2009); Waterfowl includes mallard, scaup and merganser

"-"- Data not available

1 - See Sections G.3.2 and G.3.3 for rationale on selection of TRVs.

2 - The most sensitive test species is considered to be the species with the lowest LOAEL value.

G.5 Radioactivity

The assessment of effects from exposure to radioactive constituents involves estimation of the combined (total) dose which a VEC may receive from radionuclides taken into the body as well as from exposure to radiation fields in the external environment. In addition, it is standard practice to take into account differences in the effects of alpha, beta and gamma radiation. These factors are discussed below.

G.5.1 Relative Biological Effectiveness (RBE) Factors

Radiation effects on biota depend not only on the absorbed dose, but also on the relative biological effectiveness (RBE) of the particular radiation (i.e. alpha, beta or gamma radiation). For example, alpha particles can produce observable damage at lower absorbed doses than gamma radiation. Thus, in order to estimate the potential harm to non-human biota from a given absorbed dose, the absorbed dose is multiplied by an appropriate radiation weighting factor. This in turn is derived from experimentally determined RBE. In this assessment, the terms “RBE” and “radiation weighting factor” are used interchangeably.

For the purposes of human radiological protection, each component of the absorbed dose to a tissue or organ is weighted according to the radiation quality. The appropriate relative biological effectiveness (RBE) value for biota is the subject of ongoing scientific discussion. Although an RBE of 20 is used for human radiation protection, according to the review by UNSCEAR (1996):

> “In the case of wild organisms, however, it is likely to be deterministic effects that are of greatest significance, and for alpha radiation the experimental data for animals indicate that a lower weighting factor, perhaps 5, would be more appropriate; the weighting factors for beta and gamma radiation would remain unity.” (para. 18)

A review of the literature by Trivedi and Gentner (2000) concluded that:

> “since the majority of studies report RBE values less than or equal to 10 for endpoints, and doses and dose rates that are more ecologically significant, a value of 10 might be appropriate for weighting doses to evaluate the impact of alpha emitters at the population level, if any”.

Also, the U.S. DOE (2000) reviewed the issue and recognized that the critical biological endpoint of concern in radiation exposures of biota appears to be deterministic, and that the radiation weighting factor for deterministic effects is substantially less than the corresponding average quality factor used in radiation protection of humans (i.e. 20). Based on this information, U.S. DOE concluded that the radiation weighting factor for deterministic effects appears to lie in the range of about 5 to 10.

However, as interim guidance, they recommend the use of an RBE of 20 in the proposed standard (U.S. DOE 2000).

It should be noted that uncertainty remains concerning the most appropriate RBE values for assessing risks to non-human biota. The RBE values depend on the radiation quality, the biota under consideration, the endpoint being considered and the reference photon energies. The RBE values selected to develop protection criteria should correspond to the endpoint being protected (e.g. health of a population).

A wide range of RBE values for internally deposited alpha particles has been published. The PSL2 assessment (EC/HC 2003) suggests an RBE of 40. A report of the (former) Advisory Committee on Radiological Protection suggested a nominal RBE value of 10 with a range of about 5 to 20 for non-human biota (ACRP 2002). A recent report of the European Community suggests using an RBE of 10 to illustrate the effect of alpha RBE. For the purposes of this assessment, uncertainty associated with the choices of RBE is acknowledged and a RBE value of 10 is used for consistency with N288.6 (CSA 2012).

G.5.2 Aquatic Radiation TRVs

For radioactivity, The Canadian Standards Association (CSA) suggests a dose rate of 9.6 milliGrays per day (mGy/d) as the reference dose level below which population effects to aquatic biota would not be expected (CSA 2012). This value is based on UNSCEAR (2008).The following paragraphs outline the rationale for using 9.6 mGy/d and indicate that there is ongoing debate on the appropriate dose rate limit.

The NCRP (National Council on Radiation Protection and Measurements) in Report 109 (NCRP 1991) recommends 0.4 mGy/h (9.6 mGy/d) for the protection of aquatic biota. The NCRP state that a chronic dose rate of no more than 0.4 mGy/h (9.6 mGy/d) to the maximally exposed individual in a population would ensure protection of the population. The NCRP report also includes recommendations that if modelling and/or dosimetric measurements indicate a dose level of 0.1 mGy/h (2.4 mGy/d), then a more detailed evaluation of the potential ecological consequences to the endemic population should be conducted. The 1992 review by the IAEA (Technical Report No. 332) also concluded that limiting the dose rate to individuals in an aquatic population to a maximum of 10 mGy/d would provide adequate protection for the population.

A number of reviews on the effects of radiation on aquatic organisms were published prior to the publication of NCRP 109 (i.e. Anderson and Harrison 1966, Polikarpov 1966, Templeton *et al*. 1971, Chipman 1972, IAEA 1976, Blaylock and Trabalka 1978, Egami 1980, NRCC 1983, Woodhead 1984). In those reviews, deleterious effects of chronic irradiation were not observed in natural populations at dose rates of 0.4 mGy/h (9.6 mGy/d) or less, over the entire history of exposure to ionizing radiation. Taking into consideration the combined results from laboratory and field studies, it appears that reproductive and early developmental systems of vertebrates are most sensitive to chronic irradiation in both aquatic and terrestrial environments. Invertebrates appear to be relatively radioresistant. Effects on aquatic organisms, not necessarily detrimental when evaluated in the context of population dynamics, were detected at dose rates in the range of 1 to 10 mGy/d.

The U.S. DOE (2000) concluded that applying the aquatic dose limits suggested by the NCRP (1991) and IAEA (1992) would ensure protection of aquatic populations. UNSCEAR (1996) suggests that chronic dose rates of up to 400 μGy/h (10 mGy/d) to individuals in aquatic populations are unlikely to have a detrimental effect at the population level.

Consideration of other potential reference dose rates include 0.5 mGy/d for fish (EC/HC 2003), a value of 3 mGy/d for aquatic plants (algae and macrophytes) (ACRP 2002), a value of 5.4 mGy/d for benthic invertebrates (EC/HC 2003), and a value of 2.7 mGy/d for phytoplankton and zooplankton (EC/HC 2003).

As indicated by the brief reviews of the literature cited above, the selection of reference dose levels for aquatic biota is a topic of ongoing discussion. In light of this, it is proposed that the following reference dose levels be used in this current assessment for consistency with N288.6 (CSA 2012):

- fish –9.6 mGy/d;
- aquatic plants (algae and macrophytes) –9.6 mGy/d;
- benthic invertebrates –9.6 mGy/d;
- zooplankton –9.6 mGy/d; and
- phytoplankton –9.6 mGy/d.

G.5.3 Terrestrial Wildlife Radiation TRVs

A level of 1 mGy/d is generally used as an acceptable level for terrestrial biota. In 1992, the IAEA (1992) published the results of an assessment of the effects of acute and chronic radiation on terrestrial populations and communities. They reached several general conclusions regarding chronic radiation: reproduction is likely to be the most limiting endpoint in terms of population maintenance, and irradiation at chronic dose rates of 1 mGy/d or less does not appear likely to cause observable changes in terrestrial animal populations. Also, they concluded that irradiation at chronic dose rates of 10 mGy/d or less does not appear likely to cause observable changes in terrestrial plant populations. However, reproductive effects in long-lived species with low reproductive capacity may require further consideration. The U.S. DOE (2000) has suggested that applying the terrestrial dose limits suggested by IAEA (1992) would be protective of terrestrial species populations. UNSCEAR (1996) suggests that chronic dose rates below 400 μG/h (10 mGy/d) would not likely produce any significant effects in natural plant communities; that for terrestrial mammals, dose rates below 400 μG/h (10 mGy/d) to the most exposed animal are unlikely to affect mortality in the population and that dose rates below 40 μGy/h (1 mGy/d) are unlikely to cause a loss of reproductive capacity.

The CNSC has provided a dose rate guideline of 3 mGy/d as an appropriate limit for small mammals and terrestrial plants (Bird *et al*. 2002, EC/HC 2003). This limit is based on reproductive endpoints for small mammals. In the absence of data for avian species, the CNSC suggest that the dose limit for small mammals should also apply.

From the above discussion, it is recognized that the selection of reference dose levels is a topic of ongoing debate. A dose limit of 2.7 mGy/d from N288.6 (CSA 2012) was selected for the assessment of impacts on terrestrial biota.

G.6 Human Health

The TRVs for humans are intended to protect the most sensitive individuals (i.e., the elderly, pregnant women and children). For COPC that have non-carcinogenic effects, the TRVs are based on threshold effects concentrations. For COPC that have carcinogenic effects (i.e., those COPC that can cause cancer), the TRVs are based on non-threshold effects.

For many non-carcinogenic effects, protective biological mechanisms must be overcome before an adverse effect from exposure to the chemical is manifested. For this reason, scientists generally agree that there is a level (threshold) below which no adverse effects would be measurable or expected to occur. These TRVs are generally referred to as reference doses (RfDs) or tolerable daily intakes (TDIs), but may also be referred to as minimum risk levels (MRLs). They are generally derived by regulatory agencies such as Health Canada and the United States Environmental Protection Agency (U.S. EPA). These TRVs are usually expressed as the quantity of a chemical per unit of body weight per unit of time, or mg/(kg-day), and have generally been derived for sensitive individuals in the public using the most sensitive endpoint available. Additionally, these factors involve the incorporation of “safety factors” by regulatory agencies to provide additional protection for members of the public. Non-carcinogens are often referred to as "systemic toxicants" because of their effects on the function of various organ systems.

Carcinogenesis is generally assumed to be a "non-threshold" type phenomenon whereby any level of exposure to a carcinogen is assumed to pose a finite probability of generating a carcinogenic response. Carcinogenic TRVs are generally referred to as slope factors and are used to estimate an upper-bound lifetime probability of an individual developing cancer as a result of exposure to a particular level of a potential carcinogen. The carcinogenic slope factor is, therefore, the lifetime cancer risk per unit of dose.

The COPC selected for this report are, for the most part, considered to be non-classifiable with respect to human carcinogenicity, meaning that there are insufficient human or animal data to indicate that they are carcinogens. The exception to this is arsenic, which is considered to have both carcinogenic and non-carcinogenic endpoints.

There are several regulatory sources that report TRVs (i.e. RfDs, TDIs, MRLs, slope factors). Some of the most frequently used sources are Health Canada, the U.S. EPA Integrated Risk Information System (IRIS) database, the U.S. EPA National Center for Environmental Assessment (NCEA), the World Health Organization (WHO), and the Agency for Toxic Substances and Disease Registry (ATSDR). Given that this assessment is within a Canadian jurisdiction, values provided by Health Canada were generally preferentially selected as TRVs for evaluation of the health impacts on human receptors. The Toxicology Evaluation Section of the Health Products and Food Branch of Health Canada has published TDIs for a number of trace elements found in foodstuff. These values were also considered for use in this assessment. The other above-mentioned sources were used to infill data gaps in the Health Canada database.

Table G.6-1 provides a summary of the TRVs selected for use in the assessment for oral exposure. The TRVs, toxicological endpoints and reference sources for each TRV are provided in the table. A discussion of the rationale for selecting the oral TRVs is provided below.

G.6.1 Arsenic

Oral TRVs for non-carcinogenic effects are reported by the U.S. EPA, HC and the ATSDR. The U.S. EPA (2009, last updated 1993) provides an RfD of 0.0003 mg/kg-d for chronic oral exposure to arsenic in well water in a Taiwanese study (Tseng *et al.* 1968, Tseng 1977). The toxicological endpoint is hyperpigmentation, keratosis and possible vascular complications. The ATSDR (2007) provides this same value of 0.0003 mg/kg-d as an MRL, derived from the same study. The Health Canada Food Directorate (HC 2002) has adopted the provisional tolerable weekly intake (pTWI) of 15 µg/kg determined by the Joint FAO/WHO Expert Committee on Food Additives (JECFA) in 1988 (WHO 1989), with an additional safety factor of 2 to account for uncertainty in the epidemiological studies. This is equivalent to a TDI of 0.001 mg/kg-d. The toxicological rationale for the selection of this TRV, including the endpoint, is not clear but it is meant for chronic exposure as it is derived from a WHO TDI. In conclusion, a TDI of 0.001 mg/kg-d was adopted for the current assessment.

Health Canada and the U.S. EPA have designated arsenic as a known human carcinogen. A slope factor of 2.8 $(mg/(kg\text{-}d))^{-1}$ has previously been derived by Health Canada (2004a) based on the incidence of skin cancers in the epidemiological studies by Tseng *et al.* (1968) and Tseng (1977). In a more recent evaluation Health Canada considered new data that have become available that suggest that the risk of internal cancers due to ingestion of drinking water is greater than previously believed (HC 2009). The cancer risk models based on the Taiwanese data have been updated

(Morales *et al.* 2000), and an evaluation was completed by Health Canada of the cancer potency indices for liver, lung and bladder cancers. An oral slope factor of 1.8 $(mg/(kg\text{-}d))^{-1}$ was derived.

The U.S. EPA (2009, last updated 1998) provides an oral slope factor of 1.5 $(mg/(kg\text{-}d))^{-1}$ for skin cancer based on the same study as that used in the derivation of the RfD. The Health Canada (2009) oral slope factor of 1.8 $(mg/)kg\text{-}d))^{-1}$ was selected over the U.S. EPA value as it is based on an assessment that considered internal cancers. Thus a slope factor of 1.8 $(mg/(kg\text{-}d))^{-1}$ is used in this assessment.

G.6.2 Cadmium

Cadmium has been designated as a probable carcinogen via inhalation only and can also result in non-carcinogenic toxicity (Health Canada 2004, Health Canada 2009, U.S. EPA 2009). Rodent and occupational studies have demonstrated that the critical carcinogenic endpoint for cadmium is lung cancer. Based on occupational studies, it has been shown that the critical non-carcinogenic effect endpoint for cadmium is significant proteinuria (U.S. EPA 2009). Proteinuria involves large amounts of protein in the urine, and often results from damage to the kidneys.

Both the U.S. EPA (2009 – updated in 1994) and Health Canada (2009) have derived an oral TRV for non-carcinogenic effects of 0.001 mg/kg-d. The TRV is derived based on an epidemiological study of occupational exposure.

G.6.3 Cobalt

The U.S. EPA and Health Canada do not provide exposure limits for non-cancer health effects resulting from oral exposure to cobalt. The ATSDR (2004a) provides an oral MRL of 0.01 mg/kg-d. This is based on a LOAEL of 1 mg/kg-d for haematological effects, using an uncertainty factor of 10 to account for the use of a LOAEL and an additional factor of 10 to account for human variability. This value was used in the assessment.

G.6.4 Copper

The U.S. EPA (2009) does not provide an oral RfD for copper or copper compounds, with the exception of copper cyanide. The ATSDR (2004b) provides an oral MRL for acute and intermediate duration exposure, does not provide a chronic copper MRL, citing an inadequate database. Health Canada (2009) suggests the use of a chronic TDI of 0.09 mg/kg-d (although age-depended values were derived the values were similar thus the lowest TRV was selected). The value is based on the assessment conducted by the Institute of Medicine and is based on hepatotoxicity and gastrointestinal effects following excess intake from food and supplements.

G.6.5 Lead

Neither the U.S. EPA nor the ATSDR provide non-carcinogenic oral TRVs for chronic exposure to lead. The JECFA established a provisional tolerable weekly intake (pTWI) of 0.025 mg/kg in 1986 for lead exposure to children, and has reconfirmed this value (WHO 2000). This is equivalent to an RfD of 0.0035 mg/kg-d. Health Canada (2004a) provides a very similar oral TDI of 0.0036 mg/kg-d; however, the toxicological rationale and endpoint are not explicitly stated. The Ontario Ministry of the Environment and Energy (MOEE 1994a, b) developed an Intake of Concern (IOC) for lead exposure for neurological effects. To determine the IOC, an uptake of 0.21 µg/dL per µg/d was used in conjunction with a 10 µg/dL blood lead level to provide an individual IOC (IOC_{ind}) of 47.6 µg/d, or 3.6 µg/(kg-d) for a 13 kg child (0.5 to 4 years of age). To derive an IOC for the population (IOC_{pop}), the Ontario Ministry of Energy and Environment applied an uncertainty factor of 2 to the IOC_{ind}, resulting in an IOC_{pop} of 1.85 µg/(kg-d). The Health Canada derived value of 0.0036 mg/kg-d (3.6 µg/(kg-d)) is used in this assessment.

G.6.6 Molybdenum

The U.S. EPA (2009, last updated 1993) provides an oral RfD of 0.005 mg/kg-d based on a LOAEL of 0.14 mg/kg-d for increased uric acid levels in people following oral exposure to molybdenum. This value was derived from data from a cross sectional epidemiological study, using an uncertainty factor of 30. The overall confidence in the RfD is medium. Health Canada (2009) provides a TRV of 0.023 mg/kg-d (although age-depended values were derived the values were similar thus the lowest TRV was selected). The value is based on the assessment conducted by the Institute of Medicine and is based on a reproductive endpoint. It is based on a subchronic study on rats exposed to molybdenum in drinking water. An uncertainty of 30 was applied; a factor of 10 for interspecies variability and a factor of 3 for intraspecies variability. As the U.S. EPA value is more conservative it was retained for use in the assessment.

G.6.7 Nickel

The U.S. EPA (2009, last updated 1996) provides an oral RfD of 0.02 mg/kg-d for soluble nickel salts based on decreased body and organ weights in rats after being fed nickel in the diet for 2 years. An uncertainty factor of 10 is used for interspecies extrapolation and 10 to protect sensitive populations. An additional uncertainty factor of 3 is used to account for inadequacies in the reproductive studies. The overall confidence in the RfD is medium. The ATSDR does not provide oral MRLs for acute, intermediate, or chronic duration exposure to nickel. Health Canada (2004a) provides an oral non-carcinogenic TDI of 0.0013 mg/kg-d for nickel chloride and 0.05 mg/kg-d for nickel sulphate, based on the Priority Substances List for nickel (EC/HC 1994). The toxicological rationale for the selection of these TDIs, including the endpoints, is not clear. In the Health Canada PQRA model the TRV for nickel is 0.011 mg/kg-d which is consistent with the update for soil quality (Health Canada 2009). This value is based on a 2-generation reproductive toxicity test on rats. An uncertainty factor of 100 is applied (a factor of 10 for each intra- and interspecies variability). The Health Canada of 0.011 mg/kg-d was selected as the primary TRV for nickel.

G.6.8 Selenium

The U.S. EPA (2009, last updated 1991) provides an oral RfD of 0.005 mg/kg-d, based on a NOAEL of 0.015 mg/kg-d from a study of clinical and biochemical signs of selenium intoxication in individuals living in an area of China with unusually high environmental concentrations of selenium (Yang and Zhou 1994, as cited in IRIS (U.S. EPA 2009, last updated 1991)). To derive the RfD, a factor of 3 was applied to account for human variability, and was considered appropriate because the individuals in the study were sensitive individuals drawn from the larger study population. This value is also derived by the ATSDR (2003) for recovery from clinical selenosis, using data from a follow up study to that used in the derivation by the U.S. EPA. Health Canada (2002) provides a food-based provisional TDI of 0.75 mg/day. Using a body weight of 70.7 kg, this equates to a TDI of 0.01 mg/kg-d. The toxicological endpoint and effects are not reported.

Health Canada (2009) provides a TRV of 0.0055 mg/kg-d (although age-depended values were derived the values were similar thus the lowest TRV was selected). The value is based on the assessment conducted by the Institute of Medicine and is based on selenosis. It is based epidemiological studies on exposure to selenium.

The U.S. EPA value is used in this assessment as it provides a more conservative estimate of health hazards although it is noted that the Health Canada value is very similar.

G.6.9 Uranium

Oral exposure limits for uranium were available from Health Canada (2001, 2002) and the U.S. EPA (2009, last updated 1989). Health Canada (2002) provides a food-based provisional TDI of 0.0015 mg/kg-d for reversible kidney effects, derived by the Toxicology Evaluation Section of the Chemical Health Hazard Assessment Division of Health Canada. Health Canada (2001) also provides a TDI of 0.0006 mg/kg-d, based on a subchronic study in which rats were administered uranyl nitrate hexahydrate in drinking water for 91 days. The study's endpoint was renal effects, with a LOAEL of 0.96 mg/L for degenerative lesions in the proximal convoluted tubule of the kidney in male rats. This study provides the basis for the uranium drinking water guideline. This value is repeated in Health Canada 2009. The U.S. EPA (2009, last updated 1989) provides an RfD of 0.003 mg/kg-d for uranium soluble salts, for which the toxicological endpoint is initial body weight loss and moderate nephrotoxicity. The Health Canada (2001) TDI is selected as the TRV over the value provided by the U.S. EPA because the site falls under Canadian jurisdiction and because the use of this value is more conservative. The Health Canada (2001) value of 0.0006 mg/kg-d is selected over the Health Canada (2002) value of 0.0015 mg/kg-d since it is more restrictive.

G.6.10 Zinc

The U.S. EPA (2009, last updated 2005) provides an oral RfD of 0.3 mg/kg-d for zinc, based on a LOAEL of 0.9 mg/kg-d. This value is based on a 47% decrease in erythrocyte Cu, Zn-superoxide dismutase (ESOD) activity in adult females after 10 weeks of zinc exposure. Copper status and ESOD activity are considered a sensitive measure of the effects of high levels of zinc exposure, with a reduced copper status being associated with an increased zinc intake. The ATSDR (2005) provides this same TRV, based on the same study.

Health Canada (2009) provides a TRV of 0.5 mg/kg-d (although age-depended values were derived the values were similar thus the lowest TRV was selected). The value is based on the assessment conducted by the Institute of Medicine and is based on a significant decrease in ESOD activity in adults and increased infant growth, and length, weight and head circumference As the U.S. EPA value is more conservative it was retained for use in the assessment.

Table G.6-1 Selected Oral TRVs for Human Receptors

Chemical	Effect Type [a]	Value [b]	Health Effect	Reference [c]
Arsenic	C	1.8	Internal cancers (liver, lung, bladder, kidney) (oral, human)	Health Canada (2009)
	NC	0.001	Not provided	Health Canada Food Directorate (2002)
Cadmium	NC	0.001	Significant proteinuria	Health Canada (2009) IRIS (U.S. EPA 2009, last updated 1994)
Cobalt	NC	0.01	Haematological effects (polycythemia)	ATSDR (2004a)
Copper	NC	0.09	Hepatoxicity	Health Canada (2009)
Lead	NC	0.0036	Increase in blood lead concentrations in infants	Health Canada (2004c)
Molybdenum	NC	0.005	Increased uric acid levels	IRIS (U.S. EPA 2009, last updated 1993)
Nickel	NC	0.011	Decreased body and organ weights (oral exposure, rats)	Health Canada (2009)
Selenium	NC	0.005	Clinical selenosis	IRIS (U.S. EPA 2009, last updated 1991)
Uranium	NC	0.0006	Degenerative lesions in kidney tubules	Health Canada (2001)
Zinc	NC	0.3	Diminished copper status (required for protection against free radicals and oxidative stress)	IRIS (U.S. EPA 2009, last updated 2005)

Table G.6-1 Selected Oral TRVs for Human Receptors

Notes:
a - C is carcinogenic (non-threshold) effect; NC is non-carcinogenic (threshold) effect
b - All values are in mg/kg-d except for carcinogenic (C) TRV for arsenic which is in $(mg/(kg\text{-}d))^{-1}$
c - IRIS - Integrated Risk Information System on-line database (last updated represents year of last significant revision)
ATSDR – Agency for Toxic Substances and Disease Registry

G.6.11 NOx, SO2 and Particulate Matter

In general, the adverse effects of exposure to gaseous air pollutants are associated with irritation of the tissues of the eyes and upper and lower respiratory systems. Exposures to the gaseous air pollutants (i.e., SO_2, NO_2) are assessed using values obtained from the WHO that are designed to offer guidance in reducing the health impacts of air pollution. The NO_2 guidelines are health-based values with no safety factors built in and are not targets, while the SO_2 values (Tier I and II) are only targets whereas the guideline is health-based. However, since no other TRVs are presently available to evaluate the health effects relating to NO_2 and SO_2 exposure, and since the WHO values are the most current health-based values available, they were used as health-based values in the assessment.

For NO_2, the WHO short-term guideline is based on human and animal studies which indicate that adverse effects are not observed at concentrations below 200 $\mu g/m^3$ (WHO 2005). Studies on bronchial responsiveness in asthmatics show an increased responsiveness at concentrations above 200 $\mu g/m^3$ and laboratory studies show a direct effect on pulmonary function in asthmatics at concentrations in the order of 560 $\mu g/m^3$. The use of the 200 $\mu g/m^3$ is protective of sensitive individuals (i.e., asthmatics) and therefore needs no built in safety factors. The annual guideline of 40 $\mu g/m^3$ is set to protect the public from gaseous effects of NO_2 (WHO 2005). This is based on the fact that no abatement methods are designed to reduce NO2 (WHO 2005). Epidemiological evidence in children with asthma indicates that bronchitic symptoms increase with increasing NO_2 concentrations. There are also studies which indicate that there is some evidence of effects of respiratory symptoms in infants below 40 $\mu g/m^3$ (WHO 2005). However, there are other confounding variables which make it difficult to determine whether the effects are due only to NO_2, or whether they are due to a mixture of air pollutants. Thus, the WHO indicates that there is insufficient health-based evidence at present to warrant changing the annual NO_2 guideline from the current value of 40 $\mu g/m^3$. Thus the WHO guidelines for NO_2 for acute (200 $\mu g/m^3$) and chronic (40 $\mu g/m^3$) exposures that are used in the assessment are based on the protection of sensitive individuals and are therefore health-based values.

The short-term (10 minute) value from the WHO for SO_2 of 500 $\mu g/m^3$ is based on asthmatics that showed changes in pulmonary function as well as respiratory symptoms after short-term exposure while exercising. Although the value of 500 $\mu g/m^3$ was based on 10 minute exposure, it has been used in the assessment for evaluation of 1 hour exposure effects and is a health-based value since the WHO indicates that scaling in not appropriate.

The 24 hour guideline for SO_2 has been updated in 2005 by the WHO; the new guideline is approximately 6 times lower than the 2000 guideline value and is based on epidemiological studies from 2003 onwards. These studies indicated that there was a major decrease in childhood respiratory disease and all-age mortality when the sulphur content in fuels was substantially reduced. Several studies by Wong et al. (2002), Pope et al. (2002) and Burnett el al. (2004) indicate that there is no threshold for health effects for 24 hour exposure to SO_2 concentrations in the range of 5 to 40 µg/m^3. The guideline has therefore been set at 20 µg/m^3. The WHO acknowledges the difficulty in achieving the new guideline value in the short-term, and has suggested a stepped approach using a tier I interim value of 125 µg/m^3. This is the previous guideline value (WHO 2000), which was derived by applying an uncertainty factor of 2 to a LOAEL for day-to-day changes in mortality, morbidity or lung function. The tier II interim value of 50 µg/m^3 is an intermediate goal based on a reduction of motor vehicle emissions, industrial emissions and/or emissions from power plant production. The WHO suggests that this is a reasonable and feasible goal for some developing countries and would lead to significant health improvements. In this assessment potential risks were calculated in comparison to the guideline value of 20 µg/m^3. It should be noted that these recommended guideline values for sulphur dioxide are not linked with guidelines for particles. WHO further noted in their Air Quality Guidelines Global Update (2005) that an annual guideline for SO_2 is not necessary since compliance with the 24 hour level will ensure low levels for the annual average. Therefore, no annual health-based guideline is provided.

Particulate matter (PM) describes all airborne solid and liquid particles of microscopic size, with the exception of pure water. The suspended portion of PM generally consists of particles less than 40 to 50 microns (µm) in diameter. These particles include a broad range of chemical species, such as elemental and organic carbon compounds, sulphates, nitrates and trace metals.

There is a growing body of scientific studies linking air pollutants to health effects. Recent assessments of the available health data are implying a stronger link between PM and health effects resulting from short- and long-term exposures. In addition, the effects are estimated to occur at levels that are lower than previously believed. This has motivated some regulators to re-assess the potential impact of particulate matter pollution on public health (CARB 2008). Many studies over the past few years have indicated that PM in the air aggravates symptoms of asthma, chronic pneumonia and cardiovascular problems in those people who already suffer from compromised respiratory systems.

The emphasis on particulate matter has been moving to the finer fractions of PM over the last 30 years as health studies and monitoring equipment have advanced to be able to detect differences in the particulate matter fractions. In the last 5 to 10 years health impact studies have been focussing on the impacts of particles less than 2.5 µm in diameter ($PM_{2.5}$) or ultrafine particles which are less than 0.1 µm in diameter (nanoparticles, PM0.1). Due to their small size, $PM_{2.5}$ and $PM_{0.1}$ have the ability to reach the alveoli and penetrate deep into the lung. Their large surface area to volume ratio also gives these particles a greater capacity than PM_{10} to carry bound chemical components with them into the lung. The combination of these properties gives these particles an increased potential to cause adverse health effects. Additionally, $PM_{2.5}$ and $PM_{0.1}$ are less likely than PM_{10} to be coughed out. In essence, the smaller the particle the greater the capacity to produce potentially serious respiratory and cardiovascular complications. As such, evaluation of health effects from exposure to PM tends to focus on the finer fractions. With that said, however, there are currently no criteria for evaluation of ultrafine particles and thus quantitative evaluation is generally carried out using $PM_{2.5}$ standards. The effects of $PM_{0.1}$ and $PM_{2.5}$ are essentially the same from a qualitative standpoint.

The U.S. EPA has revoked their PM_{10} standard due to a lack of evidence linking health problems to long-term exposure to coarse particle pollution. In addition, the Canadian Federal government has not developed a PM_{10} Canada Wide Standard due to insufficient knowledge on the appropriateness of the standard. The federal government also recognizes that initiatives to reduce $PM_{2.5}$ will also likely reduce PM_{10} concentrations.

The Canadian Environmental Protection Agency Federal Provincial Agency Committee Working Group on Air Quality Objectives and Guidelines (CEPA/FPAC WGAQOG 1998) recommend a reference level of 25 µg/m3 on a 24 hour averaging time for PM_{10} given the consistent associations observed in epidemiological studies with mortality and hospitalizations as well as concerns over links to chronic bronchitis and cardiovascular disease. The recommended reference level for $PM_{2.5}$ is 15 $\mu g/m^3$ on a 24 hour averaging time.

The WHO Working Group (2005) state that although clearly defined thresholds in exposure-response relationships for health effects from both long-term and short-term exposure are not available, adverse health effects from fine PM exposure are occurring at the levels of exposure currently experienced in urban areas in Europe. Since the conclusions were based on multi-city studies in the U.S., Canada and Europe, it suggests that health impacts also occur at fine PM levels commonly observed in Canada. The WHO state that there is little evidence to suggest that there is a threshold value for $PM_{2.5}$ below which adverse health effects are not anticipated since adverse health effects have been observed at PM2.5 concentrations of 3 to 5 $\mu g/m^3$. As such, the standard-setting process needs to aim at achieving the lowest concentrations possible and thus the WHO present numerical guidelines and interim target values to reflect the concentrations at which increased mortality due to PM air pollution is expected. The 24 hour and annual mean guidelines provided by the WHO are 10 $\mu g/m^3$ and 25 $\mu g/m^3$, respectively, for $PM_{2.5}$ and 20 $\mu g/m^3$ and 50 $\mu g/m^3$, respectively, for PM_{10}. The 24 hour guideline for $PM_{2.5}$ is based on the relationship between 24 hour and annual PM levels while the annual $PM_{2.5}$ guideline represents the lowest levels at which total, cardiopulmonary and lung cancer mortality have been shown to increase with more than 95% confidence in response to long-term exposure to $PM_{2.5}$ (WHO 2005). The PM_{10} values are double the $PM_{2.5}$ values. The WHO also provides three interim targets (IT). For exposure to $PM_{2.5}$, the 24 hour IT-1, -2 and -3 values are 75 μg/m^3, 50 μg/m^3 and 37.5 μg/m^3, respectively, while the annual values are 35 μg/m^3, 25 μg/m^3 and 15 μg/m^3, respectively. The PM_{10} values are again simply double the $PM_{2.5}$ values.

The California Environmental Protection Agency Air Resources Board does not have the same view. In a recent report (CARB 2008), a threshold level for $PM_{2.5}$ exposure of 7 μg/m^3 was suggested, since this was the lowest observed concentration in an American Cancer Society study carried out by Pope et al. (2002). This large cohort study provided evidence that exposure to $PM_{2.5}$ as low as 7 μg/m^3 can be associated with premature death. In addition, a level of 5 μg/m^3 was also considered since it represented a concentration for the lowest observed short term levels associated with mortality (Ostro et al. 2006; Schwartz et al. 2002; Schwartz et al. 2002). The report was endorsed by a number of scientific advisors well known in the fine particulate area.

For PM_{10}, the reference level of 25 μg/m^3, based on a 24 hour averaging time which resulted in consistent associations observed in epidemiological studies with mortality and hospitalizations as well as concerns over links to chronic bronchitis and cardiovascular disease (CEPA/FPAC WGAQOG 1998), was selected as a health-based limit.

A threshold value of 7 μg/m^3 (CARB 2008) was used as the health-based level for $PM_{2.5}$ (which encompasses ultrafine particles) and the epidemiological evidence related to short-term exposures are the most relevant to consider in this assessment. This threshold range was also considered in this assessment as a health-based limit.

G.7 References

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Attachment H Ecological Dose Calculations

H.1 Aquatic Dose Calculations

Table H.1-1 provides the dose calculations for aquatic receptor exposure to radionuclides for the maximum mean and maximum 95th percentile predicted concentrations. Following is a sample calculation for predatory fish.

Table H.1-1

Concentrations - Mean, Year 10 of Operation, JSL @ Kiggavik WTP Discharge

			U-238+	Th-230	Ra-226+	Pb-210+	Po-210	
Water concentration	Bq/m^3	Watc	1.58	7.54	4.84	13.29	5.99	calculated in model
Sediment concentration	Bq/g dw	Sedc	0.03	0.04	0.04	0.05	0.05	calculated in model
Fish concentration	Bq/g ww	Fishc	2.21E-05	2.96E-04	4.20E-04	1.09E-03	2.03E-03	calculated in model

Doses - Fish, Predatory

			U-238+	Th-230	Ra-226+	Pb-210+	Po-210	Subtotal	
Internal Dose Factor	mGy/d per Bq/g	Idcff	1.42E-01	6.58E-02	1.59E-01	6.03E-03	7.40E-02		
Internal dose	mGy/d	Iadf	3.14E-06	1.95E-05	6.67E-05	6.60E-06	1.50E-04	2.5E-04	=fishc*Idcff
External dose factor	mGy/d per Bq/g	Edcff	8.57E-03	2.93E-05	3.68E-02	2.50E-03	1.40E-07		
External dose	mGy/d	Eadf	1.35E-08	2.21E-10	1.78E-07	3.32E-08	8.38E-13	2.3E-07	'=wc*Edcff/1000000
Total dose - absorbed	mGy/d	Tadfp	3.15E-06	1.95E-05	6.69E-05	6.64E-06	1.50E-04	2.5E-04	'=Iadf+Eadf
RBE for alpha	-	RBE	10						
Total dose - equivalent	mGy/d	Tedfp	3.14E-05	1.95E-04	6.67E-04	6.60E-06	1.50E-03	2.4E-03	=Iadf*RBEf+Eadf, except for Pb-210 (RBE not applied)
Dose limit	mGy/d	Limit						9.60E+00	N288.6 CSA 2012
Screening Index - equivalent	-	SI-eq						**2.5E-04**	=Tedfp/Limit
Screening Index - Table 8.1.3, Tier 3, Technical Appendix 8A	-	Result						**<0.001**	for JSL-2, average, RBE 10, maximum mean

H.2 Terrestrial Dose Calculations

Table H.2-1 provides the dose calculations for terrestrial receptor exposure to radionuclides using a RBE of 10 and a dose limit of 2.7 mGy/d. Terrestrial dose calculations are presented for baseline (2010), year 10 of operation (2023), year 5 of final closure (2043), year 15 of final closure (2053), and year 5 for post closure (2065).

Following is a sample calculation for merganser, RBE 10 and dose rate limit of 2.7 mGy/d.

Table H.1-2

Merganser Characteristics									
Body weight	kg	Bwmer	1.0		Cornell, 2003				
Water ingestion rate	m^3/d	WIRmer	0.00006	T(3E-5, 6E-5, 9E-5)	U.S. EPA, 1993, allometric scaling				
Food ingestion rate	g FW/d	FIRmer	435	T(305, 435, 566)	U.S. EPA, 1993, allometric scaling + 50% arctic adjustment				
fraction sediment	-	fsed	0.004		calculated from Beyer *et al*., 1994.				
fraction fish	-	ffish	0.996		Based on information from Becker and Fraser 2006, NatureServe 2008, Cornell 2003				
Fraction of time at site	-	fmer	1		assumed				
Concentrations - Mean, Year 10 of Operation, JSL @ Kiggavik WTP Discharge									
			U-238+	**Th-230**	**Ra-226+**	**Pb-210+**	**Po-210**		
Water concentration	Bq/m^3	Watc	1.58	7.54	4.84	13.29	5.99	calculated in model	
Sediment concentration	Bq/g dw	Sedc	0.03	0.04	0.04	0.05	0.05	calculated in model	
Fish concentration	Bq/g ww	Fishc	2.21E-05	2.96E-04	4.20E-04	1.09E-03	2.03E-03	calculated in model	
Calculation for Merganser									
			U-238+	**Th-230**	**Ra-226+**	**Pb-210+**	**Po-210**		
Intake of COC from water	Bq/d	Iwmer	9.5E-05	4.5E-04	2.9E-04	8.0E-04	3.6E-04	=WIRmer*Watc*fmer	
Intake of COC from sediment	Bq/d	Ismer	5.6E-02	7.2E-02	6.4E-02	9.4E-02	9.6E-02	=FIRmer*fsed*Sedc*fmer	

Table H.1-2

Intake of COC from fish	Bq/d	Ifsmer	9.6E-03	1.3E-01	1.8E-01	4.7E-01	8.8E-01	=FIRmer*ffish*fish-wshd*fmer/1000 grams per kilogram
Total intake	Bq/d	Itotmer	6.6E-02	2.0E-01	2.5E-01	5.7E-01	9.8E-01	=Iwmer+Ismer+Ifsmer
Transfer factor - feed to flesh	d/g	Tfmer	2.0E-04	8.4E-04	1.7E-03	2.1E-02	6.5E-03	model input, average value
Merganser concentration	Bq/g	Merc	1.3E-05	1.7E-04	4.1E-04	1.2E-02	6.4E-03	=Itotmer*Tfmer
Internal dose factor	mGy/d per Bq/g	DCF	1.4E-01	6.6E-02	1.6E-01	6.0E-03	7.4E-02	derived from Amiro 1997
Internal dose rate	mGy/d	Intdose	1.9E-06	1.1E-05	6.6E-05	7.3E-05	4.7E-04	=Merc*DCF
External gamma	uGy/h	Extgamma	0.04					model output
External dose rate	mGy/d	Extdose	9.6E-04					=Extgamma*fmer *24 hrs/d * 1mGy/1000 uGy
Total dose- absorbed	mGy/d	Totdose	1.6E-03					=Intdose+Extdose
RBE	-	RBE	10					
High LET dose rate	mGy/d	HLETDR	7.4E-05	4.4E-04	2.6E-03	7.3E-05	1.9E-02	=Intdose*RBE, except Pb-210
Low LET dose rate	mGy/d	LLETDR	9.6E-04					=Extdose
Total dose- equivalent	mGy/d	Totdose-eq	2.3E-02					=HLETDR+LLETDR
Dose Rate Limit	mGy/d	Limit	2.7					N288.6 CSA 2012
Screening Index - Equivalent	-	SI-eq	**6.5E-03**					
Screening Index - Table 8.2.17, Tier 3, Technical Appendix 8A	-	Result	**<0.01**					for mean, year 10 of operation, JSL @ Kiggavik WTP Discharge

H.3 Aquatic Receptor Calculation For Non-Radionuclides

Following is a sample calculation for predator fish exposure to arsenic.

Arsenic Concentrations - Mean, Year 10 of Operation, JSL @ Kiggavik WTP Discharge (JSL-2)				
Water concentration	ug/L	Watc	0.37	calculated in model
Sediment concentration	ug/g dw	Sedc	8.55	calculated in model
Fish concentration	ug/g ww	Fishc	0.08	calculated in model

Doses - Fish, Predator				
TRV	ug/L	TRVfish	6.30E+02	Table 6.3-1
Screening Index	-	SI	**5.82E-04**	=Watc/TRVfish
Screening Index - Table 8.1.1, Tier 3, Technical Appendix 8A	-	Result	**<0.01**	for JSL-2, maximum mean

H.4 Terrestrial Receptor Calculation For Non-Radionuclides

Following is a sample calculation for merganser exposure to arsenic.

Merganser Characteristics					
Body weight	kg	Bwmer	1.0		Cornell, 2003
Water ingestion rate	m^3/d	WIRmer	0.00006	T(3E-5, 6E-5, 9E-5)	U.S. EPA, 1993, allometric scaling
Food ingestion rate	g FW/d	FIRmer	435	T(305, 435, 566)	U.S. EPA, 1993, allometric scaling + 50% arctic adjustment
fraction sediment	-	fsed	0.004		calculated from Beyer *et al*., 1994.
fraction fish	-	ffish	0.996		Based on information from Becker and Fraser 2006, NatureServe 2008, Cornell 2003
Fraction of time at site	-	fmer	1		assumed

Arsenic Concentrations - Mean, Year 10 of Operation, JSL @ Kiggavik WTP Discharge

Water concentration	ug/L	Watc	0.37	calculated in model
Sediment concentration	ug/g dw	Sedc	8.55	calculated in model
Fish concentration	ug/g ww	Fishc	0.08	calculated in model

Calculation for Merganser

Intake of COC from water	mg/d	Iwmer	2.2E-05	=WIRmer*Watc*fmer
Intake of COC from sediment	mg/d	Ismer	1.5E-02	=FIRmer*fsed*Sedc*fmer*1mg/1000ug
Intake of COC from fish	mg/d	Ifsmer	3.3E-02	=FIRmer*ffish*fish-wshd*fmer/1000 grams per kilogram
Total intake	mg/d	Itotmer	4.8E-02	=Iwmer+Ismer+Ifsmer
Total intake - by body weight	mg/kg-d	Itotmer-bw	4.8E-02	=Itotmer/Bwmer
TRV - LOAEL	mg/kg-d	TRVmer	5.1E+00	Table 6.3-3
Screening Index	-	SI	**9.3E-03**	=Itotmer-bw/TRVmer
Screening Index - Table 8.2.11, Tier 3, Technical Appendix 8A	-	Result	**0.01**	for mean, year 10 of operation, JSL @ Kiggavik WTP Discharge