- kimberlite only;
- kimberlite and peat;
- kimberlite and lake sediment;
- kimberlite, lake sediment and peat;
- kimberlite and sewage sludge;
- kimberlite, lake sediment and sewage sludge;
- kimberlite, lake sediment, sewage sludge and peat; and
- kimberlite and pulp and paper waste.

Soil samples were obtained from four depths (0 to 10 cm, 10 to 20 cm, 20 to 30 cm and 30 to 60 cm). Three soil samples were collected from random locations within each treatment plot and were combined to form one composite sample for each depth. Maximum soil concentrations from each soil amendment plot were calculated and used in the screening process of the risk assessment as detailed in Appendix II, Section 3.

Soil concentrations used in the risk assessment are presented in Tables I-1 and I-2, for the reference areas and the LLCF, respectively.

Table I-1
Soil Concentrations from Samples Collected from the Reference Sites

Parameter	Concentration (mg/kg)								
	Mine Site				Arnie Exploration Site				Wet Meadow
	HM-A	HM-B	HM-C	Mean (a)	HM-E	HM-F	HM-G	Mean (a)	
Aluminum	10,100	7,290	12,200	9,863	12,800	11,800	11,800	12,133	15,500
Arsenic	3	2.2	6	3.7	3.8	4.3	3.7	3.9	5.6
Barium	64	52	78	65	325	110	156	197	97
Beryllium	0.4	0.3	0.5	0.4	0.4	0.4	0.4	0.4	0.5
Bismuth	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Boron	4	2	4	3.3	5	6	6	5.7	3
Cadmium	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Calcium	1,300	1,400	1,900	1,533	2,000	2,500	2,600	2,367	1,400
Chromium	31.7	24.5	38.6	31.6	58.2	48.2	54.3	53.6	52.9
Cobalt	5.4	5.1	10.6	7	8.8	7.3	7.9	8	7.7
Copper	10	8	22	13.3	19	10	13	14	23
Iron	11,600	8,700	14,500	11,600	16,400	16,300	15,900	16,200	18,000
Lead	3.2	3	4.1	3.4	4.5	4.3	4.6	4.5	4.5

Parameter	Concentration (mg/kg)								
	Mine Site				Arnie Exploration Site				Wet Meadow
	HM-A	HM-B	HM-C	Mean [(a)]	HM-E	HM-F	HM-G	Mean [(a)]	
Magnesium	5,340	4,810	6,150	5,433	8,110	6,460	7,610	7,393	7,270
Manganese	122	99.5	190	137	177	177	173	176	165
Molybdenum	0.3	0.2	1.3	0.6	0.5	0.5	0.4	0.5	0.5
Nickel	19.2	20.2	25.2	21.5	42.1	30.1	38	36.7	33.1
Potassium	2,850	2,180	3,340	2,790	3,560	3,270	3,190	3,340	3,110
Selenium	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Silver	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Sodium	160	130	220	170	130	120	130	127	150
Strontium	7	7	12	8.7	26	16	23	21.7	10
Thallium	0.19	0.14	0.23	0.2	0.21	0.21	0.21	0.2	0.25
Tin	1	1.1	1	1	<0.1	0.1	0.1	0.1	0.8
Titanium	661	529	756	649	812	808	823	814	918
Uranium	1.7	1.8	2.6	2	2.2	2.2	2.2	2.2	3.3
Vanadium	28.3	20.8	33	27.4	36.1	34.6	36.1	35.6	39
Zinc	38	28	47	38	39	37	37	38	53

[(a)] Calculations were based on half detection limits for parameter concentrations less than detection limits.

Table I-2
Soil Concentrations from Samples Collected from the LLCF

Parameter	Concentration (mg/kg)																								
	Kimberlite			Kimberlite and Sewage Sludge			Kimberlite and Lake Sediment			Kimberlite and Sewage Sludge and Lake Sediment			Kimberlite and Lake Sediment and Peat			Kimberlite and Peat			Kimberlite and Lake Sediment and Peat and Sewage Sludge			Kimberlite and Pulp Paper Waste			Maximum [a]
	BI [b]	BII [b]	BIII [b]	BI	BII	BIII	BI	BII	BIII	BI	BII	BIII	BI	BII	BIII	BI	BII	BIII	BI	BII	BIII	BI	BII	BIII	
Aluminum	8,800	9,660	5,780	8,850	7,590	8,370	6,680	8,710	8,890	8,730	8,880	9,740	6,790	8,360	7,240	7,620	6,930	8,580	6,770	9,050	6,900	8,410	5,700	8,660	9,740
Arsenic	4.6	6.1	3.3	4.4	3.7	4.3	3.5	4.0	3.9	3.7	5.0	4.3	3.3	5.8	3.7	4.7	3.9	5.0	3.8	3.8	3.6	4.5	3.5	4.0	6.1
Barium	577	685	387	605	495	551	362	450	442	438	516	508	357	433	370	510	502	684	370	488	335	622	415	579	685
Beryllium	0.4	0.5	0.2	0.5	0.4	0.4	0.3	0.4	0.4	0.4	0.5	0.5	0.3	0.5	0.4	0.5	0.4	0.5	0.3	0.5	0.3	0.4	0.3	0.4	0.5
Bismuth	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	0
Boron	5.0	4.0	2.0	3.0	2.0	3.0	<2	2.0	3.0	3.0	3.0	3.0	<2	3.0	2.0	4.0	3.0	4.0	<2	2.0	3.0	3.0	<2	4.0	5
Calcium	15,500	17,700	9,100	14,400	13,200	13,300	11,700	10,500	10,300	11,800	15,000	13,000	8,900	11,600	12,000	14,400	13,500	15,700	9,900	14,200	8,800	14,300	9,800	16,400	17,700
Cadmium	0.5	0.5	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.2	0.3	0.3	0.2	0.2	0.3	0.5	0.5	0.4	0.2	0.3	0.2	0.4	0.3	0.3	0.5
Chromium	288	293	254	309	314	308	246	191	245	256	277	251	232	241	237	300	306	278	249	234	250	289	279	328	328
Cobalt	67.4	64.7	78.4	69.4	74.9	73.3	65.1	43.1	55.6	60.0	60.4	52.8	57.4	53.5	57.9	74.7	71.4	59.6	63.0	51.1	61.6	68.5	79.7	77.8	79.7
Copper	16	19	13	19	14	17	14	17	16	16	17	16	14	15	16	17	14	20	13	19	12	19	13	18	20
Iron	37,600	38,200	40,700	37,400	39,100	39,000	34,400	26,200	31,800	34,300	34,300	31,500	30,600	30,100	31,200	41,200	39,200	34,700	33,400	30,600	32,500	37,700	40,800	43,200	43,200
Lead	5.9	6.9	4.0	6.0	5.1	5.6	4.4	5.5	4.9	4.8	5.2	5.5	4.2	4.9	4.5	5.3	4.9	6.5	4.1	5.4	4.2	6.0	4.2	5.5	6.9
Magnesium	156,000	146,000	186,000	158,000	173,000	172,000	153,000	95,400	127,000	138,000	137,000	119,000	150,000	140,000	154,000	176,000	170,000	137,000	172,000	114,000	142,000	161,000	193,000	182,000	193,000
Manganese	699	735	684	688	706	682	593	458	552	610	677	568	527	539	545	728	702	643	592	596	560	708	697	851	851
Molybdenum	1.6	2.0	1.2	1.4	1.1	1.4	1.0	1.1	0.8	1.1	1.7	1.7	1.3	1.9	1.6	2.5	2.6	2.5	2.4	1.4	1.4	1.6	0.8	1.0	2.6
Nickel	1,160	1,090	1,380	1,190	1,320	1,280	1,150	719	967	1,050	1,040	894	1,020	912	1,000	1,280	1,250	1,010	1,110	868	1,080	1,200	1,430	1,360	1,430
Potassium	2,790	2,900	1,920	2,650	2,490	2,540	2,230	2,980	3,060	3,050	3,190	3,360	2,470	2,830	2,490	2,460	2,060	2,390	2,490	3,260	2,420	2,610	1,880	3,170	3,360
Selenium	0.6	0.8	0.5	0.6	0.5	0.6	0.5	0.4	0.4	0.5	0.4	0.4	0.4	0.5	0.5	0.6	0.5	0.8	0.4	0.5	0.4	0.6	0.5	0.4	0.8
Silver	<0.1	0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.1
Sodium	300	270	200	280	280	290	200	200	250	260	280	270	220	300	310	280	250	280	260	230	240	280	200	280	310
Strontium	231	253	150	245	211	225	175	178	173	179	222	207	146	184	180	215	200	263	154	207	143	244	165	243	263
Thallium	0.2	0.3	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.26
Tin	0.4	0.4	0.4	0.4	0.4	0.4	0.5	0.5	0.6	0.6	0.6	0.5	0.6	0.6	0.6	0.4	0.5	0.4	0.5	0.7	0.5	0.4	0.4	0.6	0.7
Titanium	250	212	154	252	242	245	221	281	330	358	354	346	259	305	262	210	212	242	242	348	256	215	154	344	358
Uranium	2.1	2.5	1.5	1.9	1.6	1.8	1.6	1.9	1.8	1.8	1.8	1.9	1.6	1.7	1.6	2.0	1.7	2.1	1.4	1.9	1.5	1.8	1.3	1.9	2.5
Vanadium	31	30	21	32	29	30	22	28	29	31	34	33	24	29	25	26	26	27	24	31	25	27	20	33	33.7
Zinc	64	68	56	61	57	58	50	52	59	53	54	55	50	55	57	66	62	67	50	53	52	64	57	60	68

[a] Calculations were based on half detection limits for parameter concentratons less than analytical detection limits.

[b] BI, BII and BIII refer to sample Block 1, Block 2 and Block 3 revegetation plots on the LLCF.

I.3 Vegetation

Amendment plots within the LLCF were seeded with seven mixed northern grasses including alyeska polargrass (*Arctagrotis latifolia*), bluejoint reedgrass (*Calamagrotis canadensis*), tundra bluegrass (*Poa glauca*), alpine bluegrass (*Poa alpine*), bering hairgrass (*Deschampsia beringensis*), Norton hairgrass (*Deschampsia caespitosa* var. Norton) and arctared fescue (*Festuca rubra*). An alkali grass (*Puccinellia distans*) was also present. Alkali grass was not a constituent of the seed mix but was a successful natural invader on the reclamation plots and was also included in the sample. Samples were collected during the 2002 growing season from the treatment combinations as described in Section I.2 above.

The 2002 vegetation data were based on chemical analyses of the four most successful grass species, (i.e., arctared fescue, bluejoint reedgrass, Norton hairgrass, bering hairgrass and alkali grass) were sampled from each amendment plot. Plant material (leaves) were collected and analyzed for 28 trace elements using standard methods (Martens and Associates 2002).

Metal concentrations in plant tissue are provided in dry weight (mg/kg). Concentrations were converted to wet weight for use in exposure estimate calculations. Plant tissue in dry weight was converted to wet weight according to the following equation:

$$\text{Concentration in wet weight} = \text{concentrations in dry weight} \times (1 - \%\ \text{water})$$

Grasses were assumed to have moisture content similar to spinach (i.e., 91.5%; U.S. EPA 1997). Concentrations of metals of concern (identified in Appendix II, Section 3) measured in plant tissue and maximum concentrations are presented in Table I-3.

Table I-3
Metal Concentrations in Vegetation Collected from the LLCF

Parameter	Concentration (mg/kg)																						
	Kimberlite and Low Peat			Kimberlite and Low Peat and Calcium			Kimberlite			Kimberlite and Calcium			Kimberlite and Lake Sediment		Kimberlite and Lake Sediment and Peat		Kimberlite and Lake Sediment and Sewage Sludge		Kimberlite and Lake Sediment and Peat and Sewage Sludge		Kimberlite and Pulp Paper Waste	Maximum Dry Weight [a]	Maximum Wet Weight
	BI	BII	BIII	BI	BII	BIII	BI	BII	BIII	BI	BII	BIII	BI	BII	BI	BII	BI	BII	BI	BII			
Cobalt	1.0	0.8	0.5	0.7	0.6	0.8	0.7	0.96	0.5	0.6	0.6	0.6	1.0	0.7	0.9	0.9	0.9	0.8	0.7	0.8	0.6	1.0	0.09
Chromium	0.7	0.6	<0.2	0.5	0.3	0.5	0.6	<0.2	1.1	0.6	1.1	0.6	2.7	1.4	1.7	1.4	1.2	1.8	1.8	1.9	3.5	3.5	0.3
Manganese	308	265	294	376	270	345	273	311	312	364	294	286	272	161	395	245	160	194	285	292	104	395	33.6
Molybdenum	6.5	6.7	4.4	6.7	5.6	6.2	8.6	5.19	4.7	4.9	3.2	6.6	17.0	12.6	12.7	11.0	14.1	15.1	17.0	9.6	13.5	17.0	1.4
Nickel	17.1	19.7	16.5	12.7	13.9	15.8	17.1	22.3	13.0	14.2	25.0	15.7	23.4	16.4	20.6	20.3	21.3	21.8	19.8	19.5	9.5	25.0	2.1
Strontium	29.3	29.8	23.7	29.8	24.2	23.3	25.2	24.0	21.4	25.1	21.5	27.5	38.2	33.8	40.8	38.6	35.4	34.1	44.1	41.0	36.5	44.1	3.7

[a] Calculations were based on half detection limits for parameter concentrations that were less than analytical detection limits.

[B] BI, BII and BIII refer to sample Block 1, Block 2 and Block 3 revegetation plots on the LLCF.

I.4 Surface Water

Water metals concentrations are based on processed kimberlite effluent data from BHPB (pers. comm. Millard 2003). These data are from water quality samples collected from the 'end-of-the-pipe' during kimberlite processing before deposition to the LLCF. The maximum concentration for the chemicals of concern was used in the risk assessment. Water quality data collected by BHPB and the calculated maximum is presented in Table I-4.

Table I-4
Water Quality Data for Processed Kimberlite Effluent

Parameter	Concentration (mg/L)													
	28-Feb-00	9-Apr-00	9-Apr-00	8-May-00	23-May-00	19-Jun-00	3-Jul-00	1-Aug-00	13-Aug-00	28-Aug-00	22-Sep-00	10-Oct-00	6-Nov-00	3-Dec-00
Chromium	0.02	<0.0008	<0.0008	<0.0008	0.003	0.003	<0.0008	<0.0008	0.001	0.001	<0.0008	0.002	<0.0008	0.001
Cobalt	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Manganese	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Molybdenum	0.2	0.2	0.3	0.3	0.2	0.2	0.2	0.3	0.3	0.5	0.3	0.4	0.4	0.4
Nickel	0.08	0.03	0.05	0.01	0.02	0.01	0.02	0.04	0.02	0.02	0.02	0.03	0.02	0.02
Strontium	0.4	0.4	0.4	0.3	0.3	0.3	0.4	0.6	0.4	0.3	0.4	0.4	0.5	0.4

Table I-4
Water Quality Data for Processed Kimberlite Effluent (continued)

Parameter	Concentration (mg/L)									
	7-Jan-01	4-Feb-01	5-Mar-01	2-Apr-01	8-Jul-01	5-Aug-01	3-Sep-01	7-Oct-01	4-Nov-01	10-Dec-01
Chromium	0.001	0.0008	0.004	0.03	0.0009	<0.0008	0.003	<0.008	0.003	0.003
Cobalt	-	-	-	-	-	-	-	-	-	-
Manganese	-	-	-	-	-	-	-	-	-	-
Molybdenum	0.3	0.4	0.3	0.4	0.4	0.5	0.4	0.5	0.4	0.4
Nickel	0.02	0.03	0.03	0.1	0.02	0.02	0.03	0.06	0.02	0.04
Strontium	0.4	0.4	0.3	0.4	0.3	0.6	0.4	0.6	0.3	0.6

Table I-4
Water Quality Data for Processed Kimberlite Effluent (continued)

Parameter	Concentration (mg/L)										
	9-Jan-02	3-Feb-02	4-Mar-02	5-Apr-02	5-May-02	9-Jun-02	7-Jul-02	1-Sep-02	7-Oct-02	11-Nov-02	3-Dec-02
Chromium	0.001	0.003	0.008	<0.0008	0.003	<0.0008	<0.0008	<0.0008	0.01	<0.0008	0.0009
Cobalt	-	-	-	-	-	-	-	-	-	-	-
Manganese	-	-	-	-	-	-	-	-	-	-	-
Molybdenum	0.3	0.5	0.5	0.2	0.6	0.4	0.7	0.5	0.5	0.6	0.4
Nickel	0.03	0.03	0.03	0.05	0.04	0.02	0.05	0.02	0.07	0.03	0.03
Strontium	0.4	0.5	0.5	7.0	0.5	0.3	0.8	0.4	0.4	0.4	0.5

Table I-4
Water Quality Data for Processed Kimberlite Effluent (continued)

Parameter	Concentration (mg/L)							
	5-Jan-03	9-Feb-03	8-Mar-03	5-Apr-03	5-May-03	8-Jun-03	6-Aug-03	Maximum
Chromium	0.005	0.03	0.002	0.01	0.01	0.002	0.002	0.03
Cobalt	-	-	-	-	-	-	-	-
Manganese	-	-	-	-	-	-	-	-
Molybdenum	0.3	0.3	0.2	0.4	0.5	0.1	0.1	0.7
Nickel	0.03	0.1	0.01	0.09	0.05	0.009	0.02	0.1
Strontium	0.2	0.3	0.2	0.3	0.4	0.4	0.5	7.0

I.5 Caribou Tissue Concentrations

Animal tissue concentrations (i.e., caribou meat) were calculated based on uptake from soil, water and vegetation into animal tissue. Empirical data on concentrations of metals in meat from caribou were not available for the LLCF area; therefore, meat tissue concentrations were calculated from soil, grass and water data. These calculations are based on metal-specific transfer factors from the literature. Meat concentrations were calculated using the following exposure equations (Table I-5):

$$C_{meat}\ (mg/kg) = C_{meatsoil} + C_{meatvegetation} + C_{meatwater}$$

Table I-5
Meat Uptake Equations

Pathway	Equation and Equation Parameters
soil ingestion	$C_{meatsoil} = BTF \times C_{soil} \times IR_{soil} \times fw$
	BTF = Biotransfer Factor (day/kg) IR_{soil} = soil ingestion rate for caribou (0.03 kg/day) C_{soil} = concentration in soil (mg/kg) fw = fraction of daily consumption (assumed 1; unitless)
vegetation ingestion	$C_{meatvegetation} = BTF \times C_{vegetation} \times IR_{vegetation} \times fw$
	BTF = Biotransfer Factor (day/kg) $IR_{vegetation}$= vegetation ingestion rate for caribou (1.6 kg/day) $C_{vegetation}$ = concentration in vegetation (mg/kg) fw = fraction of daily consumption (assumed 1; unitless)
water ingestion	$C_{meatwater} = BTF \times C_{water} \times IR_{water} \times fw$
	BTF = Biotransfer Factor (day/kg) IR_{water} = water ingestion rate for caribou (6.7 L/day) C_{water} = concentration in water (mg/L) fw = fraction of daily consumption (assumed 1; unitless)

Predicted caribou meat metal concentrations are presented in Tables I-6 to I-9.

Table I-6
Caribou Meat Concentrations Based on Soil Ingestion

Parameter	BTF (d/kg) [a]	C_{soil} (mg/kg)	IR (kg/day)	fw (unitless)	C_{meat} (mg/kg)
Chromium	0.009	328	0.03	1	0.1
Cobalt	0.0001	79.7	0.03	1	0.0003
Manganese	0.0005	851	0.03	1	0.01
Molybdenum	0.001	2.6	0.03	1	0.00008
Nickel	0.005	1,430	0.03	1	0.2
Strontium	0.008	263	0.03	1	0.07

(a) RAIS 2003.

Table I-7
Caribou Meat Concentrations Based on Vegetation Ingestion

Parameter	BTF (d/kg) [a]	C_{grass} (mg/kg)	IR (kg/day)	fw (unitless)	Cmeat (mg/kg)
Chromium	0.009	0.3	1.6	1	0.004
Cobalt	0.0001	0.1	1.6	1	0.00001
Manganese	0.0005	33.6	1.6	1	0.03
Molybdenum	0.001	1.4	1.6	1	0.002
Nickel	0.005	2.1	1.6	1	0.02
Strontium	0.008	3.7	1.6	1	0.05

(a) RAIS 2003.

Table I-8
Caribou Meat Concentrations Based on Water Ingestion

Parameter	BTF (d/kg) [a]	C_{water} (mg/L)	IR (L/day)	fw (unitless)	Cmeat (mg/kg)
Chromium	0.009	0.03	6.7	1	0.002
Cobalt	0.0001	- (b)	6.7	1	0
Manganese	0.0005	- (b)	6.7	1	0
Molybdenum	0.001	0.7	6.7	1	0.004
Nickel	0.005	0.1	6.7	1	0.004
Strontium	0.008	7.0	6.7	1	0.4

(a) RAIS 2003.
(b) not measured

Table I-9
Total Caribou Meat Concentrations

Parameter	Total Meat Concentration (mg/kg)
Chromium	0.1
Cobalt	0.0003
Manganese	0.04
Molybdenum	0.007
Nickel	0.3
Strontium	0.5

I.6 References

Martens and Associates (Harvey Martens and Associates Inc.). 2002. EKATI Diamond Mine Processed Kimberlite Tailings Reclamation Research Program 2002. Prepared for BHP Billiton Diamonds Inc. Yellowknife, NWT.

Millard, J. of BHP Billiton Diamonds Inc. 2003. Personal Communication with Cindy Robinson of Golder Associates Ltd. on November 13, 2003.

RAIS (Risk Assessment Information System). 2003. Available on the internet at http://risk.lsd.ornl.gov/cgi-bin/tox/TOX_9801. Accessed in November 2003.

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APPENDIX II

RISK ASSESSMENT APPROACH

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1. INTRODUCTION

Appendix II presents the detailed methods used for the human and wildlife risk assessments.

1.1 Risk Assessment Guidance

In Canada and the United States, risk assessment has been accepted by various levels of federal and regional governments as a valid method to guide risk management decisions. The risk assessment methodology for this assessment is based on the following provincial and federal guidance documents:

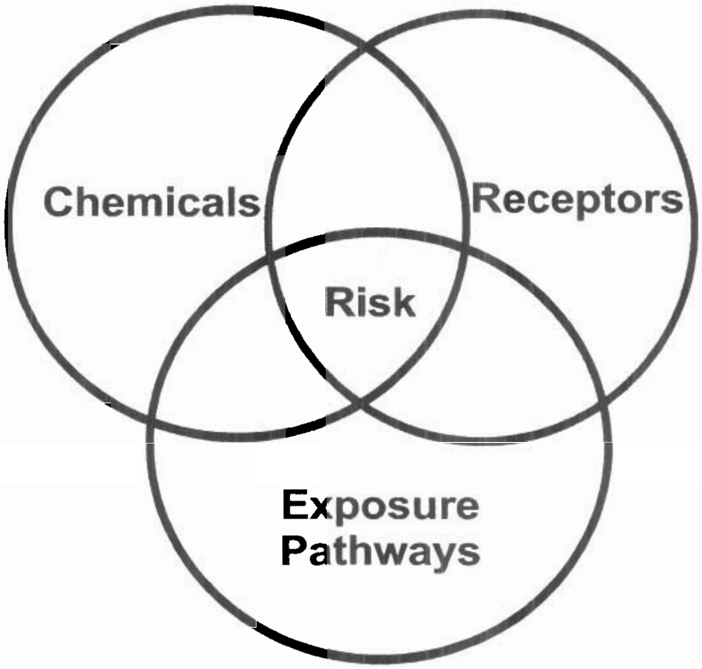
- CCME. A Framework for Ecological Risk Assessment. General Guidance. (1996).
- Health Canada. Federal Contaminated Site Risk Assessment in Canada. Version 1.1. (2003).
- Health Canada. Human Health Risk Assessment for Priority Substances. (1994).
- Health Canada. Human Health Risk Assessment of Chemicals from Contaminated Sites. Prepared by Golder Associates Ltd. and Cantox Inc. (not published 1995).
- United States Environmental Protection Agency (U.S. EPA). Guidelines for Ecological Risk Assessment (U.S. EPA 1998).
- Alberta Environment. Policy for Management of Risks at Contaminated Sites in Alberta. Draft. (2000).

2. RISK ASSESSMENT APPROACH

2.1 Risk Assessment Framework

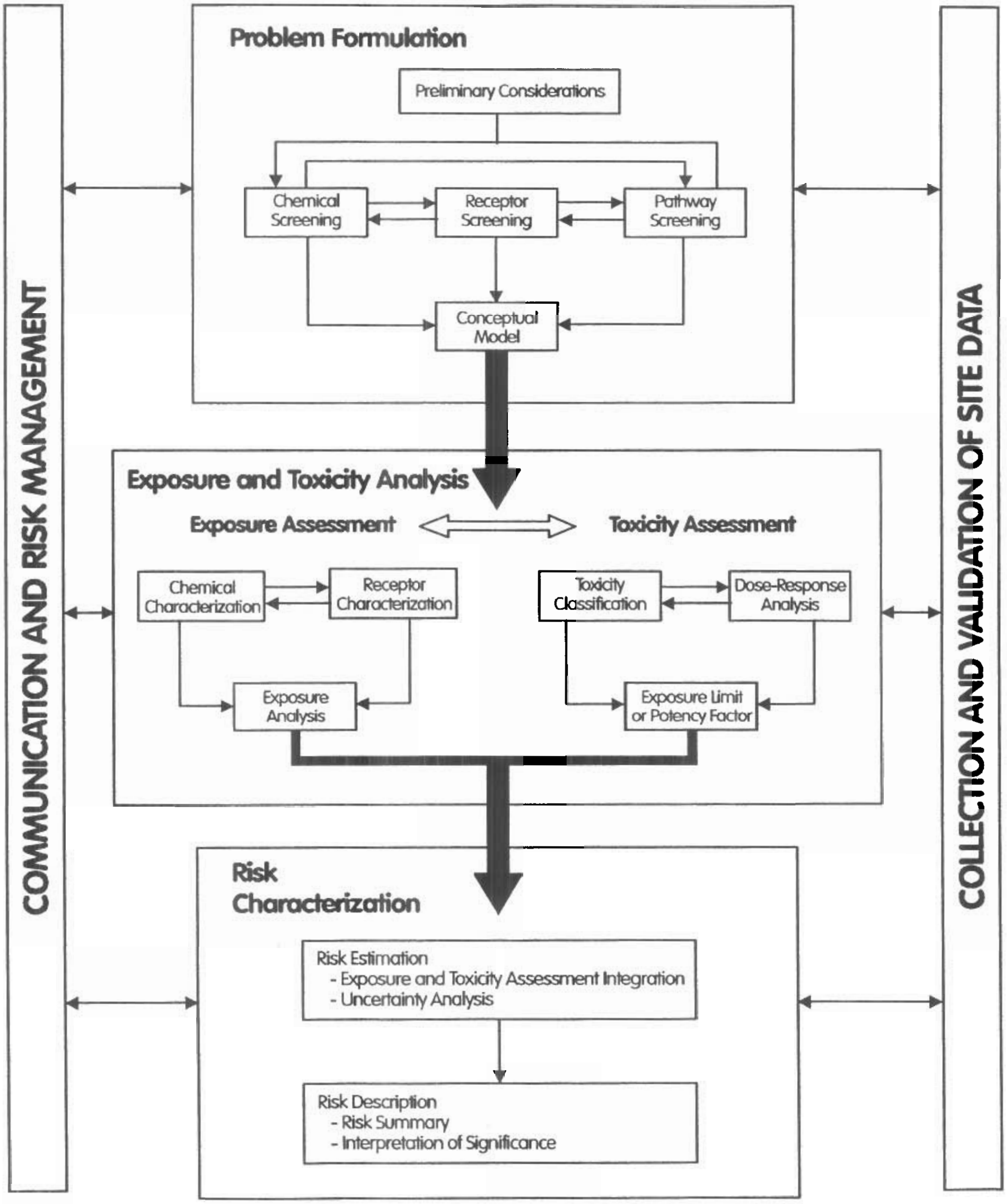
The potential for a risk to arise from exposure to chemicals is predicated on the co-existence of three elements including: i) chemicals must be present; ii) receptors (i.e., people, plants or animals) must be present; and iii) exposure pathways must exist between the source of the chemicals and the receptors (Figure II-1). In the absence of any one of the three elements outlined in Figure II-1, risks cannot occur. The presence of all three elements, however, does not necessarily indicate an unacceptable risk. In such situations, risk assessment involves addressing both the magnitude and uncertainty associated with potential health risks.

Figure II-1
Three Elements of Risk



This risk assessment followed a widely recognized framework, as illustrated in Figure II-2 (Health Canada [unpublished] 1995). The framework progresses from a qualitative initial phase (Problem Formulation) through Exposure and Toxicity Analysis, and culminates in quantitative Risk Characterization.

Figure II-2
Risk Assessment Framework



Source: Health Canada [unpublished] 1995.

2.1.1 Problem Formulation

The objective of the problem formulation stage is to develop a focused understanding of how metals in processed kimberlite might affect the health of ecological receptors that spend time near the Long Lake Containment Facility (LLCF) and the health of people that may consume game (i.e., caribou) that have been exposed to metals from the LLCF. This is achieved by the following:

- considering the attributes of the LLCF;
- identifying the ecological receptors that are expected to access the area;
- focusing on the metals that may be hazardous; and
- identifying the plausible exposure pathways between metals and receptors.

The problem formulation helps to focus the risk assessment on the substances, receptors and exposure pathways of greatest concern (i.e., metals with the greatest toxic potential; receptors with the greatest likelihood of being exposed; and exposure pathways that account for the majority of exposure to metals). If unacceptable health risks are not predicted for these, it is unlikely that there will be unacceptable health risks for other metals, receptors or exposure pathways.

The three main components of problem formulation are:

1. Receptor screening: The objective of the receptor screening process is to select a representative set of receptors that may be exposed to metals in soil-amended processed kimberlite, water and food from the LLCF area. For the human health risk assessment, a child is typically evaluated as the most susceptible receptor. For the ecological risk assessment, representative receptors are those that would be most exposed and/or susceptible, that play a key role in the ecological food web and that have sufficient characterization data to facilitate calculations of exposure and health risks. Species lists compiled by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC 2002) were also consulted to determine whether any local species have been designated as sensitive or threatened.

2. Chemical screening: The objective of chemical screening is to focus on the chemicals of greatest concern. Only metals were evaluated because other potential chemicals of concern (e.g., organic compounds) are not associated with kimberlite. Metals were not evaluated in the risk assessment if concentrations in the study area were equivalent to or less than reference concentrations; if concentrations from the LLCF were less than applicable guidelines/criteria; and/or metals were essential nutrients or were fundamentally not toxic. The remaining metals, which have the potential to contribute to increased health risks, were evaluated in the risk assessment.

3. Exposure pathway screening: The objective of exposure pathway screening is to determine all of the potential routes by which ecological receptors and people could be exposed to metals in soil, (i.e., amended processed kimberlite), water and food from the LLCF area. A list of plausible exposure pathways was developed. The list was then evaluated to determine whether each pathway would be operable for each receptor. For example, the soil ingestion exposure pathway is operable for all ecological receptors, but vegetation ingestion is only operable for wildlife species that are herbivorous or omnivorous.

2.1.2 Exposure Assessment

Exposure assessment is the process of estimating the exposure of a substance to a human or ecological receptor under a given exposure scenario. An exposure assessment is conducted for each chemical of concern identified in the problem formulation. For humans and wildlife, exposure is determined as a dose. This value is called the estimated daily intake (EDI) and is typically expressed as mg of a chemical per kg of body weight per day (mg/kg-day). The EDI is calculated from site-specific concentrations of metals in soil, water and food (vegetation for herbivorous wildlife receptors and caribou meat for people and carnivorous wildlife), the amount of time a receptor spends near the LLCF and receptor-specific parameters, such as body weight, ingestion rates and dietary preferences.

2.1.3 Toxicity Assessment

Toxicity assessment involves identification of the potentially toxic effects of chemicals and determination of the amount of chemicals that a receptor can be exposed to without experiencing unacceptable effects. This value is called the toxicity reference value (TRV) or toxicity benchmark. For humans and wildlife, the TRV is expressed as mg of a chemical per kg of body weight per day (mg/kg-day) and is referred to as the tolerable daily intake (TDI). The toxicity assessment provides the basis for evaluating what is an acceptable exposure and what level of exposure may adversely affect human and ecological health.

2.1.4 Risk Characterization

In the risk characterization step, information from the exposure and toxicity assessments are combined to determine if a potential risk exists. Risks may be estimated qualitatively based on scientific judgement for a screening level risk assessment, or quantitatively using exposure ratios for a more detailed risk assessment (CCME 1996). Exposure ratios (ERs) for chemicals of concern are calculated as the ratio of the estimated exposure (based on the exposure assessment) to the TRV (based on the toxicity assessment), according to the following equations:

Humans and Wildlife: ER = estimated exposure ÷ TRV; based on dose or daily intake.

The ER indicates whether the amount of a metal taken in by people or animals is greater than the amount of the metal below which there would be no health effect or no unacceptable risk of cancer. If the ER is greater than 1, then the amount taken in is greater than the threshold amount for which there are no health effects. This does not mean that there will be health effects but that further consideration is necessary. If the ER is less than 1, then we can be certain that no health effects or unacceptable risks would occur.

For this assessment, the acceptable risk threshold for the human health risk assessment was adjusted from an ER of 1 to an ER of 0.2. This is a standard practice in human health risk assessments, and has been recommended by Health Canada (2003) and Alberta Environment (AENV 2000) to account for evaluation of only one exposure pathway. This adjustment protects the health of people who are exposed to metals from multiple sources. In the case of the EKATI Diamond Mine risk assessment, this method protects the health of people who may be exposed to metals from ingestion of caribou by taking into account that these people may also be exposed to metals from other areas and other sources (for example, drinking water). Using an ER of 0.2 means that the risk assessment only allows for people to acquire a maximum of 20% of their total daily metals exposure from caribou that are exposed to metals from the LLCF.

For wildlife, the acceptable risk threshold is an ER of 1, since all of their food and water was assumed to be from the LLCF area.

It is important to note that ER values greater than the toxicity benchmark do not necessarily indicate that health effects will occur because of the layers of safety incorporated into the assessment. Thus, when an ER is greater than the threshold, it is important to consider the conservative assumptions upon which the assessment is based in combination with the degree of exceedance when determining the magnitude of risk.

2.2 Structure of the Appendix

The remainder of this appendix describes the methods and assumptions used in the risk assessment. The first step in the Problem Formulation, chemical screening, is presented in Section 3. The remainder of the appendix presents the rest of the steps in the assessments for wildlife health (Section 4) and human health (Section 5). These steps include receptor and exposure pathway screening, exposure assessment, toxicity assessment and risk characterization.

3. CHEMICAL SCREENING FOR HUMAN AND WILDLIFE HEALTH RISK ASSESSMENTS

The human and wildlife risk assessments focused on metals that have been identified as chemicals of concern in processed kimberlite from the EKATI Diamond Mine. In order to identify these metals, a chemical screening process was used. Soil (i.e., processed kimberlite) data collected by Harvey Martens and Associates Ltd. were used for the screening (Martens and Associates 2002).

Data used in the risk assessment are presented in Appendix I. The chemical screening process focused on metal concentrations in soil because soil is the primary residency media for metals from processed kimberlite (i.e., plants take up metals from soil). Also, regulatory guidelines are not available for plant tissue quality. The chemical screening process is presented in Figure II-3 and is described below.

3.1 Step 1: Compile Relevant Data

Data from the 2002 field trial (Martens and Associates 2002) were used in this assessment and presented in Appendix I.

3.2 Step 2: Comparison to Reference Concentrations

Metal concentrations measured in soil-amended kimberlite from the LLCF were compared with metal concentrations measured in the reference area. For each metal, the maximum concentration from the LLCF was compared to the mean reference concentrations. If metal concentrations from the LLCF were greater than concentrations from all three reference sites, these metals were carried forward to Step 3 of the chemical screening process. Comparisons are presented in Table II-1.