9.4 WATER QUALITY

9.4.1 Baseline Setting

9.4.1.1 Introduction

Snap Lake is in the Lockhart River watershed

Snap Lake is located near the headwaters of the Lockhart River watershed northeast of Great Slave Lake (Figure 9.4-1). The Lockhart River watershed (27,237 square kilometres [km^2]) encompasses the Snap Lake watershed (67 km^2). Outflow from Snap Lake follow a flow path outlined in Figure 9.4-1, eventually discharging into Great Slave Lake.

Water quality samples were collected from Snap Lake, streams, and small lakes in the Snap Lake watershed

A baseline study of water and sediment quality conditions in the local study area (LSA) (Section 9.1) was undertaken as part of the Snap Lake Diamond Project environmental assessment (EA). Between 1998 and 2001 water was collected from Snap Lake, streams flowing into and out of Snap Lake and from small lakes in the Snap Lake watershed (Figures 9.4-2 and 9.4-3, Table 9.4-1). Samples were also collected from an un-named reference lake to the southwest of Snap Lake in 1999. The majority of water samples were analyzed for routine parameters, nutrients, and total and dissolved metals. Sediment samples from Snap Lake and the reference lake were collected in September 1999 to determine baseline metal levels (Figure 9.4-2, Table 9.4-1).

Historical water and sediment quality data provide a regional context for conditions in the Lockhart River watershed

Historical water and sediment quality data are summarized to provide a regional context for water and sediment quality conditions in the Lockhart River watershed, the regional study area (RSA). The Department of Indian and Northern Affairs Canada (INAC) has collected baseline water and sediment quality throughout the Northwest Territories (NWT) as part of their commitment to provide information and support for assessments of current and potential developments (Puznicki 1996, 1997). As part of this program, water and sediment quality stations were sampled throughout the Lockhart River watershed in July 1993 and 1994 (Puznicki 1996, 1997) (Figure 9.4-4). Additional monitoring data were collected from Lockhart River water and sediment quality stations in March and August of 1999 (unpublished INAC data) (Figure 9.4-5). Water samples were analyzed for routine parameters, nutrients, and total metals. All sediment samples were analyzed for total metals. Sediment samples collected in 1999 were also analyzed for pH, percent sand-silt-clay, and nutrients.

Table 9.4-1 Sampling Periods and Number of Sampling Stations in the Aquatic Baseline Sampling Program

Description	Site	Water Quality [a]		Water Quality [a]				Sediment [b]	Water Quality [a]						
		1998		1999					2000	2001					
		Feb	Jul	Mar	May/Jun	July	Aug	Sept	Jun	Feb	Mar	Apr	May	Jun	Jul
Snap Lake															
Sediment quality stations	SH1							1							
	SH2							1							
	SH3							1							
Water quality stations (1998-2001)	WQ1	1	2	2			1				1				1
	WQ2	1	1	2			1								1
	WQ3	1	1	1			1	1			1				1
	WQ4			1			1								1
	WQ6			2			1								1
	WQ7		1	2			1				1				1
Additional water quality stations (2001)	AS1								1					1 [d]	
	AS2										1				
	AS3									1		1			
	AS4											1			
Reference Lake															
Water and sediment quality stations	SHR2							1							
	WQR1						1	1							
	WQR3						1	1							
	WQR7						1	1							
North Lake															
Water quality stations	WQ10			2											
	WQ11			2											
	WQ12			2											
Other Lakes															
Lakes near active mine area	IL1			1		1	1								
	IL3				1		1								
	IL4				1		1 [c]								
	IL5				1		1								
Lakes near the north shore of Snap Lake	NL1			1			1								
	NL2			1			1								
	NL3			1			1								
	NL4						1								
Downstream lake	WQ5			2			1								1
Streams															
Outlet streams	H1				1								1		1
	H2				2								1		1
Inlet streams	S1				2										
	S2				1								1		1
	S7				1										
	S10				1								1		
	S20				1										
	S25		1		1										
	S27				1										
	S30				1										

[a] Full suite of chemical parameters, including nutrients.
[b] Percent composition and total metal analysis.
[c] Too shallow to sample.
[d] Samples were collected periodically between June 2000 and June 2001.

Figure 9.4-1 Lockhart Watershed and Flow Path

Figure 9.4-2 Water Sediment and Benthic Sampling Locations for Snap Lake, North Lake and Reference Lake (1998-2001)

Figure 9.4-3 Water Sampling Locations for Streams and Small Lakes (1999-2001)

Figure 9.4-4 Lockhart Watershed Water and Sediment Sampling Stations – 1993 and 1994

Figure 9.4-5 Lockhart Watershed Water and Sediment Sampling Stations – 1999 and Artillery Lake Long-term Monitoring Station

Environment Canada maintains a long-term water quality station at Artillery Lake

Environment Canada (EC) maintains a long-term monitoring station on the Lockhart River at the outlet of Artillery Lake (Figure 9.4-5). Historical water quality data are available from this station between 1969 to 2000.

Methods and detailed results tables are presented in Appendix IX.5 and IX.6

Summaries of the local and regional data are provided in the following section. Summary statistics, including the median, minimum and maximum values, as well as the range of sample sizes, are presented in each table. Water and sediment sampling methods and tables containing all available water and sediment quality results are provided in Appendix IX.5 and IX.6. The summary statistics were calculated using the method outlined in Appendix IX.5, which includes a description of how results that were recorded as less than the method detection limit were managed. Detection limits for all baseline water quality analyses undertaken for the Snap Lake Diamond Project are also summarized in Appendix IX-5.

Baseline water and sediment quality results are compared to aquatic life and drinking water guidelines

Baseline water and sediment quality results were compared to guideline levels to provide a point of reference for the EA. Guidelines include Canadian Water Quality Guidelines (CWQC) and Canadian Interim Sediment Quality Guidelines (CISQG) for the protection of aquatic life, and Canadian Drinking Water Guidelines (CDWG).

Guidelines are meant to provide guidance for evaluating water quality

Water and sediment quality guidelines are intended to be protective of all forms of aquatic life including the most sensitive species over the long-term (CCME 1999, with 2000 updates). They are based on toxicity tests of the effects on sensitive aquatic species and tend to be conservative in nature.

Water quality parameters above guidelines are common in waterbodies not affected by human activities

Concentrations of water and sediment parameters above guidelines are common in northern remote lakes and rivers that are not affected by human activities within the watershed. Baseline conditions may result from natural influences such as surficial and bedrock geology, interaction between lake water and ground water, physical features of the lake and its drainage basin, local weather and seasonal hydrological changes. For example, elevated concentrations of metals (*e.g.*, aluminum, iron, and manganese) and nutrients (*e.g.*, total phosphorus [TP]) are often associated with spring runoff, which typically has elevated concentrations of suspended solids. When total metals are above a guideline, a portion is often associated with suspended particles in the water and is not necessarily bioavailable.

Samples may naturally have concentrations that are above or below guidelines

Natural variability of baseline water and sediment quality commonly results in some concentrations being above guideline levels. This is not considered to be of concern since it is a natural phenomenon and the distribution of species will be adapted to or selected based on the natural levels present.

9.4.1.2 Snap Lake Water Quality

Baseline water quality data have been collected in Snap Lake from 1998 to 2001

Baseline water quality data were collected in Snap Lake from 1998 to 2001 for the months and locations shown in Table 9.4-1. Sampling results from 1998 were reported by Hallam Knight Piésold (1998). Additional samples were collected in 2000 and 2001 as part of the water license conditions for the advanced exploration program (AEP). Snap Lake temperature, dissolved oxygen (DO), and pH profile data were collected in winter and summer of 1999.

Snap Lake is generally a clear, soft-water lake with a neutral to slightly acidic pH

Snap Lake is a relatively clear, soft-water lake, with a neutral to slightly acidic pH (Tables 9.4-2 and 9.4-3). Samples collected from stations in Snap Lake in 1999, and from site AS1 in 2001, had pH values that were occasionally lower than the minimum CWQG of 6.5 (CCME 1999, with 2000 updates). Median total dissolved solids (TDS) concentrations are very low, typically near laboratory detection limits. Turbidity was higher than the CWQG at sampling station WQ1 in July 1999 and at AS1 in April 2001.

Hardness is inversely related to the toxicity of some metals

The hardness of water can be calculated mainly from its calcium and magnesium concentrations. Hardness was originally developed as a measure of the capacity of water to precipitate soap. The hardness of water is environmentally important since it is inversely related to the toxicity of some metals (*e.g.*, copper, nickel, lead, cadmium, chromium, silver, and zinc). Specifically, some metals are toxic at lower concentrations when the hardness of the water is lower. Lakes are often referred to as soft-water lakes if the hardness is low.

Alkalinity is a measure of acid neutralizing capacity

The alkalinity of water can be used to gauge the sensitivity of lakes to acid deposition. Because of its low alkalinity (median = 6 milligrams per litre [mg/L]), Snap Lake is susceptible to acidification, as are many lakes in the Canadian Shield, within which the Lockhart River watershed and much of the north is located.

Snap Lake has an upper oligo-mesotrophic status which means it has moderately low productivity

Lakes can be broadly classified into one of several trophic states according to their inputs of TP and productivity. These classifications range from unproductive (oligotrophic) to nutrient-rich and highly productive (eutrophic). Nutrient concentrations in Snap Lake are moderately low and, based on TP concentrations, the trophic status of Snap Lake is in the upper oligotrophic to lower mesotrophic (moderate to low nutrient inputs) range (Tables 9.4-2 and 9.4-3). This means that the lake would be expected to have a moderately low biological productivity.

Table 9.4-2 Summary of Baseline Water Quality in Snap Lake from 1998-2001

Parameter	Units	Snap Lake[a]												Water Quality Guidelines[b]	
		1998 (n = 5 to 8)[c]			1999 (n = 6 to 16)			2001 (n = 3 to 9)			Summary (1998-2001) (n = 3 to 33)			Drinking Water	Aquatic Life
		min	median	max	min	median	max	min	median	max	min	median	max		
Conventional Parameters															
pH	pH	6.8	6.8	6.9	**6.3**	6.5	6.9	6.5	6.7	6.8	**6.3**	6.7	6.9	6.5-8.5	6.5-9.0
Alkalinity	mg/L	4	4	8	4	6	7	6	8	10	4	6	10	-	-
Total Dissolved Solids	mg/L	< 10	13	25	<10	15	19	<10	30	70	<10	15	70	≤500 [d]	-
Total Suspended Solids	mg/L	< 3	< 3	4	<3	<3	7	<3	<3	3	<3	<3	7	-	-
Total Hardness	mg/L	0.04	4	5	5	6	7	5	6	10	0.04	6	10	-	-
Conductivity	µS/cm	15	15	25	14	18	24	18	19	31	14	19	31	-	-
Colour	TCU	-	-	-	-	-	-	<3	10	10	<3	10	10	<15[d]	-
Turbidity	NTU	0.3	0.5	0.6	0.4	0.6	**1.8**	<0.1	0.3	0.5	<0.1	0.4	**1.8**	1	short-term increase <8 long-term increase <2
Nutrients															
Ammonia	mg/L	0.002	0.004	0.026	0.016	0.028	0.086	<0.005	<0.005	0.027	0.002	0.024	0.086	-	11.1
Nitrate + Nitrite	mg/L	< 0.008	< 0.008	< 0.008	< 0.008	<0.008	0.041	<0.006	<0.006	0.04	<0.006	<0.008	0.041	-	-
Nitrate	mg/L	-	-	-	-	-	-	<0.006	0.02	0.04	<0.006	0.02	0.04	-	-
Nitrite	mg/L	-	-	-	-	-	-	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002		0.06
Total Phosphorus	mg/L	<0.002	0.004	0.01	0.008	0.011	0.026	<0.001	0.003	0.009	<0.001	0.009	0.026	-	-
Dissolved Phosphorus	mg/L	-	-	-	0.007	0.009	0.012	<0.001	<0.001	0.008	<0.001	0.003	0.012	-	-
Orthophosphate	mg/L	< 0.002	< 0.002	< 0.002	<0.002	0.004	0.005	<0.001	0.001	0.005	<0.001	0.002	0.005	-	-
Total Kjeldahl Nitrogen	mg/L	-	-	-	0.2	0.2	0.2	<0.05	0.3	0.7	<0.05	0.2	0.7	-	-
Dissolved Organic Carbon	mg/L	-	-	-	3	3	4	4	4	4	3	4	4	-	-
Total Organic Carbon	mg/L	< 1	3	7	3	4	5	3	4	5	<1	4	7	-	-
Major Ions															
Bicarbonate	$mgCO_3/L$	-	-	-	5	6	7	7	10	12	5	7	12	-	-
Carbonate	mg/L	-	-	-	-	-	-	<5	<5	<5	<5	<5	<5		
Calcium	mg/L	0.93	0.99	1.81	1.06	1.34	1.76	1.26	1.38	2.43	0.93	1.34	2.43	-	-
Chloride	mg/L	0.2	0.5	0.81	<0.2	<0.2	0.2	<1	<1	<1	<0.2	<0.2	<1	≤250[d]	230
Fluoride	mg/L	-	-	-	0.04	0.04	0.04	<0.05	<0.05	0.06	0.04	<0.05	0.06	1.5	-
Hydroxide	mg/L	-	-	-	-	-	-	<5	<5	<5	<5	<5	<5		

Table 9.4-2 Summary of Baseline Water Quality in Snap Lake from 1998-2001 (continued)

Parameter	Units	Snap Lake[a]												Water Quality Guidelines[b]	
		1998 (n = 5 to 8)[c]			1999 (n = 6 to 16)			2001 (n = 3 to 9)			Summary (1998-2001) (n = 3 to 33)			Drinking Water	Aquatic Life
		min	median	max	min	median	max	min	median	max	min	median	max		
Magnesium	mg/L	0.48	0.52	0.94	0.56	0.63	0.78	0.54	0.58	1.01	0.48	0.61	1.01	-	-
Potassium	mg/L	0.40	0.41	0.78	0.32	0.47	0.58	0.41	0.43	0.77	0.32	0.44	0.78	-	-
Silica	mg/L	-	-	-	-	-	-	0.4	0.4	0.6	0.4	0.4	0.6	-	-
Sodium	mg/L	0.44	0.47	0.94	0.44	0.53	0.7	0.5	0.6	1	0.44	0.57	1	≤200[d]	-
Sulphate	mg/L	3	3.5	6	<3	<3	36	1.3	1.5	2.7	1.3	3	36	≤500[d]	-
Total Metals															
Aluminum	µg/L	5.1	6.9	14.1	< 30	< 30	< 30	8	9.5	14.6	5.1	22.3	<30	-	100
Antimony	µg/L	0.3	0.5	0.7	0.4	0.5	0.7	<0.03	0.04	0.8	<0.03	0.5	0.8	-	-
Arsenic	µg/L	-	-	-	< 0.2	< 0.2	< 0.2	<0.03	<0.03	0.12	<0.03	<0.2	<0.2	25	5
Barium	µg/L	2.1	2.4	3.9	2	2.5	3.6	2.4	2.6	4.8	2	2.6	4.8	1000	-
Beryllium	µg/L	< 0.1	< 0.1	0.1	< 0.1	< 0.1	< 2	<0.2	<0.2	<0.2	<0.1	<0.1	<2	-	-
Bismuth	µg/L	< 0.1	< 0.1	0.1	< 0.1	< 0.1	< 0.4	<0.03	<0.03	<0.03	<0.03	<0.1	<0.4	-	-
Boron	µg/L	-	-	-	-	-	-	<1	1.5	3	<1	1.5	3	-	-
Cadmium	µg/L	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.3	<0.05	<0.05	<0.05	<0.05	<0.1	<0.3	5	0.003
Cesium	µg/L	< 0.1	< 0.1	0.1	< 0.1	< 0.1	< 0.4	<0.1	<0.1	<0.1	<0.1	<0.1	<0.4	-	-
Chromium	µg/L	< 0.2	0.3	1.3	< 2	< 2	< 3	<0.06	<0.06	0.23	<0.06	<2	<3	50	1
Chromium (Hexavalent)	µg/L	-	-	-	-	-	-	<5	<5	<5	<5	<5	<5	-	1
Chromium (Trivalent)	µg/L	-	-	-	-	-	-	<5	<5	<5	<5	<5	<5	-	8.9
Cobalt	µg/L	< 0.1	0.1	0.1	0.1	0.2	< 1	<0.1	<0.1	<0.1	<0.1	0.1	<1	-	-
Copper	µg/L	0.7	1.4	**3.5**	0.5	1	**2**	<0.6	0.6	**2.6**	0.5	0.9	**3.5**	≤1000[d]	2
Iron	mg/L	< 0.012	0.03	0.03	< 0.02	0.03	0.06	0.013	0.019	0.033	<0.012	0.03	0.1	≤0.3[d]	0.3
Lead	µg/L	< 0.2	0.3	**1.4**	< 0.2	0.8	**2**	<0.05	0.2	0.4	<0.05	0.3	**2**	10	1
Lithium	µg/L	0.8	0.9	1.4	0.8	1.1	< 3	0.6	0.8	1.4	0.6	1	<3	-	-
Manganese	µg/L	2.8	3.4	7.5	2.1	4	14.1	2.5	3.4	4.8	2.1	3.4	14.1	≤50[d]	
Mercury	µg/L	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	<0.02	<0.02	<0.02	<0.01	<0.01	<0.02	1	0.1
Molybdenum	µg/L	0.1	0.1	0.1	< 0.1	< 0.1	< 1	<0.06	<0.06	0.1	<0.06	<0.1	<1	-	73
Nickel	µg/L	< 0.1	0.2	1.1	0.2	0.4	< 1	0.08	0.2	0.8	0.08	0.3	1.1	-	25
Rubidium	µg/L	-	-	-	-	-	-	<1	<1	2	<1	<1	2		
Selenium	µg/L	< 0.1	< 1	**1**	< 10	< 10	< 10	<0.1	<0.1	<0.1	<0.1	<5.5	<10	10	1

Table 9.4-2 Summary of Baseline Water Quality in Snap Lake from 1998-2001 (continued)

Parameter	Units	Snap Lake[a]												Water Quality Guidelines[b]	
		1998 (n = 5 to 8)[c]			1999 (n = 6 to 16)			2001 (n = 3 to 9)			Summary (1998-2001) (n = 3 to 33)			Drinking Water	Aquatic Life
		min	median	max	min	median	max	min	median	max	min	median	max		
Silver	µg/L	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.3	<0.1	<0.1	<0.1	<0.1	<0.1	<0.3	-	0.1
Strontium	µg/L	5.7	6.3	13.3	6	6.9	9.5	7.3	8.7	11.9	5.7	7.3	13.3	-	-
Thallium	µg/L	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.4	<0.03	<0.03	<0.03	<0.03	<0.1	<0.4	-	0.8
Titanium	µg/L	0.1	0.2	0.5	< 0.2	<0.3	< 3	<0.1	<0.1	<0.1	<0.1	<0.2	<3	-	-
Uranium	µg/L	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.3	<0.05	<0.05	<0.05	<0.05	<0.1	<0.3	20	-
Vanadium	µg/L	< 0.1	0.1	0.6	< 0.1	< 0.1	< 1	<0.05	<0.05	<0.05	<0.05	<0.1	<1	-	-
Zinc	µg/L	0.9	2.4	3.4	< 10	< 10	< 10	<0.8	1.3	19.3	<0.8	<10	19.3	≤5000[d]	30
Dissolved Metals															
Aluminum	µg/L	1.9	3.1	8.7	< 30	< 30	< 30	4.2	7.3	10.3	1.9	10.3	<30	-	-
Antimony	µg/L	0.3	0.3	0.5	0.4	0.6	1.9	<0.03	<0.03	0.18	<0.03	0.4	1.9	-	-
Arsenic	µg/L	-	-	-	< 0.2	< 0.2	< 0.2	<0.03	<0.03	0.1	<0.03	<0.2	<0.2	-	-
Barium	µg/L	1.8	2.1	3.5	1.9	2.4	3.6	2.3	2.6	4.5	1.8	2.4	4.5	-	-
Beryllium	µg/L	< 0.1	< 0.1	0.1	< 0.1	< 0.1	< 0.2	<0.2	<0.2	<0.2	<0.1	<0.1	<0.2	-	-
Bismuth	µg/L	< 0.1	0.1	0.1	< 0.1	< 0.1	< 0.1	<0.03	<0.03	<0.03	<0.03	<0.1	0.1	-	-
Boron	µg/L	-	-	-	-	-	-	<1	1	3	<1	1	3	-	-
Cadmium	µg/L	< 0.1	< 0.1	0.1	< 0.1	< 0.1	< 0.1	<0.05	<0.05	<0.05	<0.05	<0.1	0.1	-	-
Cesium	µg/L	< 0.1	< 0.1	0.1	< 0.1	< 0.1	< 0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.1	-	-
Chromium	µg/L	< 0.2	0.2	0.7	< 0.3	0.3	0.8	<0.06	<0.06	0.2	<0.06	0.3	0.8	-	-
Cobalt	µg/L	< 0.1	< 0.1	0.1	< 0.1	0.1	0.2	<0.1	<0.1	<0.1	<0.1	<0.1	0.2	-	-
Copper	µg/L	0.4	0.5	2.1	0.5	0.7	1.3	<0.6	1	4.4	0.4	0.7	4.4	-	-
Iron	mg/L	< 0.012	< 0.02	< 0.02	< 0.02	< 0.02	0.041	<0.005	0.005	0.02	<0.005	<0.02	0.04	-	-
Lead	µg/L	< 0.2	0.2	0.9	0.1	0.2	1.4	<0.05	0.09	0.2	<0.05	<0.2	1.4	-	-
Lithium	µg/L	0.7	0.8	1.5	0.8	0.9	1.1	0.5	0.7	1.4	0.5	0.9	1.5	-	-
Manganese	µg/L	< 0.1	0.1	0.4	0.2	0.5	10	0.4	0.9	4.2	<0.1	0.5	10	-	-
Mercury	µg/L	-	-	-	< 0.01	< 0.01	< 0.01	<0.02	<0.02	<0.02	<0.01	<0.01	<0.02	-	-
Molybdenum	µg/L	< 0.1	0.1	0.1	< 0.1	< 0.1	< 1	<0.06	<0.06	0.1	<0.06	<0.1	<1	-	-
Nickel	µg/L	< 0.1	0.1	0.9	0.2	0.3	0.4	0.09	0.5	3.7	0.09	0.3	3.7	-	-
Rubidium	µg/L	-	-	-	-	-	-	<1	<1	2	<1	<1	2		
Selenium	µg/L	< 1	1	1	< 1	< 10	< 10	<0.1	<0.1	<0.1	<0.1	<1	<10	-	-

Table 9.4-2 Summary of Baseline Water Quality in Snap Lake from 1998-2001 (continued)

Parameter	Units	Snap Lake[a]												Water Quality Guidelines[b]	
		1998 (n = 5 to 8)[c]			1999 (n = 6 to 16)			2001 (n = 3 to 9)			Summary (1998-2001) (n = 3 to 33)			Drinking Water	Aquatic Life
		min	median	max	min	median	max	min	median	max	min	median	max		
Silver	µg/L	< 0.1	< 0.1	0.1	< 0.1	< 0.1	< 0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.1	-	-
Strontium	µg/L	5.6	6.0	11.2	5.6	6.9	9.5	6.8	8.3	12.1	5.6	7.4	12.1	-	-
Thallium	µg/L	< 0.1	< 0.1	0.1	< 0.1	< 0.1	< 0.1	<0.03	<0.03	<0.03	<0.03	<0.1	0.1	-	-
Titanium	µg/L	0.1	< 0.2	0.2	< 0.2	< 0.2	< 0.3	<0.1	<0.1	<0.1	<0.1	<0.2	<0.3	-	-
Uranium	µg/L	< 0.1	< 0.1	0.1	< 0.1	< 0.1	< 0.1	<0.05	<0.05	<0.05	<0.05	<0.1	0.1	-	-
Vanadium	µg/L	< 0.1	0.1	0.1	< 0.1	< 0.1	0.1	<0.05	<0.05	<0.05	<0.05	<0.1	0.1	-	-
Zinc	µg/L	< 0.5	0.8	6.9	< 10	< 10	< 10	<0.8	1.7	24.2	<0.5	<10	24.2	-	-
Biological Parameters															
Fecal Coliform	CFU/100mL	-	-	-	-	-	-	<1	<1	<1	<1	<1	<1	-	-
Total Coliform	CFU/100mL	-	-	-	-	-	-	<1	<1	<1	<1	<1	<1	-	-
Organics															
Oil and Grease	mg/L	-	-	-	-	-	-	<1	<1	<1	<1	<1	<1	-	-

(a) Numbers in bold are equal to or above guidelines.

(b) All guidelines are from CCME (1999), with the exception of the aquatic life guideline for chloride, which is from U.S. EPA (1999). Hardness dependent guidelines are determined for a median baseline hardness of 6 mg/L, and the ammonia guideline was determined using a median baseline pH of 6.7 and temperature of 15 °C.

(c) The parameters analyzed vary between sampling events. Refer to Appendix IX.6 for detailed results.

(d) Aesthetic objective.

Notes: < = less than detection limit (refer to glossary for definition).

Statistics (*i.e.,* minimum, median and maximum) were calculated using the method outlined in Appendix IX.5.

µS/cm = micro Seimens per centimetre; TCU = true colour unit; NTU = nephelometric turbidity unit; mgCO$_3$/L = milligram carbonate per litre; µg/L = microgram per litre; CFU/100 mL = colony forming unit per 100 millilitres.

Table 9.4-3 Baseline Water Quality from Additional Snap Lake Stations in 2000 and 2001

Parameter	Units	Snap Lake [a] AS1 June 26/00 to June 11/01 (n = 1 to 21)[c] min	median	max	AS2 18-Mar-01	AS3 12-Feb-01	AS3 07-Apr-01	AS4 07-Apr-01	Water Quality Guidelines[b] Drinking Water	Aquatic Life
Conventional Parameters										
pH	pH	**6.1**	6.6	7.1	6.6	6.5	6.6	6.6	6.5-8.5	6.5-9.0
Alkalinity	mg/L	4.2	5.6	8.7	10	9	7.1	7.3	-	-
Total Dissolved Solids	mg/L	<10	18	50	10	40	23	24	≤500[d]	-
Total Suspended Solids	mg/L	<3	<3	**21**	5	<3	<3	<3	-	
Total Hardness	mg/L	7	7.4	8	10	9	8.2	8.4	-	-
Conductivity	µS/cm	20.8	20.9	23.7	27.8	24.2	22.8	22.4	-	-
Colour	TCU	-	5	-	5	10	-	-	<15[d]	-
Turbidity	NTU	**-**	**1.6**	**-**	<0.1	0.4	-	-	1	short-term increase <8 long-term increase <2
Nutrients										
Ammonia	mg/L	<0.005	0.012	0.087	0.017	0.057	-	-	-	11.1
Nitrate + Nitrite	mg/L	0.013	0.017	0.052	0.017	0.014	0.016	0.018	-	-
Total Phosphorus	mg/L	<0.001	0.008	0.009	<0.001	0.003	0.006	0.005	-	-
Dissolved Phosphorus	mg/L	<0.001	0.006	0.008	<0.001	0.002	0.004	<0.004	-	-
Orthophosphate	mg/L	<0.002	-	0.006	<0.001	-	-	-	-	-
Total Kjeldahl Nitrogen	mg/L	0.11	0.25	0.37	0.24	0.24	0.6	0.49	-	-
Total Organic Carbon	mg/L	3.9	4	5.1	5	4	5.9	5.5	-	-
Dissolved Organic Carbon	mg/L	3.9	4.1	5.4	5	3	5.4	5.1	-	-
Major Ions										
Bicarbonate	mg/L	-	8	-	12	11	-	-	-	-
Carbonate	mg/L	-	<5	-	<5	<5	-	-	-	-
Calcium	mg/L	1.5	1.6	1.7	2.3	2.0	1.9	1.9	-	-
Chloride	mg/L	0.4	1	9.9	<1	<1	0.7	0.3	≤250[d]	230
Fluoride	mg/L	0.04	0.04	0.07	0.1	0.18	0.05	0.05	1.5	-
Hydroxide	mg/L	-	-	-	<5	<5	-	-	-	-
Magnesium	mg/L	0.72	0.78	0.82	1.03	0.92	0.87	0.92	-	-
Potassium	mg/L	0.5	0.51	0.54	0.76	0.71	0.73	0.67	-	-
Silica	mg/L	0.5	0.64	0.7	0.4	0.4	0.5	0.52	-	-

Table 9.4-3 Baseline Water Quality from Additional Snap Lake Stations in 2000 and 2001 (continued)

Parameter	Units	Snap Lake [a]							Water Quality Guidelines[b]	
		AS1 June 26/00 to June 11/01 (n = 1 to 21)[c]			AS2	AS3	AS3	AS4		
		min	median	max	18-Mar-01	12-Feb-01	07-Apr-01		Drinking Water	Aquatic Life
Sodium	mg/L	0.58	0.62	0.7	1	1	0.9	0.8	≤200[d]	-
Sulphate	mg/L	1.94	3	9	2.17	2.03	<3	<3	≤500[d]	-
Total Metals					**UL[e]**	**UL**				
Aluminum	µg/L	5.3	<30	38	12	8.7	<30	<30	-	100
Antimony	µg/L	0.12	0.75	1.6	0.06	0.2	2.3	2	-	-
Arsenic	µg/L	0.08	<1	<1	0.1	0.1	-	-	25	5
Barium	µg/L	2	3	4	4	4	4	4	1000	-
Beryllium	µg/L	<0.2	<2	3	<0.2	<0.2	<2	<2	-	-
Bismuth	µg/L	<0.1	<5	<10	-	-	0.9	0.5	-	-
Boron	µg/L	1	-	2	3	3	-	-	-	-
Cadmium	µg/L	<0.05	<0.3	**0.5**	<0.05	<0.05	<0.3	<0.3	5	0.003
Cesium	µg/L	<0.4	<0.4	<0.4	-	-	<0.4	<0.4	-	-
Chromium (hexavalent)	µg/L	-	-	-	<5	-	-	-	-	1
Chromium (trivalent)	µg/L	-	-	-	<5	-	-	-	-	8.9
Chromium (total)	µg/L	<0.06	<3	<3	0.2	0.2	<3	<3	50	1
Cobalt	µg/L	<0.1	<1	<1	<0.1	<0.1	<1	<1	-	-
Copper	µg/L	<0.6	<2	<2	1.4	1	<2	<2	≤1000[d]	2
Iron	mg/L	0.04	0.15	**0.39**	0.02	0.06	0.11	0.05	≤0.3[d]	0.3
Lead	µg/L	<0.05	<1	<1	0.2	0.2	**1**	<1	10	1
Lithium	µg/L	0.7	<3	<3	1.4	2	<3	<3	-	-
Manganese	µg/L	5	9	22	3	3	3	2	≤50[d]	-
Mercury	µg/L	<0.01	<0.02	<0.02	<0.02	<0.02	-	-	1	0.1
Molybdenum	µg/L	<0.06	<1	<1	0.06	0.07	<1	<1	-	73
Nickel	µg/L	0.4	<1	2	0.5	0.6	<1	<1	-	25
Rubidium	µg/L	0.9	1	1.2	1	2	1.4	1.4	-	-
Selenium	µg/L	<0.1	<10	<10	<0.1	<0.1	<10	<10	10	1
Silver	µg/L	<0.1	<0.3	**0.4**	<0.1	<0.1	<0.3	<0.3	-	0.1
Strontium	µg/L	6	8	9	10.4	11.5	10	10	-	-
Thallium	µg/L	<0.4	<0.4	<0.4	-	-	<0.4	<0.4	-	0.8

Table 9.4-3 Baseline Water Quality from Additional Snap Lake Stations in 2000 and 2001 (continued)

Parameter	Units	Snap Lake [a]							Water Quality Guidelines[b]	
		AS1 June 26/00 to June 11/01 (n = 1 to 21)[c]			AS2	AS3	AS3	AS4		
		min	median	max	18-Mar-01	12-Feb-01	07-Apr-01		Drinking Water	Aquatic Life
Titanium	µg/L	<3	<3	<3	-	-	<3	<3	-	-
Uranium	µg/L	<0.05	<0.3	<0.3	<0.05	<0.05	<0.3	<0.3	-	-
Vanadium	µg/L	<0.05	<1	<1	<0.05	<0.05	<1	<1	20	-
Zinc	µg/L	<10	19	**43**	5	3	<10	<10	≤5000[d]	30
Dissolved Metals					**UL**	**UL**				
Aluminum	µg/L	2.7	<30	<30	5	3.9	<30	<30	-	-
Antimony	µg/L	<0.1	0.4	1.1	0.3	0.2	2.3	1.1	-	-
Arsenic	µg/L	0.09	0.12	<1	0.13	0.11	-	-	-	-
Barium	µg/L	2.1	3.0	4.6	4.0	3.8	3.2	3.5	-	-
Beryllium	µg/L	0.1	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	-	-
Bismuth	µg/L	<0.1	<5	<10	-	-	0.8	0.2	-	-
Boron	µg/L	1	-	2	3	3	-	-	-	-
Cadmium	µg/L	<0.05	<0.1	<0.1	<0.05	<0.05	<0.1	<0.1	-	-
Cesium	µg/L	<0.1	<0.1	<0.1	-	-	<0.1	<0.1	-	-
Chromium	µg/L	<0.06	<0.3	0.67	0.11	0.07	<0.3	<0.3	-	-
Cobalt	µg/L	<0.1	0.1	0.3	<0.1	<0.1	0.2	0.1	-	-
Copper	µg/L	0.6	0.8	2.3	4.5	0.8	3.7	1.5	-	-
Iron	mg/L	0.008	0.035	0.12	<0.005	<0.005	0.03	<0.03	-	-
Lead	µg/L	<0.05	0.1	0.4	<0.05	0.09	0.2	0.1	-	-
Lithium	µg/L	0.7	1.0	1.1	1.6	2.1	1.2	1.3	-	-
Manganese	µg/L	2.7	5	21.6	0.6	1	0.6	0.7	-	-
Mercury	µg/L	<0.02	-	<0.02	<0.02	<0.02	-	-	-	-
Molybdenum	µg/L	<0.06	0.1	0.1	0.07	0.09	0.1	0.1	-	-
Nickel	µg/L	0.3	0.4	46.1	18.1	0.41	4.5	0.8	-	-
Selenium	µg/L	<0.1	<1	<1	<0.1	<0.1	<1	<1	-	-
Silver	µg/L	<0.1	<0.1	0.2	<0.1	<0.1	0.1	<0.1	-	-
Strontium	µg/L	5.9	7.7	10.4	11	12.3	9	9.9	-	-
Rubidium	µg/L	<1	1	1.2	2	2	1.2	1.4	-	-
Thallium	µg/L	<0.1	<0.1	<0.1	-	-	<0.1	<0.1	-	-

Table 9.4-3 Baseline Water Quality from Additional Snap Lake Stations in 2000 and 2001 (continued)

Parameter	Units	Snap Lake [a] AS1 June 26/00 to June 11/01 (n = 1 to 21)[c]			AS2	AS3	AS3	AS4	Water Quality Guidelines[b]	
		min	median	max	18-Mar-01	12-Feb-01	07-Apr-01		Drinking Water	Aquatic Life
Titanium	µg/L	<0.3	<0.3	0.3	-	-	<0.3	<0.3	-	-
Uranium	µg/L	<0.05	<0.1	<0.1	<0.05	<0.05	<0.1	<0.1	-	-
Vanadium	µg/L	<0.05	<0.1	0.21	<0.05	<0.05	<0.1	<0.1	-	-
Zinc	µg/L	<10	18	54	11	3	<10	<10	-	-
Biological Parameters										
Fecal Coliform	CFU/100mL	-	<1	-	2	1	-	-	-	-
Total Coliform	CFU/100mL	-	8	-	<1	5	-	-	-	-
Eschericia coli	CFU/100mL	-	<1	-	-	-	-	-	-	-
Biological Oxygen Demand	mg/L	-	<2	-	<2	<2	-	-	-	-
Organics										
Oil and Grease	mg/L	<0.2	0.9	3.3	<1	<1	6.8	1.1	-	-

(a) Numbers in bold are equal to or above guidelines.

(b) All guidelines are from CCME (1999, with 2000 updates), with the exception of the aquatic life guideline for chloride, which is from U.S. EPA (1999). Hardness dependent guidelines are determined for a median baseline hardness of 6 mg/L, and the ammonia guideline was determined using a median baseline pH of 6.7 and temperature of 15 °C.

(c) The parameters analyzed vary between sampling events. Refer to Appendix IX.6 for detailed results.

(d) Aesthetic objective.

(e) UL indicates ultra-low metal analysis. Samples AS2 (Mar 18, 2001) and AS3 (Feb 12, 2001) were analyzed by ultra-low methods. The remainder of samples were analyzed using low-level methods.

Notes: < = less than detection limit (refer to glossary for definition).

Statistics (*i.e.,* minimum, median and maximum) were calculated using method outlined in Appendix IX.5.

Median values were not calculated when sample size was 2. Data was represented as a median if sample size was 1.

µS/cm = micro Seimens per centimetre; TCU = true colour unit; NTU = nephelometric turbidity unit; mgCO$_3$/L = milligram carbonate per litre; µg/L = microgram per litre; CFU/100 mL = colony forming unit per 100 millilitres.

Median metal concentrations were below guidelines with occasional natural metal levels above guidelines

Most metals in Snap Lake were present at low concentrations, with median metal concentrations (Tables 9.4-2 and 9.4-3) that were below CWQG. Concentrations in individual samples were occasionally above CWQG for cadmium, copper, iron, lead, silver, and zinc.

Snap Lake is well-mixed in the summer and has vertical temperature and DO gradients in the winter

Some lakes will stratify into two non-mixing layers in the summer: a layer of warmer, less dense water lying on a cooler, denser layer with a thin transitional layer in between. The reverse can happen in the winter with very cold (<4 degrees Celsius [°C]), less dense water overlying warmer, denser water (approximately 4°C). However, Snap Lake does not become stratified in summer or winter. It is relatively well mixed in the summer with no vertical gradients of temperature, DO, and pH. Snap Lake is relatively a shallow (mean depth 5.2 m) and wind-driven circulation of bottom and surface waters well mixed. During the winter, temperatures increase and DO levels decrease with depth (Appendix IX.6, Tables IX.6-1 and 2). The decline in oxygen is likely due to the consumption of oxygen by bacterial decomposition of lake-bottom organic matter. Surface DO concentrations remain above CWQG levels, indicating adequate oxygen levels for aquatic life. In March 1999, DO concentrations were slightly below minimum CWQG aquatic life levels at the lowest depth at site WQ2. Low DO concentrations in winter seasons are common in lakes due to oxygen consumption and lack of mixing.

9.4.1.3 Reference Lake and North Lake Water Quality

The reference lakes were sampled in March and August of 1999

An unnamed lake to the north of Snap Lake (hereafter referred to as the north lake) was sampled for water quality in March 1999. This lake was originally intended as a reference lake; however, after the spring melt, it was evident the lake was very shallow relative to Snap Lake and was not suitable as a reference site for benthic invertebrates or fish habitat. Another reference lake was chosen and sampled in August 1999 (Figure 9.4-2).

Reference lake water quality was similar to Snap Lake

Water quality in the reference lake and the north lake was very similar to Snap Lake (Table 9.4-4). They are mildly acidic, soft-water lakes with low concentrations of alkalinity, nutrients and metals. Lead concentrations were equal to the CWQG in one sample collected from the reference lake. Metal concentrations were below CWQG levels in all other samples.

The reference lake was well-mixed in August

The reference lake was well mixed in August 1999. Like Snap Lake, the reference lake had no vertical gradients in temperature, DO or pH during the summer (Appendix IX.6.1, Tables IX.6-3 and 4).

Table 9.4-4 Baseline Water Quality in the Reference Lake and North Lake, 1999

Parameter	Units	North Lake[a] (n = 1 to 6)[b]			Reference Lake (n = 3)			Water Quality Guidelines[c]	
		min	median	max	min	median	max	Drinking Water	Aquatic Life
Conventional Parameters									
pH	pH	6.5	6.6	6.7	6.5	6.5	6.6	6.5-8.5	6.5-9.0
Alkalinity	mg/L	8	8.5	9	4	4	4	-	-
Total Dissolved Solids	mg/L	13	16	22	<10	19	22	$\leq$500[d]	-
Total Suspended Solids	mg/L	<3	<3	<3	3	4	4	-	
Total Hardness	mg/L	9	9.5	11	4	5	5	-	-
Conductivity	µS/cm	26	28	32	13	17	18	-	-
Turbidity	NTU	-	-	-	0.4	0.5	0.7	1	short-term increase <8 long-term increase <2
Nutrients									
Ammonia	mg/L	0.021	0.025	0.029	0.044	0.045	0.075	-	11.1
Nitrate + Nitrite	mg/L	<0.008	<0.008	0.012	<0.008	<0.008	<0.008	-	-
Total Phosphorus	mg/L	0.009	0.014	0.023	0.012	0.014	0.014	-	-
Dissolved Phosphorus	mg/L	-	-	-	0.009	0.011	0.012	-	-
Orthophosphate	mg/L	0.004	0.004	0.004	<0.002	<0.002	<0.002	-	-
Total Kjeldahl Nitrogen	mg/L	-	5	-	0.2	0.2	0.2	-	-
Dissolved Organic Carbon	mg/L	-	-	-	3	4	4	-	-
Total Organic Carbon	mg/L	3.4	4	4.4	3.3	3.6	3.7	-	-
Major Ions									
Bicarbonate	mgCO3/L	7.5	8.3	9.3	-	-	-	-	-
Calcium	mg/L	1.96	2.19	2.54	1.1	1.2	1.4	-	-
Chloride	mg/L	<0.2	<0.2	<0.2	0.3	0.5	0.7	$\leq$250[d]	230
Fluoride	mg/L	-	-	-	0.1	0.1	0.1	1.5	-
Magnesium	mg/L	0.9	1	1.15	0.4	0.4	0.4	-	-
Potassium	mg/L	0.7	0.8	1.0	0.2	0.2	0.2	-	-
Silica	mg/L	-	-	-	-	-	-	-	-
Sodium	mg/L	0.6	0.7	0.8	0.5	0.5	0.6	$\leq$200[d]	-
Sulphate	mg/L	<3	4	13	<3	<3	<3	$\leq$500[d]	-
Total Metals									
Aluminum	µg/L	<30	<30	<30	<30	<30	<30	-	100
Antimony	µg/L	0.3	0.6	0.6	<0.5	<0.5	<0.5	-	-
Arsenic	µg/L	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	25	5
Barium	µg/L	3.5	4.1	7.5	2	2	2	1000	-
Beryllium	µg/L	<0.1	<0.1	<0.1	<2	<2	<2	-	-
Bismuth	µg/L	<0.1	<0.1	<0.1	<0.4	<0.4	<0.4	-	-
Cadmium	µg/L	<0.1	<0.1	<0.1	<0.3	<0.3	<0.3	5	0.003
Cesium	µg/L	<0.1	<0.1	<0.1	<0.4	<0.4	<0.4	-	-
Chromium	µg/L	<2	<2	<2	<3	<3	<3	50	1
Cobalt	µg/L	0.1	0.1	0.1	<1	<1	<1	-	-
Copper	µg/L	0.7	0.9	1.2	<2	<2	<2	$\leq$1000[d]	2
Iron	mg/L	<0.02	<0.02	0.02	0.04	0.04	0.05	$\leq$0.3[d]	0.3
Lead	µg/L	<0.2	0.3	0.9	<1	<1	**1**	10	1
Lithium	µg/L	1.1	1.3	1.9	<3	<3	<3	-	-
Manganese	µg/L	1	2.1	3.2	3	4	5	$\leq$50[d]	-
Mercury	µg/L	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	1	0.1

Table 9.4-4 Baseline Water Quality in the Reference Lake and North Lake, 1999 (continued)

Parameter	Units	North Lake[a] (n = 1 to 6)[b]			Reference Lake (n = 3)			Water Quality Guidelines[c]	
		min	median	max	min	median	max	Drinking Water	Aquatic Life
Molybdenum	µg/L	<0.1	0.1	0.1	<1	<1	<1	-	73
Nickel	µg/L	0.6	0.7	1.3	<1	<1	<1	-	25
Selenium	µg/L	<10	<10	<10	<10	<10	<10	10	1
Silver	µg/L	<0.1	<0.1	<0.1	<0.3	<0.3	<0.3	-	0.1
Strontium	µg/L	9.3	10.7	11.6	7	7	9	-	-
Thallium	µg/L	<0.1	<0.1	<0.1	<0.4	<0.4	<0.4	-	0.8
Titanium	µg/L	<0.2	<0.2	<0.2	<3	<3	<3	-	-
Uranium	µg/L	<0.1	<0.1	<0.1	<0.3	<0.3	<0.3	20	-
Vanadium	µg/L	<0.1	<0.1	0.2	<1	<1	<1	-	-
Zinc	µg/L	<10	<10	<10	<10	<10	<10	≤5000[d]	30
Dissolved Metals									
Aluminum	µg/L	<30	<30	<30	<30	<30	<30	-	-
Antimony	µg/L	0.3	0.6	0.9	1.6	2.1	2.3	-	-
Arsenic	µg/L	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	-	-
Barium	µg/L	3.6	4.3	33.6	1.8	2	2.2	-	-
Beryllium	µg/L	<0.1	<0.1	<0.1	<0.2	<0.2	<0.2	-	-
Bismuth	µg/L	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	-	-
Cadmium	µg/L	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	-	-
Cesium	µg/L	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	-	-
Chromium	µg/L	<0.2	0.2	1.1	<0.3	<0.3	<0.3	-	-
Cobalt	µg/L	<0.1	0.1	0.2	<0.1	<0.1	<0.1	-	-
Copper	µg/L	0.7	0.9	2.8	0.5	0.5	0.6	-	-
Iron	mg/L	<0.02	<0.02	<0.02	<0.03	<0.03	0.03	-	-
Lead	µg/L	<0.2	0.2	0.3	0.2	0.2	1	-	-
Lithium	µg/L	1.1	1.2	1.5	0.7	0.8	0.8	-	-
Manganese	µg/L	0.1	0.4	3.5	0.8	1	1.3	-	-
Mercury	µg/L	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	-	-
Molybdenum	µg/L	<0.1	0.1	0.1	<1	<1	<1	-	-
Nickel	µg/L	0.6	0.7	0.9	<0.1	<0.1	<0.1	-	-
Selenium	µg/L	<10	<10	<10	<1	<1	<1	-	-
Silver	µg/L	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	-	-
Strontium	µg/L	9.6	10.6	11.4	7	7.6	9.4	-	-
Thallium	µg/L	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	-	-
Titanium	µg/L	<0.2	<0.2	<0.2	<0.3	<0.3	<0.3	-	-
Uranium	µg/L	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	-	-
Vanadium	µg/L	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	-	-
Zinc	µg/L	<10	<10	<10	<10	<10	<10	-	-

(a) Numbers in bold are equal to or above guidelines.
(b) The parameters analyzed vary between sampling events. Refer to Appendix IX.6 for detailed results.
(c) All guidelines are from CCME (1999, with 2000 updates), with the exception of the aquatic life guideline for chloride, which is from U.S. EPA (1999). Hardness dependent guidelines are determined for a median baseline hardness of 6 mg/L, and the ammonia guideline was determined using a median baseline pH of 6.7 and temperature of 15 °C.
(d) Aesthetic objective.

Notes: < = less than detection limit (refer to glossary for definition).
Statistics (*i.e.,* minimum, median and maximum) were calculated using method outlined in Appendix IX.5.
Median values were not calculated when sample size was 2. Data was represented as a median if sample size was 1.
µS/cm = micro Seimens per centimetre; TCU = true colour unit; NTU = nephelometric turbidity unit; mgCO_3/L = milligram carbonate per litre; µg/L = microgram per litre; CFU/100 mL = colony forming unit per 100 millilitres.

9.4.1.4 Small Lakes Water Quality

The majority of water quality sampling in the small inland and downstream lakes occurred in 1999

In early spring 1999, surface samples were collected from one lake immediately downstream of Snap Lake (WQ5), a lake near the active mine area (formerly IL1), and three lakes near the north shore of Snap Lake (NL1 through NL3) (Figure 9.4-3). When the proposed airstrip location was determined and more details concerning the site were available, additional inland lakes within or near the footprint of the Snap Lake Diamond Project were identified. Surface water quality samples were collected from three lakes (IL3, IL4, and IL5) in June 1999 (Figure 9.4-3). With the exception of IL1, which was also sampled in July 1999, all of the sites sampled in the early spring 1999 were sampled again in August. NL4 was sampled only in August 1999. The only small lake sampled after 1999 was the lake immediately downstream of Snap Lake (WQ5), which was sampled again in July 2001.

The small lakes in the Snap Lake watershed have characteristics similar to Snap Lake

Most small lakes monitored in the Snap Lake watershed were found to have similar water quality to Snap Lake (Table 9.4-5). They were soft-water lakes with low concentrations of alkalinity and nutrients. Major ion and TDS concentrations were also low, but tended to be somewhat higher than in Snap Lake. Some of the lakes were clear, but many had a distinctively brown colour, reflecting natural organic compounds in drainage from wetlands. Dissolved organic carbon (DOC) concentrations were higher in the small brown-water lakes than in small clear-water lakes or Snap Lake. Some of the small brown-water lakes had turbidity measurements that were above CWQG levels, due to the natural colouration of the lakes. With the exception of the first downstream lake (WQ5), all lakes were mildly acidic (Appendix IX.6, Table IX.6-5).

The lakes in the Snap Lake watershed contain metals that are occasionally above guidelines

Similar to Snap Lake, metal concentrations in the small lakes were generally low, but occasionally contained metal concentrations (aluminum, copper, iron, lead, and thallium) that were above CWQG levels.

The other lakes were well-mixed

Depth profiles in the small lakes indicated that they were well mixed during the summer, with no vertical gradients in temperature, DO, or pH (Appendix IX.6, Table IX.6 through 8).

Table 9.4-5 Baseline Water Quality in Small Lakes in the Snap Lake Watershed

Parameter	Units	Downstream Lake [a] (n = 1 to 4)[b]			Lakes Near Active Mine Area (n = 1 to 8)			North Shore Lakes (n = 3 to 7)			Water Quality Guidelines[c]	
		min	median	max	min	median	max	min	median	max	Drinking Water	Aquatic Life
Conventional Parameters												
pH (lab)	pH	6.6	6.7	6.8	**6.1**	6.4	6.6	**6.3**	6.5	6.6	6.5-8.5	6.5-9.0
pH (field)	pH	6.5	-	6.7	**6.1**	6.6	6.7	7.2	7.3	7.5	6.5-8.5	6.5-9.0
Alkalinity	mg/L	4	6	6.2	3	3	22	4	5	11	-	-
Total Dissolved Solids	mg/L	12	15	20	12	37	52	10	26	41	≤500[d]	-
Total Suspended Solids	mg/L	<3	4	4	<3	5.5	22	<3	<3	<3	-	-
Total Hardness	mg/L	5	6.5	7	4	5	23	5	7	18	-	-
Conductivity	µS/cm	19	21	22	11	13	59	7	19	50	-	-
Colour	TCU	-	5	-	-	-	-	-	-	-	≤15[d]	-
Turbidity	NTU	0.2	-	0.6	**1.2**	**1.5**	**3.5**	0.7	0.75	0.9	1	short-term increase <8 long-term increase <2
Nutrients												
Ammonia	mg/L	<0.005	0.017	0.041	0.005	0.0315	0.225	0.024	0.04	0.091	-	11.1
Nitrate + Nitrite	mg/L	<0.008	0.025	0.065	<0.008	0.008	0.038	<0.008	<0.008	0.026	-	-
Total Phosphorus	mg/L	0.001	0.009	0.011	0.009	0.0165	0.037	<0.004	0.014	0.017	-	-
Dissolved Phosphorus	mg/L	<0.001	-	0.01	0.013	0.013	0.021	0.002	0.011	0.014	-	-
Orthophosphate	mg/L	<0.001	0.003	0.004	<0.002	0.002	0.004	<0.002	0.003	0.004	-	-
Total Kjeldahl Nitrogen	mg/L	0.06	-	0.3	0.3	0.5	0.6	0.2	0.2	0.3	-	-
Dissolved Organic Carbon	mg/L	3	-	3	7	9	14	4	4.5	6	-	-
Total Organic Carbon	mg/L	2.7	3.3	3.8	6.7	10.1	14	4.3	5.3	7.1	-	-
Major Ions												
Bicarbonate	mg/L	6.2	6.3	7	4.2	-	21.6	6.8	10.7	11.3	-	-
Calcium	mg/L	1.3	1.5	1.6	0.8	1	4.2	1.1	1.5	3.6	-	-
Chloride	mg/L	0.2	0.5	<1	<0.2	0.2	11.7	<0.2	<0.2	0.2	≤250[d]	230
Fluoride	mg/L	0.05	-	0.06	0.04	0.1	0.1	0.04	0.1	0.1	1.5	-
Magnesium	mg/L	0.5	0.6	0.7	0.5	0.6	3.0	0.5	0.8	2.3	-	-
Potassium	mg/L	0.3	0.5	0.5	0.2	0.3	1	0.3	0.5	1.3	-	-

Table 9.4-5 Baseline Water Quality in Small Lakes in the Snap Lake Watershed (continued)

Parameter	Units	Downstream Lake [a] (n = 1 to 4)[b]			Lakes Near Active Mine Area (n = 1 to 8)			North Shore Lakes (n = 3 to 7)			Water Quality Guidelines[c]	
		min	median	max	min	median	max	min	median	max	Drinking Water	Aquatic Life
Silica	mg/L	-	-	-	-	0.9	-	-	-	-	-	-
Sodium	mg/L	0.56	0.67	0.9	0.5	0.5	1.84	0.5	0.5	1	≤200[d]	-
Sulphate	mg/L	1.36	<3	<3	<3	4.5	8	3	3	8	≤500[d]	-
Total Metals												
Aluminum	µg/L	7	<30	<30	32	89.5	**340.5**	<30	<30	32	-	100
Antimony	µg/L	<0.04	<0.5	0.6	<0.5	0.5	0.9	<0.5	<0.5	0.6	-	-
Arsenic	µg/L	0.08	<0.2	<0.2	<0.2	<0.2	0.6	<0.2	<0.2	<0.2	25	5
Barium	µg/L	2	2.7	3	2	2.6	15	2	3	7.1	1000	-
Beryllium	µg/L	<0.1	<0.15	<2	0.4	<2	<2	<0.1	<2	<2	-	-
Boron	µg/L	-	3	-	-	-	-	-	-	-	-	-
Bismuth	µg/L	<0.03	<0.1	<0.4	<0.1	<0.4	<0.4	<0.1	<0.4	<0.4	-	-
Cadmium	µg/L	<0.05	<0.1	<0.3	<0.1	<0.3	<0.3	<0.1	<0.3	<0.3	5	0.003
Cesium	µg/L	<0.1	<0.1	<0.4	0.1	<0.4	<0.5	<0.1	<0.4	<0.4	-	-
Chromium	µg/L	<0.06	<2	<3	<3	<3	5	<2	<3	<3	50	1
Cobalt	µg/L	<0.1	0.1	<1	<1	<1	2.7	0.2	<1	<1	-	-
Copper	µg/L	<0.6	0.8	<2	<2	<2	**5.9**	0.8	<2	**2.3**	≤1000[d]	2
Iron	mg/L	<0.02	0.025	0.032	0.2	**0.55**	**1.4**	0.1	0.1	0.2	≤0.3[d]	0.3
Lead	µg/L	<0.05	**1.6**	**2.6**	0.7	<1	**1.1**	0.2	<1	<1	10	1
Lithium	µg/L	0.8	1	<3	<3	<3	3	1.3	<3	<3	-	-
Manganese	µg/L	2.2	2.6	3.1	3	5.3	**61.6**	3	6	29.6	≤50[d]	-
Mercury	µg/L	<0.01	<0.01	<0.02	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	1	0.1
Molybdenum	µg/L	0.06	<0.1	<1	0.8	<1	<1	0.1	<1	<1	-	73
Nickel	µg/L	0.14	0.2	<1	<1	<1	2.3	0.2	<1	1.9	-	25
Rubidium	µg/L	-	<1	-	-	-	-	-	-	-	-	-
Selenium	µg/L	0.1	<10	<10	<10	<10	<10	<10	<10	<10	10	1
Silver	µg/L	<0.1	<0.1	<0.3	<0.1	<0.3	<0.3	<0.1	<0.3	<0.3	-	0.1
Strontium	µg/L	8	9.1	10.3	4	5.9	22.6	6	8	13.7	-	-

Table 9.4-5 Baseline Water Quality in Small Lakes in the Snap Lake Watershed (continued)

Parameter	Units	Downstream Lake [a] (n = 1 to 4)[b]			Lakes Near Active Mine Area (n = 1 to 8)			North Shore Lakes (n = 3 to 7)			Water Quality Guidelines[c]	
		min	median	max	min	median	max	min	median	max	Drinking Water	Aquatic Life
Thallium	µg/L	<0.03	<0.1	<0.4	<0.1	<0.4	**1.7**	<0.1	<0.4	<0.4	-	0.8
Titanium	µg/L	<0.1	<0.2	<3	<3	<3	11.8	0.3	<3	<3	-	-
Uranium	µg/L	<0.05	<0.1	<0.3	0.2	<0.3	<0.3	<0.1	<0.3	<0.3	20	-
Vanadium	µg/L	0.09	<0.1	<1	0.8	<1	<1	<0.1	<1	<1	-	-
Zinc	µg/L	<0.8	<10	<10	<10	<10	13	<10	<10	<10	≤5000[d]	30
Dissolved Metals												
Aluminum	µg/L	5.8	<30	<30	<30	56	138	<30	<30	<30	-	-
Antimony	µg/L	0.08	0.5	1.6	0.6	0.9	1.9	0.7	1.6	1.9	-	-
Arsenic	µg/L	0.08	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	-	-
Barium	µg/L	2	2.54	2.8	1.7	2.2	10.1	2.2	2.5	6.8	-	-
Beryllium	µg/L	<0.1	<0.15	<0.2	<0.1	<0.2	<0.2	<0.1	<0.2	<0.2	-	-
Bismuth	µg/L	<0.03	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.6	-	-
Boron	µg/L	-	4	-	-	-	-	-	-	-	-	-
Cadmium	µg/L	<0.05	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	-	-
Cesium	µg/L	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	-	-
Chromium	µg/L	<0.06	0.45	1	<0.3	<0.3	76.4	<0.3	<0.5	18.7	-	-
Cobalt	µg/L	<0.1	<0.1	0.1	<0.1	0.2	1.5	<0.1	<0.1	0.4	-	-
Copper	µg/L	0.6	0.7	0.7	1	1.4	3.1	0.7	1.3	2.4	-	-
Iron	mg/L	0.014	<0.02	<0.03	0.072	0.259	0.76	<0.02	0.068	0.09	-	-
Lead	µg/L	0.06	0.95	3	<0.1	0.2	0.3	0.1	0.7	1.3	-	-
Lithium	µg/L	0.8	0.95	1	0.8	0.9	1.8	1.2	1.3	1.9	-	-
Manganese	µg/L	0.4	0.6	1.5	0.8	1.9	53	0.7	0.9	28	-	-
Mercury	µg/L	<0.01	<0.01	<0.02	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	-	-
Molybdenum	µg/L	<0.06	<0.1	<1	0.2	0.2	0.5	0.1	0.2	0.3	-	-
Nickel	µg/L	0.1	0.25	0.86	0.2	0.5	1.4	<0.1	0.7	1.8	-	-
Rubidium	µg/L	-	<1	-	-	-	-	-	-	-	-	-
Selenium	µg/L	<0.1	<5.5	<10	<1	<1	<10	<1	<1	<10	-	-
Silver	µg/L	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	-	-

Table 9.4-5 Baseline Water Quality in Small Lakes in the Snap Lake Watershed (continued)

Parameter	Units	Downstream Lake [a] (n = 1 to 4)[b]			Lakes Near Active Mine Area (n = 1 to 8)			North Shore Lakes (n = 3 to 7)			Water Quality Guidelines[c]	
		min	median	max	min	median	max	min	median	max	Drinking Water	Aquatic Life
Strontium	µg/L	8.1	8.8	10.2	4.7	5.8	20.4	5.7	8	13.6	-	-
Thallium	µg/L	<0.03	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	-	-
Titanium	µg/L	<0.1	<0.2	<0.3	<0.3	0.4	39.3	<0.2	<0.3	<0.3	-	-
Uranium	µg/L	<0.05	<0.1	<0.1	<0.1	<0.1	0.1	<0.1	<0.1	<0.1	-	-
Vanadium	µg/L	0.05	<0.1	<0.1	<0.1	<0.1	0.3	<0.1	<0.1	<0.1	-	-
Zinc	µg/L	1.2	<10	<10	<10	<10	11	<10	<10	<10	-	-

(a) Numbers in bold are equal to or above guidelines.

(b) The parameters analyzed vary between sampling events. Refer to Appendix IX.6 for detailed results.

(c) All guidelines are from CCME (1999, with 2000 updates), with the exception of the aquatic life guideline for chloride, which is from U.S. EPA (1999). Hardness dependent guidelines are determined for a median baseline hardness of 6 mg/L, and the ammonia guideline was determined using a median baseline pH of 6.7 and temperature of 15 °C.

(d) Aesthetic objective.

Notes: < = less than detection limit (refer to glossary for definition).

Statistics (*i.e.,* minimum, median and maximum) were calculated using method outlined in Appendix IX.5.

Median values were not calculated when sample size was 2. Data was represented as a median if sample size was 1.

µS/cm = micro Seimens per centimetre; TCU = true colour unit; NTU = nephelometric turbidity unit; $mgCO_3/L$ = milligram carbonate per litre; µg/L = microgram per litre; CFU/100 mL = colony forming unit per 100 millilitres.

9.4.1.5 Stream Water Quality

Stream samples were collected in spring 1999, and spring and summer 2001

Stream water samples were collected during the spring freshet of 1999 from eight streams flowing into Snap Lake (S1, S2, S7, S10, S20, S25, S27, S30) and two streams (H1, H2) flowing out of Snap Lake (Figure 9.4-3). The single stream sampled in 1998 (site WQ8, Hallam Knight Piésold 1998), was re-sampled in 1999 and renamed as Stream 25 (S25). Mid-channel grab samples were collected from each stream site. Stream water quality data were collected from tributary and outlet streams S2, H1, and H2 in May and July 2001 (Figure 9.4-3). The inlet stream S10 was sampled in May 2001.

Stream water quality was similar to small lakes and Snap Lake

The water quality of the tributary streams was similar to the water quality of the small lakes (Table 9.4-6). The water quality of the outlet stream from Snap Lake is essentially the same as water quality in Snap Lake. Concentrations of several metals (aluminum, lead, copper, iron, and zinc) in tributary streams were occasionally above CWQG levels. Colour and turbidity were occasionally above the CWQG levels. Detailed results are located in Appendix IX.6, Table IX.6-9.

9.4.1.6 Sediment Quality in Snap Lake and Reference Lake

Lake bottom sediments were collected from Snap Lake and the reference lake

Fine lake-bottom sediments were collected from four sites in Snap Lake and the reference lake in 1999. Sediments were analyzed for metals, carbon, and particle size.

Reference lake copper levels, and Snap Lake cadmium, chromium, copper, and zinc concentrations were above ISQG levels

Sediment quality was very similar in Snap Lake and the reference lake (Table 9.4-7). Sediment in both lakes was predominantly sand and silt with very little clay. Sediment metal concentrations were very similar in Snap Lake and the reference lake. Concentrations of several metals (cadmium, chromium, copper and zinc) were above CISQG levels. Detailed results are located in Appendix IX.6, Table IX.6-10+11.

9.4.1.7 Summary and Conclusions

Overall, the water and sediment quality in samples collected from the LSA (Snap Lake, small lakes in the Snap Lake watershed, and tributaries) were similar. The waterbodies are not impacted by human activities and the majority of water and sediment quality meet guidelines for the protection of aquatic life. Occasionally, samples had parameter levels that were slightly above guidelines, however this is a result of natural conditions and geologic characteristics common to northern regions.

Table 9.4-6 Baseline Water Quality in Inlet and Outlet Streams, 1998-2001

Parameter	Units	Inlet Streams [a] (n = 1 to 13)[b]			Outlet Streams (n = 1 to 7)			Water Quality Guidelines[c]	
		min	median	max	min	median	max	Drinking Water	Aquatic Life
Conventional Parameters									
pH	pH	**6.1**	6.5	8.4	6.6	6.7	6.8	6.5-8.5	6.5-9.0
Alkalinity	mg/L	3	5	8.4	4	5	8	-	-
Total Dissolved Solids	mg/L	22	30	50	<10	22	60	≤500[d]	-
Total Suspended Solids	mg/L	<3	3	3	<3	<3	3	-	-
Total Hardness	mg/L	4	5	12	5	6	7	-	-
Conductivity	µS/cm	11	15	33	15	18.2	19.7	-	-
Colour	TCU	**30**	**60**	**60**	5	10	**15**	≤15[d]	-
Turbidity	NTU	0.4	1	**2.3**	0.15	0.2	**1.2**	1	short-term increase <8 long-term increase <2
Nutrients									
Ammonia	mg/L	<0.005	<0.005	0.06	<0.005	0.007	0.047	-	11.1
Nitrate + Nitrite	mg/L	<0.008	0.01	0.039	<0.008	0.016	0.026	-	-
Total Phosphorus	mg/L	0.006	0.01	0.02	<0.001	0.004	0.02	-	-
Dissolved Phosphorus	mg/L	0.005	0.01	0.01	<0.001	0.003	0.01	-	-
Orthophosphate	mg/L	<0.001	<0.002	0.002	<0.001	<0.001	0.002	-	-
Total Kjeldahl Nitrogen	mg/L	0.15	0.3	0.6	<0.05	0.24	1.8	-	-
Dissolved Organic Carbon	mg/L	5	6.5	8	3	3	4	-	-
Total Organic Carbon	mg/L	5	7.3	9	3	4	4.2	-	-
Major Ions									
Bicarbonate	mg/L	2.9	8	9	4.4	6.5	10	-	-
Carbonate	mg/L	<5	<5	<5	<5	<5	<5	-	-
Calcium	mg/L	0.91	1.18	2.99	1.12	1.17	1.57	-	-
Chloride	mg/L	0.2	0.2	<1	0.2	<1	<1	≤250[d]	230
Fluoride	mg/L	<0.05	<0.05	0.07	<0.05	<0.05	0.07	1.5	-
Hydroxide	mg/L	<5	<5	<5	<5	<5	<5	-	-
Magnesium	mg/L	0.38	0.55	1.14	0.51	0.52	0.7	-	-
Potassium	mg/L	0.27	0.43	0.85	0.36	0.41	0.49	-	-
Silica	mg/L	-	-	-	-	-	-	-	-
Sodium	mg/L	0.27	0.47	0.7	0.46	0.6	0.9	≤200[d]	-
Sulphate	mg/L	0.69	3	4	1.28	1.64	3	≤500[d]	-
Total Metals									
Aluminum	µg/L	<30	51.7	**101**	7.6	18.2	<30	-	100
Antimony	µg/L	0.03	0.6	1.6	0.04	0.06	1.6	-	-
Arsenic	µg/L	0.07	<0.2	<0.2	0.07	0.09	<0.2	25	5
Barium	µg/L	2.2	3.5	6.3	2.4	3.1	6.4	1000	-
Beryllium	µg/L	<0.1	<0.1	0.3	<0.1	<0.2	<0.2	-	
Bismuth	µg/L	<0.03	<0.1	<0.1	<0.03	<0.03	<0.1	-	-
Boron	µg/L	1	2	2	2	2.5	3	-	-
Cadmium	µg/L	<0.05	<0.1	<0.1	<0.05	<0.05	<0.1	5	0.003

Table 9.4-6 Baseline Water Quality in Inlet and Outlet Streams, 1998-2001 (continued)

Parameter	Units	Inlet Streams [a] (n = 1 to 13)[b]			Outlet Streams (n = 1 to 7)			Water Quality Guidelines[c]	
		min	median	max	min	median	max	Drinking Water	Aquatic Life
Cesium	µg/L	<0.1	<0.1	0.2	<0.1	<0.1	<0.1	-	-
Chromium	µg/L	0.15	<2	<2	<0.06	0.42	2	50	1
Cobalt	µg/L	<0.1	0.4	1.4	<0.1	<0.1	0.5	-	-
Copper	µg/L	0.5	1.2	**4.2**	<0.6	0.7	1.1	≤1000[d]	2
Iron	mg/L	0.08	0.23	**0.52**	0.022	0.051	0.12	≤0.3[d]	0.3
Lead	µg/L	<0.05	<0.2	**2.2**	<0.05	<0.05	0.6	10	1
Lithium	µg/L	0.4	0.8	1.3	0.8	1	2	-	-
Manganese	µg/L	1.6	17.9	**61.5**	3.8	5.8	14	≤50[d]	-
Mercury	µg/L	<0.01	<0.01	<0.02	<0.01	<0.02	<0.02	1	0.1
Molybdenum	µg/L	0.07	0.1	0.2	<0.06	<0.06	<0.1	-	73
Nickel	µg/L	0.1	0.5	3.9	0.19	0.36	0.5	-	25
Rubidium	µg/L	<1	<1	1	<1	1	1	-	-
Selenium	µg/L	<0.1	<10	<10	<0.1	<0.1	<10	10	1
Silver	µg/L	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	-	0.1
Strontium	µg/L	4	6.3	8.6	5.6	7.4	8.4	-	-
Thallium	µg/L	<0.03	<0.1	<0.1	<0.03	<0.03	0.6	-	0.8
Titanium	µg/L	0.1	1	1.8	<0.1	0.2	0.8	-	-
Uranium	µg/L	<0.05	<0.1	0.13	<0.05	<0.05	<0.1	20	-
Vanadium	µg/L	<0.1	0.1	0.3	<0.05	<0.1	0.4	-	-
Zinc	µg/L	0.8	<10	**44**	<0.8	<1.1	<10	≤5000[d]	30
Dissolved Metals									
Aluminum	µg/L	<30	58	94	4.9	16.1	<30	-	-
Antimony	µg/L	0.03	0.5	0.9	0.05	0.1	1.6	-	-
Arsenic	µg/L	0.06	<0.2	<0.2	0.07	0.08	<0.2	-	-
Barium	µg/L	2.2	3.34	6	2.26	3	3.26	-	-
Beryllium	µg/L	<0.1	<0.1	<0.2	<0.1	<0.2	<0.2	-	-
Bismuth	µg/L	<0.03	<0.1	0.2	<0.03	<0.03	<0.1	-	-
Boron	µg/L	1	2	2	2	2.5	3	-	-
Cadmium	µg/L	<0.05	<0.1	<0.1	<0.05	<0.05	<0.1	-	-
Cesium	µg/L	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	-	-
Chromium	µg/L	<0.06	<2	5	<0.06	<0.13	14.2	-	-
Cobalt	µg/L	<0.1	0.2	1.4	<0.1	<0.1	0.4	-	-
Copper	µg/L	0.8	1.1	4.2	0.7	0.9	2	-	-
Iron	mg/L	0.038	0.176	0.4	0.009	0.022	0.052	-	-
Lead	µg/L	<0.05	<0.2	4.4	<0.05	0.27	21.4	-	-
Lithium	µg/L	0.6	0.9	1.2	0.8	0.9	1.1	-	-
Manganese	µg/L	1.5	17.9	64.9	0.8	3.5	11.4	-	-
Mercury	µg/L	<0.01	<0.01	<0.02	<0.01	<0.02	<0.02	-	-
Molybdenum	µg/L	<0.06	<0.1	0.2	<0.06	<0.06	0.2	-	-
Nickel	µg/L	0.1	0.5	3.2	0.3	0.39	1.28	-	-
Rubidium	µg/L	<1	<1	1	<1	1	1	-	-
Selenium	µg/L	<0.1	<10	<10	<0.1	<0.1	<10	-	-

Table 9.4-6 Baseline Water Quality in Inlet and Outlet Streams, 1998-2001 (continued)

Parameter	Units	Inlet Streams [a] (n = 1 to 13)[b]			Outlet Streams (n = 1 to 7)			Water Quality Guidelines[c]	
		min	median	max	min	median	max	Drinking Water	Aquatic Life
Silver	µg/L	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	-	-
Strontium	µg/L	4	5.9	8.5	5.5	7.2	8.6	-	-
Thallium	µg/L	<0.03	<0.1	<0.1	<0.03	<0.03	<0.1	-	-
Titanium	µg/L	<0.1	0.5	0.8	<0.1	<0.2	0.2	-	-
Uranium	µg/L	<0.05	<0.1	0.1	<0.05	<0.05	<0.1	-	-
Vanadium	µg/L	0.06	0.1	0.2	<0.05	<0.05	<0.1	-	-
Zinc	µg/L	1.4	<10	22	1.1	4.1	25	-	-
Organics									
Oil and Grease	mg/L	<1	<1	<1	<1	<1	<1	-	-

(a) Numbers in bold are equal to or above guidelines.

(b) The parameters analyzed vary between sampling events. Refer to Appendix IX.6 for detailed results.

(c) All guidelines are from CCME (1999, with 2000 updates), with the exception of the aquatic life guideline for chloride, which is from U.S. EPA (1999). Hardness dependent guidelines are determined for a median baseline hardness of 6 mg/L, and the ammonia guideline was determined using a median baseline pH of 6.7 and temperature of 15 °C.

(d) Aesthetic objective.

Notes: < = less than detection limit (refer to glossary for definition).

Statistics (*i.e.,* minimum, median and maximum) were calculated using method outlined in Appendix IX.5.

µS/cm = micro Seimens per centimetre; TCU = true colour unit; NTU = nephelometric turbidity unit; $mgCO_3/L$ = milligram carbonate per litre; µg/L = microgram per litre; CFU/100 mL = colony forming unit per 100 millilitres.

Table 9.4-7 Baseline Sediment Chemistry in Snap Lake and the Reference Lake

Parameter	Units	Snap Lake (n = 4)			Reference Lake (n = 4)			CCME Guidelines [a] Aquatic Life	
		min	median	max	min	median	max	ISQG [b]	PEL [c]
Clay	%	1	1	2	1	1	1	-	-
Silt	%	19	21.5	22	21	22.5	26	-	-
Sand	%	76	77.5	80	73	76.5	78	-	-
Moisture Content	%	78	87	91	86	91	94	-	-
Total Inorganic Carbon	%	0.2	0.2	0.4	0.2	0.2	0.4	-	-
Total Organic Carbon	%	11	12.5	20	9	16	18	-	-
Metals (total)									
Aluminum	Wt.%	1.1	1.25	1.3	0.8	1.2	1.3	-	-
Antimony	µg/g	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	-	-
Arsenic	µg/g	0.9	1.4	1.6	0.4	0.75	1.5	-	-
Barium	µg/g	79	80.6	97.5	44.6	51.9	60.3	-	-
Beryllium	µg/g	0.7	0.8	1.1	0.4	0.6	0.6	-	-
Bismuth	µg/g	<0.2	0.3	0.4	<0.2	<0.2	<0.2	-	-
Cadmium	µg/g	**0.6**	**0.7**	**0.7**	0.2	0.3	0.4	0.6	3.5
Cesium	µg/g	1.3	1.65	1.7	1.1	1.3	1.4	-	-
Chromium	µg/g	29.5	29.7	**42.1**	19.5	25.3	28	37.3	90
Cobalt	µg/g	10.4	11.9	20.7	4.6	7.3	9.5	-	-
Copper	µg/g	**66.5**	**69.6**	**88.6**	28.1	35.6	**45.7**	35.7	197
Iron	%	1.6	2.15	3.3	1.7	2.05	7.5	-	-
Lead	µg/g	3.8	4.9	6.4	3.6	4.7	5.8	35	91.3
Lithium	µg/g	14.7	22.9	25.1	14.9	16	17.1	-	-
Manganese	µg/g	247	264.5	395	115	197.5	299	-	-
Mercury	µg/g	0.04	0.05	0.1	0.04	0.06	0.07	0.17	0.486
Molybdenum	µg/g	5.5	7	9.2	2.1	2.75	4.9	-	-
Nickel	µg/g	35.8	38.3	44.2	15.3	19.9	23	-	-
Rubidium	µg/g	9.4	13.7	16.4	8.7	9.4	10.6	-	-
Selenium	µg/g	<2	<2	<2	<2	<2	<2	-	-
Silver	µg/g	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	-	-
Strontium	µg/g	25.7	26.4	27.6	17.5	20.9	23.5	-	-
Thallium	µg/g	<0.2	<0.2	0.3	<0.2	<0.2	0.3	-	-
Titanium	µg/g	222	444.5	611	257	306.5	317	-	-
Uranium	µg/g	5.4	5.95	6.2	3.7	6.2	8.8	-	-
Vanadium	µg/g	27.5	30.2	32.4	24.1	26.1	28.6	-	-
Zinc	µg/g	**160**	**176**	**233**	66	99	104	123	315

[a] Numbers in bold are equal to or above guidelines.
[b] Interim freshwater sediment quality guideline (ISQG).
[c] Probable effect levels (PEL).
Notes: < = less than detection limit (refer to glossary for definition).
Statistics (*i.e.,* minimum, median and maximum) were calculated using method outlined in Appendix IX.6.
PEL = probable effects level; µg/g = micrograms per gram; wt.% = percent weight.

9.4.1.8 Lockhart River Watershed

9.4.1.8.1 Water Quality

Lockhart River Watershed

Low hardness, alkalinity, total dissolved solids levels, and nutrient and metal concentrations characterize waterbodies in the Lockhart River watershed

The baseline data indicate that waterbodies in the Lockhart River watershed are characterized by soft water, low alkalinity, and very low to moderately low nutrient concentrations (Tables 9.4-8 and 9.4-9). Based on TP levels, the trophic status of lakes would range from ultra-oligotrophic to mesotrophic. TDS levels range from very low to moderately low. Baseline pH levels ranged from slightly basic to slightly acidic, and were below the minimum CWQG level in a number of waterbodies. Total suspended solids (TSS) and turbidity levels were consistently low in regional waterbodies. Metal concentrations in the regional water bodies are generally low and below CWQG levels. Concentrations of lead in some lakes were slightly above the CWQG level.

There were no spatial trends in water quality with distance downstream of Snap Lake

Water quality was evaluated for spatial trends in the Lockhart watershed, and no trends were apparent with distance downstream of Snap Lake as illustrated by plots of pH, TP, and TDS (Figure 9.4-6). These parameters are representative of general water quality.

Outlet of Artillery Lake

Discharge from Artillery Lake is soft, slightly acidic, relatively turbid, and generally low in nutrients and metals

The long-term monitoring station maintained by EC on the Lockhart River at the outlet of Artillery Lake (Figure 9.4-5) provides an opportunity to examine water quality conditions over a relatively long time period (1969-2000). The water quality at Artillery Lake was similar to the mean water quality of lakes in the Lockhart River watershed, and to Snap Lake (Tables 9.4-10 and 9.4-11). Metal concentrations were also generally low at the Artillery Lake station, with concentrations of cadmium, copper, nickel, and silver occasionally above CWQG levels.

There were no temporal changes observed at the outlet of Artillery Lake

Baseline water quality at the outlet of Artillery Lake has remained relatively constant over time, as illustrated by plots of pH, TSS and TDS levels (Figure 9.4-7). Detailed information is located in Appendix IX.6, Tables IX.6-13 through 16.

Table 9.4-8 Summary of Water Quality in the Lockhart River Watershed, 1993/1994

Parameter	Units	Summary Statistics[a] (n = 2 to 33)[b]			Water Quality Guidelines [c]	
		min	median	max	Drinking Water	Aquatic Life
Conventional Parameters						
pH	pH	6.2	6.6	7.7	6.5-8.5	6.5-9.0
Alkalinity	mg/L	<0.3	2	30.5	-	-
Total Dissolved Solids	mg/L	<10	19	53	≤500(d)	-
Total Suspended Solids	mg/L	<3	<3	4	-	-
Total Hardness	mg/L	2	4	34	-	-
Conductivity	µS/cm	10.4	13.5	71.4	-	-
Colour	TCU	<5	<5	8	≤15(d)	-
Turbidity	NTU	0.4	0.5	1.6	1	short-term increase <8 long-term increase <2
Nutrients						
Ammonia	mg/L	<0.002	0.004	0.022	-	11.1
Nitrate+Nitrite	mg/L	<0.008	<0.008	0.051	-	-
Total Phosphorus	mg/L	<0.002	0.004	0.024	-	-
Major Ions						
Calcium	mg/L	0.3	1	7.3	-	-
Chloride	mg/L	0.26	0.48	3.7	≤250[(d)]	230
Magnesium	mg/L	0.3	0.4	3.8	-	-
Potassium	mg/L	0.1	0.4	1.5	-	-
Reactive Silica	mg/L	0.04	0.1	1.22	-	-
Sodium	mg/L	0.2	0.4	1.3	≤200[(d)]	-
Sulphate	mg/L	<3	<3	3	≤500[(d)]	-
Total Metals						
Aluminum	µg/L	<0.5	5.7	16.6	-	100
Antimony	µg/L	0.003	0.15	0.44	-	-
Arsenic	µg/L	0.1	<0.3	0.6	25	5
Barium	µg/L	0.54	1.54	5.13	1000	-
Beryllium	µg/L	<0.1	<0.1	<0.1	-	-
Bismuth	µg/L	<0.1	<0.1	<0.1	-	-
Cesium	µg/L	<0.1	<0.1	<0.1	-	-
Chromium	µg/L	<0.2	<0.2	0.5	50	1
Cobalt	µg/L	<0.1	<0.1	<0.1	-	-
Copper	µg/L	0.18	0.43	0.83	≤1000[(d)]	2
Iron	mg/L	<0.02	<0.02	0.076	≤0.3[(d)]	0.3
Lead	µg/L	<0.2	<0.2	0.5	10	1
Lithium	µg/L	0.51	0.84	1.36	-	-
Manganese	µg/L	0.71	2.8	10.3	≤50[(d)]	-
Mercury	µg/L	<0.02	-	<0.02	1	0.1
Molybdenum	µg/L	0.002	0.026	0.092	-	73
Nickel	µg/L	<0.1	0.3	1.2	-	25
Selenium	µg/L	<1	<1	<1	10	1
Silver	µg/L	<0.1	<0.1	<0.1	-	0.1
Strontium	µg/L	2.7	5.3	17.4	-	-
Thallium	µg/L	<0.1	<0.1	<0.1	-	0.8

Table 9.4-8 Summary of Water Quality in the Lockhart River Watershed, 1993/1994 (continued)

Parameter	Units	Summary Statistics[a] (n = 2 to 33)[b]			Water Quality Guidelines [c]	
		min	median	max	Drinking Water	Aquatic Life
Titanium	µg/L	0.001	0.33	1.56	-	-
Uranium	µg/L	<0.1	<0.1	0.2	20	-
Vanadium	µg/L	<0.1	<0.1	0.15	-	-
Zinc	µg/L	<0.5	<0.5	1.5	≤5000[d]	30

(a) Numbers in bold are equal to or above guidelines.
(b) The parameters analyzed vary between sampling events. Refer to Appendix IX.6 for detailed results.
(c) All guidelines are from CCME (1999, with 2000 updates), with the exception of the aquatic life guideline for chloride, which is from U.S. EPA (1999). Hardness dependent guidelines are determined for a median baseline hardness of 6 mg/L, and the ammonia guideline was determined using a median baseline pH of 6.7 and temperature of 15 °C.
(d) Aesthetic objective.

Notes: < = less than detection limit (refer to glossary for definition).
Statistics (*i.e.,* minimum, median and maximum) were calculated using method outlined in Appendix IX.5.
Median values were not calculated when sample size was 2.
Source: Puznicki (1996).
µS/cm = micro Seimens per centimetre; TCU = true colour unit; NTU = nephelometric turbidity unit; mgCO3/L = milligram carbonate per litre; µg/L = microgram per litre; CFU/100 mL = colony forming unit per 100 millilitres.

Table 9.4-9 Summary of Water Quality in the Lockhart River Watershed, 1999

Parameter	Units	1999 Statistics[a] (n = 19 to 59)[b]			March 1999 Statistics (n = 38 to 40)			August 1999 Statistics (n = 18 to 19)			Water Quality Guidelines[c]	
		min	median	max	min	median	max	min	median	max	Drinking Water	Aquatic Life
Conventional Parameters												
pH	pH	**6.4**	6.6	6.9	**6.4**	6.7	6.9	6.5	6.6	6.8	6.5-8.5	6.5-9.0
Alkalinity	mg/L	3	4.4	17.8	3.6	4.6	8.5	3	4	17.8	-	-
Total Dissolved Solids	mg/L	<10	19	42	<10	20.5	42	10	15.5	26	≤500[d]	-
Total Suspended Solids	mg/L	<3	<3	**16**	<3	<3	5	<3	3.5	16	-	-
Total Hardness	mg/L	3.8	4.4	6.2	-	-	-	3.8	4.4	6.2	-	-
Total Organic Carbon	mg/L	2.8	3.4	5	-	-	-	2.8	3.4	5	-	-
Dissolved Organic Carbon	mg/L	2.4	3	4.1	-	-	-	2.4	3	4.1	-	-
Conductivity	µS/cm	12.5	16.5	146	13.6	17.6	29.5	12.5	15.3	146	-	-
Colour	TCU	<5	<5	10	<5	<5	10	<5	5	10	≤15[d]	-
Turbidity	NTU	0.1	0.7	**2.1**	0.1	0.65	**2.1**	0.4	0.7	**1.1**	1	short-term increase <8 long-term increase <2
Nutrients												
Ammonia	mg/L	<0.005	0.015	0.058	0.006	0.013	0.057	<0.005	0.025	0.058	-	11.1
Nitrate+Nitrite	mg/L	<0.008	0.01	<0.08	<0.008	0.012	0.054	<0.008	<0.008	<0.08	-	-
Nitrate	mg/L	<0.008	<0.008	0.009	-	-	-	<0.008	<0.008	0.009	-	-
Nitrite	mg/L	<0.008	<0.008	<0.008	-	-	-	<0.008	<0.008	<0.008	-	0.06
Total Phosphorus	mg/L	<0.002	0.004	0.023	<0.002	0.0045	0.013	<0.002	0.004	0.023	-	-
Phosphate	mg/L	<0.002	<0.002	0.003	-	-	-	<0.002	<0.002	0.003	-	-
Major Ions												
Calcium	mg/L	0.64	1.1	2.01	0.96	1.21	2.01	0.64	1.03	1.61	-	-
Chloride	mg/L	<0.2	<0.2	1.2	<0.2	0.2	1.2	<0.2	<0.2	0.3	≤250[d]	230
Magnesium	mg/L	0.43	0.54	1.1	0.47	0.59	1.1	0.43	0.52	0.56	-	-
Potassium	mg/L	0.34	0.46	0.88	0.34	0.52	0.88	0.38	0.44	0.52	-	-

Table 9.4-9 Summary of Water Quality in the Lockhart River Watershed, 1999 (continued)

Parameter	Units	1999 Statistics[a] (n = 19 to 59)[b]			March 1999 Statistics (n = 38 to 40)			August 1999 Statistics (n = 18 to 19)			Water Quality Guidelines[c]	
		min	median	max	min	median	max	min	median	max	Drinking Water	Aquatic Life
Silica	mg/L	0.1	0.23	1.3	0.1	0.22	1.3	0.14	0.25	0.72	-	-
Sodium	mg/L	0.39	0.52	1.1	0.47	0.57	1.1	0.39	0.47	0.53	≤200[d]	-
Sulphate	mg/L	<2	<3	11	<3	3	11	<2	<3	<3	≤500[d]	-
Total Metals												
Aluminum	µg/L	<10	<10	<30	<10	<10	29	<30	<30	<30	-	100
Antimony	µg/L	0.4	0.5	1	0.4	0.5	1	<0.5	<0.5	0.8	-	-
Arsenic	µg/L	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	25	5
Barium	µg/L	1	2	4.1	1.6	2	4.1	1	2	2	1000	-
Beryllium	µg/L	<0.1	<0.1	<2	<0.1	<0.1	<0.1	<2	<2	<2	-	-
Bismuth	µg/L	<0.1	<0.1	<0.4	<0.1	<0.1	<0.1	<0.4	<0.4	<0.4	-	-
Cadmium	µg/L	<0.01	<0.01	<0.3	<0.01	<0.01	0.08	<0.3	<0.3	<0.3	5	0.003
Cesium	µg/L	<0.01	0.01	<0.4	<0.01	0.01	0.02	<0.4	<0.4	<0.4	-	-
Chromium	µg/L	<0.05	0.2	<3	<0.05	<0.1	0.9	<3	<3	<3	50	1
Cobalt	µg/L	<0.1	<0.1	<1	<0.1	<0.1	0.2	<1	<1	<1	-	-
Copper	µg/L	0.3	0.8	<2	0.3	0.6	1.2	<2	<2	<2	≤1000[d]	2
Iron	mg/L	<0.012	<0.02	0.14	<0.012	<0.02	0.14	<0.03	<0.03	0.05	≤0.3[d]	0.3
Lead	µg/L	0.06	0.37	**2.37**	0.06	0.25	**2.37**	<1	<1	<1	10	1
Lithium	µg/L	0.7	1.2	<3	0.7	1.1	2.3	<2	<3	<3	-	-
Manganese	µg/L	0.5	2	32	0.5	1	32	1	4	7	≤50[d]	
Mercury	µg/L	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	-	-	-	1	0.1
Molybdenum	µg/L	<0.05	<0.05	<1	<0.05	<0.05	0.12	<1	<1	<1	-	73
Nickel	µg/L	0.1	0.8	1.2	0.1	0.6	1.2	<1	<1	1	-	25
Selenium	µg/L	<1	<1	<10	<1	<1	<1	<10	<10	<10	10	1
Silver	µg/L	<0.01	<0.01	<0.3	<0.01	<0.01	<0.01	<0.3	<0.3	<0.3	-	0.1
Strontium	µg/L	4	6.3	11.7	5.2	6.6	11.7	4	6	8	-	-
Thallium	µg/L	0.02	<0.05	<0.4	0.02	<0.05	0.05	<0.4	<0.4	<0.4	-	0.8
Titanium	µg/L	<0.05	<0.07	<3	<0.05	<0.05	0.5	<3	<3	<3	-	-
Uranium	µg/L	<0.05	<0.05	<3	<0.05	0.05	0.06	<0.3	<0.3	<3	20	-
Vanadium	µg/L	<0.1	<0.1	<1	<0.1	<0.1	0.1	<1	<1	<1	-	-
Zinc	µg/L	<5	<5	<10	<5	<5	9	<10	<10	<10	≤5000[d]	30

[a] Numbers in bold are equal to or above guidelines.
[b] The parameters analyzed vary between sampling events. Refer to Appendix IX.6 for detailed results.
[c] All guidelines are from CCME (1999, with 2000 updates), with the exception of the aquatic life guideline for chloride, which is from U.S. EPA (1999). Hardness dependent guidelines are determined for a median baseline hardness of 6 mg/L, and the ammonia guideline was determined using a median baseline pH of 6.7 and temperature of 15 °C.
[d] Aesthetic objective.

Notes: < = less than detection limit (refer to glossary for definition).

Statistics (*i.e.,* minimum, median and maximum) were calculated using method outlined in Appendix IX.5.

Median values were not calculated when sample size was 2.

Source: Unpublished INAC Data supplied by Bart Blais (July 26 2001).

µS/cm = micro Seimens per centimetre; TCU = true colour unit; NTU = nephelometric turbidity unit; $mgCO_3/L$ = milligram carbonate per litre; µg/L = microgram per litre; CFU/100 mL = colony forming unit per 100 millilitres.

Figure 9.4-6 Water Quality in Lakes Downstream of Snap Lake in March 1999
(Numbers refer to lakes shown on Figure 9.4-5)

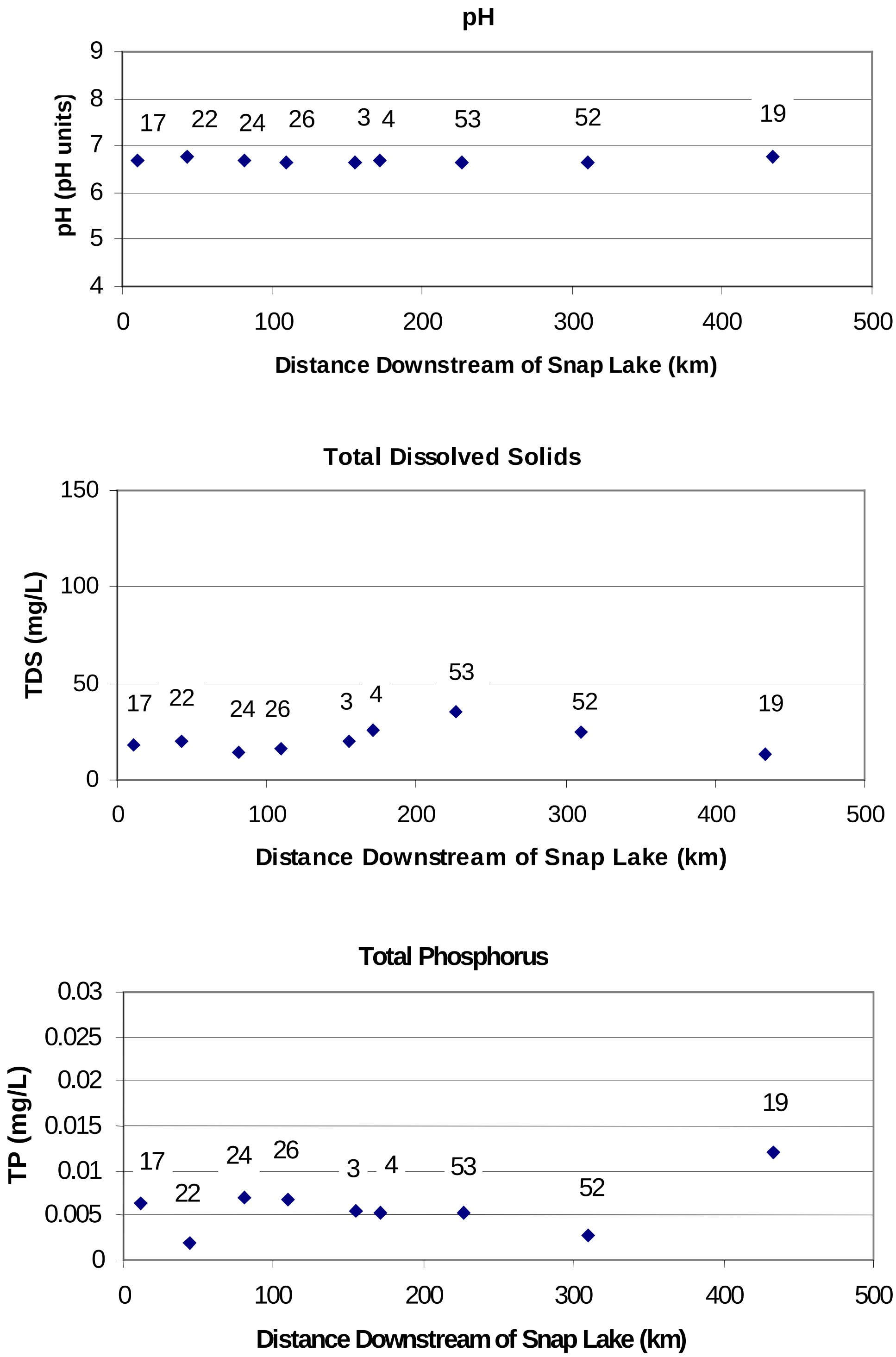


Table 9.4-10 Summary of Water Quality in the Lockhart River at the Outlet of Artillery Lake, 1969 to 2000

		1969-2000[a] (n = 1 to 106) [b]			Water Quality Guidelines[c]	
Parameter	Units	min	median	max	Drinking Water	Aquatic Life
Conventional Parameters						
pH (Lab)	pH	**5.9**	6.9	7.7	6.5-8.5	6.5-9.0
pH (Field)	pH	**4.2**	7.2	**9**	6.5-8.5	6.5-9.0
Alkalinity	mg/L	<0.1	4.6	13.2	-	-
Total Dissolved Solids	mg/L	<10	16	32	≤500[d]	-
Total Suspended Solids	mg/L	<1	<1	9	-	-
Hardness	mg/L	2.2	5.8	28.3	-	-
Conductivity (Lab)	µS/cm	11	16	34.7	-	-
Conductivity (Field)	µS/cm	4.7	14	32	-	-
Colour (True)	Rel. Units	<5	<5	7.5	≤15[d]	-
Turbidity	NTU	0.08	0.4	**5.5**	1	short-term increase <8 long-term increase <2
Nutrients						
Ammonia	mg/L	0.001	0.02	<0.1	-	11.1
Nitrate + Nitrite	mg/L	<0.001	0.02	1	-	-
Total Kjeldahl Nitrogen	mg/L	<0.1	0.45	1.28	-	-
Total Phosphorus	mg/L	<0.002	0.004	**0.042**	-	-
Dissolved Phosphorus	mg/L	<0.002	0.003	0.019	-	-
Orthophosphate	mg/L	<0.002	<0.002	0.003	-	-
Dissolved Organic Carbon	mg/L	0.8	2	3.4	-	-
Total Organic Carbon	mg/L	1	3.3	5	-	-
Major Ions						
Calcium	mg/L	0.6	1.3	59	-	-
Chloride	mg/L	<0.1	0.43	76.1	≤250[d]	230
Fluoride	mg/L	<0.01	0.03	0.12	1.5	-
Magnesium	mg/L	0.4	0.6	23	-	-
Potassium	mg/L	<0.1	0.4	9.2	-	-
Silica	mg/L	0.06	0.1	13.6	-	-
Sodium	mg/L	<0.1	0.5	47.4	≤200[d]	-
Sulphate	mg/L	<0.2	1.4	14.8	≤500[d]	-
Total Metals						
Aluminum	µg/L	0.2	6	23	-	100
Barium	µg/L	2.1	<50	120	1000	-
Beryllium	µg/L	<0.005	<0.05	<0.05	-	-
Cadmium	µg/L	<0.1	<0.1	**1.1**	5	0.003
Chromium	µg/L	<0.2	<0.2	6	50	1
Cobalt	µg/L	<0.1	<0.5	4	-	-
Copper	µg/L	0.4	0.75	**8**	≤1000[d]	2
Iron	mg/L	0.002	0.005	0.025	≤0.3[d]	0.3
Lead	µg/L	<0.2	<0.7	<4	10	1

Table 9.4-10 Summary of Water Quality in the Lockhart River at the Outlet of Artillery Lake, 1969 to 2000 (continued)

Parameter	Units	1969-2000[a] (n = 1 to 106) [b]			Water Quality Guidelines[c]	
		min	median	max	Drinking Water	Aquatic Life
Lithium	µg/L	<0.1	0.8	1	-	-
Manganese	µg/L	0.1	0.6	2	≤50[d]	-
Mercury	µg/L	<0.02	<0.02	0.05	1	0.1
Molybdenum	µg/L	<0.1	<0.1	0.1	-	73
Nickel	µg/L	<0.2	0.6	**31.9**	-	25
Silver	µg/L	<0.1	<0.1	**0.2**	-	0.1
Strontium	µg/L	5.2	5.7	6.9	-	-
Vanadium	µg/L	<0.1	<0.5	1.2	-	-
Zinc	µg/L	<0.2	1	19	≤5000[d]	30
Dissolved Metals						
Arsenic	µg/L	<0.1	<0.1	1.5	-	-
Boron	µg/L	10	<20	<50	-	-
Copper	µg/L	1	2	3	-	-
Iron	µg/L	<0.001	<0.02	0.08	-	-
Lead	µg/L	<1	<1	<1	-	-
Manganese	µg/L	<10	<10	<10	-	-
Selenium	µg/L	<0.1	<0.1	1.4	-	-
Zinc	µg/L	3	4.5	22	-	-
Biological Parameters						
Chlorophyll a	µg/L	-	5	-	-	-

(a) Numbers in bold are equal to or above guidelines.

(b) The parameters analyzed vary between sampling events. Refer to Appendix IX.6 for detailed results.

(c) All guidelines are from CCME (1999, with 2000 updates), with the exception of the aquatic life guideline for chloride, which is from U.S. EPA (1999). Hardness dependent guidelines are determined for a median baseline hardness of 6 mg/, and the ammonia guideline was determined using a median baseline pH of 6.7 and temperature of 15 °C.

(d) Aesthetic objective.

Notes: < = less than detection limit (refer to glossary for definition).

Statistics (*i.e.,* minimum, median and maximum) were calculated using method outlined in Appendix IX.5.

Median values were not calculated when sample size was 2. Data was represented as a median if sample size was 1.

Source: Unpublished INAC Data supplied by Bart Blais (July 26 2001).

Rel Units = relative units.

µS/cm = micro Seimens per centimetre; TCU = true colour unit; NTU = nephelometric turbidity unit; mgCO_3/L = milligram carbonate per litre; µg/L = microgram per litre; CFU/100 mL = colony forming unit per 100 millilitres.

Table 9.4-11 Summary of Seasonal Water Quality in the Lockhart River at the Outlet of Artillery Lake, 1969-2000

Parameter	Units	1969-2000 [(a)]												Water Quality Guidelines [(b)]	
		Spring (n = 1 to 14)[(c)]			Summer (n = 2 to 46)			Fall (n = 1 to 18)			Winter (n = 1 to 29)			Drinking Water	Aquatic Life
		min	median	max	min	median	max	min	median	max	min	median	max		
Conventional Parameters															
pH (Lab)	pH	**6.4**	6.9	7.41	**6.3**	6.9	7.6	**5.9**	6.9	7.7	**6.1**	6.8	7.7	6.5-8.5	6.5-9.0
pH (Field)	pH	**5.4**	7.1	7.6	**4.2**	7.1	8.1	**6.6**	6.8	7.4	**6.6**	7.3	**9**	6.5-8.5	6.5-9.0
Alkalinity	mg/L	2.5	4.6	6.1	<0.1	4.6	<10	2.1	4.9	6.8	3.6	4.6	13.2	-	-
Total Dissolved Solids	mg/L	<10	16	20	<10	13	32	<10	14	30	<10	17	26	≤500[(d)]	-
Total Suspended Solids	mg/L	<1	<1	4	<1	<1	4	<1	<3	9	<1	<1	3	-	-
Hardness	mg/L	5.4	11.3	28.3	4.9	5.5	8.7	2.2	6.1	10.9	4.8	-	7	-	-
Conductivity (Lab)	µS/cm	13.8	16.4	18.9	11	16.1	34.7	14.6	15.4	19	13.5	16.2	26	-	-
Conductivity (Field)	µS/cm	10	14.4	20	10	13.0	32	10	15.3	28	4.7	11.5	23	-	-
Colour (True)	Rel Units	<5	<5	5	<5	<5	6	<5	<5	7.5	<5	<5	5	≤15[(d)]	-
Turbidity	NTU	0.1	0.5	**5.5**	<0.1	0.3	**5.5**	0.08	0.5	**3.7**	0.1	0.3	**1.7**	1	short-term increase <8 long-term increase <2
Nutrients															
Ammonia	mg/L	0.01	0.01	0.02	0.001	0.01	<0.1	<0.002	<0.01	0.1	0.011	0.02	0.092	-	11.1
Nitrate + Nitrite	mg/L	0.01	0.02	1	<0.001	0.01	0.045	0.009	0.01	0.05	<0.001	0.02	0.069	-	-
Total Kjeldahl Nitrogen	mg/L	0.9	1.1	1.28	<0.1	<0.1	<0.5	<0.1	0.2	0.45	-	-	-	-	-
Total Phosphorus	mg/L	<0.003	0.005	0.01	<0.002	0.005	**0.042**	<0.003	0.004	0.01	<0.002	0.004	0.016	-	-
Dissolved Phosphorus	mg/L	<0.003	0.004	0.009	<0.002	0.003	0.019	<0.002	0.003	0.004	<0.002	<0.003	0.009	-	-
Orthophosphate	mg/L	-	<0.002	-	<0.002	<0.002	0.003	<0.002	-	<0.002	-	0.002	-	-	-
Dissolved Organic Carbon	mg/L	1.7	2.2	2.8	1.3	2.1	3.4	1	2.0	2.6	0.8	2.0	2.5	-	-
Total Organic Carbon	mg/L	-	1	-	1	4	5	3	3	3.5	-	4	-	-	-
Major Ions															
Calcium	mg/L	<1	1.2	8.2	0.9	1.3	2.7	0.6	1.3	5.4	0.7	1.2	59	-	-
Chloride	mg/L	<0.1	0.5	0.7	<0.1	0.5	3.6	0.25	0.4	0.45	0.1	0.4	76.1	≤250[(d)]	230
Fluoride	mg/L	<0.01	0.02	0.06	0.01	0.03	<0.1	0.01	0.04	<0.05	0.01	0.03	0.12	1.5	-
Magnesium	mg/L	0.5	0.6	1.1	0.4	0.6	0.8	0.4	0.6	0.8	0.5	0.6	23	-	-

Table 9.4-11 Summary of Seasonal Water Quality in the Lockhart River at the Outlet of Artillery Lake, 1969-2000 (continued)

		1969-2000 [a]												Water Quality Guidelines [b]	
		Spring (n = 1 to 14)[c]			Summer (n = 2 to 46)			Fall (n = 1 to 18)			Winter (n = 1 to 29)			Drinking Water	Aquatic Life
Parameter	Units	min	median	max	min	median	max	min	median	max	min	median	max		
Potassium	mg/L	0.25	0.44	0.5	<0.1	0.40	0.9	0.3	0.40	0.48	0.38	0.43	9.2	-	-
Silica	mg/L	0.08	0.14	0.23	0.08	0.10	0.8	<0.1	0.10	0.3	0.06	0.10	13.6	-	-
Sodium	mg/L	0.25	0.5	0.6	<0.1	0.5	3	0.3	0.5	0.8	0.4	0.5	47.4	<200[d]	-
Sulphate	mg/L	<1	1.5	2.2	0.6	1.4	6.8	<1	1.2	2	<0.2	1.5	14.8	<500[d]	-
Total Metals															
Aluminum	µg/L	4	6	8	3	7	14	0.2	2	10	4	6	23	-	100
Barium	µg/L	2.4	<80	<100	2.1	50	120	2.2	26	<100	2.2	<80	<100	1000	-
Beryllium	µg/L	<0.05	<0.05	<0.05	<0.005	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	-	-
Cadmium	µg/L	<0.1	<0.25	**1.1**	<0.1	<0.1	<1	<0.1	<0.1	<1	<0.1	<0.1	<1	5	0.003
Chromium	µg/L	<0.2	<0.2	<0.2	<0.2	<0.2	0.2	<0.2	<0.2	6	<0.2	<0.2	3	50	1
Cobalt	µg/L	<0.1	<0.5	4	<0.1	<0.5	3	<0.1	<0.30	<2	<0.1	<0.5	<1	-	-
Copper	µg/L	0.4	0.75	**3**	0.4	0.80	**5**	<0.5	0.75	**6**	0.4	0.8	**8**	≤1000[d]	2
Iron	mg/L	0.004	0.004	0.004	0.003	0.009	0.025	0.004	0.004	0.015	0.002	0.005	0.014	≤0.3[d]	0.3
Lead	µg/L	<0.2	<0.7	<4	<0.2	<0.7	<4	<0.2	<0.5	<4	<0.2	<0.7	1.6	10	1
Lithium	µg/L	0.6	0.8	1	<0.1	0.7	0.9	0.7	0.8	0.9	0.7	0.9	1	-	-
Manganese	µg/L	0.4	0.7	1	0.5	0.9	2	0.5	0.6	0.6	0.1	0.4	1	≤50[d]	
Mercury	µg/L	-	<0.02	-	0.03	0.03	0.05	-	<0.02	-	<0.02	-	<0.02	1	0.1
Molybdenum	µg/L	<0.1	<0.1	0.1	<0.1	<0.1	0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.1	-	73
Nickel	µg/L	<0.2	<0.5	6	<0.2	0.8	**31.9**	0.4	0.5	3	<0.5	0.5	2	-	25
Silver	µg/L	**-**	**0.1**	**-**	<0.1	<0.1	<0.1	<0.1	<0.1	**0.2**	<0.1	<0.1	<0.1	-	0.1
Strontium	µg/L	5.8	5.8	5.9	5.2	5.7	6	5.3	5.6	5.6	5.6	5.7	6.9	-	-
Vanadium	µg/L	<0.1	<0.5	<1	<0.1	<0.5	<1	<0.1	<0.1	<1	<0.1	<0.5	1.2	-	-
Zinc	µg/L	0.2	0.9	11.2	<0.2	1	9.7	0.2	0.45	19	<0.2	1.3	6	≤5000[d]	30
Dissolved Metals															
Arsenic	µg/L	<0.1	<0.1	<0.5	<0.1	<0.1	1.5	<0.1	<0.1	<0.5	<0.1	<0.1	<0.5	-	-
Boron	µg/L	<20	<20	30	<20	<20	<50	<20	<20	<20	10	<20	20	-	-
Copper	µg/L	-	2	-	1	-	2	-	3	-	-	3	-	-	-
Iron	mg/L	<0.04	-	<0.05	<0.001	<0.001	0.08	0.02	-	<0.05	-	<0.001	-	-	-

Table 9.4-11 Summary of Seasonal Water Quality in the Lockhart River at the Outlet of Artillery Lake, 1969-2000 (continued)

		1969-2000 [(a)]												Water Quality Guidelines [(b)]	
		Spring (n = 1 to 14)[(c)]			Summer (n = 2 to 46)			Fall (n = 1 to 18)			Winter (n = 1 to 29)			Drinking Water	Aquatic Life
Parameter	Units	min	median	max	min	median	max	min	median	max	min	median	max		
Lead	µg/L	-	<1	-	<1	-	<1	-	<1	-	-	<1	-	-	-
Manganese	µg/L	<10	-	<10	<10	<10	<10	-	<10	-	-	-	-	-	-
Selenium	µg/L	<0.1	<0.1	<0.5	<0.1	<0.1	0.6	<0.1	<0.1	1.4	<0.1	<0.1	1	-	-
Zinc	µg/L	-	-	-	5	-	22	-	3	-	-	4	-	-	-
Biological Parameters															
Chlorophyll *a*	µg/L	-	-	-	-	-	-	-	5	-	-	-	-	-	-

(a) Numbers in bold are equal to or above guidelines.

(b) All guidelines are from CCME (1999, with 2000 updates), with the exception of the aquatic life guideline for chloride, which is from U.S. EPA (1999). Hardness dependent guidelines are determined for a median baseline hardness of 6 mg/L, and the ammonia guideline was determined using a median baseline pH of 6.7 and temperature of 15 °C.

(c) The parameters analyzed vary between sampling events. Refer to Appendix IX.6 for detailed results.

(d) Aesthetic objective.

Notes: < = less than detection limit (refer to glossary for definition).

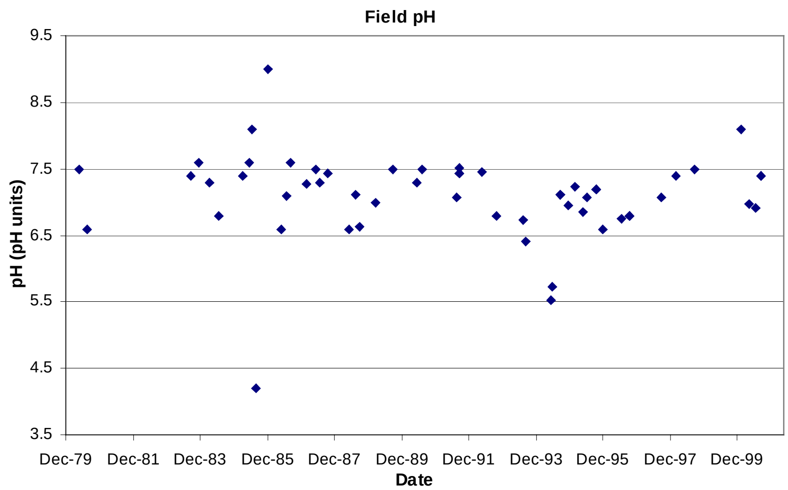
Statistics (*i.e.,* minimum, median and maximum) were calculated using method outlined in Appendix IX.5.

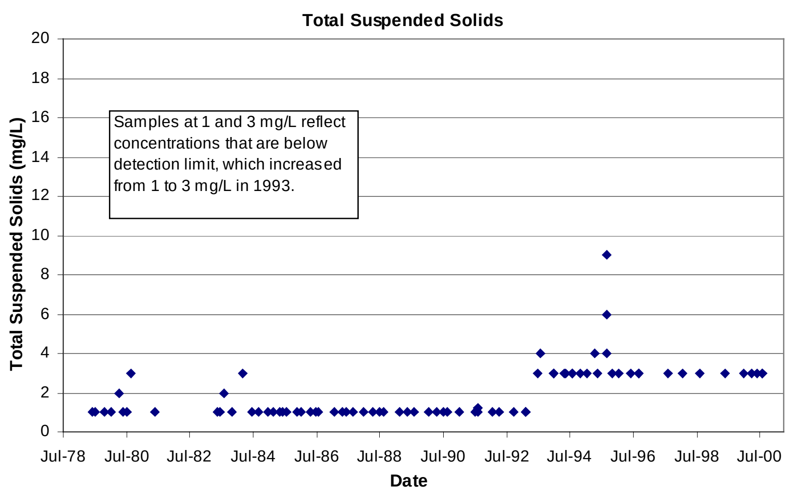
Median values were not calculated when sample size was 2. Data was represented as a median if sample size was 1.

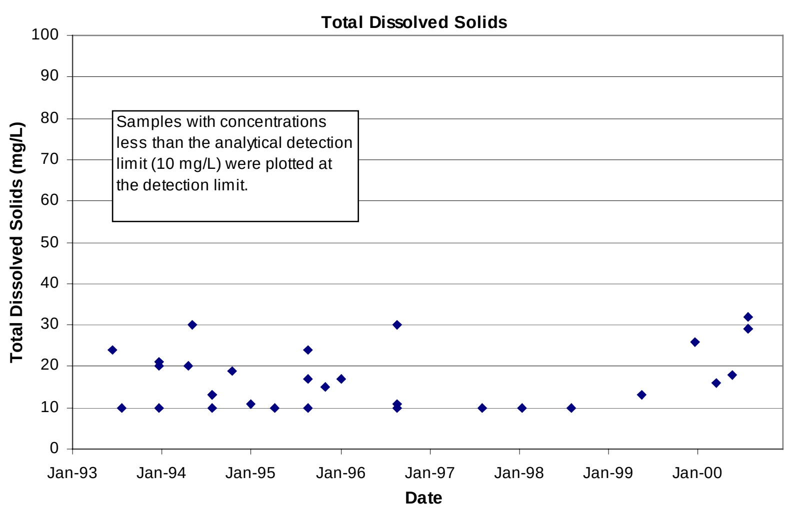
Source: Environment Canada.

µS/cm = micro Seimens per centimetre; TCU = true colour unit; NTU = nephelometric turbidity unit; $mgCO_3/L$ = milligram carbonate per litre; µg/L = microgram per litre; CFU/100 mL = colony forming unit per 100 millilitres.

Figure 9.4-7 Water Quality at the Outlet of Artillery Lake (OA1)







9.4.1.8.2 Sediment Quality

Sediment quality in the Lockhart River watershed was similar to the quality in the Snap Lake watershed

Sediment quality in lakes throughout the Lockhart River watershed (Tables 9.4-12 and 9.4-13) was generally similar to Snap Lake and the reference lake. Typically, sediment was predominantly sand and silt with very little clay. Concentrations of several metals (cadmium, chromium, copper, lead, and zinc) were above CISQG levels in some waterbodies. Copper concentrations were above the CISQG level in more than half of the waterbodies sampled. Concentrations of lead in some waterbodies were also above the less stringent probable effects level (PEL) for aquatic life (CCME 1999) (Appendix IX.6).

9.4.1.9 Lake Acidification in the Regional Study Area

9.4.1.9.1 Background Information

Acidifying emissions input may affect pH levels in lakes

Acidifying emissions may result in a reduction in pH in lakes in the RSA. A substantial reduction in pH levels could have a detrimental impact to the ecosystem of a lake.

Alkalinity or acid neutralizing capacity (ANC) can be used to gauge the acid sensitivity of lakes

The sensitivity of lakes to acid deposition can be gauged on the basis of alkalinity or acid neutralizing capacity (ANC). Alkalinity is a measure of inorganic buffering capacity via the carbonate/bicarbonate buffering system (Wetzel 1983). ANC is a more exact measure of buffering capacity; it is the difference between the concentrations of nonmarine base cations and strong acid anions (Hindar *et al*. 1998) and also incorporates buffering provided by organic compounds and dissolved metals. Alkalinity is the more commonly used indicator of acid-sensitivity in North America (*e.g.*, Saffran and Trew 1996).

A critical load estimates the amount of acidic deposition below which substantial harmful effects would occur

At the present, the most sophisticated approach to assess sensitivity of lakes to acidification is the calculation of lake-specific critical loads (CLs), which are based on ANC (*e.g.*, Hindar *et al*. 1998). The CL can be thought of as an estimate of the amount of acidic deposition below which no substantial harmful effects occur to a specified component of a lake's ecosystem (*e.g.*, a valued fish species) (Sullivan 2000). CLs are discussed in greater detail in the water quality impact assessment (Section 9.4.2.4). CLs are used to evaluate potential impacts of acidifying emissions from the Snap Lake Diamond Project. Detailed methodology used in calculations of CLs is located in Appendix IX.5.

Table 9.4-12 Summary of Sediment Quality in the Lockhart River Watershed, 1993/1994

Parameter	Units	Summary Statistics			CCME Guidelines [(a)] Aquatic Life	
		min	median	max	ISQG [(b)]	PEL [(c)]
Total Metals						
Aluminum	µg/g	6678	12237	32806	-	-
Antimony	µg/g	0.01	0.03	0.17	-	-
Arsenic	µg/g	0.6	8.4	49.0	-	-
Barium	µg/g	36	67	322	-	-
Beryllium	µg/g	0.15	0.4	1.35	-	-
Bismuth	µg/g	0.01	0.28	1.02	-	-
Cadmium	µg/g	0.03	0.22	**0.76**	0.6	3.5
Calcium	µg/g	295	1255	3514	-	-
Cesium	µg/g	0.7	2.0	4.2	-	-
Chromium	µg/g	16.7	30.4	**47.6**	37.3	90
Cobalt	µg/g	4.1	10.1	78.7	-	-
Copper	µg/g	13.2	**42.4**	**92.9**	35.7	197
Iron	%	0.01	0.019	0.176	-	-
Lead	µg/g	1.9	4.2	**501.5**	35	91.3
Lithium	µg/g	7.4	17.9	33.7	-	-
Magnesium	µg/g	1747	3760	6634	-	-
Manganese	µg/g	80	212	17610	-	-
Mercury	µg/g	0.024	0.088	**0.739**	0.170	0.486
Molybdenum	µg/g	0.3	2.1	11.0	-	-
Nickel	µg/g	11.4	32.8	78.5	-	-
Potassium	µg/g	858	1774	4223	-	-
Rubidium	µg/g	5	13.9	28.4	-	-
Selenium	µg/g	0.06	0.6	1.9	-	-
Silver	µg/g	0.004	0.1	0.3	-	-
Sodium	µg/g	50	80.1	212	-	-
Strontium	µg/g	4.0	9.2	22.2	-	-
Thallium	µg/g	0.1	0.2	0.4	-	-
Uranium	µg/g	1.1	4.1	27.7	-	-
Vanadium	µg/g	16.9	28.3	41.7	-	-
Zinc	µg/g	27.4	75	**145**	123	315

[(a)] Numbers in bold are equal to or above guidelines.
[(b)] Interim freshwater sediment quality guideline (ISQG).
[(c)] Probable effect levels (PEL).
Notes: < = less than detection limit (refer to glossary for definition).
Statistics (*i.e.,* minimum, median and maximum) were calculated using method outlined in Appendix IX.5.
Source: Puznicki (1996).
µS/cm = micro Seimens per centimetre; TCU = true colour unit; NTU = nephelometric turbidity unit; $mgCO_3/L$ = milligram carbonate per litre; µg/L = microgram per litre; CFU/100 mL = colony forming unit per 100 millilitres.

Table 9.4-13 Summary of Sediment Quality in the Lockhart River Watershed, 1999

		1999 Statistics			March 1999 Statistics			August 1999 Statistics			CCME Guidelines [(a)] Aquatic Life	
Parameter	Units	min	median	max	min	median	max	min	median	max	ISQG [(b)]	PEL [(c)]
% Organic Matter	%	0.98	12.98	39.3	0.98	12.98	30.1	1.4	11.7	39.3	-	-
% Moisture Content	%	33.5	83.1	91.7	33.5	83.1	91.7	-	-	-	-	-
%Clay	%	0.33	3.0	18.6	-	-	-	0.33	3.0	18.6	-	-
% Silt	%	5.5	36.5	67.1	-	-	-	5.5	36.5	67.1	-	-
% Sand	%	14.4	60.8	94.2	-	-	-	14.4	60.8	94.2	-	-
pH - Soil	pH	4.67	5.21	6.3	4.67	4.88	5.95	5.1	5.4	6.3	-	-
Avail Nitrogen (Soil)	mg/g	2.94	5.6	17.2	2.94	7.25	17.2	<4	<4	12.8	-	-
Avail Phosphorus (Soil)	mg/g	1.8	74.2	1330	17.4	59.2	337	1.8	330	1330	-	-
Calcium (Soil External)	µg/g	<100	700	2300	557	740	1570	<100	600	2300	-	-
Potassium - Soil	µg/g	60	224	673	200	341.5	673	60	90	290	-	-
Sodium (Soil External)	µg/g	<40	115	197	115	153	197	<40	<40	80	-	-
Total Metals												
Aluminum	µg/g	8400	15200	31000	9000	16500	31000	8400	15100	20000	-	-
Antimony	µg/g	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	-	-
Arsenic	µg/g	0.6	9.7	55.3	0.6	4.9	22.1	2.6	11	55.3	-	-
Barium	µg/g	50.1	90.1	205	62.2	101	205	50.1	84.9	176	-	-
Beryllium	µg/g	0.2	0.5	1.4	0.2	0.5	1.4	<0.4	0.5	0.9	-	-
Bismuth	µg/g	<0.2	<0.2	1.5	<0.2	0.3	0.4	<0.2	<0.2	1.5	-	-
Cadmium	µg/g	<0.2	0.4	**1**	<0.2	0.4	**0.8**	<0.2	0.4	**1**	0.6	3.5
Calcium	µg/g	1600	2450	4200	1600	2450	4200	-	-	-	-	-
Cesium	µg/g	0.4	1.9	4	0.4	1.9	4	1	1.9	2.7	-	-
Chromium	mg/g	12.1	33.4	**60**	12.1	34.4	**60**	17.1	33.1	**41.7**	37.3	90
Cobalt	µg/g	3.9	14.6	124	3.9	13	45.1	4	15.9	124	-	-
Copper	µg/g	6.8	**47.2**	**86.9**	6.8	**48.4**	**81**	15.1	**47.2**	**86.9**	35.7	197
Iron	%	0.01	0.022	0.164	0.0113	0.024	0.055	0.01	0.0221	0.164	-	-
Lead	µg/g	3.2	15.9	**153**	3.2	28.35	**86**	3.5	5	**153**	35	91.3
Lithium	µg/g	6.5	19	42.6	6.5	17.95	42.6	12.9	20	32.9	-	-
Magnesium	µg/g	3800	4800	10400	3800	4800	10400	-	-	-	-	-
Manganese	µg/g	112	451	21200	134	446.5	2270	112	451	21200	-	-
Mercury	µg/g	0.008	0.024	0.05	0.008	0.024	0.05	-	-	-	0.17	0.486
Molybdenum	µg/g	<0.2	2.5	10.2	<0.2	2.3	10.2	0.2	2.6	6.5	-	-
Nickel	µg/g	8.7	42.9	92.5	8.7	35.7	78.6	22.3	45.5	92.5	-	-
Potassium	µg/g	2100	3000	7400	2100	3000	7400	-	-	-	-	-
Rubidium	µg/g	8.9	14.9	42.7	9.3	17.8	42.7	8.9	14.4	23.3	-	-
Selenium	µg/g	<2	<20	<20	<20	<20	<20	<2	<2	<2	-	-
Silver	µg/g	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	-	-
Sodium	µg/g	300	500	1000	300	500	1000	-	-	-	-	-
Strontium	µg/g	9.3	15.9	33.9	13.7	19.5	33.9	9.3	14.4	21.1	-	-
Thallium	µg/g	<0.2	<0.2	0.7	<0.2	0.2	0.4	<0.2	<0.2	0.7	-	-

Table 9.4-13 Summary of Sediment Quality in the Lockhart River Watershed, 1999 (continued)

Parameter	Units	1999 Statistics min	1999 Statistics median	1999 Statistics max	March 1999 Statistics min	March 1999 Statistics median	March 1999 Statistics max	August 1999 Statistics min	August 1999 Statistics median	August 1999 Statistics max	CCME Guidelines [a] Aquatic Life ISQG [b]	CCME Guidelines [a] Aquatic Life PEL [c]
Titanium	µg/g	244	467	1280	244	480	1280	263	467	962	-	-
Uranium	µg/g	0.6	3	44.8	0.6	2.9	44.8	1.5	3	8.6	-	-
Vanadium	µg/g	16.9	33.4	51.4	20.9	34.9	51.4	16.9	29.4	40.1	-	-
Zinc	µg/g	23	73	**167**	23	90	**167**	24.4	72	**134**	123	315

[a] Numbers in bold are equal to or above guidelines.
[b] Interim freshwater sediment quality guideline (ISQG).
[c] Probable effect levels (PEL).
Notes: < = less than detection limit (refer to glossary for definition).
mg/g = milligram per gram.
µS/cm = micro Seimens per centimetre; TCU = true colour unit; NTU = nephelometric turbidity unit; mgCO3/L = milligram carbonate per litre; µg/L = microgram per litre; CFU/100 mL = colony forming unit per 100 millilitres.
Statistics (*i.e.,* minimum, median and maximum) were calculated using method outlined in Appendix IX.5.
Source: Unpublished INAC Data supplied by Bart Blais (July 26 2001).

9.4.1.9.2 Acid-sensitivity of Regional Lakes

The majority of lakes in the Lockhart River watershed are highly sensitive to acidification

To provide an indication of basic water chemistry and acid sensitivity of lakes in the Snap Lake and Lockhart River watersheds, acid sensitivity of a representative subset of the lakes is shown in Table 9.4-14. Using the classification system of Saffran and Trew (1996), 61 of the 62 lakes, for which there were alkalinity data, are highly sensitive to acidification (alkalinity between 0 and 10 mg/L). One lake (lake 43) can be classified as having a low sensitivity (21 to 40 mg/L) to acidification. The locations of lakes are shown in Figures 9.4-4 and 9.4-5.

Table 9.4-14 Summary of Water Chemistry Data Related to Acid Sensitivity of Regional Lakes

Sampling Station	Conductivity (µS/cm)	Hardness (mg/L)	TDS (mg/L)	Colour (TCU)	pH	Alkalinity (mg/L)	Data Source [a]
Lakes in the Snap Lake Watershed							
Snap Lake	18	6	17	10	6.7	6.0	Hallam Knight Piesold (1998), present study
IL1	18	6	27	-	6.5	5.0	present study
IL4	13	5	47	-	6.1	3.0	present study
IL3	13	5	43	-	6.2	3.0	present study
NL1	29	12	30	-	6.5	8.0	present study
IL5	12	4	26	-	6.4	3.0	present study
NL3	23	9	20	-	6.6	6.0	present study
NL2	24	10	18	-	6.4	8.0	present study
NL4	19	7	27	-	6.5	4.0	present study
Lakes in the Lockhart River Watershed							
Original	28	10	16	-	6.6	8.5	present study

Table 9.4-14 Summary of Water Chemistry Data Related to Acid Sensitivity of Regional Lakes (continued)

Sampling Station	Conductivity (µS/cm)	Hardness (mg/L)	TDS (mg/L)	Colour (TCU)	pH	Alkalinity (mg/L)	Data Source [(a)]
reference lake							
WQ5	21	7	15	5	6.7	6.0	present study
Reference lake	17	5	19	-	6.5	4.0	present study
1	21	4	19	< 5	6.6	4.9	Unpublished INAC data
2	13	3	< 10	5	6.5	1.4	Puznicki (1996)
3	22	-	20	< 5	6.6	5.8	Unpublished INAC data
4	16	4	18	5	6.6	4.0	Unpublished INAC data
5	14	4	10	5	6.5	2.0	Puznicki (1996)
6	11	3	< 10	< 5	6.3	0.4	Puznicki (1996)
7	14	4	11	< 5	6.5	1.8	Puznicki (1996)
8	17	6	22	< 5	6.6	2.5	Puznicki (1996)
11	15	4	12	< 5	6.6	2.5	Puznicki (1996)
12	19	6	15	< 5	6.8	6.4	Unpublished INAC data
13	15	14	21	< 5	6.6	2.3	Puznicki (1996)
14	19	5	21	< 5	6.7	4.6	Unpublished INAC data
16	13	4	34	< 5	6.6	3.7	Puznicki (1996)
17	16	-	13	< 5	6.7	4.5	Unpublished INAC data
18	14	4	19	7	6.7	3.5	Puznicki (1996)
19	20	-	14	< 5	6.8	5.5	Unpublished INAC data
20	18	5	19	< 5	6.8	4.1	Puznicki (1996)
21	45	15	28	< 5	7.0	8.0	Puznicki (1996)
22	16	-	24	< 5	6.9	4.9	Unpublished INAC data
23	15	5	10	< 5	6.6	4.1	Unpublished INAC data
24	19	5	17	< 5	6.6	4.4	Puznicki (1996), unpublished INAC data
25	15	5	16	< 5	6.5	2.9	Puznicki (1996)
26	20	5	16	5	6.7	5.3	Unpublished INAC data
27	19	-	< 10	< 5	6.6	4.5	Unpublished INAC data
28	17	4	14	5	6.6	3.7	Unpublished INAC data
29	14.4	4	13	< 5	6.67	2.2	Puznicki (1996)
30	13	4	12	10	6.5	3.0	Unpublished INAC data
31	12	4	24	< 5	6.5	1.4	Puznicki (1996)
32	13	4	20	5	6.5	3.2	Unpublished INAC data
33	13	4	16	5	6.5	3.0	Unpublished INAC data
34	13	4	13	5	6.5	3.0	Unpublished INAC data
35	13	4	26	8	6.5	2.5	Puznicki (1996), unpublished INAC data
36	12	4	29	< 5	6.6	1.9	Puznicki (1996)
37	15	5	17	< 5	6.6	2.2	Puznicki (1996)
38	10	2	16	< 5	6.2	< 0.3	Puznicki (1996)
39	10	3	13	5	6.4	1.4	Puznicki (1996)
40	12	3	25	< 5	6.7	2.0	Puznicki (1996)
41	11	4	21	< 5	6.4	0.9	Puznicki (1996)
42	12	4	13	< 5	6.5	1.5	Unpublished INAC data

Table 9.4-14 Summary of Water Chemistry Data Related to Acid Sensitivity of Regional Lakes (continued)

Sampling Station	Conductivity (µS/cm)	Hardness (mg/L)	TDS (mg/L)	Colour (TCU)	pH	Alkalinity (mg/L)	Data Source [(a)]
43	71	34	53	7	7.7	30.5	Puznicki (1996)
44	13	4	12	< 5	6.6	1.5	Puznicki (1996)
45	13	3	11	< 5	6.6	1.5	Puznicki (1996)
46	12	3	11	< 5	6.6	1.3	Puznicki (1996)
47	13	5	26	7	6.4	1.2	Puznicki (1996)
49	16	6	17	< 5	6.6	3.4	Puznicki (1996)
50	14	5	23	< 5	6.4	1.0	Puznicki (1996)
51	29	-	38	10	6.5	8.5	Unpublished INAC data
52	15	-	28	< 5	6.6	3.9	Unpublished INAC data
53	17	-	37	< 5	6.6	4.3	Unpublished INAC data
100	22	5	31	8	6.8	3.0	Puznicki (1996)
101	18	6	20	< 5	6.7	3.4	Puznicki (1996)

[(a)] Data are shown for open-water season; mean values are shown for lakes with more than one sample.

- = No data.

µS/cm = micro Seimens per centimetre; TCU = true colour unit; NTU = nephelometric turbidity unit; mgCO3/L = milligram carbonate per litre; µg/L = microgram per litre; CFU/100 mL = colony forming unit per 100 millilitres.

9.4.2 Impact Assessment

9.4.2.1 Introduction

Community consultation recognizes water as the most important element of life

Issues relating to water quality and levels were raised during community site visits and community consultation sessions, during the review of the Yellowknives Dene Elder’s traditional knowledge work, the North Slave Métis’ review of Diavik, and during the Lutsel K’e Elder’s traditional knowledge work at Snap Lake. Elders described how water is the most important element of life, how it ties all life together. They identified that it is important to keep surface runoff clean.

> *Even if the ground is contaminated, it can be fixed. But if water is contaminated, everything will be affected. We need to watch (monitor) even the smallest streams* (J.B. Rabesca, May 25, 2001) (Lutsel K’e Dene First Nation 2001).

Communities identified that water in the Lockhart River should also be studied

Water quality was also regarded as a regional issue and the importance of the Lockhart River was identified.

> *You should protect the areas and waterways that flow into the Lockhart River. Even as far as McKinley Point to MacKay Lake should be protected. At one time in the dry years – it may not seem like the water flows that way but in the spring you can see it*

– *it all flows to Great Slave Lake* (P. Catholique, January 20, 2001) (Lutsel K'e Dene First Nation 2001).

Key questions for assessing impacts on water quality were developed

To address the concerns raised by traditional knowledge and to meet the EA Terms of Reference (Table 9.1-1 in Section 9.1), the issues were consolidated into key questions. Key questions for assessing the impacts of the Snap Lake Diamond Project on water quality in the receiving environment include the following:

Key Question WQ-1: What impacts will the Snap Lake Diamond Project have on surface water quality in the Snap Lake area?

Key Question WQ-2: What impacts will the Snap Lake Diamond Project have on regional water quality in the Lockhart River Watershed?

Key Question WQ-3: What impacts will acidifying emissions from the Snap Lake Diamond Project have on Snap Lake and regional waterbodies?

The water quality assessment follows a framework for evaluating potential impacts

The assessment approach for water quality consisted of the following steps, which provide an overall framework for evaluating the potential impacts of the Snap Lake Diamond Project (the project) on water quality:

1. Identify the project activities and associated physical or chemical changes that may affect water quality.
2. Identify the potential effects on water quality, and illustrate the linkages between project activities and impacts in the form of a linkage diagram.
3. Evaluate the validity of each linkage (pathway) contributing to a potential effect.
4. Describe the mitigation that will be implemented to minimize or prevent potential impacts on surface water quality.
5. For the valid linkages, conservatively predict changes in water quality after mitigation.
6. Evaluate and classify the predicted changes in water quality by comparison with regulatory guidelines or other appropriate site-specific benchmarks.
7. Describe the monitoring program that will be implemented to verify predictions.

9.4.2.1.1 General Water Quality Assessment Methods

Some general concepts and methods are consistent for all pathways, while others are more specific to a particular pathway

There are some general assessment concepts and methods that are common to all water quality impact pathways. These include the general environmental quality guidelines and site-specific benchmarks that are used to measure impacts, and the general assessment methodology by which the environmental consequences of impacts are determined. A discussion of the general concepts and methods is provided in this section. Details on models used to predict impacts are provided in Appendix IX.7. Details on the derivation of site-specific benchmarks are provided in Appendix IX.8. Methods that are specific to particular impact pathways are presented within the sections that address each key question.

Potential impacts of changes in water quality are compared to general guidelines, site-specific benchmarks for protection of aquatic life and drinking water guidelines

Environmental quality guidelines and site-specific benchmarks are used to assess the potential impact of changes in water and sediment quality resulting from the Snap Lake Diamond Project. The potential impacts of changes in water quality were evaluated by comparing predicted concentrations to general guidelines and site-specific benchmarks for the protection of aquatic life, as well as drinking water guidelines for the protection of the drinking water supply. Potential impacts to sediment quality were evaluated qualitatively based on changes in water quality and consideration of sediment-water interactions. Sediment quality guidelines for the protection of aquatic life are used as a measure of the potential for impacts related to changes in sediment quality.

Water quality changes compared to Health Canada drinking water guidelines for protection of drinking water supplies

Health Canada has established Canadian Drinking Water Guidelines (CDWG), which are intended to protect community drinking water supplies (Health Canada 1996). Potential impacts on drinking water supply were assessed by comparing predicted water quality changes in surface water bodies to the CDWG.

Canadian Council of Ministers of the Environment provides science-based goals to protect the most sensitive life stages of the most sensitive species in all surface waters

The Canadian Council of Ministers of the Environment (CCME) has established Canadian Water Quality Guidelines (CWQG) and Canadian Sediment Quality Guidelines (CSQG) for the protection of aquatic life that are nationally endorsed by the ten provinces, three territories and the federal government (CCME 1999, with 2000 updates). The CWQG and CSQG are science-based goals for protecting the quality of aquatic ecosystems. They are defined as numerical concentrations or narrative statements that should result in negligible risk to biota, their functions, or any interactions that are critical to sustaining ecosystem health. In the case of metals and most other parameters that can be toxic to aquatic life, the CWQG are intended to protect the most sensitive life stage of the most sensitive species in the long-term for all surface waters.

Substances of potential concern with no Canadian Council of Ministers of the Environment guideline were compared to other regulatory criteria

There are some parameters that are of potential concern for the protection of aquatic life due to the project, for which CCME has not established CWQG. These include TDS, major ions (chloride, in particular) and phosphorus. The U.S. Environmental Protection Agency (U.S. EPA) has established an aquatic life criterion for chloride (U.S. EPA 1999), which was used in the assessment. The potential for changes in TDS and major ions to impact aquatic biota are assessed in Section 9.5.

Phosphorous is not toxic but increases can alter the productivity or trophic level of a waterbody; no general guideline is available but any substantial increases were assessed, if present

The potential impact of phosphorus is different than most other parameters considered, in that it is not toxic to aquatic life. Phosphorus is the nutrient that limits primary productivity (phytoplankton and benthic algae biomass) in lakes and streams throughout the LSA and RSA. The productivity or trophic level of water bodies has been classified based on total phosphorus concentrations in the water column (Vollenweider 1968; Auer *et al*. 1986). There is no generally accepted guideline or benchmark for assessing the impact of changes in the trophic status of a lake. Potential changes in the phosphorus concentrations and the secondary effect on primary biological productivity (*e.g.*, phytoplankton biomass) were predicted if the phosphorus concentrations and loads in the water release are more than 10% higher than under baseline conditions. Potential impacts of changes in primary productivity on the aquatic ecosystem would be evaluated qualitatively in Section 9.5.

Canadian Water Quality Guidelines are generic recommendations, site-specific benchmarks can be established to account for modifying factors

The CWQG are generic recommendations based on current scientific information, but do not directly consider site-specific factors or address community level effects. Site-specific water quality benchmarks can be established that are based on the same body of scientific information as the CWQG, but that also consider site-specific factors and that represent thresholds at which community level impacts could occur.

Step 1 was to compare predicted water quality at the discharge to guidelines; all parameters below these guidelines were determined to have a negligible impact potential

CWQG have been developed for a broad range of parameters and are used in the water quality assessment to identify parameters that do not have the potential to impact water quality due to the Snap Lake Diamond Project. The first step was to compare the predicted water quality of water releases to the CWQG and CDWG. All those parameters with concentrations that were below the CWQG and CDWG prior to release were determined to have a negligible potential to impact water quality when released to the environment (*i.e.*, the concentration would be below a level that would have an adverse impact on aquatic life).

Step 2 was to predict parameter concentrations in the receiving waterbody and compare to these guidelines

The remaining parameters were carried forward to the second step, which was to predict the concentration of the parameters in the receiving water body and compare these concentrations to CWQG and CDWG. All parameters with predicted concentrations that were below CWQG and CDWG within the surface water body would have a negligible potential to impact water quality. In some cases there was a potential for a gradient in parameter concentrations to exist within the waterbody. In these cases, the highest predicted concentration at the boundary of a small area that, even if impacted, would have a negligible impact on the aquatic ecosystem was compared to the CWQG.

Step 3 was to develop site-specific benchmarks for any remaining substances not screened out in the first two steps; benchmarks were developed as hazard concentrations based on community level effects

Site-specific water quality benchmarks were developed for all parameters remaining after the first two screening steps. The site-specific water quality benchmarks differ from general guidelines in that they incorporate a risk-based approach to quantify potential impacts to the aquatic community as a whole, (*i.e.*, not single organism protection), and consider the aquatic species potentially present in the Snap Lake region. Three benchmark concentrations are defined that provide different levels of protection to the aquatic community. The benchmarks are expressed as hazard concentrations (HC) that represent the percent of the species in the aquatic community that could be affected by long-term exposure. The effects endpoint for all test results used to define HC values was the lowest observable effects concentration (LOEC). LOEC is the lowest concentration for which a toxicological effect (*e.g.*, impairment to growth, reproduction, *etc*.) could be detected in laboratory toxicity tests. Three different site-specific HC benchmark values were defined:

- HC_5, which protects 95% of the aquatic community from potential chronic exposure;
- HC_{10}, which protects 90% of the aquatic community from potential chronic exposure; and,
- HC_{20}, which protects 80% of the aquatic community from potential chronic exposure.

Methodology for benchmarks is provided in Appendix IX.8

The detailed methodology used to derive site-specific water quality benchmarks, and the complete results for all benchmarks derived are provided in Appendix IX.8.

Environmental consequences of the impact to water quality were based on comparisons of the predicted concentrations to the site-specific benchmarks and followed specific impact criteria

For parameters that were not determined to have a negligible impact during the two step screening, site-specific benchmarks were compared to predicted concentrations and the environmental consequences of the impacts to water quality were evaluated using the following impact criteria (as defined in Section 9.1):

- direction, which may be either neutral or negative;
- magnitude, which may be negligible, low, moderate or high;
- geographic extent, which is local if it is restricted to the LSA and regional if it extends beyond the LSA;
- duration, which is short-term if the duration of the activity causing the effect is ≤3 years, medium-term if the activity duration is >3 years and ≤26 years, and long-term if the activity duration is >26 years;
- reversibility, which is short-term if the effect can be reversed within 30 years after the source of the effect has ceased, is long-term if the effect can be reversed in more than 30 years, and is irreversible if the effect can not be reversed; and,
- frequency, which is low if the activity causing the effect occurs only once, medium if the activity occurs intermittently, and high if the activity occurs continuously.

For post-closure impacts to the lakes to the north of Snap Lake, long-term is much greater than 26 years. Since impacts are not expected to begin until 80 years after closure, and they are expected to continue at a relatively constant magnitude for about 300 years before gradually declining, duration could exceed 380 years. This estimate has a high degree of uncertainty.

If a site-specific benchmark was not derived, then environmental consequence was based on the general guideline

No site-specific benchmarks were developed for sediment quality, and the CSQG were used to classify environmental consequence. In any circumstances where a site-specific water quality benchmark could not be or was not derived, then the general guideline would be used to classify environmental consequence.

Detailed discussion on impact criteria and classification are provided in Section 9.1

A more detailed discussion of the impact criteria and the classification of environmental consequence are provided in Section 9.1. The definition of magnitude used for water quality is different than for other aquatic components, and is described in more detail below.

Magnitude of a water or sediment impact depends on both concentration and area of exposure

The magnitude of a water or sediment quality impact depends on the area of the waterbody in which a concentration exceeds a general guideline or site-specific benchmark. The definition of magnitude for CWQG and CSQG differs from the definition for CDWG.

Chronic exposure to 20% of an aquatic community was used as a maximum benchmark threshold for maintaining ecosystem structure and function

For CWQG and CSQG, the concern is the potential impact on the aquatic ecosystem. There are a number of studies that have indicated that an affect to 20% of an aquatic ecosystem is a threshold, below which the integrity of the aquatic ecosystem will be preserved (Suter *et al*. 1995). Although this threshold level is generally applied to population level effects, it is well known that community structure and function operate outside of the properties of their component populations (Pianka 1978). Therefore, communities can be considered as open and dynamic ecological systems with a continual inflow and outflow of materials, energy, and organisms (Pianka 1978). Because organisms can flow in and out of an ecological system, there is niche overlap which allows for replacement of some species by other species with a similar function. Thus, a reduced abundance of 20% of the aquatic community should not impair the overall function of the ecological system. A conservative interpretation of this threshold was used in the water quality assessment. For parameters with site-specific thresholds, the magnitude of impact was high if the maximum predicted concentration exceeded the HC_{20} benchmark (*i.e.*, potential chronic exposure to >20% of the aquatic community) in 20% or more of the waterbody (by area or volume).

Impact magnitude was considered high if the predicted concentration was above the HC_{20} concentration or general guideline in more than 20% of the waterbody

For parameters without site-specific benchmarks (*e.g.*, ammonia), the magnitude of impact was high if the maximum predicted concentration was above the CWQG in more than 20% of the lake. The impact magnitude based on general guidelines will be as restrictive or more restrictive than those based on site-specific benchmarks, because most general guidelines (*e.g.*, metals) are developed to be protective of the most sensitive aquatic organism (*i.e.*, are more restrictive than the HC_5 benchmark). General guidelines that are not based on protecting the most sensitive organism (*e.g.*, ammonia and chloride) are comparable to the HC_5 benchmark.

Moderate and low impact magnitudes are less than the HC_{20} and dependant on the HC_{10} and HC_5 benchmarks and the specific area/volume of the predicted concentrations

For a moderate and low impact magnitude, thresholds of 10% and 5%, respectively, were used. The magnitude of impact was moderate if the maximum predicted concentration was above the HC_{10} benchmark but below the HC_{20} benchmark (or above the general guideline) in 10% to 20% of the waterbody (by area or volume). The magnitude of impact was low if the maximum predicted concentration was above the HC_5 benchmark but below the HC_{10} benchmark (or above the general guideline) in 1% to 10% of the waterbody (by area or volume).

Predicted concentrations less than a HC_5 benchmark were considered negligible

The impact magnitude was negligible, if the maximum predicted concentration in the waterbody was below the general water quality guideline or the site-specific HC_5 benchmark (*i.e.*, chronic exposure to less than 5% of the aquatic community) or, if the concentration was above these levels in less than 1% of the waterbody.

The rating of impact magnitude based on the predicted concentrations and the percent of a waterbody affected is summarized in Table 9.4-15.

Table 9.4-15 Water Quality and Sediment Quality Impact Magnitudes Ratings for the Protection of Aquatic Life

Concentration	Percent of Waterbody Affected			
	0 – 1%	1 – 10%	10 – 20%	20-100%
<HC_5	negligible	negligible	negligible	negligible
HC_5 - HC_{10}	negligible	low	low	low
HC_{10} - HC_{20}	negligible	low	moderate	moderate
>HC_{20}	negligible	low	moderate	high
> General Guideline	negligible	low	moderate	high

Note: magnitude is rated based on a general guideline only if a site-specific hazard concentration (HC_x) benchmark is not available.

HC = hazard concentration.

general guideline refers to CCME or U.S. EPA guidelines.

Impact magnitude for drinking water was classified according to proximal location to a potable water intake, and definition of the Canadian Drinking Water Guidelines (i.e., health or aesthetic)

CDWG are intended to protect potential drinking water supplies. Like the impact magnitude definitions for protection of aquatic life, the impact magnitude for protection of drinking water supply was based on the extent of the waterbody that was above the guideline; however, the boundaries were defined differently. The impact magnitude was classified as high if the maximum average predicted concentration in the water body or the maximum predicted concentration at a potable water intake was greater than or equal to the CDWG. The impact would be reduced to moderate if the CDWG that was exceeded was only an aesthetic objective. The impact magnitude was classified as negligible if the maximum average predicted concentration in the water body or the maximum predicted concentration at a potable water intake was less than the CDWG. There was no low impact magnitude defined for drinking water quality.

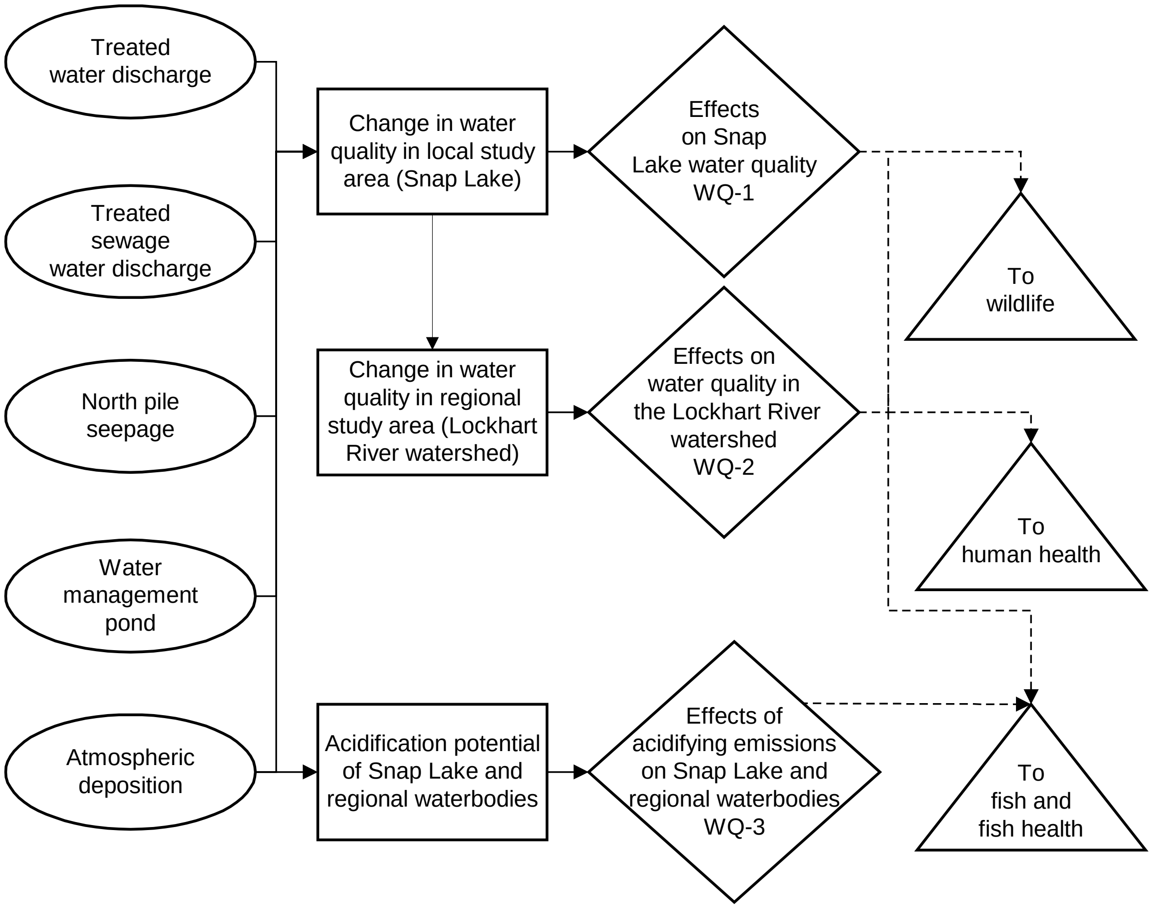
9.4.2.2 Key Question WQ-1: What Impacts Will the Snap Lake Diamond Project Have on Surface Water Quality?

9.4.2.2.1 Linkage Analysis

The mine water management plan minimizes potential impacts on surface water quality

The project has the potential to impact surface water quality through a number of pathways (Figure 9.4-8). De Beers' water management plan (Appendix III.4) was designed to minimize potential impacts to surface water quality. During construction and operations, runoff, seepage and underground mine water will be collected and treated prior to release into Snap Lake. After mine closure, a sustainable reclamation drainage system will be established to restore the natural drainage system within the area affected by the project footprint. Description of the water management system and water treatment plants is provided in Section 3.6 and Appendix III.4.

Figure 9.4-8 Water Quality Assessment Linkage Diagram



Underground mine water accounts for 98.9% of the total water generated on the site

The single largest source of water that must be managed is underground mine water, which will result from groundwater inflow to the mine workings during construction and operations. Underground mine water will account for 98.9% of the total water generated as part of the project. Seepage and runoff from surface facilities and treated domestic wastewater will account for only a small proportion of the total water. In total, approximately 99.7% of the water generated from the project will be collected and treated prior to release into Snap Lake.

All underground mine water and most runoff and seepage water will be collected and treated prior to discharge

During construction and operations, almost all sources of water will be collected and treated in the water treatment plant. This includes all underground mine water, and most runoff and seepage from surface facilities. There is a small proportion of seepage and runoff that cannot be collected, including the following:

- seepage from the north pile into Snap Lake;

- seepage from the water management pond (WMP) into Snap Lake; and,
- runoff from a small portion of the surface disturbance.

A single submerged discharge point for both treated domestic wastewater and treated mine water will be present in Snap Lake

Sewage produced during construction and operations will undergo tertiary treatment, including nutrient removal, prior to release into Snap Lake. Water from the water treatment plant and the sewage treatment plant will be combined into a single line and discharged into Snap Lake through a submerged multi-port diffuser.

Natural drainage systems will be re-established following closure of the mine

At closure, the site will be reclaimed and a sustainable drainage system will be re-established that is equivalent to the baseline drainage system. The north pile will be capped with non potentially acid generating (PAG) granite and graded to provide a post-closure drainage system. All buildings and other infrastructure will be removed and the project footprint will be graded to provide a drainage system that is equivalent to baseline conditions. The dam at the south end of the WMP will be breached and the natural drainage system will be re-established. Runoff collection ponds will be established as required for flood attenuation and sediment control.

The following sources of runoff and seepage have the potential to impact surface water quality during post-closure:

- seepage and runoff from the reclaimed north pile into Snap Lake; and,
- runoff from the reclaimed footprint of the project into Snap Lake.

Runoff and seepage waters will enter Snap Lake and potentially impact smaller lakes near the project site

Runoff and seepage water from the north pile and runoff from the project footprint will ultimately find its way into Snap Lake; however, there is also the potential to impact some small lakes near the project during construction, operations, and post-closure.

The potential linkage for site impacts on water quality are valid

The combined water discharge and all sources of seepage and runoff during construction and operations have the potential to impact surface water quality and, therefore, the linkages are valid and are carried forward into the impact assessment.

Dewatering during construction and operation will reduce groundwater discharge to lakes north of Snap Lake

Snap Lake is at a higher elevation than surrounding lakes and groundwater outflow from Snap Lake recharges several nearby lakes to the north (see Section 9.2.1). During construction and operations, dewatering of the underground mine workings will reduce groundwater discharge to lakes to the north of Snap Lake. The potential changes from reduction in groundwater inflows include the following:

- a small change in lake water level (Section 9.3); and,
- a minor decrease in the concentrations of some major ions and metals, which are present at higher concentrations in groundwater.

Changes to water quality in the north lakes during construction and operation are negligible

These changes would have a negligible effect on water quality in lakes to the north of Snap Lake during construction and operations. Therefore, this linkage is not valid.

Post-closure changes to water quality in the north lakes are possible

At post-closure, groundwater passing through the reclaimed mine workings is expected to have higher concentrations of some water quality parameters, notably chromium (Section 9.2), which could impact water quality in lakes to the north of Snap Lake. Therefore, this linkage is valid for post-closure conditions.

Lakes that will be used as sediment ponds for the north pile will not be assessed

There are a number of small lakes located around the perimeter of the north pile that will be partially covered by the north pile or will be utilized as seepage and runoff collection ponds for the north pile. In addition, Lake IL1 was used for processed kimberlite containment during the AEP and will continue to be used as the WMP during construction and operations of the project. These lakes will no longer be considered natural waterbodies for the life of the project, and therefore, impacts to water quality were not addressed. The impact of the loss of these lakes on fisheries and aquatic resources was assessed as part of Section 9.5 (Aquatic Organisms and Habitat). There were no other small waterbodies near the project site that would receive water releases from the Snap Lake Diamond Project. Therefore, this linkage is not valid.

The impacts to sediments in Snap Lake are considered negligible because the water treatment plant removes sediment; the linkage to sediment is considered invalid

The treated discharge from the Snap Lake Diamond Project to Snap Lake will consist primarily of major ions, with low concentrations of metals and fine TSS. Mixing and dispersion at the discharge location will result in lower concentrations of the parameters in Snap Lake. The majority of dissolved metals and fine TSS is expected to remain in the water column. A minor amount of biological uptake and subsequent deposition to the sediments may occur; however, the impact to sediment quality is expected to be negligible. Therefore, the linkage between the discharge and impacts on sediment in Snap Lake was not considered valid, and was not carried forward in the assessment.

Impacts to sediments in the north lakes will be assessed

Post-closure groundwater discharge to the north and northeast lakes does have the potential to affect sediment porewater quality in areas receiving mine-affected groundwater inflow. Therefore, this is a valid linkage and was carried forward into the assessment.

Contaminant loading to lakes from air emissions is small and the linkage is not valid; acidification of lakes from air emissions is possible and therefore it is a valid linkage for construction and operation

Air emissions generated by the project were evaluated as part of the air quality assessment and the predicted contaminant loadings are very small (Section 7.3). Therefore, the linkage to changes in water or sediment quality from air emissions is not valid. Activity during construction and operations will produce emissions that could contribute to acidification of surface waterbodies. Therefore, this is a valid linkage and was carried forward into the impact assessment (see Section 9.4.2.4). There will be no air emissions at post-closure and, therefore, this linkage is not valid during post-closure.

9.4.2.2.2 Mitigation

Water management strategies are in place to reduce potential impacts to water quality

A number of water management programs were incorporated into the Snap Lake Diamond Project to reduce potential impacts to water quality. These were discussed above in the linkage analysis section and are summarized below:

- Prior to release into Snap Lake, 99.7% of the water will be collected and treated, including all underground mine water and most site runoff and seepage.
- Sewage will receive tertiary treatment including phosphorus reduction.
- The treated water and treated domestic sewage will be combined into a single line and discharged into Snap Lake through a submerged multi-port diffuser, maximizing initial mixing and attenuating short-term fluctuations in discharge concentrations.
- A sustainable reclamation drainage system will be established at closure;
- The north pile will be capped with granite and graded to provide a post-closure drainage system.
- All buildings and other infrastructure will be removed and the project footprint will be graded to provide a drainage system that is equivalent to baseline conditions.
- The dam at the south end of the WMP will be breached and the natural drainage system will be re-established.
- Runoff collection ponds will be established as required for flood attenuation and sediment control during post-closure.

An explosives management plan will reduce ammonia and nitrate sources

The Snap Lake Diamond Project is developing an explosives management plan to minimize the loss of explosives, which is the main source of ammonia and nitrate.

9.4.2.2.3 Impact Analysis Methods

All valid linkages were included in the impact assessment

The water quality impact assessment analyzed all valid linkages in two separate sections addressing the following:

- impacts to Snap Lake from runoff, seepage, and mine water discharge; and,
- impacts to lakes north of the project from changes in groundwater recharge resulting from underground mining.

Both specific and general methods are applied

In addition to the assessment methods for each impact pathway, the General Water Quality Assessment Methods (Section 9.4.2.1.1) apply to each pathway.

Snap Lake

Several water release points were included in the assessment

As described in the linkage analysis section (Section 9.4.2.2.1), water will be released to Snap Lake from the following sources:

- a combined discharge of treated water and treated sewage (construction and operations);
- runoff from a small portion of the surface disturbance that will be controlled prior to release into Snap Lake (construction, operations, and post-closure);
- seepage from the north pile (construction, operations, and post-closure);
- seepage from the water management pond into Snap Lake (construction and operations); and,
- runoff from the reclaimed north pile and mine-site (post-closure).

Each of the three potential impact pathways were evaluated

The treated mine water accounts for 98.9% of the water released to Snap Lake (Table 9.4-16) and has the greatest potential to affect water quality. Treated sewage contributes 0.8% of the water released to Snap Lake, and seepage and runoff contribute the remaining 0.3%. The locations of potential project water releases are shown in Figure 9.4-9.

Figure 9.4-9 Potential Seepage Areas and Proposed Project Water Discharge Location In Snap Lake

Table 9.4-16 Summary of Project Water Release Rates to Snap Lake

Water Release	Maximum Release (m^3/d)		Percentage of Total (%)	
	Operations	Post-Closure	Operations	Post-Closure
Treated mine water discharge	25320	0	98.9	0.0
Treated sewage	200	0	0.8	0.0
Site runoff	25	25	0.1	2.9
North pile seepage	34	34	0.1	4.0
WMP seepage	34	0	0.1	4.0
Runoff from reclaimed north pile	0	564	0.0	65.7
Discharge from reclaimed lake IL1 [a]	0	202	0.0	23.5
TOTAL	25579	825	100.0	100.0

[a] Lake IL1 will be used as the WMP during construction and operations and then will be reclaimed at closure.
m^3/d = cubic metres per day.

Hydrodynamic and water quality models were used to predict water quality in Snap Lake

The RMA (Research Management Associates) suite of hydrodynamic and water quality models (King 1998) were used to simulate two-dimensional, depth-averaged circulation and water quality in Snap Lake. Water quality was simulated for a continuous 40-year period that included construction (3 years), operations (22 years), and 15 years of post-closure. Details of the configuration and calibration of the RMA models are provided in Appendix IX.7.

Water inflows and outflows to Snap Lake were incorporated into the model

The Snap Lake water quality model included all sources of water releases to Snap Lake, as well as average annual watershed runoff. Outflows from the Snap Lake model included surface discharge at the outlet of Snap Lake and groundwater recharge back into the underground mine workings. Baseline groundwater recharge from Snap Lake to lakes to the north was not explicitly included in the model, but was accounted for in the surface discharge at the lake outlet.

Whole effluent toxicity tests were completed during advance exploration to provide supportive information for characterization and treatment plant design

In addition to parameter specific water discharge concentrations, the whole effluent toxicity characteristics of the water discharge were evaluated by a comprehensive program of aquatic toxicity testing of underground mine water collected during the AEP. Samples of untreated mine water and treated mine water (pilot plant testing) were analyzes with the following broad range of acute and chronic aquatic toxicity tests:

- 48 hour acute *Daphnia magna* test;
- 96 hour acute rainbow trout (*Oncorhynchus mykiss*) test;
- 7 day chronic *Ceriodaphnia dubia* test;
- 21 day chronic *Daphnia magna* test;

- 7 day chronic fathead minnow (*Pimephales promelas*) test; and,
- 72 hour chronic *Selanstrum* test.

Toxic units were used to estimate expected toxicity from the discharge water

The pilot mine water treatment (Section 3.6 and Appendix III.4) and aquatic toxicity testing programs are ongoing; however, the expected toxicity of the combined discharge has been estimated from the available test results. The acute or chronic toxicity can be expressed as toxic units (TUa or TUc) by dividing 100 by the percent sample strength. The percent sample strength for acute toxicity is the lowest sample strength that causes mortality to 50% of the organisms (LC_{50}). The percent sample strength for chronic toxicity is the lowest sample strength that causes a non-lethal effect (or inhibition) to 25% of the test organisms (IC_{25}, which is equivalent to a LOEC).

Chronic and acute toxicities of mine water discharge were calculated and modelled

The estimated chronic toxicity for the treated mine water discharge was 1.75 TUc, based on reproductive effects to *Daphnia magna*. The estimated acute toxicity for the mine water discharge was <0.3 TUa, because the treated mine water caused no mortality to *Daphnia magna,* rainbow trout or any of the chronic test species. When expressed as toxic units, acute or chronic toxicity can be modelled like any other parameter. Results and interpretation of the available whole effluent toxicity testing at the time of submission are provided in Appendix IX.8.

Whole effluent toxicity will not behave as a conservative substance

Whole effluent toxicity in the mine water discharge is not expected to behave as a conservative substance. A review of the water quality results of samples tested for aquatic toxicity indicates that hexavalent chromium and ammonia are probable contributors to the chronic whole effluent toxicity (Appendix IX.8). Both of these parameters will react with other parameters and will be less toxic in Snap Lake. Ammonia will react to form nitrate and hexavalent chromium will react to form trivalent chromium. Both of these reactions are relatively rapid; however, the rate of toxicity reduction in Snap Lake has not been measured. A conservatively low toxicity reduction rate of 0.25 per year and a first order exponential loss relationship were used in the Snap Lake water quality model. This rate was selected because it allows for the potential that toxicity could be relatively persistent. The actual toxicity reduction rate is expected to be more rapid.

GoldSim water quality model was used to provide continuous simulation of on-site water quality; model uses a conservative assumption of total suspended solids removal to 5 mg/L

The flows and quality of project water releases to Snap Lake were derived from the site water quality model GoldSim, which provided a continuous simulation of all on-site water quality and water releases on a weekly time-step (Appendix IX.1). Average annual inflow was derived on a weekly time-step from the baseline hydrological analysis (Section 9.3). The site-water quality model uses a very conservative assumption to account for the removal of metals in the water treatment plant. The model assumes that the water treatment plant will remove TSS to a concentration of 5 mg/L, along with associated particulate bound metals. The model does not assume any reduction in dissolved metal concentrations during treatment. The two exceptions are aluminum and iron. These metals are present in the untreated mine water at much higher concentrations than the other metals, and the treatment tests have indicated a very high level of removal of both total and dissolved metals, to levels well below the CWQG values. Pilot testing has determined that for all parameters mine water treatment can meet or exceed the level of treatment used for the assessment of water quality impacts.

Treated sewage water quality based on design specifications

The water quality of effluent from the sewage treatment plant was based on the treatment plant specifications (Table 9.4-17).

Table 9.4-17 Sewage Treatment Plant Discharge Water Quality Specifications

Parameter	Units	Maximum Average Concentration
Total phosphorus	mg/L	0.2
Biological oxygen demand (BOD)	mg/L	15
Total suspended solids	mg/L	10
Oil and grease	mg/L	3
Residual chlorine		<0.5
Fecal coliforms	CFU/100mL	10

mg/L = milligram per litre.
μg/L = microgram per litre.
CFU/100mL = Colony forming units per 100 millilitres.

Metals and major ions were modelled assuming conservative behaviour; conservative chromium speciation reactions were used for both trivalent and hexavalent states

Model simulations for metals (except chromium) and major ions assumed conservative behaviour (*i.e.*, no settling, speciation, or precipitation). Water releases are expected to be predominantly hexavalent chromium based on geochemical equilibrium, whereas the stable form in surface waters will be trivalent chromium. The reaction of hexavalent chromium to trivalent chromium results from an increase in the redox potential and lower pH in Snap Lake relative to the underground mine water. This is expected to occur rapidly; however, the rate of reaction can not be accurately predicted. To be conservative, it was assumed that the reaction would take approximately one year to complete when assessing hexavalent chromium and that the reaction would be instantaneous when assessing trivalent chromium.

Eutrophication model calibrated to baseline water quality conditions

The RMA models include an eutrophication model, which was used to simulate phosphorus, nitrogen (including nitrate and ammonia), and phytoplankton biomass (also expressed as chlorophyll *a*). The eutrophication model was calibrated to the baseline water quality conditions.

A multi-port diffuser will maximize initial mixing and minimizes short-term spikes in discharge concentrations

The combined water discharge (treated water and treated sewage) will be discharged into Snap Lake through a multi-port diffuser. The purpose of the diffuser is to maximize initial mixing in Snap Lake, which will attenuate the potential impact of short-term spikes in discharge concentrations associated with specific events, such as storm events or spring runoff. The site water quality model, GoldSim predicted a spike in the concentration of some dissolved metals in the spring associated with the melting and release of water accumulated in the north pile over the winter (Appendix IX.1). The duration of this predicted spring release could not be accurately predicted and to be conservative, it was assumed to occur rapidly, over one model time-step (one week).

Diffuser provides a minimum dilution factor of 34:1, predicted using the United States Environmental Protection Agency Cormix Mixing Zone Model

The multi-port diffuser for the discharge was predicted to provide a minimum bulk dilution factor of 34 to 1 (*i.e.*, 1 part discharge to 34 parts of lake water). The multi-port diffuser will result in an initial turbulent mixing area that was estimated to encompass an area around the diffuser that would have a radius of between 80 and 150 metres (m). Initial mixing around the diffuser was predicted using the U.S. EPA Cormix Mixing Zone Model. Details of the multi-port diffuser and predicted initial mixing characteristics are provided in Appendix IX.7.

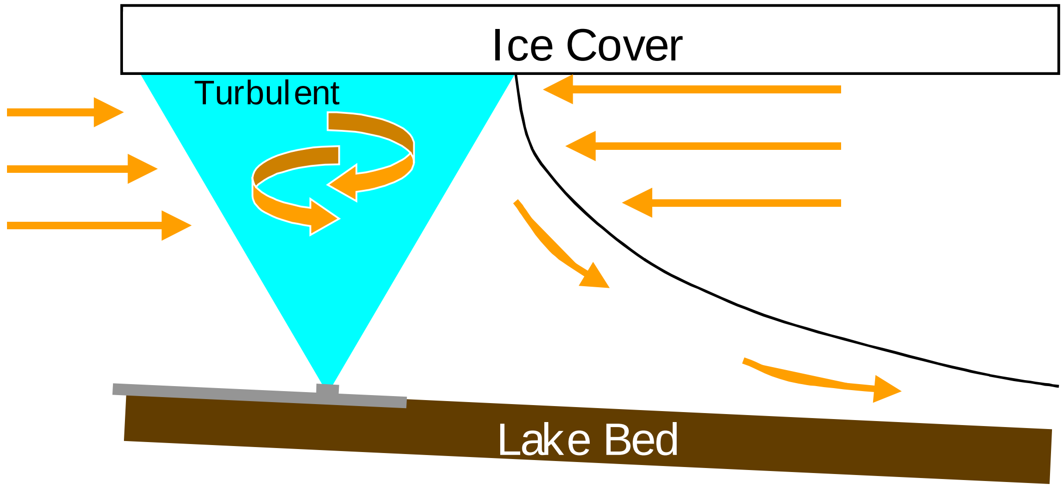
Hydrodynamic and water quality model representative for ice-free conditions

The Snap Lake hydrodynamic and water quality model (RMA 10 and 11) provided a good representation of mixing conditions in Snap Lake during ice-free conditions, when wind-driven turbulence would maintain vertical mixing provided by the multi-port diffuser. The Snap Lake water quality model will tend to under-estimate initial mixing and, therefore, over-estimate concentrations very close to the discharge, because it does not account for the three-dimensional mixing caused by the diffuser. This results in conservatively worst-case prediction of water quality near the discharge. The maximum concentrations near the boundary of the initial turbulent mixing area and the maximum area affected for the entire period of construction and operations were used to assess impacts on water quality.

Ice-covered conditions and density differences limit mixing to the initial mixing provided by the diffuser

The Snap Lake hydrodynamic and water quality model does not provide a good representation of mixing conditions in Snap Lake during ice-covered conditions. During ice-covered conditions, the turbulence would only occur within the initial turbulent mixing area, beyond which there would be essentially no turbulence in Snap Lake. The discharge to Snap Lake will be slightly denser than water in Snap Lake. During construction and initial operations, the ambient TDS concentration will be low relative to the combined discharge TDS concentration. After initial mixing, the denser discharge water moves beyond the turbulent mixing zone, and will sink back down to the bottom of the lake and flow downstream in a direction dictated by the topography of the lake bottom (Figure 9.4-10). Because lake turbulence is negligible under ice-cover conditions, there would be little additional mixing of the combined discharge outside of the initial mixing zone. Later in operations when the ambient TDS concentration will be higher, density differences will be smaller and the discharge will restratify after initial mixing, but less rapidly.

Figure 9.4-10 Conceptual Representation of Initial Mixing Characteristics of the Combined Discharge During Ice-Covered Conditions



Hydrodynamic and water quality model was used for ice-free conditions

During construction and operations, the maximum concentrations in Snap Lake during ice-free conditions are predicted using the Snap Lake hydrodynamic and water quality model.

The Cormix model was used to predict concentrations in Snap Lake during ice-covered conditions

During construction and operations, the maximum concentrations in Snap Lake during ice-covered conditions were predicted based on the Cormix modelling results (Appendix IX.7). During the first seven years of construction and operation, the flows will be sufficiently low that the bulk dilution factor of 34 to 1 predicted using Cormix would be achievable for the entire ice-covered period. During the remaining 18 years of operations, predicted flows are sufficiently high such that total loadings will limit the amount of near-field dilution than can be achieved to approximately 12 to 1.

A bulk dilution factor for the diffuser of 34 to 1 was used during early operations, and 12 to 1 was used for the remainder of operations

For the first seven years of construction and operations, this lake concentration was mixed 34 to 1 with the maximum, average annual discharge concentration to predict the concentration after initial mixing. For the next 18 years of operations a bulk dilution factor of 12 to 1 was used. The maximum predicted concentration after initial mixing for the entire 25-years of construction and operations was used for the assessment of impacts to water quality.

Impact magnitudes for water quality would be negligible if guidelines or benchmarks are met within 1% of Snap Lake

Initial mixing of the discharge and lakewater ice-free conditions would occur within 1% of Snap Lake by area or volume. Concentrations within this area cannot be predicted and concentrations at this boundary were used for initial impact screening. The impact magnitude for water quality would be negligible if guideline or site-specific benchmarks are met within 1% of Snap Lake.

Local effects from runoff and seepage based on maximum concentrations at 100 m from release point to Snap Lake

The potential local effects of runoff and seepage flows during construction, operations, and post-closure were evaluated based on the maximum simulated concentrations in Snap Lake, using the Snap Lake hydrodynamic and water quality model. The maximum concentration was within 100 m of the point of release into Snap Lake, which represents the minimum resolution of the model. This model provided a conservatively low estimate of mixing close to the discharge and could be applied year round to these sources. Estimates of seepage flows were provided by a model SEEP/W, discussed in Section 9.2.

Concentrations of all parameters will slowly return to baseline concentrations

During post-closure, the underground workings will be allowed to flood, and the discharge to Snap Lake will cease. Concentrations of all parameters will slowly return to baseline concentrations. The Snap Lake hydrodynamic and water quality model was used to evaluate the recovery of any parameters that were above site-specific benchmarks or water quality guidelines at the end of operations.

Groundwater Discharge to Lakes North of Snap Lake

Groundwater recharge from Snap Lake flows to the north lake and northeast lake

Groundwater recharge from Snap Lake flows north and eventually discharges into two unnamed lakes situated at a lower elevation (Figure 9.2-3). For the purposes of the impact assessment, these lakes are referred to as the north lake and the northeast lake. The north lake is a headwater lake and outflow drains through two small lakes (NL5 and NL6) and into the northeast lake.

Groundwater flow from the underground mine will reach the north lakes 80 years after closure

During post-closure, a fraction of the groundwater recharge from Snap Lake will pass through the flooded underground mine workings, and is expected to chemically equilibrate with the cemented paste backfill present in the workings. It was estimated that it will require approximately 80 years for groundwater flow passing through the underground mine workings to reach (breakthrough) the north and northeast lakes.

Groundwater does not flow into lakes NL5 and NL6 but surface water does

Groundwater is not expected to flow up in Lakes NL5 and NL6 because these lakes do not have taliks and are hydraulically isolated from the deep groundwater. However, they will be assessed because the north lake outflows to these lakes. The model assumed that water quality in the small lakes (NL5 and NL6) at post-closure would be equal to concentrations in the main part of the north lake.

Continuous mixed reactor model used to model chemical concentrations in north lakes

Chemical concentrations in each lake were simulated using a continuous, mixed reactor model that subdivided each of the larger lakes (north and northeast) into two connected segments; one that received groundwater affected by the underground mine workings and one that did not. In each lake, the two segments were assumed to be separate during ice-covered conditions and well-mixed during ice-free conditions. This assumption is consistent with simulated mixing conditions in Snap Lake (Appendix IX.7).

A conservative one year reaction period for transformation of hexavalent chromium to trivalent chromium was used in the model

The model accounts for the reaction of hexavalent chromium, which is the stable form in the groundwater, to trivalent chromium, which is the stable form in the lakes. The reaction is expected to occur rapidly; however, the exact rate of reaction could not be estimated. To be conservative, it was assumed that the reaction would occur at a rate that would take one year to complete, following a first order exponential relationship.

Estimates for chemical concentrations from various sources were required

The model required estimated chemical concentrations for watershed runoff, natural groundwater inflow (*i.e.*, unaffected by the project), and groundwater inflow from the mine workings, as well as water balance information for each lake. The estimated water quality of lake inflows is provided in the following section and the estimated water balance information is provided in Table III.4-1 and Table 9.3-34. The prediction of groundwater quality and flow are described in Section 9.2, and the water balance calculations are described in Section 9.3.

Baseline water quality in north lakes is similar to Snap Lake

The baseline water quality of the north lake, NL5, NL6, and the northeast lake are expected to be similar to Snap Lake. Water quality was sampled in the north lake in March 1998, and was very similar to Snap Lake. Median Snap Lake water quality was used to represent the baseline water quality of all four lakes. The water quality of watershed runoff was assumed to be equal to median water quality of tributaries to Snap Lake.

Processes influencing sediment concentrations were considered on a metal specific basis

With the exception of chromium as described above, chemical concentrations in the lakes were conservatively modelled without out any chemical reactions and without settling or other physical processes that could reduce concentrations. The potential impact on sediment porewater concentrations was based on groundwater inflow quality (Section 9.2). The potential impact of speciation, precipitation, settling, *etc*., on sediment metal concentrations was considered on a metal specific basis, where appropriate.

9.4.2.2.4 Impact Analysis Results

Snap Lake

Screening of Discharge (Step 1)

Predicted maximum of 10 parameters were above water quality guidelines and three were above drinking water guidelines

The predicted maximum discharge concentrations for the discharge to Snap Lake are summarized in Table 9.4-18 for screening water quality parameters. Selected other parameters that are of environmental interest for aquatic life, wildlife health, and human health, but which do not have water quality guidelines, are included in Table 9.4-18. The predicted maximum concentrations of 10 parameters (ammonia, chloride, cadmium, copper, mercury, molybdenum, nickel, lead, selenium and whole effluent chronic toxicity) were greater than water quality guidelines, and three parameters (manganese, TDS, and nitrate) were above drinking water guidelines. Thus a total of 13 parameters were above guidelines and will be discussed further.

Predicted mercury concentrations in the discharge were below detection limits and were not carried forward

Predicted mercury concentrations in the discharge were below detection limits; however, detection limits were above the water quality guideline. The Snap Lake Diamond Project does not use or release any mercury nor it is expected to mobilize any natural mercury; therefore, the impact of mercury in the combined discharge is expected to be negligible and was not carried forward into Step 2.

Table 9.4-18 Predicted Water Chemistry for the Mine Water Discharge during Construction and Operations

Parameter	Units	Maximum Weekly Concentration	Maximum Average Annual Concentration	Average Concentration	Drinking Water Quality Guideline[(a)]	General Water Quality Guideline[(b)]
Conventional Parameters						
Total Suspended Solids	mg/L	5	5	5	-	-
Alkalinity	mg/L	405	344	187	-	-
Nutrients						
Ammonia	mg/L	**15.4**	**12.9**	5.4	-	5.7 – 60 [(c)]
Nitrate	mg/L	**15.8**	**13.3**	5.8	-	-
Phosphate	mg/L	0.023	0.011	0.008	-	-
Total Kjeldahl Nitrogen	mg/L	9.3	8.6	6.8	-	-
Major Ions						
Total Dissolved Solids	mg/L	**1332**	**929**	**592**	≤500[(d)]	-
Calcium	mg/L	558	235	153	-	-
Chloride	mg/L	**425**	**374**	237	≤250[(d)]	230
Potassium	mg/L	17	16	12	-	-
Magnesium	mg/L	25	21	16	-	-
Sodium	mg/L	78	69	38	≤200[(d)]	-
Silica	mg/L	9.3	1.1	0.7	-	-
Sulphate	mg/L	46	40	17	≤500[(d)]	-

Table 9.4-18 Predicted Water Chemistry for the Mine Water Discharge during Construction and Operations (continued)

Parameter	Units	Maximum Weekly Concentration	Maximum Average Annual Concentration	Average Concentration	Drinking Water Quality Guideline[(a)]	General Water Quality Guideline[(b)]
Total Metals						
Silver	µg/L	0.21	0.06	0.06	-	0.1
Aluminum[(d)]	µg/L	<100	<100	<100	-	100
Arsenic	µg/L	2.1	1.88	1.4	25	5
Barium	µg/L	437	416	337	1000	-
Beryllium	µg/L	1.78	0.16	0.12	-	-
Cadmium	µg/L	**1.00**	**0.10**	**0.07**	5	0.003 - 0.085[(e)]
Cobalt	µg/L	3.4	3.15	0.6	-	-
Chromium	µg/L	7.51	7.49	7.46	50	-
Copper	µg/L	**7.83**	**4.46**	**3.12**	≤1000[(d)]	2 – 4[(e)]
Iron[(d)]	µg/L	<300	<300	<300	-	300
Mercury	µg/L	**<0.51**	<0.09	<0.08	-	0.1
Manganese	µg/L	**156**	**146**	30	≤50[(d)]	-
Molybdenum	µg/L	**79.9**	9.98	8.4	-	73
Nickel	µg/L	**60.6**	15.1	13.8	-	25 – 150[(e)]
Lead	µg/L	**9.20**	0.93	0.73	-	1 – 7[(e)]
Selenium	µg/L	**10.34**	**2.00**	0.61	10	1
Strontium	µg/L	2616	2346	1501	-	-
Thallium	µg/L	0.36	0.13	0.12	-	0.8
Uranium	µg/L	17.71	1.17	0.68	20	-
Vanadium	µg/L	43.9	3.12	2.3	-	-
Zinc	µg/L	22	16.7	14	≤5000[(d)]	30
Whole Effluent Toxicity						
Acute Toxicity	TUa	<1.0	-	-	-	1
Chronic Toxicity	TUc	**>1**	-	-	-	1

(a) Numbers in bold are equal to or above guidelines.
(b) All guidelines are from CCME (1999, with 2000 updates), with the exception of the aquatic life guideline for chloride, which is from U.S. EPA (1999).
(c) Ammonia guideline is based on a pH range of 6.5 to 7 and a temperature range of 0 to 15°C.
(d) Aesthetic objective.
(e) Hardness dependent metal guidelines were determined using a range from the median baseline hardness in Snap Lake (*i.e.*, 6 mg/L to 300 mg/L).
Notes: < = less than detection limit (refer to glossary for definition).
Pilot treatment results (Appendix IX.8) indicate a high level of removal of total and dissolved iron and aluminum. Therefore, maximum expected concentrations are below CWQG levels.
Median values were not calculated when sample size was 2. Data were represented as a median if sample size was 1.

Selenium concentrations in mine water were consistently below detection limits and water quality guidelines

Detailed review of the 2001 analytical results for selenium proved that the values were erroneous. Chloride interference in the analysis led to the generation of false positives. Follow-up analysis with a method not subject to interference (atomic adsorption) resulted in selenium concentrations consistently below the detection limit of 0.4 micrograms per litre (µg/L). Given this, the site water quality model predictions, which were based on the erroneous data, were rejected and selenium was not carried forward in the assessment.

Molybdenum exceeds guideline for one week over the 25 year period and was considered to have a negligible impact potential

The maximum weekly molybdenum concentration was only marginally above the water quality guideline and the maximum average annual concentration was well below the guideline. There was only one week in the entire 25 year simulation, when the predicted molybdenum in the discharge was above the water quality guideline. Molybdenum would, therefore, have a negligible potential to be above the water quality guideline in Snap Lake and was not carried forward in the assessment.

Screening of Concentrations in Snap Lake (Step 2)

Modelling in Snap Lake was completed on 10 parameters, 4 parameters were carried forward past the screening phase

The remaining 10 parameters were carried forward and concentrations were modelled in Snap Lake. The maximum predicted concentrations within an area or volume of 1% of Snap Lake are summarized in Table 9.4-19. Three parameters (cadmium, copper, and hexavalent chromium) were above the water quality guideline and were carried forward past the screening phase. There were no parameters that were above drinking water guidelines in Snap Lake.

Ammonia will be below guidelines beyond <1% of the lake

Ammonia concentrations were predicted to be well below CWQG concentrations except for within <1% of Snap Lake. Predicted ammonia concentrations at a number of distances from the combined discharge are shown in Figure 9.4-11.

The impact of ammonia in Snap Lake would be negligible

The predicted ammonia concentrations were based on an explosives loss rate of 5%; explosives are the primary source of ammonia. Explosives loss represents the percentage of explosives that is spilled, remains unexploded, or is only partially exploded during normal mining activities. A 5% loss rate is expected to be achievable; however, the results indicate that ammonia concentrations would be well below the guideline values at this rate and would remain below the guideline even at explosives loss rates up to twice this value. The predicted concentrations were also well below U.S. EPA chronic ammonia criteria (U.S. EPA 1999) and the earlier CWQG for ammonia (CCME 1986). The impact of ammonia in Snap Lake was classified as negligible.

Phosphorus, chlorophyll a and TDS will be carried forward

Phosphorus, chlorophyll *a* and TDS were also carried forward in the assessment. There are no guidelines or site-specific benchmarks for these parameters and their potential impacts are discussed separately. The potential impact on winter DO concentrations was also carried forward and is discussed separately.

Figure 9.4-11 Time Series of Simulated Ammonia Concentrations in Snap Lake, during Construction and Operations

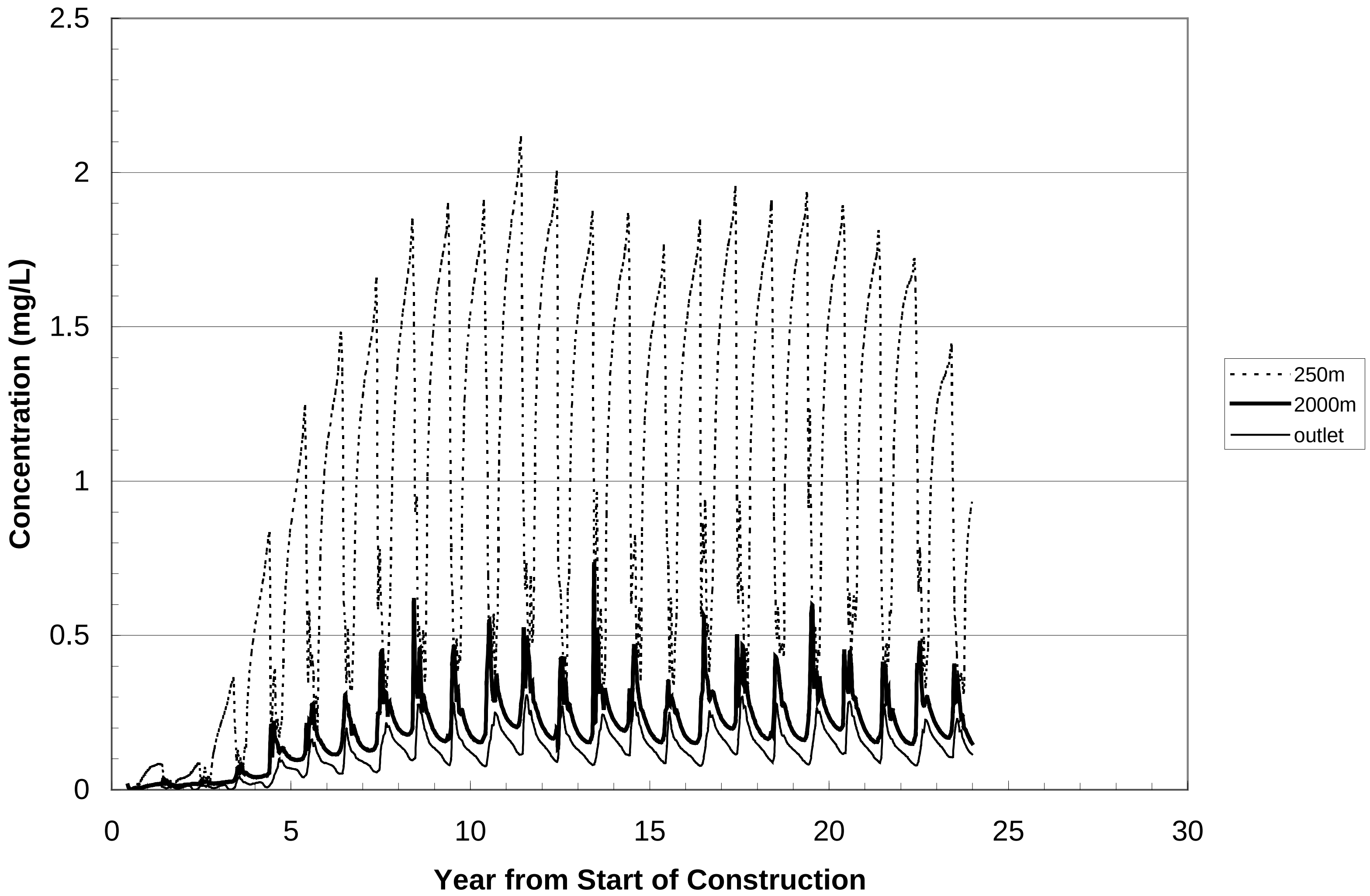


Table 9.4-19 Predicted Water Chemistry in Snap Lake during Construction and Operations

Parameter	Units	Maximum Ice-Covered Concentration After Initial Mixing	Maximum Ice-free Concentration Within 1% of Snap Lake	Drinking Water Quality Guideline[a]	General Water Quality Guideline[b]
Nutrients					
Ammonia	mg/L	1.1	2.1	-	5.7 – 60 [c]
Nitrate	mg/L	6.0	6.3	-	-
Major Ions					
Total Dissolved Solids	mg/L	350	444	≤500[d]	-
Calcium	mg/L	88	113	-	-
Chloride	mg/L	137	177	≤250[d]	230
Magnesium	mg/L	9	12	-	-
Total Metals					
Cadmium	µg/L	**0.058**	**0.069**	5	0.003 - 0.085[e]
Hexavalent Chromium	µg/L	0.8	**2.54**	-	1
Trivalent Chromium	µg/L	4.3	5.6	-	8.9
Copper	µg/L	2.2	2.57	≤1000[d]	2 – 4[e]
Manganese	µg/L	19	23.5	≤50[d]	
Nickel	µg/L	8.1	<10.6	-	25 – 150[e]
Lead	µg/L	0.58	<0.67	-	1 – 7[e]
Selenium	µg/L	0.42	<0.54	10	1
Whole Effluent Toxicity					
Chronic Toxicity	TUc	<1	**1.03**		1

(a) Numbers in bold are equal to or above guidelines.
(b) All guidelines are from CCME (1999, with 2000 updates), with the exception of the aquatic life guideline for chloride, which is from U.S. EPA (1999).
(c) Ammonia guideline is based on a pH range of 6.5 to 7 and a temperature range of 0 to 15°C.
(d) Aesthetic objective.
(e) Hardness dependent metal guidelines were determined using a range from the median baseline hardness in Snap Lake (*i.e.*, 6 mg/L to 300 mg/L).
Notes: < = less than detection limit (refer to glossary for definition).

Detailed Water Quality Assessment (Step 3)

Site-specific benchmarks developed for copper, cadmium, and hexavalent chromium

Site-specific water quality benchmarks were established for cadmium, copper, and hexavalent chromium (Table 9.4-20). The derivation of these benchmarks is described in Appendix IX.8. The estimated maximum chronic whole effluent toxicity was based on site-specific toxicity testing and the threshold for effects is 1 chronic toxic unit (TU_c).

Maximum extent of concentrations above guideline or benchmark values are provided

The maximum extent of Snap Lake that would be above the site-specific water quality benchmarks for cadmium, copper, and hexavalent chromium, or above the chronic toxicity threshold is summarized in Table 9.4-21.

Table 9.4-20 Summary of Site-specific Water Quality Benchmarks

Parameter	Units	General Water Quality Guideline[(a)]	Site-Specific Water Quality Benchmarks		
			HC_5	HC_{10}	HC_{20}
Cadmium	µg/L	0.055	0.36	1.0	3.4
Copper	µg/L	4	7.9	12.6	21.3
Trivalent chromium	µg/L	8.9	46.0	72.2	118.2
Hexavalent chromium	µg/L	1	2.1	3.5	10

[(a)] All guidelines are from CCME (1999, with 2000 updates).
Note: Hardness specific guidelines (cadmium and copper) were calculated at a hardness of 180 mg/L, which is less than or equal to the minimum predicted hardness in Snap Lake.

Table 9.4-21 Maximum Extent of Snap Lake that is Predicted to Exceed Site-specific Water Quality Benchmarks or a General Water Quality Guideline

Guideline/Threshold or Site-Specific Benchmark	Cadmium	Copper	Hexavalent Chromium	Chronic Whole Effluent Toxicity
$>HC_5$	<1%	0	<1%	-
$>HC_{10}$	0	0	<1%	-
$>HC_{20}$	0	0	0	-
>Threshold	-	-	-	1.1%

Overall magnitude of impact from the Snap Lake Diamond Project on Snap Lake would be low

The maximum magnitude of impacts of the Snap Lake Diamond Project on water quality in Snap Lake would be classified as low because of predicted concentrations of chronic toxicity and hexavalent chromium in Snap Lake. The maximum extent of Snap Lake that is predicted to be above any water quality guideline, site-specific benchmark or toxicity threshold is shown in Figure 9.4-12. The predicted impact magnitudes for copper and cadmium were negligible.

The impact magnitude of chronic whole effluent toxicity will be low

The maximum predicted concentration of chronic whole effluent toxicity exceeded the chronic threshold in greater than 1%, but less than 10% of Snap Lake. The discharge was not predicted to be acutely toxic. Therefore, the impact magnitude was classified as low.

The impact magnitude of hexavalent chromium will be low

The maximum predicted hexavalent chromium concentration in the combined discharge was above the HC_{10} benchmark, but below the HC_{20} benchmark. Predicted concentrations in Snap Lake exceeded the HC_5 and HC_{10} benchmarks in <1% of Snap Lake. Therefore, the impact magnitude was classified as low.

Figure 9.4-12 Maximum Extent of Water Concentrations Predicted to be Above a Benchmark, Threshold, or Guideline in Snap Lake

The impact magnitude of cadmium will be negligible

The maximum predicted cadmium concentration exceeded the site-specific HC_5 benchmark in <1% of Snap Lake, and did not exceed the HC_{10} benchmark in the discharge. Therefore, the impact magnitude was classified as negligible.

The impact magnitude of copper will be negligible

The maximum predicted copper concentration did not exceed the site-specific HC_5 benchmark in the discharge or in Snap Lake. Therefore, the impact magnitude was classified as negligible.

Total Dissolved Solids

Total dissolved solids concentrations will increase in Snap Lake

TDS concentrations were predicted to increase in Snap Lake from the median baseline concentration of about 15 mg/L to a maximum average concentration in Snap Lake of about 330 mg/L. The major constituents of the increased TDS would include chloride, calcium, sodium, sulphate, and magnesium. The predicted change in TDS concentration in Snap Lake over time is shown in Figure 9.4-13. Concentrations in Figure 9.4-13 are shown at 250 m representing less than 1% of Snap Lake and a 2000 m representing average lake concentrations. The predicted spatial distribution of TDS concentrations in Snap Lake for a typical period during year 19 of operations is shown in Figure 9.4-14. Maximum simulated TDS concentrations in Snap Lake occur during year 19 of operations, and, therefore this year represents worst-case conditions for TDS. There are no established general water quality guidelines or site-specific water quality benchmarks established for TDS and major ions; therefore the impact on water quality could not be classified. The potential impacts of increases in TDS and major ions were carried forward into Section 9.5 (Aquatics Organisms and Habitat) where the potential impacts on aquatic life were evaluated qualitatively.

Dissolved Oxygen

During the winter, dissolved oxygen concentrations in Snap Lake may be affected by the discharge

During the winter, nitrification of ammonia and breakdown of labile organic matter has the potential to alter the natural dissolved oxygen regime in Snap Lake. DO profiles measured during baseline studies in March 1999, showed that DO concentrations were near saturation at the surface but declined with depth in the lower half of the water column at three of the six sites measured (Appendix IX.6). The minimum measured DO concentrations at the bottom of profiles ranged from 4.8 to 7.6 mg/L.

Figure 9.4-13 Time Series of Simulated Total Dissolved Solids Concentrations in Snap Lake, during Construction, Operations, and Post-closure

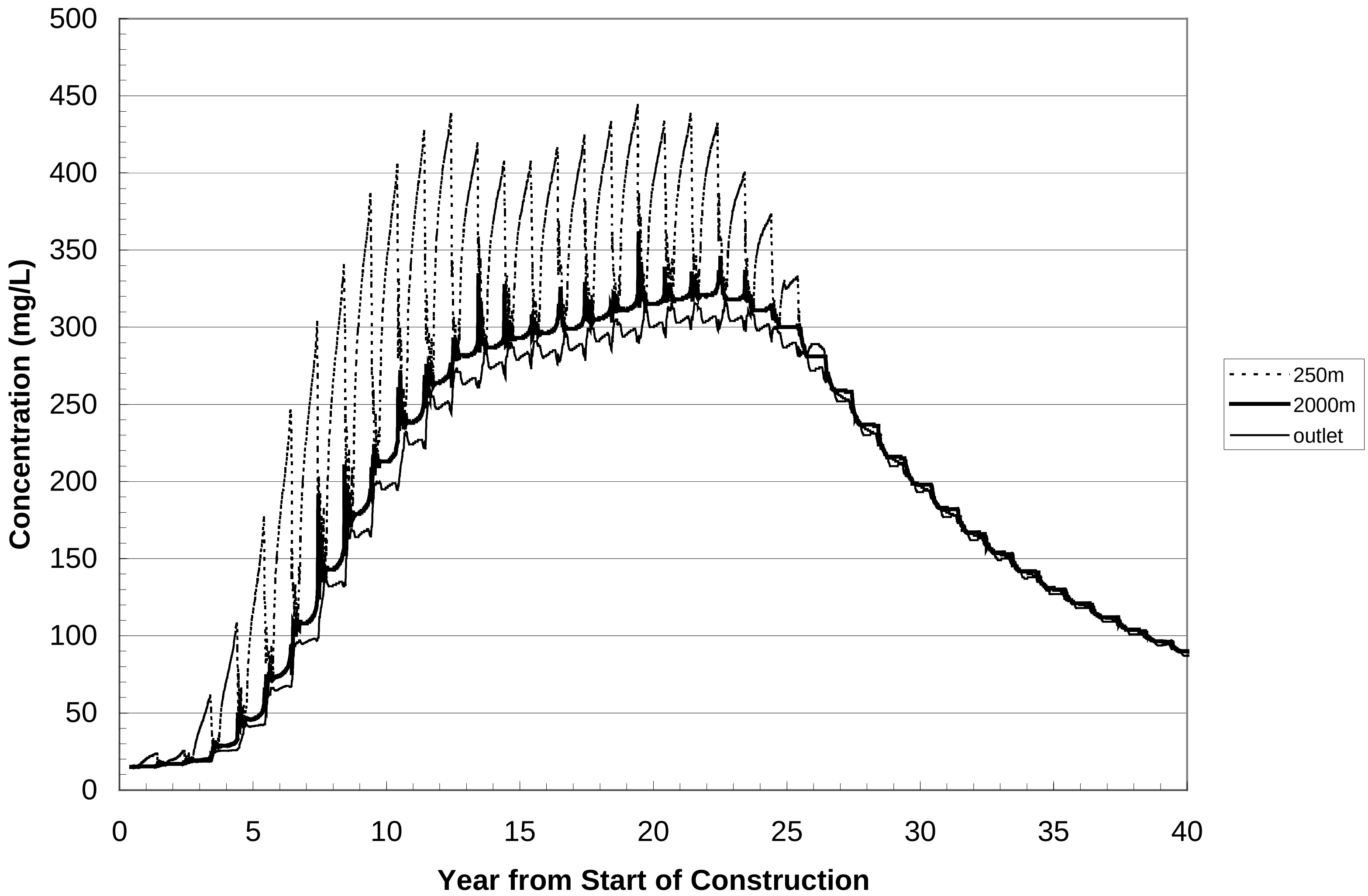


Figure 9.4-14 Spatial Pattern of Total Dissolved Solids Concentrations in Snap Lake during Operations (year 19)

Minimum winter DO concentrations could decrease by a maximum of 2.2 mg/L

The potential change in oxygen consumption was calculated based on predicted winter oxygen concentrations in Snap Lake. Minimum DO concentrations at the bottom of Snap Lake could decline by a maximum of 1.0 to 2.2 mg/L, due primarily to increased nitrification and algal decomposition. The maximum decrease in near surface DO concentrations would be near zero to 1.0 mg/L.

The impact of reduced DO concentrations would be negligible

With these maximum predicted decreases, dissolved oxygen concentrations in the majority of Snap Lake (by volume and area), including all spawning shoals, would remain at levels that would not impact aquatic life. The area of bottom sediments, and consequently benthic invertebrates, exposed to reduced DO concentrations would increase. However, the area is expected to be small, and would certainly be less than 10% of the surface area of Snap Lake. Because of the limited extent of impacts affecting a small proportion of the aquatic community, the predicted impact magnitude would be negligible.

Phosphorous and Chlorophyll *a*

Phosphorous concentrations in the combined discharge during operations were similar to concentrations in baseline water inflows to Snap Lake

Predicted phosphorus concentrations in the combined discharge during operations (range 4 to 110 μg/L, median 10 μg/L) were similar to concentrations in baseline water inflows to Snap Lake (range 6 to 20 μg/L, median 10 μg/L). Mine water discharge concentrations will be highest during construction, when underground mine water flows are low and the discharge concentration would be dominated by effluent from the sewage treatment plant. The main difference between the baseline watershed inflows and the project discharge is that the phosphorus in the discharge has a higher proportion of phosphate and a very low proportion of organic phosphorus.

Total phosphorus and chlorophyll a concentrations were simulated

Nutrients and chlorophyll *a* were simulated with the eutrophication model (of the RMA models) in Snap Lake during construction and operations using worst case assumptions that maximized the uptake of phosphate. The maximum potential changes in nutrients and chlorophyll *a* are summarized in Table 9.4-22. Continuous simulation results at two selected locations in Snap Lake are shown in Figures 9.4-15 and 9.4-16, for total phosphorous and chlorophyll *a*, respectively. Concentrations at 250 m represent conditions in less than 1% of Snap Lake around the discharge and concentrations at 2000 m represent average conditions in Snap Lake.

Concentrations of chlorophyll a in Snap Lake could increase and total phosphorus could decrease relative to baseline conditions

The predicted concentrations of total phosphorus (Figure 9.4-15) and chlorophyll *a* (Figure 9.4-15) were based on the model calibrated to simulate the maximum potential change in chlorophyll a concentrations in Snap Lake. Under these conditions, chlorophyll *a* could increase by up to 40% and total phosphorus concentration could decrease by up to 60% from baseline conditions.

Table 9.4-22 Simulated Average Summer Nutrient and Chlorophyll *a* Concentrations in Snap Lake, Baseline and Operations

Parameter	Units	Baseline			Maximum during Operations [(a)]		
		min	mean	max	min	mean	max
Ammonia	mg/L	.001	.001	.017	0.11	0.39	1.23
Nitrate	mg/L	.011	.024	.031	3.38	5.28	5.87
Total Phosphorus	µg/L	7	10	13	3	5	7
Phosphate	µg/L	1	2	3	2	2	2
Chlorophyll *a*	µg/L	0.2	0.9	1.8	0.6	1.3	2.6

(a) Years 17 - 19 were used to represent the maximum effect of the Snap Lake Diamond Project on nutrients and chlorophyll *a* in Snap Lake.

Figure 9.4-15 Simulated Total Phosphorus Concentrations in Snap Lake during Construction and Operations (250 and 2000 m from the discharge)

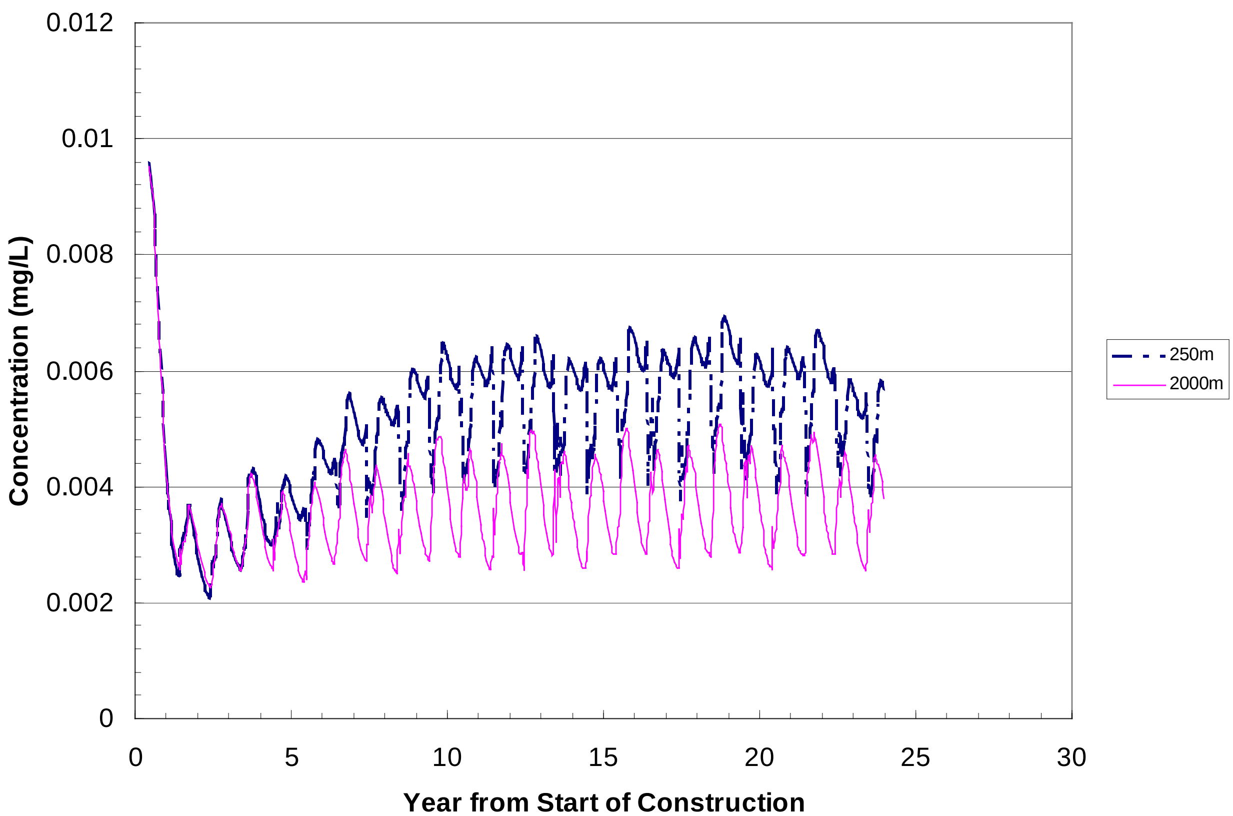
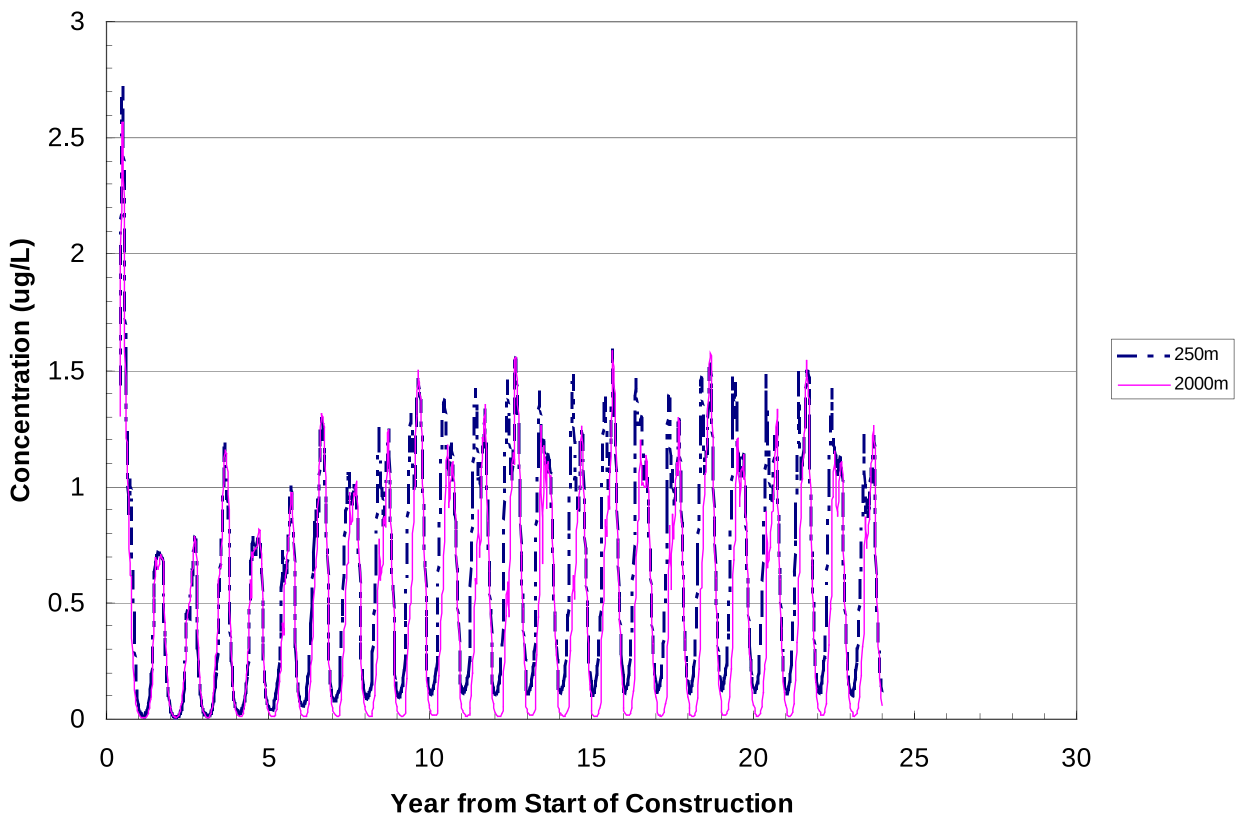


Figure 9.4-16 Simulated Chlorophyll *a* Concentrations in Snap Lake during Construction and Operations (250 and 2000 m from the discharge)



A low rate of mineralization of organic phosphorus was selected for the model

The eutrophication model is relatively sensitive to the rate of mineralization of organic phosphorus. A low range value was selected for calibration, to provide an upper estimate of the utilization of phosphate released from the combined discharge during construction and operations. The predicted total phosphorous concentration decreases because of the low proportion of organic phosphorus in the discharge. The use of higher rates of mineralization of organic phosphorous in the model would result in smaller increases in simulated chlorophyll *a* concentrations during operations.

Low primary productivity will have a negligible effect on pH

A large increase in the primary productivity of a lake can lead to high maximum pH concentrations. However, given the relatively low maximum predicted increase in primary productivity in Snap Lake, the secondary impact on pH would be negligible.

Primary productivity could not be classified

There are no general or site-specific water quality guidelines for an increase in the primary productivity of water bodies. Therefore, the impact could not be classified. The predicted range of changes in primary productivity in Snap Lake were carried forward into Section 9.5 as part of an overall evaluation of the Snap Lake Diamond Project on aquatic life in Snap Lake.

Runoff and Seepage

Maximum predicted concentrations in Snap Lake near runoff and seepage points are below water quality guidelines

The maximum predicted concentrations of runoff and seepage into Snap Lake are summarized in Table 9.4-23. These concentrations were predicted using the Mine Site Water Quality Model and are discussed in more detail in Appendix IX.1. The predicted concentrations are conservatively worst-case. Although maximum concentrations of chloride and many of the metal exceed water quality guidelines, the flows (Table 9.4-16) and consequently total loads are very small, and the maximum predicted concentrations in Snap Lake are below water quality guidelines for all parameters. Concentrations were predicted within 100 m of the points of release, which represents the minimum resolution of the Snap Lake Water Quality Model.

Magnitude of impacts from seepage and runoff during construction, operation, and post-closure would be negligible

The maximum total area that could be affected by all seepage and runoff sources would be <0.5% of the lake by area or volume. Therefore, the impact magnitude of runoff and seepage sources during construction, operations and post-closure would be negligible for all parameters.

Table 9.4-23 Predicted Maximum Water Chemistry for Seepage and Runoff during Construction, Operations, and Post-Closure

Parameter	Units	Seepage from WMP	Seepage from North Pile	Site Runoff	Runoff from North Pile	Discharge from WMP	Drinking Water Quality Guideline[(a)]	Ambient or Nutrient Guideline[(b)]
		Construction and Operations	Construction, Operations, and Post-Closure	Construction, Operations, and Post-Closure	Post-Closure	Post-Closure		
Conventional Parameters								
Total Dissolved Solids	mg/L	**743**	409	367	395	248	≤500[(c)]	-
Total Suspended Solids	mg/L	0	0	25	25	25	-	-
Alkalinity	mg/L	205	104	0.001	257	92	-	-
Nutrients								
Ammonia	mg/L	8.2	5.4	1.2	1.0	0.9	-	5.7 – 60 [(d)]
Nitrate	mg/L	9.0	19.1	9.4	3.4	4.2	-	-
Phosphate	mg/L	0.008	0.03	0.002	0.08	0.004	-	-
Total Kjeldahl Nitrogen	mg/L	5.3	13.4	0.9	7	3.2	-	-
Major Ions								
Calcium	mg/L	258	63	64	82	66	-	-
Chloride	mg/L	**252**	41	123	19	81	≤250[(c)]	230
Potassium	mg/L	10	20	4.3	26	6	-	-

Table 9.4-23 Predicted Maximum Water Chemistry for Seepage and Runoff during Construction, Operations, and Post-Closure (continued)

Parameter	Units	Seepage from WMP Construction and Operations	Seepage from North Pile Construction, Operations, and Post-Closure	Site Runoff Construction, Operations, and Post-Closure	Runoff from North Pile Post-Closure	Discharge from WMP Post-Closure	Drinking Water Quality Guideline[(a)]	Ambient or Nutrient Guideline[(b)]
Magnesium	mg/L	19	45	45	396	18	-	-
Sodium	mg/L	43	22	6.0	9	6	≤200[(c)]	-
Silica	mg/L	2	9	4.5	14	1.8	-	-
Sulphate	mg/L	45	127	111	82	45	≤500[(c)]	-
Total Metals								
Silver	µg/L	0.05	**0.3**	0.05	**0.9**	0.05	-	0.1
Aluminum	µg/L	65	**248**	**280**	**1218**	**254**	-	100
Arsenic	µg/L	0.03	**7.6**	0.19	4.5	0.5	25	5
Barium	µg/L	223	141	83	254	203	1000	-
Beryllium	µg/L	0.07	3.4	0.1	9.5	0.08	-	-
Cadmium	µg/L	**0.09**	**1.8**	**0.19**	**4.2**	**0.09**	5	0.003 - 0.085[(e)]
Cobalt	µg/L	4.8	4.1	12	9.1	5.0	-	-
Chromium	µg/L	**2.8**	**1.8**	**2.7**	**15.4**	**6.1**	50	-
Copper	µg/L	**2.9**	**11**	**9.2**	**26.5**	**3.9**	≤1000[(c)]	2 – 4[(e)]
Iron	µg/L	2.9	1.2	**379**	**1067**	**390**	≤300[(c)]	300
Mercury	µg/L	0.05	**0.9**	0.01	**2.5**	0.02	1	0.1
Manganese	µg/L	**213**	**83**	**530**	**290**	**218**	≤50	-
Molybdenum	µg/L	5	**189**	4.3	**527**	5.3	-	73
Nickel	µg/L	8.4	114	20	**192**	12.1	-	25 – 150[(e)]
Lead	µg/L	0.09	**17.4**	**1.0**	**37.9**	0.44	-	1 – 7[(e)]
Selenium	µg/L	**2.7**	**15.3**	**1.9**	**44.6**	**1.9**	10	1
Strontium	µg/L	1481	1074	221	1729	456	-	-
Thallium	µg/L	0.07	**0.94**	**0.08**	**1.3**	**0.09**	-	0.8
Uranium	µg/L	0.22	33	0.28	91	0.43	-	-
Vanadium	µg/L	1.3	89	0.4	248	0.99	-	-
Zinc	µg/L	17	17.7	**41**	**62**	18	≤1000[(c)]	30
Acute Toxicity	TUa					<1.0	-	-
Chronic Toxicity	TUc					<1.0	-	-

(a) Numbers in bold are equal to or above guidelines.
(b) All guidelines are from CCME (1999, with 2000 updates), with the exception of the aquatic life guideline for chloride, which is from U.S. EPA (1999).
(c) Aesthetic objective.
(d) Ammonia guideline is based on a pH range of 6.5 to 7 and a temperature range of 0 to 15°C.
(e) Hardness dependent metal guidelines were determined using a range from the median baseline hardness in Snap Lake (*i.e.*, 6 mg/L) to 300 mg/L.

Notes: < = less than detection limit (refer to glossary for definition); WMP = water management pond.

Groundwater Discharge to Lakes North of Snap Lake

Changes in groundwater chemistry at post-closure may have impacts on deep water areas of the north lakes

Groundwater recharged from Snap Lake will discharge into the deeper areas of north and northeast lakes through the lake bottom sediments. During post-closure, a portion of this groundwater will pass through the flooded underground mine workings, changing the chemistry of the groundwater. Groundwater affected by the underground workings (mine affected groundwater) will discharge into a relatively small area, consisting of less than 10% of the surface area of the north and northeast lakes (Figure 9.2-13). Two small lakes (NL5 and NL6), located between the north lake and the northeast lake are not expected to have taliks and do not receive groundwater inflow from Snap Lake, but will receive surface outflow from the north lake.

Differences in ice-free and ice-covered mixing behaviour is expected

The mixing behaviour of groundwater discharge in the lakes will be different under ice-free and ice-covered conditions. During the ice-free period, wind driven currents will keep the lakes relatively well mixed and appreciable water quality gradients are not expected to develop. During the ice-covered period, there will be little mixing within the lakes, and, as a worst-case, the denser groundwater inflow is expected to collect by gravity flow in the deeper pockets, with very little vertical or horizontal mixing.

Six parameters are expected to increase in concentration in the north lake and northeast lake

The maximum expected concentrations of mine affected groundwater are summarized in Table 9.4-24. Mine affected groundwater concentrations were below aquatic life guidelines for all except five parameters: pH, aluminum, chromium, copper, and molybdenum. Mine affected groundwater concentrations were below the drinking water guidelines for all except two parameters: TDS and nitrates. Of these seven parameters, all except TDS were expected to be present at higher concentrations in mine affected groundwater than in unaffected groundwater. The expected concentration of total TDS in mine affected groundwater (897 mg/L) was essentially the same as the expected baseline groundwater concentration (920 mg/L) (Section 9.2). Therefore, post-closure TDS concentrations are not expected to increase in the north or northeast lakes.

Concentrations were simulated

The concentrations of the remaining six parameters were simulated in the north and northeast lakes during post-closure. The model predicted an average lake concentration that is representative of the majority of the lake.

Table 9.4-24 Predicted Water Chemistry for Groundwater Flow to the North and Northeast Lakes during Closure

Parameter	Units	Baseline Concentrations (not affected by underground mine workings)	Expected Post-Closure Concentrations Affected by Underground Mine Workings	Drinking Water Quality Guideline[(a)]	Water Quality Guideline[(b)]
Conventional Parameters					
pH	-	**9.2**	**11.8**	-	6.5-9.0
Total Dissolved Solids	mg/L	**920**	**897**	≤500[(c)]	-
Total Suspended Solids	mg/L	0	0	-	-
Alkalinity	mg/L	80	760	-	-
Hardness	mg/L	286	286	-	-
Nutrients					
Ammonia	mg/L	4.1	6.6	-	5.7-60[(d)]
Nitrate	mg/L	2.4	**42.7**	-	10
Phosphate	mg/L	0.003	0.01	-	-
Total Kjeldahl Nitrogen	mg/L	3.2	26.6	-	-
Total Organic Carbon	mg/L	4		-	-
Major Ions					
Calcium	mg/L	110	389	-	-
Chloride	mg/L	**248**	8.6	≤250[(c)]	230
Potassium	mg/L	9.3	19.0	-	-
Magnesium	mg/L	7.8	<0.03	-	-
Sodium	mg/L	76.7	18.6	≤200[(c)]	-
Silica	mg/L	12.5	-	-	-
Sulphate	mg/L	10.0	5.3	≤500[(c)]	-
Total Metals					
Silver	µg/L	<0.1	<0.05	-	0.1
Aluminum	µg/L	7.2	**468**	-	100
Arsenic	µg/L	1.1	0.7	25	5
Barium	µg/L	55.4	440	1000	-
Beryllium	µg/L	<0.2	<3.0	-	-
Cadmium	µg/L	<0.05	<0.3	5	0.003-0.085[(e)]
Cobalt	µg/L	0.1	<0.5	-	-
Chromium	µg/L	0.1	**313**	50	-
Copper	µg/L	**2.8**	**5.1**	≤1000 [c)]	2-4[(e)]
Iron	µg/L	21	<10	≤300[(c)]	300
Mercury	µg/L	0.1	<0.1	-	0.1
Manganese	µg/L	7.1	<0.3	50	-
Molybdenum	µg/L	5.6	**81.1**	-	73
Nickel	µg/L	0.8	<3	-	25-150[(e)]
Lead	µg/L	0.2	0.4	-	1-7[(e)]
Selenium	µg/L	<0.4	0.4	10	1
Strontium	µg/L	1760	4950	-	-

Table 9.4-24 Predicted Water Chemistry for Groundwater Flow to the North and Northeast Lakes during Closure (continued)

Parameter	Units	Baseline Concentrations (not affected by underground mine workings)	Expected Post-Closure Concentrations Affected by Underground Mine Workings	Drinking Water Quality Guideline[a]	Water Quality Guideline[b]
Thallium	µg/L	<0.03	<0.5	-	0.8
Uranium	µg/L	0.1	<0.05	-	-
Vanadium	µg/L	1.8	<5	-	-
Zinc	µg/L	3.4	<5	≤5000[c]	30

[a] Numbers in bold are equal to or above guidelines.

[b] All guidelines are from CCME (1999, with 2000 updates), with the exception of the aquatic life guideline for chloride, which is from U.S. EPA (1999).

[c] Aesthetic objective.

[d] Ammonia guideline is based on a pH range of 6.5 to 7 and a temperature range of 0 to 15°C.

[e] Hardness dependent metal guidelines were determined using a range from the median baseline hardness in Snap Lake (*i.e.*, 6 mg/L to 300 mg/L).

Notes: < = less than detection limit (refer to glossary for definition).

Porewater concentrations were assumed to be equal to groundwater concentrations

Groundwater will enter the north and northeast lakes through the lake bottom sediments. Consequently, sediment porewater concentrations in areas receiving groundwater inflow will be higher than predicted water column concentrations. For the purposes of the impact assessment, it was assumed that porewater concentrations in these areas would equal the groundwater concentrations.

Concentrations during ice-cover were assumed to be equal to groundwater at a layer of 0.1 to 0.2 m

During ice-covered conditions, the denser groundwater inflow may not mix effectively with the overlying water column and may collect as a thin, bottom layer (<0.2 m average thickness) in up to 10% of the surface area of each lake (Figure 9.2-13). For the purposes of the impact assessment, it was assumed that this layer would have a maximum average thickness of 0.1 to 0.2 m and would have concentrations equal to mine affected groundwater.

Potential impacts to benthic invertebrates of primary concern

The primary concern in the porewater and the shallow overlying water column layer during ice-covered conditions would be impact on benthic invertebrates. The total volume of the lake affected would be very small (estimated at <2%).

Predicted average water column concentrations for 5 of 6 parameters are below guideline concentrations and/or site-specific benchmark

Predicted lake water quality and porewater quality for the north and northeast lakes are summarized in Table 9.4-25. Predicted maximum, average water column concentrations of pH, nitrate, aluminum, and molybdenum in the north and northeast lakes were below water quality guideline concentrations, and copper was below the site-specific HC_5 water quality benchmark. Therefore, all of these parameters would have a negligible impact on water quality in the north and northeast lakes.

Table 9.4-25 Simulated Water Quality in the North and Northeast Lakes during Post-closure

Parameter	Units	Maximum Concentrations in Majority of Lake		Maximum Concentrations in Porewater and a Shallow Bottom Layer in the Water Column Under Ice [(a)]		General Guidelines [(b)]	Site-specific Water Quality Benchmarks
		North Lake	Northeast Lake	North Lake	Northeast Lake		Hazard Concentration Values (HC_5, HC_{10}, HC_{20}) [(c)]
Conventional Parameters							
pH	-	7.1	6.7	11.8	11.8	6.5-9 (AL)	-
Nitrate	mg/L	1.7	0.7	42.7	42.7	10 (DW)	-
Aluminum	µg/L	40	29	468	468	100 (AL)	-
Hexavalent Chromium	µg/L	0.4	0.2	313	313	1 (AL)	2.1, 3.5, 10
Trivalent Chromium	µg/L	12.3	4.8	12.5	12.5	8.9 (AL)	7.6, 12, 19.5
Copper	µg/L	1.1	1.0	5.1	5.1	2 (AL)	1.2, 1.9, 3.3
Molybdenum	µg/L	3.3	1.3	81.1	81.1	73 (AL)	-

(a) The area affected is the less than 10% of the lake area that receives groundwater affected by the underground mine workings.

(b) AL = aquatic life water quality guideline, DW = drinking water quality guideline.

(c) Trivalent chromium and copper benchmarks were calculated at a hardness of ≤20 µg/L, which is the predicted post-closure hardness in the north and northeast lakes. Hexavalent chromium benchmarks are not hardness dependent.

Chromium predicted to increase over 20 to 30 years and remain constant for 80 years

Following a breakthrough, which occurs 80 years after mine closure, chromium concentrations in the north and northeast lakes were predicted to increase over a 20 to 30 year period. Concentrations will then remain relatively constant for a period of 300 or more years before gradually declining. Maximum, average chromium concentrations in the north and northeast lakes for a representative 10-year period are shown in Figures 9.4-17 and 9.4-18, respectively.

Hexavalent chromium predicted to be below the HC_5 for majority of the lake

Hexavalent chromium was predicted to be below the aquatic life guideline and below the site-specific HC_5 water quality benchmark in the majority of each lake. Therefore, the impact of hexavalent chromium on water quality in the north and northeast lakes was expected to be negligible.

Trivalent chromium predicted to have a moderate impact on the north lake and negligible impact on the northeast lake

The predicted maximum average water column concentration of trivalent chromium would fall between site-specific HC_{10} and HC_{20} water quality benchmarks in the north lake and would be below the HC_5 benchmark in the northeast lake. Consequently, the magnitude of impact would be moderate in the north lake and negligible in the northeast lake. The impact magnitude is moderate in the north lake, because predicted concentrations could affect between 10 and 20% of the aquatic species in the entire lake. The impact magnitude for the northeast lake would be negligible, because less than 5% of aquatic species could be affected in the entire lake.

Aluminum, hexavalent chromium, copper, molybdenum, and pH were predicted to exceed guideline and site-specific benchmarks in less than 10% of the lake

Concentrations of aluminum, hexavalent chromium, copper, molybdenum, and pH in the porewater and thin layer of water above the sediment under ice were predicted to be above water quality guidelines in areas that would receive mine affected groundwater. The predicted concentration of hexavalent chromium was also above the site-specific HC_{20} water quality benchmark. The impact magnitude for water quality would be classified as low; because concentrations were above water quality guidelines or in the case of hexavalent chromium above the site-specific HC_{20} benchmark, but in less than 10% of the lake by area and volume.

The magnitude of water quality impacts for Lakes NL5 and NL6 would be classified as moderate

The magnitude of water quality impacts for lakes NL5 and NL6 would be classified as moderate, because concentrations in these lakes would be equivalent to the average concentrations in the north lake.

Figure 9.4-17 Predicted Maximum, Average Chromium Concentrations in the North Lake

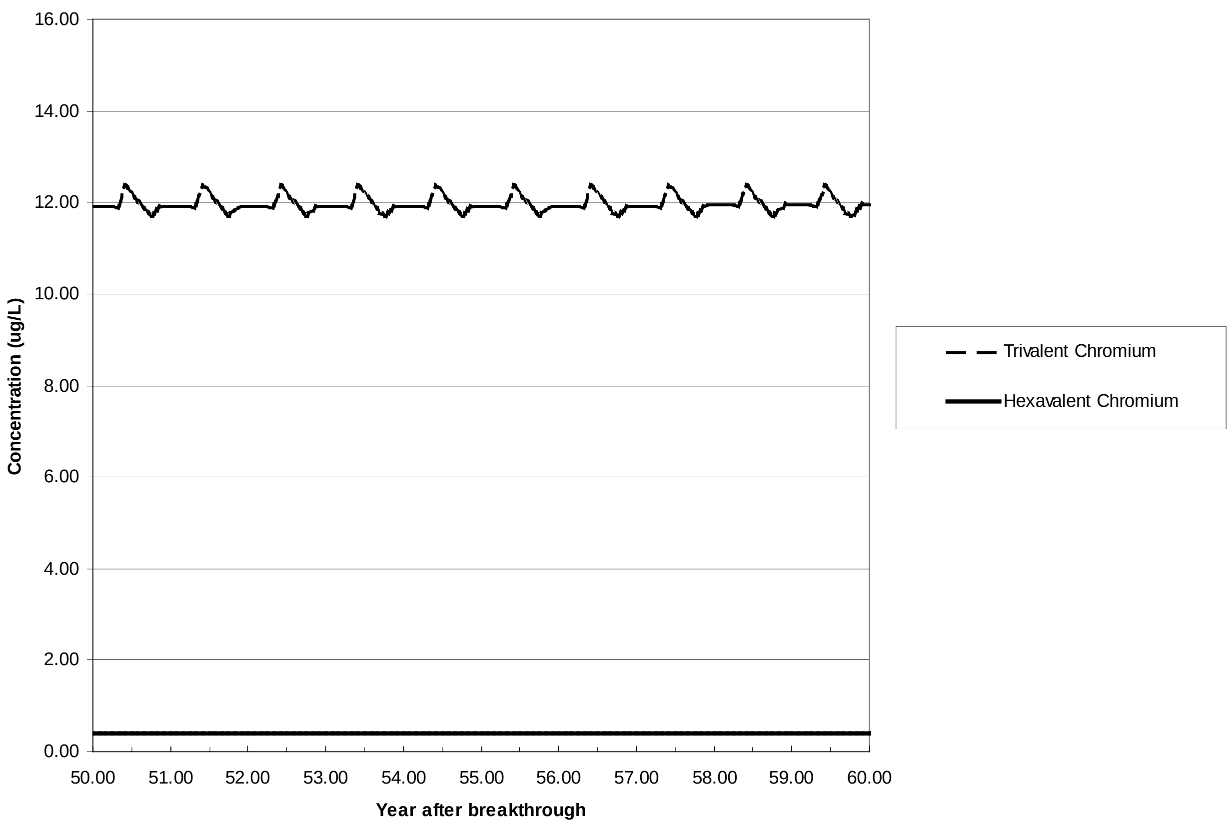
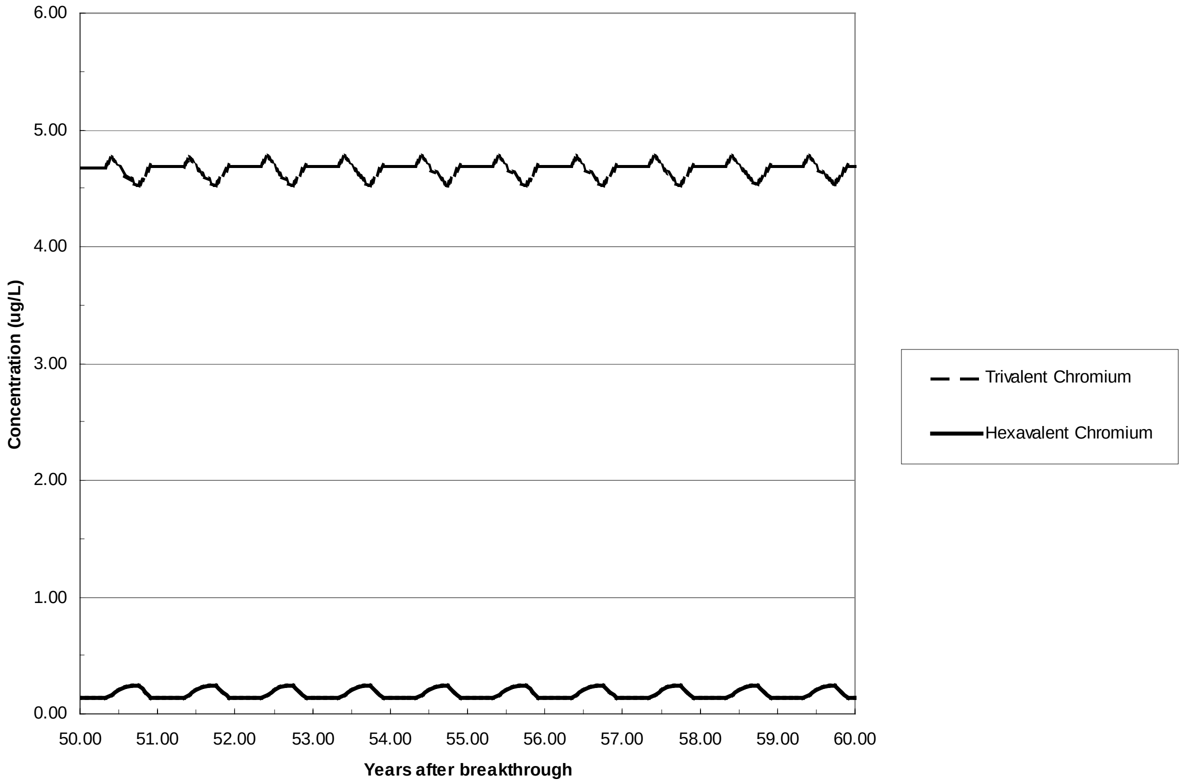


Figure 9.4-18 Predicted Maximum, Average Chromium Concentrations in the Northeast Lake



Geographic extent of impact from groundwater is local

The geographic extent for these impacts would be local, because predicted maximum concentrations within the boundary of the LSA (at the outlet of the northeast lake) were below site-specific HC_5 water quality benchmarks, or water quality guidelines (for parameters without site-specific benchmarks).

9.4.2.2.5 Residual Impact Classification

Snap Lake

Low impact magnitude assigned to Snap Lake due to aluminum and hexavalent chromium in the combined discharge during operations; all other parameters are negligible

The residual impacts of the Snap Lake Diamond Project on the water quality of Snap Lake are summarized in Table 9.4-26 for the protection of aquatic life, and in Table 9.4-27 for drinking water supply. The low impact magnitude for the protection of aquatic life during construction and operation was based on the highest magnitude impact, which resulted from chronic toxicity and hexavalent chromium in the combined discharge during operations. The impact magnitudes for aquatic life were negligible for all other parameters during construction and operations. The impact magnitudes for drinking water supply were negligible for all parameters during construction, operations and post-closure.

The overall aquatic community in Snap Lake would be protected with a low magnitude impact. The overall environmental consequence of impacts to Snap Lake would be negligible to low. There is the potential for effects to the most sensitive species, notably cladocerans, in a small percentage of the lake during operations. These predicted effects were carried forward into Section 9.5, which assesses the overall impact of all impact pathways, including water quality, on aquatic life in Snap Lake.

Ongoing pilot water treatment testing and whole effluent toxicity testing will continue to refine the water quality and toxicological characteristics of the treated mine water discharge, and identify whether any further reductions in discharge concentrations of chronic toxicity are feasible.

Table 9.4-26 Classification of Residual Impacts on the Water Quality of Snap Lake for the Protection of Aquatic Life

Waterbody	Time-frame	Direction	Magnitude	Geographic Extent	Duration	Frequency	Reversibility	Environmental Consequence
Snap Lake	construction, operations	negative	low	local	medium-term	high	reversible (short-term)	low
Snap Lake	post-closure	negative	negligible	local	long-term	high	reversible (short-term)	low

Note: Numerical score for ranking of environmental consequence is explained in Section 9.1, Table 9.1-2.

Table 9.4-27 Classification of Residual Impacts on the Water Quality of Snap Lake for Drinking Water Supply

Waterbody	Time-frame	Direction	Magnitude	Geographic Extent	Duration	Frequency	Reversibility	Environmental Consequence
Snap Lake	construction, operations	negative	negligible	local	medium-term	high	reversible (short-term)	negligible
Snap Lake	post-closure	negative	negligible	local	long-term	high	reversible (short-term)	low

Note: Numerical score for ranking of environmental consequence is explained in Section 9.1, Table 9.1-2.

The probability that water releases will alter water quality in Snap Lake is very high

Water releases from the Snap Lake Diamond Project will occur and the probability that they will affect water quality in Snap Lake is very high.

A high degree of conservatism ensures that the level of certainty is high that water quality impacts will not be higher than predicted

The confidence level that water quality impacts resulting from water releases to Snap Lake will not be greater than predicted is high. Predicted water releases concentrations and flows were based on conservatively high assumptions. The methodology by which maximum predicted concentrations in Snap Lake were used to determine impact magnitudes also contributed in conservatively high estimates of potential impact.

Groundwater Discharge to Lakes North of Snap Lake

Post-closure impacts to water quality in the north lake and northeast lake are moderate and low, respectively

The residual impacts of post-closure groundwater discharge on water quality in the north and northeast lakes is summarized in Table 9.4-28 for the protection of aquatic life, and in Table 9.4-29 for drinking water supply. The residual impacts were based on the highest magnitude impact, which for aquatic life in the north lake was the impact of trivalent chromium throughout the lake, resulting in a magnitude rating of moderate. The residual impact for the northeast lake was based on the impact of hexavalent chromium in porewater and in the overlying bottom layer of mine affected water under ice-covered conditions. Based on this scenario, the magnitude rating in the northeast lake was low. The residual impact magnitude for drinking water supply were negligible because maximum lake average concentrations were below drinking water guidelines.

Table 9.4-28 Classification of Residual Impacts of Post-Closure Groundwater Discharge to Lakes North of Snap Lake for the Protection of Aquatic Life

Waterbody	Time-frame	Direction	Magnitude	Geographic Extent	Duration	Frequency	Reversibility	Environmental Consequence
North lake, NL5 and NL6	post-closure	negative	moderate	local	long-term	high	reversible (short-term)	low
Northeast lake	post-closure	negative	low	local	long-term	high	reversible (short-term)	low

Note: Numerical score for ranking of environmental consequence is explained in Section 9.1, Table 9.1-2.

Table 9.4-29 Classification of Residual Impacts of Post-Closure Groundwater Discharge to Lakes North of Snap Lake for Drinking Water Supply

Waterbody	Time-frame	Direction	Magnitude	Geographic Extent	Duration	Frequency	Reversibility	Environmental Consequence
North lake, NL5 and NL6	post-closure	negative	negligible	local	long-term	high	reversible (short-term)	low
Northeast lake	post-closure	negative	negligible	local	long-term	high	reversible (short-term)	low

Note: Numerical score for ranking of environmental consequence is explained in Section 9.1, Table 9.1-2.

Post-closure groundwater flows and chemistry are based on conservatively high assumptions

The probability that post-closure groundwater flow will affect sediment porewater and water quality in the north and the northeast lakes is moderate. When additional testing is done to reduce uncertainty, the revised predictions may be less than shown here. The confidence level that water quality impacts resulting from post-closure groundwater flow would not be higher than predicted is high. Predicted groundwater quality and flow volumes were based on conservatively high assumptions.

Additional information indicates that refinement of the flows and concentrations to more accurate values would reduce expected chromium concentrations

Further refinement of water quality of mine affected groundwater during post-closure would likely reduce expected chromium concentrations. Additional leachate testing, completed after the water quality assessment predictions were complete (Appendix III.2), indicated that expected mine affected chromium concentrations used in the assessment could be overestimated by at least one-third. The expected values used in the assessment do not account for geochemical reactions that may further reduce chromium concentrations during the 80+ years of travel time between the flooded underground workings and the north and northeast lakes. Additional work that is underway or proposed to refine the predictions is described in Section 9.4.2.2.6 below.

Impacts to aquatic resources is provided in Section 9.5

The aquatic resources assessment (Section 9.5) considers the combined impact of all valid pathways on aquatic life in the north and northeast lakes, including water quality. A more detailed assessment of water quality impacts on the aquatic organism expected to be present in the study area was provided therein.

Refinement to post-closure chromium impact predictions is currently underway and will be provided as supplemental information

Elevated chromium concentrations in the mine affected groundwater during post-closure was predicted to have the highest potential for impact to aquatic life in the north and northeast lakes. Additional work is currently underway to refine the impact predictions for pH, chromium, and other metals, including:

- additional leachate testing and geochemical modelling to refine predictions of mine affected groundwater concentrations at post-closure;
- review of the rate of groundwater recharge from Snap Lake based on a review of the winter water and mass balance in Snap Lake; and,
- ongoing literature searches for additional chromium toxicity information to refine the site-specific hazard concentrations.

9.4.2.2.6 Monitoring

9.4.2.2.7 Additional Studies

Refinement to post-closure groundwater quality and flow predictions will be provided as supplemental information

The predicted rate of groundwater outflow from Snap Lake and the chemistry of the mine-affected groundwater used in the environmental assessment were based on conservative worst-case assumptions. Further refinement of groundwater flows and the chemistry of mine affected groundwater during post-closure is expected to reduce the magnitude of predicted impacts to the north and northeast lakes. The following additional work is proposed or currently underway to refine the impact predictions for mine affected groundwater, with the results to be filed as supplemental information:

- Additional column leach testing will be undertaken to refine predictions of mine affected groundwater concentrations at post-closure. Preliminary results of additional leachate testing, indicated that expected mine affected chromium concentrations used in the assessment could be overestimated by at least one-third.
- Geochemical modelling will be undertaken to account for attenuation during the 80 years of travel time between the flooded underground workings and the north and northeast lakes, which will provide a more realistic estimate of the chemistry of mine affected groundwater.
- Sampling of lake water, porewater, and sediment in the north and northeast lakes will be combined with transport modelling to provide a more realistic estimate of the porewater and lake water concentrations in areas receiving mine affected groundwater.
- A detailed evaluation of the winter water balance in Snap Lake will be undertaken to refine estimates of groundwater outflow from Snap Lake.
- There are options available to reduce the amount of cement required in the mine, which could reduce the pH and metal concentrations in mine affected groundwater. A review of these options is currently underway.

9.4.2.2.8 Monitoring

De Beers is committed to monitoring the status of Snap Lake

De Beers is committed to monitoring water quality in Snap Lake during construction, operations, and closure. The monitoring program would include biological and water chemistry sampling. A detailed aquatic effects monitoring program will be developed for Snap Lake as a condition of the water license for the project. The results of the impact assessment indicate that the monitoring program should include the following:

- seasonal monitoring to verify impact predictions related to changes in water quality in Snap Lake; and,
- monitoring under ice-free and ice-cover conditions near the multi-port diffuser to verify the three-dimensional mixing and dilution properties of the diffuser.

Samples will be collected near the Snap Lake outlet

The number and location of sampling locations will be selected to characterize the spatial distribution of water quality in Snap Lake. One site should be located near the lake outlet.

Additional toxicity characterization is recommended

Additional acute and chronic aquatic toxicity testing of ongoing pilot water treatment testing is recommended to verify the toxicity characteristics of the treated discharge. A toxicity reduction experiment should be undertaken to determine the toxicity degradation rate in the treated water discharge, if ongoing testing work indicates that the treated discharge could be chronically toxic.

9.4.2.3 Key Question WQ-2: What Impacts Will the Snap Lake Diamond Project Have on Regional Water Quality in the Lockhart River Watershed?

9.4.2.3.1 Linkage Analysis

Impacts from the Snap Lake Diamond Project on the regional water quality will be negligible

The magnitude of impact and environmental consequence of the Snap Lake Diamond Project on water quality at the outlet of Snap Lake were predicted to be negligible. The maximum concentrations of all parameters were predicted to be below general guidelines or site-specific water quality benchmarks. Baseline water quality was consistent throughout the Lockhart River watershed. Therefore, general environmental guidelines and site-specific water quality benchmarks appropriate for Snap Lake were appropriate for lakes throughout the watershed. Based on these factors, there was no valid linkage for the Snap Lake Diamond Project to impact regional water quality in the Lockhart River watershed. Therefore, no further assessment was necessary.

Potential impacts from TDS were carried forward into the aquatic resources section

The one qualification to the linkage analysis is that there is no general water quality guideline or site-specific water quality benchmark for TDS or major ions. Therefore, they could not be evaluated as part of the water quality assessment for impacts to Snap Lake, and were carried forward into Section 9.5.

Watershed area and inflows to lakes decreases TDS with distance downstream from Snap Lake

The maximum predicted increase in TDS concentrations in lakes downstream of Snap Lake is summarized in Table 9.4-30. The maximum change in TDS (and major ions) decreases with distance downstream, because the total watershed areas and inflows to the lakes increase, attenuating the effect of the Snap Lake Diamond Project. The potential impact of increases in major ions and TDS on aquatic life in regional water bodies was also carried forward into Section 9.5.

Table 9.4-30 Maximum Predicted Changes in Total Dissolved Solids Concentrations in Lakes Downstream of Snap Lake

Downstream Site [a]	Baseline TDS Concentration (mg/L)	Maximum TDS Concentration During Project Operations (mg/L)
17	18	150
37	17	119
22	20	41
11	12	16
23	10	13
24	14	16
26	17	19
3	20	21
4[b]	21	22
53	35	36
52	24	25
43	53	54
19	14	15

[a] Numbers refer to downstream sites as illustrated in Figures 9.4-4 and 9.4-5.
[b] Site 4 (1999) is equivalent to Site 7 (1993/1994).
TDS = total dissolved solids.

9.4.2.3.2 Monitoring

The outlet of Snap Lake will be monitored

As a component of the aquatic effects monitoring program, the water quality at the outlet of Snap Lake would be monitored to ensure that the Snap Lake Diamond Project does not impact water quality at the outlet of Snap Lake.

9.4.2.4 Key Question WQ-3: What Impacts Will Acidifying Emissions from the Snap Lake Diamond Project Have on Regional Waterbodies?

9.4.2.4.1 Background

pH changes due to acid deposition are dependent on deposition rates and neutralizing capability of the catchment basin

Acidification of surface waters resulting from the deposition of acids and acid-forming substances is a well-documented phenomenon in both Europe and North America (NRCC 1981; RMCC 1990; Environment Canada 1997; Henriksen *et al*. 1992). Emissions of nitrogen and sulphur oxides (NO_X and

SO_X) resulting from human activities are the main contributors to acid deposition. The impact of acid deposition on the pH of a surface waterbody depends on the rates of deposition relative to the capability of the waterbody and its surrounding catchment basin to neutralize the deposited acids. Since acidification can affect lakes and streams differently, the two are discussed separately below.

Lake Acidification

Biodiversity and species interactions may be affected by toxicity due to increased acidity

Adverse effects of lake acidification on aquatic biota have been reported by numerous studies (*e.g.*, RMCC 1990, Herrmann *et al*. 1993). In general, the diversity of aquatic ecosystems begins to decline at a pH of 6, although loss of highly acid-sensitive species may occur as pH drops below 6.5 (Sullivan 2000).

The sensitivity of lakes to acid deposition can be evaluated based on alkalinity or acid neutralizing capacity (ANC)

Alkalinity is a measure of inorganic buffering capacity via the carbonate/bicarbonate buffering system (Wetzel 1983). Acid neutralizing capacity (ANC) is a more exact measure of buffering capacity; it is the difference between the concentrations of nonmarine base cations and strong acid anions (Hindar *et al*. 1998), and also incorporates buffering provided by organic compounds and dissolved metals. Alkalinity is the more commonly used indicator of acid-sensitivity in North America and has been used in Alberta to classify lakes with regard to acid-sensitivity (Saffran and Trew 1996).

Lake sensitivity to acidification is defined

Saffran and Trew (1996) presented a scale of lake sensitivity to acidification based on alkalinity. Sensitivity categories were defined as follows:

Acid sensitivity	Alkalinity (mg/L as $CaCO_3$)
high	0 to 10
moderate	11 to 20
low	21 to 40
least	>40

Critical loads are calculated to assess sensitivity to acidification

Presently, the most sophisticated approach to assess the sensitivity of lakes to acidification is the calculation of lake-specific critical loads (CLs), which are based on ANC (*e.g.*, Hindar *et al*. 1998). The CL can be thought of as an estimate of the amount of acidic deposition below which no substantial harmful effects occur to a specified component of a lake’s ecosystem (*e.g.*, a valued fish species) (Sullivan 2000).

Acidification of Streams

Acid sensitivity is highest during the spring snowmelt (episodic acidification)

The primary concern regarding acidification of streams is episodic acidification during the spring snowmelt, also referred to as a spring acid pulse. Episodic acidification has been documented in surface waters, most frequently in response to hydrological events, such as snowmelt or rainfall (Sullivan 2000). Acidic deposition from industrial sources can contribute to episodic acidification, potentially resulting in a more severe depression of pH and a longer recovery period.

Episodic acidification results from runoff picking up organic acids

Episodic acidification in sensitive streams typically results from a certain combination of events (Sullivan 2000). During periods of high runoff, meltwaters typically flow on the surface (if the ground is frozen) or through shallow flowpaths through the upper soil horizons. These upper horizons tend to have low pH and ANC, and higher organic content relative to deeper layers. This is reflected in the chemistry of drainage waters in the form of low base cation concentrations and enrichment by organic acids. Large volumes of runoff reaching streams during such events can cause dilution of base cations in the receiving waters and may also contribute natural acidity. The end result of these processes is a rapid lowering of pH in the affected waters, with subsequent recovery once flows return to normal.

9.4.2.4.2 Linkage Analysis

Lake Acidification

Acidifying emissions from the Snap Lake Diamond Project may affect lakes in the regional study area

The Snap Lake Diamond Project will produce acidifying emissions (Section 7) and there are a number of acid-sensitive lakes in the RSA (Section 9.4.1.9). Therefore, the potential for acidifying emissions from the Snap Lake Diamond Project to affect lakes in the RSA is a valid pathway and this linkage is valid.

Stream Acidification

Acidifying emissions from the Snap Lake Diamond Project may affect streams in the regional study area

The Snap Lake Diamond Project will result in the release of acidifying emissions (Section 7). Therefore, the potential for acidifying emissions from the Snap Lake Diamond Project to affect the water quality of streams in the RSA by a spring acid pulse (episodic acidification) is a valid linkage.

9.4.2.4.3 Mitigation

The Snap Lake Diamond Project has been designed to minimize the release of acidifying emissions. A discussion of air emissions and mitigation measures is provided in Section 7.

9.4.2.4.4 Impact Analysis Methods

Acidification of Lakes

The threshold of acid deposition that a lake can receive with no adverse effects on the aquatic ecosystem is referred to as the critical load

The concept of CL has been used to assess the impacts of acid deposition on lakes. The CL represents an estimate of the threshold of acidic deposition that a lake can receive without experiencing adverse changes to its ecosystem. The World Health Organization (WHO) has developed guidelines for CL ranges from simple steady-state mass balance models applied in European lakes (WHO 1994). An interim CL of 0.25 keq/ha/yr was adopted to provide a 95% level of protection for sensitive waterbodies (WHO 1994). This value has also been adopted in Canada (*e.g.*, CASA 1996).

If potential acid input exceeds the critical load of a lake, the lake pH is likely to decrease

CLs and PAI are expressed in units of keq/ha/yr, which is a measure of H+ equivalents deposited per year to a unit area. An exceedance of the CL, by the PAI, is considered an indication that the buffering capacity of a lake may be exceeded by acid deposition, with a subsequent drop in pH.

Individual lake critical loads can be calculated using a number of easily measured lake parameters

More recently, lake specific CLs have been calculated to allow the assessment of effects to individual waterbodies. CL calculations are based on a model developed by Henriksen *et al*. (1992), which calculates CLs using the following easily measured lake parameters:

- watershed and lake surface area;
- net annual water yield; and,
- base cation water chemistry (Na^+, K^+, Ca^{2+}, and Mg^{2+}).

Potential acid input represents acid deposition from all sources

Usually, CLs are compared with acid deposition rates expressed as the Potential Acid Input (PAI), which are predicted as part of the Air Quality Assessment (Section 7), on a lake specific basis. PAI is a measure of the total deposition of sulphur and nitrogen species in both wet and dry forms, minus base cations, and represents an estimate of acid deposition from all sources.

Detailed methods for the assessment of lake acidification are provided in Appendix IX.5.

Acidification of Streams

Acid deposition was evaluated based on basin characteristics and spatial patterns

It is not possible to quantify the occurrence or severity of spring acid pulses in streams based on the current level of scientific understanding of this phenomenon. Therefore, the potential for increases in the frequency and/or severity of spring acid pulses resulting from acidifying emissions from the Snap Lake Diamond Project was evaluated qualitatively. The evaluation was based on basin characteristics in the RSA and predicted changes in the spatial pattern of PAI deposition due to the Snap Lake Diamond Project.

9.4.2.4.5 Impact Analysis Results

Acidification of Lakes

Critical loads and potential acid inputs are summarized for lakes in the regional study area under baseline and application conditions

Contours of predicted PAI deposition resulting from the Snap Lake Diamond Project are shown in Figure 9.4-19. Critical loads and PAI deposition rates with and without the project are summarized for a number of lakes in the RSA in Table 9.4-31.

Potential impacts from the Snap Lake Diamond Project acidifying emissions will be localized

The most obvious characteristic of the data is that elevated PAIs are restricted to a very small area around the mine site (Figure 9.4-19). This is consistent with the relatively small quantity of low level (*i.e.*, no tall stacks) NO_X and SO_X emissions from the project (Section 7). Consequently, the potential impact of acidifying emissions from the project will be very localized. Predicted background PAI loadings are lower than the CL for all of the 48 lakes in Table 9.4-31, including Snap Lake.

Acid deposition may exceed the buffering capacity in one lake in the local study area

Lakes in the LSA and RSA have CLs ranging from 0.048 to 1.068 keq/ha/year. The CL for Snap Lake (0.125 keq/ha/year) is greater than the predicted acidic deposition on Snap Lake (0.084 keq/ha/year). Therefore, there are no anticipated impacts of predicted acidic deposition in Snap Lake (baseline plus the Snap Lake Diamond Project). There are a number of smaller waterbodies near the project site that will receive higher PAI loadings due to the project, including lakes IL3-5 and NL1-4 (Table 9.4-31, Figure 9.4-19); however, there are no lakes for which the predicted PAI (due to baseline deposition plus deposition from the Snap Lake Diamond Project) would exceed the lake-specific CL.

Potential acid input deposition does not exceed the critical load regionally

For most of the regional lakes, there was no predicted increase in PAI deposition due to the Snap Lake Diamond Project. PAI deposition under the baseline or application cases does not exceed the critical load of any regional lakes.

Effects of acidifying emissions will be restricted to a small area; effects on Snap Lake will be negligible

In summary, predicted PAI deposition rates indicated that acidifying emissions from the Snap Lake Diamond Project will not result in PAI deposition exceeding the critical load in any lakes in the LSA or RSA.

Figure 9.4-19 Potential Acid Input (PAI) Predictions for the Snap Lake Diamond Project

Table 9.4-31 Predicted Acid Input (PAI) Deposition Rates and Critical Loads for Select Lakes in the Regional Study Area

Lake Sampling Station	Distance (km)[a]	Critical Load (keq/ha/yr)	Baseline PAI (keq/ha/yr)[b]	Baseline + Project PAI (keq/ha/yr)[b]
Lakes in the Snap Lake Watershed (LSA)				
Snap Lake [c]	2.4	0.125	0.040	0.084
IL4 [d]	1.91	0.108	0.040	0.095
IL3 [d]	2.01	0.095	0.040	0.089
NL1 [d]	2.27	0.265	0.040	0.072
IL5 [d]	2.28	0.098	0.040	0.073
NL3 [d]	2.38	0.177	0.040	0.072
NL2 [d]	2.94	0.221	0.040	0.069
NL4 [d]	3.25	0.133	0.040	0.067
Lakes in the Lockhart Watershed (RSA)				
North Lake [d]	5.43	0.198	0.040	0.056
WQ5 [e]	6.87	0.151	0.040	0.047
Reference Lake [d]	13.27	0.093	0.040	0.044
12 [d]	13.39	0.127	0.040	0.045
17 [d]	13.40	0.107	0.040	0.043
37 [f]	20.40	0.104	0.040	0.043
27 [d]	53.23	0.133	0.040	0.040
21 [f]	53.88	0.331	0.040	0.040
47[f]	55.35	0.098	0.040	0.040
40 [f]	57.08	0.075	0.040	0.040
20 [f]	57.11	0.104	0.040	0.040
101 [f]	63.14	0.132	0.040	0.040
35 [f]	64.39	0.096	0.040	0.040
50 [f]	66.24	0.102	0.040	0.040
100 [f]	72.27	0.107	0.040	0.040
8 [f]	72.46	0.136	0.040	0.040
13,14 [d],[f],[g]	77.19	0.124	0.040	0.040
16 [f]	79.67	0.079	0.040	0.040
11 [f], 22-24 [d],25 [f],26 [d],49 [f],[g]	79.69	0.153	0.040	0.041
28 [d]	80.32	0.085	0.040	0.040
51 [d]	86.18	0.213	0.040	0.040
30 [d]	86.30	0.087	0.040	0.040
39 [f]	98.08	0.055	0.040	0.040
32,33,34 [d],[g]	108.91	0.084	0.040	0.040
31 [f]	111.74	0.081	0.040	0.040
1 [d],2 [f],[g]	112.30	0.111	0.040	0.040

Table 9.4-31 Predicted Acid Deposition (PAI) and Critical Loads for Select Lakes in the Regional Study Area (continued)

Lake Sampling Station	Distance (km)[(a)]	Critical Load (keq/ha/yr)	Baseline PAI (keq/ha/yr)[(b)]	Baseline + Project PAI (keq/ha/yr)[(b)]
18 [(f)]	115.37	0.084	0.040	0.040
52 [(d)]	131.70	0.151	0.040	0.040
42 [(d)]	132.07	0.098	0.040	0.040
19 [(d)]	132.51	0.104	0.040	0.040
43 [(f)]	133.02	1.068	0.040	0.040
36 [(f)]	137.11	0.079	0.040	0.040
44 [(f)]	140.51	0.097	0.040	0.040
45 [(f)]	141.69	0.060	0.040	0.040
46 [(f)]	143.32	0.058	0.040	0.040
3-4 [(d)], 5-7 [(f),(g)]	148.96	0.097	0.040	0.040
53 [(d)]	151.86	0.126	0.040	0.040
38 [(f)]	153.59	0.048	0.040	0.040
41 [(f)]	162.23	0.080	0.040	0.040

(a) Distance from the Snap Lake Diamond Project central facilities.
(b) PAI predictions include a background value of 0.040 keq/ha/yr.
(c) Critical load calculated using 1998, 1999, and 2001 data.
(d) Critical load calculated using 1999 data.
(e) Critical load calculated using 1999 and 2001 data.
(f) Critical load calculated using 1993-1994 data.
(g) Data were averaged as sampling stations were located in one waterbody.

Acidification of Streams

Streams in the Snap Lake area are sensitive to acidification

Streams in the Snap Lake area are expected to be sensitive to acidification, because of the low concentrations of base cations and the high proportion of flows that is associated with spring runoff due to snowmelt.

Potential impacts from the Snap Lake Diamond Project are restricted to streams near the project

As described above for lake acidification, the increase in PAI loadings due to the Snap Lake Diamond Project will be very localized and, therefore, the potential impact will be restricted to streams near the project. The streams of most concern are the larger tributaries to Snap Lake that could provide spring spawning habitat for fish. Given the small increase in PAI loadings, the magnitude of the effect on spring acid pulse is expected to be negligible to low.

Streams near the project site with potential spawning habitat may be at risk for spring acid pulses

PAI isopleths resulting from Snap Lake Diamond Project emissions indicate that elevated PAI loadings would be restricted to two streams (S1 and S27) near the project site that have the potential to provide spring spawning habitat (Figure 9.4-19, Figure 9.5-3). It is not possible to predict whether the Snap Lake Diamond Project will result in any increase in spring acid pulse in these streams, only that they are at increased risk.

9.4.2.4.6 Residual Impact Classification

Residual Impacts are classified for regional waterbodies

The residual impacts of the Snap Lake Diamond Project on acidification to the waterbodies selected for the impact analysis are classified in Table 9.4-32.

Geographical extent is considered when classifying water quality impacts

When classifying impacts on water quality, geographic extent was considered relevant only to the specific waterbody or waterbodies being classified, rather than the impact in general. This was necessary for consistency with other impact attributes, which are "lake-specific". The relatively small area of increased PAI deposition due to the project also contributes to the classification of geographic extent as local for Snap Lake and lakes near the project.

Table 9.4-32 Classification of Residual Impacts of Acidifying Emissions on Regional Waterbodies

Waterbody	Time-Frame	Direction	Magnitude	Geographic Extent	Duration	Frequency	Reversibility	Environmental Consequence
Local (LSA) lakes	construction, operations	negative	negligible	local [a]	medium-term	high	reversible (short-term)	negligible
Regional (RSA) lakes	construction, operations	negative	negligible	regional	medium-term	high	reversible (short-term)	low
Regional streams	construction, operations	negative	undetermined	local	undetermined	undetermined	undetermined	undetermined

Note: Numerical score for ranking of environmental consequence is explained in Section 9.1, Table 9.1-3.
[a] When classifying geographic extent for impacts to single lakes, the rating applies only to one lake.

Acidification is reversible

Lake acidification is considered reversible because natural recovery has been widely reported.

The impacts on the remaining lakes are negligible, regional, medium-term, continuous, and reversible

The magnitudes of impacts to all lakes in the LSA and RSA were predicted to be negligible because the predicted PAIs were below the lake-specific CLs. The geographic extent was classified as regional for regional lakes and the impacts would be medium-term and continuous. The predicted impacts to these lakes would be reversible. The environmental consequence for these lakes was classified as low (because the lakes are regional). The probability that acidifying emissions will affect water quality in Snap Lake is low.

The confidence level is high that impacts of acidifying emissions will not be higher than predicted

The confidence level that lake acidification impacts, resulting from air emissions will not be greater than predicted is high. Assumptions used in the prediction of air emissions and in the calculation of CLs are conservatively worst-case. There are sources of uncertainty in impact predictions, including:

- Use of CLs: Application of CLs to lakes in Canada is in the process of being developed and is thus subject to refinement. Adjustments to the calculation methods used herein may be necessary in the future based on results of ongoing research.
- Data quality: CLs were calculated based on limited data, in some cases collected during a single sampling event (*e.g.*, the data for some of the lakes in the RSA).

Uncertainties associated with model predictions of PAI are discussed separately in the air quality assessment (Section 7).

The impacts on streams are local; the other impact criteria are undetermined

The magnitude of the impacts to streams in the form of spring acid pulses was undetermined, largely because of limited information regarding this phenomenon. Therefore, the environmental consequence was classified as undetermined. The small area of increased PAI loadings due to the project restricts the geographic extent of the potential impact to local.

9.4.2.4.7 Monitoring

Annual summer monitoring will occur in lakes where predicted potential acid inputs are above or very close to the critical load; spring monitoring will be undertaken in streams that are potentially at risk

Annual summer water quality monitoring will be carried out in lakes IL3 and IL4, for which the predicted PAI and CL were close. The predicted PAI loading (0.073 keq/ha/yr) was less than the critical load (0.098 keq/ha/yr) for Lake IL5; however, this lake provides important fish habitat (Section 9.5) and as such, annual summer water quality related to lake acidification will be monitored. Snap Lake monitoring was described in Section 9.4. Annual spring water quality monitoring will be undertaken in streams S1 and S27 (Figure 9.4-19, Figure 9.4-3), which were identified as being potentially at risk of increased spring acid pulse due to the Snap Lake Diamond Project.