APPENDIX IX.5

SNAP LAKE BASELINE WATER AND SEDIMENT QUALITY METHODS

TABLE OF CONTENTS

LIST OF TABLES

TABLE OF CONTENTS (Continued)

LIST OF FIGURES

LIST OF APPENDICES

1.0 SNAP LAKE BASELINE WATER AND SEDIMENT QUALITY METHODS

1.1 Water Quality

1.1.1 Snap Lake Watershed

Water samples were collected from six stations in Snap Lake (water quality [WQ]1-4, WQ6, and WQ7) in 1998, 1999, and 2001. In February 1998, water quality samples (WQ1-3) were collected by drilling through ice and sampling water from the surface (Hallam Knight Piésold 1998). In July 1998, samples (WQ1-3 and WQ7) were collected from the surface of Snap Lake, and i*n situ* pH, temperature, and dissolved oxygen measurements were recorded at each station. Detailed methods for the 1998 baseline aquatics are provided in Hallam Knight Piésold (1998). Samples were collected in March 1999 using a Kemmerer bottle from two depths, near surface and near bottom. In August 1999, integrated euphotic zone samples were collected (0 – 6 meters [m]). During these sampling events, pH, temperature, and dissolved oxygen measurements were determined at one-metre intervals (±0.5 m) to measure vertical water quality gradients. Snap Lake samples were collected under ice in March 2001 and July 2001 samples were collected using a Kemmerer bottle at a depth of 3 m.

The 2000 and 2001 sampling program included Snap Lake water quality samples from locations near the advanced exploration program (AEP) site, specifically, the Snap Lake potable water intake location (additional station [AS]1), near the previous exploration camp (AS2), and near the mine discharge location (AS3 and AS4) (Section 9.4.1, Figure 9.4-2, Table 9.4-1). An authorized advanced exploration discharge from the water management pond (WMP) occurred from April 9 to June 7, 2001. AS1 monitoring data from June 26, 2000 until June 11, 2001 were considered baseline because this station was not located near the discharge location. There was no difference in water quality at the Snap Lake intake from pre-, during, and post discharge periods. Only samples collected from AS3 and AS4 prior to April 9, 2001 were considered baseline data since these stations are near the advanced exploration discharge location. Samples from AS1 were collected from the water intake pumphouse after water was drawn from Snap Lake. Samples from AS2-4 were surface samples collected under ice.

All water quality stations sampled by Golder Associates Ltd. (Golder Associates) were sampled according to methods outlined in Golder Associates' Technical Procedure (TP) 8.3-1 (Appendix IX.5-A). Samples collected in 1998 and 1999 were analyzed for conventional chemistry, nutrients, total metals, and dissolved metals by Taiga Environmental Laboratory (Taiga) in Yellowknife, NWT. Enviro-Test Laboratories (ETL) in Edmonton, Alberta, analyzed the majority of samples collected in 2001 using Ultra-Low (UL) detection methods. Samples collected from AS1 were generally analyzed by Taiga. Samples from AS1 on January 15 and April 15 2001 were analyzed by ETL.

A quality assurance and quality control (QA/QC) program was implemented to test the validity of field and sampling methods. Travel blanks, filter blanks, and field blanks were analyzed for chemical parameters, nutrients, total metals, and dissolved metals.

In May, June, and August 1999, travel blanks and water-sampling containers were provided by Taiga. Travel blanks are sealed bottles that are pre-filled with distilled water and preservative at the laboratory and accompany empty sample bottles to the field site. The unopened blanks are subjected to same holding and transport conditions as samples collected in the field. They are returned to the laboratory and used to detect sample contamination during transport from the field to the analytical laboratory. Filter blanks (distilled water filtered in the field) were used to test for contamination during filtration in March, May, and June 1999.

In March 1999, a field blank was prepared in the field, by filling a container with laboratory-provided de-ionized water, and was subjected to the same storage and transport conditions as the field samples. The blank sample was submitted to the laboratory for metals analysis and was used to detect contamination during sample collection and transport, and to check the accuracy of analytical results. All 2000 and 2001 samples also underwent a QA/QC program as per the AEP water license.

1.1.2 Lockhart River Watershed

Water quality stations were sampled by the Indian and Northern Affairs Canada (INAC) throughout the Lockhart River watershed in 1993/94 and 1999. Samples from the 1993/94 water quality program were collected from a depth of 4 m using a 3-litre (L) Van Dorne water sampler (Puznicki 1996). At each sampling site, pH, conductivity, temperature, and lake depth were measured and recorded. Detailed methods for the 1993/94 water quality sampling program are provided in Puznicki (1996).

Samples from March 1999 were collected under ice using a vertical Van Dorne water sampler (B. Blais, INAC, pers. comm.). A horizontal Van Dorne water sampler was used

to collect the August 1999 samples. For both sampling events, if depth was sufficient, water samples were taken at three separate depths within the water column. Duplicate and triplicate samples were collected at approximately 10 percent (%) of the sites. Detailed methods for the 1999 sampling program are unpublished to date, but can be obtained from Bart Blais, Aquatic Quality Specialist, INAC, Yellowknife, Northwest Territories (NWT). Taiga analyzed water quality samples from both studies for routine parameters, nutrients, and total metals.

1.2 Sediment Sampling

1.2.1 Snap Lake Watershed

In September 1999, sediment sampling was conducted using an Ekman grab sampler at four stations in Snap Lake (shallow habitat [SH]1-SH3, WQ3) and the reference lake (shallow habitat reference [SHR]1, water quality reference [WQR]1, WQR3, WQR7) (Section 9.4.1, Figure 9.4-2, Table 9.4-1). A sub-sample of one Ekman grab sample was taken for particle size, total inorganic carbon, and total organic carbon analyses. Three grab samples were homogenized and sub-sampled for metals analysis. Sediment collection methods are summarized in Golder Associates TP 8.2-2 (Appendix IX.5-B). Sediment samples were analyzed by Taiga for particle size, moisture content, total inorganic carbon, total organic carbon, and total metals.

1.2.2 Lockhart River Watershed

Sediment quality stations were sampled throughout the Lockhart River watershed in July of 1993 and 1994. Sediment samples from this sampling program were collected using a Birge-Ekman grab sampler (B. Blais, INAC, pers. comm.). A sub-sample was removed from the centre of the grab sample for analysis. Complete methods for the 1993/94 sediment quality sampling program are provided in Puznicki (1997). March and August 1999 sediment samples were collected using an Ekman Grab. About 10% of the samples were split in order to obtain duplicates. Detailed methods for the 1999 sampling program are unpublished to date, but can be obtained from Bart Blais, Aquatic Quality Specialist, INAC, Yellowknife, NWT. Sediment samples were analyzed by Taiga for total metals in 1993/94. In 1999, samples were analyzed for total metals, nutrients, pH, and percent composition.

2.0 DERIVATION OF WATER/SEDIMENT QUALITY STATISTICS

2.1 Detection limits

The summary statistics (minimum, median, maximum) presented in the water quality baseline setting (Section 9.4) of the environmental assessment (EA) were generated using the raw data presented in Appendix IX.6. This data includes results that were recorded as less than the analytical detection limit. A detection limit is the lowest concentration of a chemical parameter that an analytical laboratory can determine by a specific method of analysis. For example, a concentration that is reported as <10 units is equivalent to a concentration that is some value less than 10 units, but the value cannot be determined.

2.1.1 Published and Reported Detection Limits

Both of the laboratories that analyzed the baseline data, ETL and Taiga, publish their detection limits for each parameter and method of analyses. These detection limits vary by parameter and may change depending on the sample matrix (*i.e.,* detection limits may increase if samples contain high concentrations of suspended solids) and laboratory method. In cases where the method detection limit (MDL) differed from the published MDL, a laboratory would report the revised MDL. Table IX.5-1 and Table IX.5-2 list the published and reported MDLs from Taiga and ETL. When the reported MDL varied from the published MDL, data analysts would contact the laboratory to determine the source of the variation. The acceptability of a variation in MDL was determined on a case-specific basis. For example, if the reported MDL was simply a mis-report of the published value, than a revised MDL was requested. If the reported MDL had been deliberately adjusted by the laboratory due the nature of the sample or a problem with the analysis method, then the new MDL was accepted and integrated into the data set. Statistical summary tables in Section 9.4 contain a footnote that lists when a MDL was misreported and the revised MDL used in data analysis.

Table IX.5-1
Published Detection Limits from Enviro-Test Laboratories and Taiga Environmental Laboratory for Water Sample Analysis

		Standard Published			Reported[a]			
		Taiga[b]	ETL[c]		Taiga		ETL	
Parameter	**Units**		**UL[d]**	**LL[e]**	**min**	**max[f]**	**min - UL**	**max - UL**
Conventional Parameters								
pH	unitless	0.02	0.1	0.1	-	0.05	0.1	0.1
Alkalinity	mg/L	0.3	5	5	-	0.3	5	5
Total Dissolved Solids	mg/L	10	1	1	10	10	10	10
Total Suspended Solids	mg/L	3	3	3	3	3	3	3
Total Hardness	mg/L	0.17	1	1	0.17	0.17	-	-
Conductivity	µS/cm	0.1	0.2	0.2	0.3	0.3	0.2	0.2
Colour	TCU	5	3	3	5	5	3	3
Turbidity	NTU	0.2	0.1	0.1	0.1	0.1	0.1	0.1
Nutrients								
Ammonia	mg/L	0.05	0.005	0.005	-	0.005	0.005	0.2
Nitrate + Nitrite	mg/L	0.008	0.006	0.006	0.008	0.008	0.006	0.2
Nitrate-N	mg/L	0.008	0.006	0.006	0.008	0.008	0.006	0.006
Nitrite-N	mg/L	0.008	0.002	0.002	0.008	0.008	0.002	0.002
Total Phosphorus	mg/L	0.004	0.001	0.001	0.002	0.004	0.001	0.01
Dissolved Phosphorus	mg/L	0.002	0.001	0.001	0.002	0.004	0.001	0.01
Orthophosphate	mg/L	0.001	0.001	0.001	0.002	0.002	0.001	0.01
Total Kjeldahl Nitrogen	mg/L	0.01	0.05	0.05	0.01	0.05	0.05	0.05
Dissolved Organic Carbon	mg/L	0.5	1	1	0.2	0.5	1	1
Total Organic Carbon	mg/L	0.2	1	1	0.2	0.2	1	1
Major Ions								
Bicarbonate	mg/L	0.5	5	5	0.3	0.3	5	5
Carbonate	mg/L	0.5	5	5	-	-	5	5
Calcium	mg/L	0.05	0.05	0.05	0.05	0.05	0.05	0.5
Chloride	mg/L	0.5	1	1	0.1	0.2	1	1
Fluoride	mg/L	0.03	0.05	0.05	0.03	0.05	0.05	0.05
Hydroxide	mg/L	0.5	5	5	-	-	5	5
Magnesium	mg/L	0.01	0.01	0.01	0.01	0.02	0.01	0.1

Table IX.5-1
Published Detection Limits from EnviroTest Laboratories and Taiga Environmental Laboratory for Water Sample Analysis (Continued)

		Standard Published			Reported[a]			
		Taiga[b]	ETL[c]		Taiga		ETL	
Parameter	**Units**		**UL[d]**	**LL[e]**	**min**	**max[f]**	**min - UL**	**max - UL**
Potassium	mg/L	0.03	0.01	0.01	0.02	0.03	0.01	0.1
Silica	mg/L	0.017	0.1	0.1	0.017	0.02	0.1	50
Sodium	mg/L	0.02	0.1	0.1	0.02	0.03	0.1	1
Sulphate	mg/L	3	0.05	0.05	0.3	3	0.05	0.5
Total Metals								
Aluminum	µg/L	30	0.3	20	30	150	0.3	0.3
Antimony	µg/L	0.5	0.03	0.8	-	5	0.03	0.03
Arsenic	µg/L	0.2	0.03	1	0.2	2	0.0004	0.03
Barium	µg/L	1	0.05	0.2	0.1	5	0.05	0.05
Beryllium	µg/L	2	0.2	1	0.1	10	0.2	0.2
Bismuth	µg/L	0.4	0.03	0.05	0.1	50	0.03	0.03
Boron	µg/L	50	1	4	-	-	1	1
Cadmium	µg/L	0.3	0.02	0.2	0.1	2	0.05	0.05
Cesium	µg/L	0.4	0.1	50	0.1	2	0.1	0.1
Chromium	µg/L	3	0.06	0.8	2	15	0.06	0.06
Chromium (Hexavalent)	µg/L	-	0.005	0.005	-	-	-	-
Chromium (Trivalent)	µg/L	-	0.005	0.005	-	-	-	-
Cobalt	µg/L	1	0.1	0.2	0.1	5	0.1	0.1
Copper	µg/L	2	0.6	1	0.1	10	0.6	0.6
Iron	µg/L	30	5	0.02	-	30	5	5
Lead	µg/L	1	0.05	0.1	0.2	5	0.05	0.05
Lithium	µg/L	3	0.1	6	0.1	15	0.1	0.1
Manganese	µg/L	1	0.1	0.2	0.1	5	0.1	0.1
Mercury	µg/L	0.01	0.02	0.2	0.01	0.01	0.02	0.02
Molybdenum	µg/L	1	0.06	0.1	0.1	5	0.06	0.06
Nickel	µg/L	1	0.06	0.2	0.1	5	0.06	0.06
Rubidium	µg/L	0.5	1	50	-	2.5	1	1
Selenium	µg/L	10	0.1	0.8	0.4	10	0.1	0.1
Silver	µg/L	0.3	0.1	0.4	0.1	2	0.1	0.1
Strontium	µg/L	1	0.1	0.2	0.1	5	0.1	0.1
Thallium	µg/L	0.4	0.03	0.05	-	2	0.03	0.03
Titanium	µg/L	3	0.1	0.3	0.2	15	0.1	0.1

Table IX.5-1
Published Detection Limits from EnviroTest Laboratories and Taiga Environmental Laboratory for Water Sample Analysis (Continued)

		Standard Published			Reported[a]			
		Taiga[b]	ETL©		Taiga		ETL	
Parameter	**Units**		**UL[d]**	**LL[e]**	**min**	**max[f]**	**min – UL**	**max – UL**
Uranium	µg/L	0.3	0.05	0.1	0.1	2	0.05	0.05
Vanadium	µg/L	1	0.05	0.2	0.1	5	0.05	1
Zinc	µg/L	10	0.8	4	10	50	0.8	0.8
Dissolved Metals								
Aluminum	µg/L	30	0.3	10	30	30	0.3	0.3
Antimony	µg/L	0.1	0.03	0.8	-	0.1	0.03	0.03
Arsenic	µg/L	0.2	0.03	0.4	0.2	2	0.0004	0.03
Barium	µg/L	0.1	0.05	0.1	-	0.1	0.05	0.05
Beryllium	µg/L	0.2	0.2	0.5	0.1	0.2	0.2	0.2
Bismuth	µg/L	0.1	0.03	0.05	0.1	10	0.03	0.03
Boron	µg/L	50	1	2	-	-	1	1
Cadmium	µg/L	0.1	0.05	0.1	0.1	0.1	0.05	0.05
Cesium	µg/L	0.1	0.1	0.1	-	0.4	0.1	0.1
Chromium	µg/L	0.3	0.06	0.4	-	2	0.06	0.06
Cobalt	µg/L	0.1	0.1	0.1	-	0.1	0.1	0.1
Copper	µg/L	0.2	0.6	0.6	-	0.2	0.6	0.6
Iron	µg/L	30	10	10	-	30	0.005	5
Lead	µg/L	0.1	0.05	0.01	-	0.2	0.05	0.05
Lithium	µg/L	0.3	0.1	3	-	0.3	0.1	0.1
Manganese	µg/L	0.1	0.1	0.1	-	1	0.1	0.1
Mercury	µg/L	0.01	0.02	0.1	0.01	0.01	0.02	0.02
Molybdenum	µg/L	0.1	0.06	0.1	-	0.1	0.06	0.06
Nickel	µg/L	0.1	0.06	0.1	-	0.1	0.06	0.06
Rubidium	µg/L	0.1	1	50	-	0.5	1	1
Selenium	µg/L	1	0.1	0.4	0.4	10	0.1	0.1
Silver	µg/L	0.1	0.1	0.2	-	0.3	0.1	0.1
Strontium	µg/L	0.1	0.1	0.1	-	1	0.1	0.1
Thallium	µg/L	0.1	0.03	0.05	-	0.1	0.03	0.03
Titanium	µg/L	0.3	0.1	0.3	-	0.3	0.1	0.1
Uranium	µg/L	0.1	0.05	0.1	-	0.1	0.05	0.05
Vanadium	µg/L	0.1	0.05	0.1	-	0.1	0.05	1
Zinc	µg/L	10	0.8	2	10	10	0.8	0.8

Table IX.5-1
Published Detection Limits from EnviroTest Laboratories and Taiga Environmental Laboratory for Water Sample Analysis (Continued)

		Standard Published			Reported[a]			
		Taiga[b]	ETL[c]		Taiga		ETL	
Parameter	**Units**		**UL[d]**	**LL[e]**	**min**	**max[f]**	**min - UL**	**max - UL**
Biological Parameters								
Fecal Coliform	CFU/100 mL	1	1	1	1	100	1	1
Total Coliform	CFU/100 mL	1	1	1	1	10	1	1
Organics								
Oil and Grease	mg/L	0.2	0.2	1	-	0.2	1	3

Notes (a) Range of reported detection limits from the analytical laboratory. These detection limits may differ from published values.

(b) Taiga Environmental Laboratory.

(c) Enviro-Test Laboratories.

(d) Ultra-low level method (UL).

(e) Low level method (LL).

(f) Maximum values reflect high concentrations of suspended sediments.

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

Table IX.5-2
Published Detection Limits from Enviro-Test Laboratories and Taiga Environmental Laboratory for Sediment Sample Analysis

Parameter	Units	Standard Published		Reported			
		Taiga[a]	ETL[b]	Taiga		ETL	
				min	max	min	max
Clay	%	0.01	0.1	0.01	0.01	-	-
Silt	%	0.01	0.1	0.01	0.01	-	-
Sand	%	0.01	0.1	0.01	0.01	-	-
Moisture Content	%	0.01	0.1	-	-	0.1	0.1
Total Inorganic Carbon	%	-	-	-	-	-	-
Total Organic Carbon	%	-	-	-	-	0.1	0.1
Total Metals							
Aluminum	wt%	-	-	0.006	0.75	-	-
Aluminum	µg/g	30	1	-	-	1	10
Antimony	µg/g	0.1	0.4	0.2	25	0.04	5
Arsenic	µg/g	0.1	0.2	0.1	0.4	0.1	0.5
Barium	µg/g	0.1	0.08	0.2	25	0.08	0.5
Beryllium	µg/g	0.2	0.2	0.4	50	0.2	1
Bismuth	µg/g	0.1	0.1	0.2	1250	0.003	0.1
Cadmium	µg/g	0.1	0.08	0.2	25	0.08	0.5
Cesium	µg/g	0.1	-	0.2	25	0.05	10
Chromium	µg/g	0.3	0.2	0.6	75	0.2	0.5
Cobalt	µg/g	0.1	0.08	0.2	25	0.08	1
Copper	µg/g	0.2	0.08	0.4	50	0.08	1
Iron	wt. %	-	-	0.006	0.06	-	-
Iron	µg/g	30	2	-	-	2	100
Lead	µg/g	0.1	0.04	0.2	25	0.04	5
Lithium	µg/g	0.3	-	0.6	75	0.5	20
Manganese	µg/g	0.1	0.04	0.2	25	0.02	0.02
Mercury	µg/g	0.2	-	0.01	0.01	0.01	0.2
Molybdenum	µg/g	0.1	0.04	0.2	25	0.04	1
Nickel	µg/g	0.1	0.08	0.2	25	0.08	2
Rubidium	µg/g	0.1	-	0.2	25	0.05	5
Selenium	µg/g	1	0.2	2	250	0.1	0.2
Silver	µg/g	0.2	0.08	0.2	25	0.08	1
Strontium	µg/g	0.1	0.04	0.2	25	0.04	1
Thallium	µg/g	0.1	0.04	0.2	25	0.04	1
Titanium	µg/g	0.3	0.05	0.2	75	0.05	5
Uranium	µg/g	0.1	0.1	0.2	25	0.04	0.1
Vanadium	µg/g	0.1	0.08	0.2	25	0.08	1
Zinc	µg/g	1	0.2	1	2500	0.2	0.5

Notes: (a) range of reported detection limits from the analytical laboratory. These detection limits may differ from published values.

(b) Taiga Environmental Laboratory.

(c) Enviro-Test Laboratories.

% = percent; µg/g = microgram per gram; wt% = percent weight.

2.2 Statistical Analysis of Results Reported at a Detection Limit

A result reported at the detection limit is difficult to analyze because it is not a numerical field (*i.e.*, it is a symbol [<] and a numeric). A result reported at the detection limit must be replaced with numeric values before statistics, such as minimums, maximums, and medians can be developed. This section describes the methods used to replace results that were reported at the detection limit, in the baseline aquatic data, with numeric values that could be analyzed statistically. The other sections of the EA report calculations of statistical data individually as is relevant to each discipline.

A visual basic computer program, designed to calculate medians, minimums, maximums, and sample numbers based on the specific dataset, was used to analyze the baseline aquatic data (Section 9.4.1) and to assist with the handling of results reported at the detection limit. The program handles each of the following four scenarios:

- non-detects (NDs) = -MDL;
- NDs = MDL;
- NDs are eliminated form the dataset; and,
- all detectable results are eliminated from the dataset and NDs = -MDL.

The results of this exercise were tabulated, as shown on Table IX.5-3. Using the selection criteria detailed below, single values were chosen from the tabulated results to represent sample medians, minimums, maximums and numbers.

Table IX.5-3
General Representation of the Result Matrix Produced from the Four Different Non-detect Replacement Methods used in this Assessment

Statistic	Dataset Contains			
	NDs = -MDL	no NDs	NDs = MDL	only NDs (NDs = -MDL)
Median	a	b	c	d
Minimum	e	f	g	h
Maximum	I	j	k	l
Sample number	m	n	o	p

Notes: ND = non-detects; MDL = method detection limit; -MDL = negative of the method detection limit.

1.1.1.1.1.1 Selection Criteria

The following logic trees were used to select representative median, maximum, minimum, and sample number values from the sample matrix shown in Table IX.5-3. Each logic tree is written here with reference to the letters listed in Table IX.5-3.

2.2.1 Median

If **p** = 0, then the median = **a**, **b** or **c** (since **a** = **b** = **c**)
If **n** = 0, then the median = **a**, **-c**, or **d** (since **a** = **-c** = **d**)
If **m** is odd, then
if **p** > **n**, then the median = **-c** [(a)]
if **p** < **n**, then the median = **c**

If m is even, then
if **p** = **n**, then the median = **c**
if **p** > **n**, then the median = **-c**[(a)]
if **p** < **n**, then the median = **c**

(a)using the inverse of **c** to indicate that the majority of the existing data were NDs

2.2.2 Minimum

If **p** = 0, then the minimum = **e**, **f** or **g** (since **e** = **f** = **g**)
If **n** = 0, then the minimum = **-g**
If **-h** > **f**, then the minimum = **f**
If **-h** < **f**, then the minimum = **h**

This logic tree was constructed on the assumption that when NDs = -MDL, the minimum value is equal to the number closest to zero. For example, the minimum value for the dataset -0.1, -1, -0.2, -0.3 is -0.1.

2.2.3 Maximum

Maximum = **i**

This assumes that the maximum value is equal to the largest number in the dataset while maintaining true to its origin. For example, the maximum value for the dataset <1, 0.3, 0.8, <0.2 is <1.

2.2.4 Sample Number

Sample number = **m** or **o** (since **m** = **o**).

3.0 ACID DEPOSITION

3.1 Background

To protect lakes from the effects of acid deposition, scientists have calculated the critical loads (CL) of acidity (RMCC 1990; Henriksen *et al.* 1992; Kämäri *et al.* 1992a, b; Posch *et al.* 1992; Rihm 1995; CASA 1996 WHO 1994). The CL can be defined in general terms as "a quantitative estimate of an exposure to one or more pollutants below which significant harmful effects on specified sensitive elements of the environment do not occur according to present knowledge" (Nilsson and Grennfelt 1988). For this assessment, the CL represents an estimate of the amount of acidic deposition below which significant adverse changes are not expected to occur in a lake ecosystem.

The calculation of CL is based on a dose-response relationship between the acid neutralization capacity (ANC) and an aquatic organism considered important to the ecosystem. ANC is used, rather than pH, because pH measurements are sensitive to carbon dioxide (CO_2) effects (Stumm and Morgan 1981; Sullivan 2000). Changes in dissolved CO_2 concentration can cause considerable variation in measured pH, even within a single day. Such variation is not relevant to acidification, but may mask subtle changes in ANC. A number of studies have shown that the effects of acidification on aquatic organisms are better correlated with ANC than with pH (as reviewed by Sullivan 2000).

In this assessment, the basis for identifying impacts due to acidic deposition was a lake-specific CL. A CL was calculated for each lake selected for the impact analysis and the potential for acidification was evaluated by comparing the CLs with the corresponding modelled potential acid input (PAI) value (provided by the air quality component) for each lake. Thus, the CL served as a lake-specific "guideline" in these comparisons. Comparisons were made for each case considered in the impact assessment (*i.e.*, baseline, application and cumulative effects assessment [CEA] cases). The PAI represents an estimate of acid deposition from all sources; it is the total deposition of sulphur and nitrogen species in both wet and dry forms, minus base cations.

The lakes selected for impact analysis included nine lakes in the Snap Lake Watershed and 39 lakes in the Lockhart watershed. These lakes were selected based on distance from the Snap Lake Diamond Project and the availability of water chemistry data.

3.2 Calculation of Critical Loads

Critical loading levels for acidity were calculated for lakes in the Snap Lake regional study area (RSA) using the Henriksen steady-state model (Henriksen *et al.* 1992; Forsius 1992; Rhim 1995). In the Henriksen model, the critical load for a lake is calculated as:

$$CL = ([BC]^*_0 - [ANC_{lim}]) \times Q - BC^*_d$$

where,

CL = critical load (kiloequivalents per hectare per year [keq/ha/yr]);

$[BC]^*_0$ = pre-industrial non-marine base cation concentration (kiloequivalents per litre [keq/L]), assumed to correspond to the current values in NWT lakes, because they are considered unaffected by acidification at the present;

$[ANC_{lim}]$ = critical value for acid neutralizing capacity for brown trout, a European species (20 microequivalents per litre [µeq/L]);

Q = mean annual runoff to lake (litres per hectare per year [L/ha/yr]); and

BC^*_d = the non-marine base cation deposition (keq/ha/yr).

Predicted PAI values have already been corrected for base cations and, therefore, the last term in the equation (BC^*_d) is not required in this assessment.

3.3 Assumptions and Data Sources for Critical Load Calculations

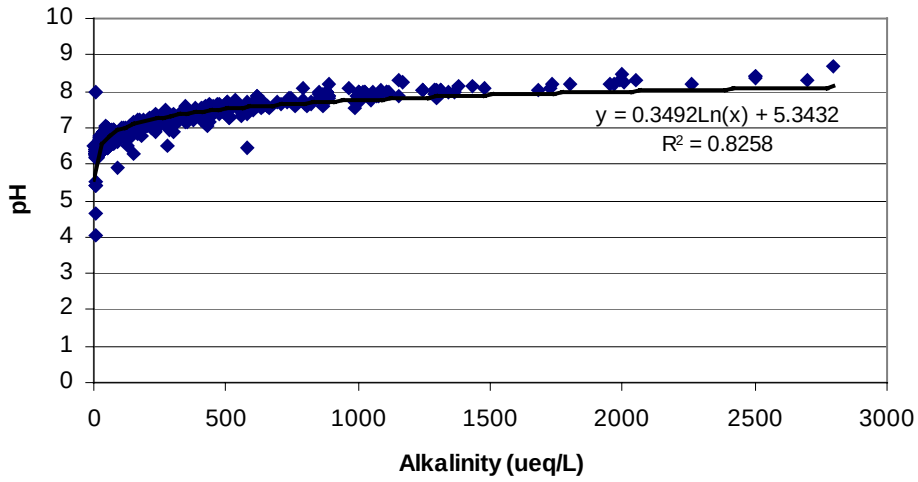
3.3.1.1 Critical Value for Acid Neutalizing Capacity

The calculation of CL is based on a dose-response relationship between the acid neutralization capacity (ANC) and an aquatic organism considered important to the ecosystem. In the Henriksen model, the critical threshold ANC ($ANC_{lim)}$ is set to protect brown trout, the most common European salmonid, from toxic acidic episodes during the year. The ANC_{lim} was derived from water chemistry, critical load exceedances and fish population status data from 1000 Norwegian lakes (Henriksen *et al.* 1988; Lien *et al.* 1992). A value of 20 µeq/L was deemed the most appropriate value for the Norwegian lakes and most Scandinavian countries (Henriksen *et al.* 1992) have adopted this value. However, ANC_{lim} values have been set at 0 and 50 µeq/L in various applications (*e.g.*, Kämäri *et al* 1992c; Harriman *et al.* 1995).

Brown trout is a European species that was introduced to North America, and as such, may not be the most appropriate species for calculating CLs outside Europe. In North America, there has not been a large-scale investigation (of critical loads and appropriate ANC_{lim} values) comparable to that done in Norway. However, to estimate ANC_{lim} for the Oil Sands Region in northern Alberta, Western Resource Solutions (WRS) (2000) suggested the use of a pH effects threshold, which is then converted to ANC. Numerous studies have shown that a pH of 6 is sufficient to maintain a healthy aquatic ecosystem and to protect fish and other aquatic organisms (based on reviews by RMCC 1990; Environment Canada 1997; Jeffries and Lam 1993; Sullivan 2000). To convert this value to an estimated ANC for the Lockhart Watershed, a numerical relationship between pH and ANC was developed using the results of a water quality survey (Puznicki 1996) of over 500 lakes in the Slave Geological Province. Lakes outside the Lockhart Watershed were included in this dataset to incorporate a wider range of pH and alkalinity values.

ANC of surface waters with low dissolved organic concentrations is determined primarily by differences between base cations (Ca^{2+}, Mg^{2+}, K^{+}, Na^{+}) and mineral acid anions. Generally, in waters with low dissolved organic carbon (DOC) concentrations, alkalinity is a good approximation of ANC (WRS 2000). In waters with high DOC concentrations, alkalinity may underestimate ANC, as organic anions can contribute to the ANC. For this analysis, lakes with tea-stained, highly coloured water (>15 true colour units [TCU]) were omitted as this coloration resulted from contact with humic or peaty materials (*i.e.*, high DOC) (Puznicki 1996). Therefore, in the remaining lakes, alkalinity concentrations were used to estimate ANC and regression analysis showed that for the lakes in the Slave Geological Province, a pH of 6.0 corresponds to an ANC (alkalinity) of about 6.7 µeq/L (Figure IX.5-1). Therefore, the adoption of an ANC_{lim} value of 20 µeq/L in this evaluation of acidification in the Lockhart and Snap Lake watersheds should ensure a conservative assessment of impacts.

Figure IX-5.1
Lake pH Versus Alkalinity for Lakes with Colour ≤ 15 Total Colour Units in the Slave Geological Province



Data source: Puznicki (1996).

Critical loads calculated in Europe (Finland, UK) have been based on a range of ANC_{lim} values (0, 20 and 50 µeq/L) (Kamari *et al.* 1992; Harriman *et al.* 1995). These values were intended to protect salmonid fisheries (Harriman *et al.* 1995), or correspond to the ANC where significant changes are expected to occur in the lake diatom flora (Jenkins *et al.* 1997). The ANC_{lim} value used in this assessment is anticipated to result in CLs that are protective of lake ecosystems in general.

3.3.1.2 Runoff

The runoff (Q) for each lake was calculated from based on watershed areas and regional water yield coefficients.

3.3.1.3 Base Cation Concentration

Base cation concentrations ($[BC]^*_0$) were calculated for lakes in the Snap Lake area (using EA baseline data) and the Lockhart River watershed (using INAC data) to represent the baseline base cation concentrations.

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5.0 UNITS AND ACRONYMS

UNITS

%	percent
µeq/L	microequivalents per litre
µg/g	micrograms per gram
µg/L	micrograms per litre
µS/cm	micro Seimens per centimetre
CFU/100mL	colony forming unit per 100 millilitres
keq/ha/yr	kiloequivalents per hectare per year
keq/L	kiloequivalents per litre
L	litres
L/ha/yr	litres per hectare per year
m	metres
mg/L	milligram per litre
NTU	nephelometric turbidity unit
TCU	true colour unit
Wt.%	percent weight

ACRONYMS

$[BC]^*_0$	pre-industrial non-marine base cation concentration
AEP	advanced exploration program
ANC	acid neutralizing capacity
ANC_{lim}	critical value for acid neutralizing capacity
AS	additional station
BC^*_d	the non-marine base cation deposition

CEA	cumulative effects assessment
CL	critical loads
CO_2	carbon dioxide
DOC	dissolved organic carbon
EA	environmental assessment
INAC	Indian and Northern Affairs Canada
MDL	method detection limit
ND	non-detect
NWT	Northwest Territories
PAI	potential acid input
Q	runoff
QA/QC	quality assurance and quality control
RSA	regional study area
SH	shallow habitat
SHR	shallow habitat reference
TP	technical procedure
UL	ultra-low metal analysis
WMP	water management pond
WQ	water quality
WQR	water quality reference
WRS	Western Resource Solutions

APPENDIX A

GOLDER ASSOCIATES' TECHNICAL PROCEDURES TP-8.3-1
SURFACE WATER SAMPLING METHODS

1 PURPOSE

This document describes the sampling protocols used by Golder Associates to collect surface water samples. It contains sampling instructions and information concerning appropriate containers, preservation and handling of water quality samples.

2 APPLICABILITY

This technical procedure is applicable to any persons involved in the collection of surface water samples. It is applicable to all geographic areas.

3 DEFINITIONS

3.1 Analytical Request Form

Standard form provided by analytical laboratories. This form is filled out by the person collecting samples and is used to indicate how each sample is to be analyzed. This form is often combined with the Chain-of-Custody Form in a single document.

3.2 Chain-of-Custody Form

Standard form used to track the movement of sample containers from the time they leave the field until they arrive at the specified laboratory. The Chain-of-Custody form provides a clear record of sample transport and handling, thereby reducing the risk of sample loss during transport. This form may be combined with the Analytical Request Form in a single document.

3.3 Chemical Analysis

Analytical procedure used to measure the *amount* of a certain compound, or group of compounds, present in a sample.

3.4 Preservatives

Preservatives are used to maintain sample integrity from the time a sample is collected until it is analyzed. Sample preservation may involve adding acid or other fixatives to collected waters or simply keeping them refrigerated. Sample-specific requirements are outlined in this document (Table 1); preservatives, when required, are provided by the analytical laboratory.

3.5 Quality Assurance/Quality Control (QA/QC)

Quality Assurance refers to a detailed protocol used to produce high quality products, while Quality Control refers to the process by which this protocol is tested to ensure that final products are of the

specified quality. With reference to water sampling, QA protocol includes the use trained personnel, proper sampling methods, clean containers and equipment, proper sample preservation and transportation and detailed documentation of the entire process; field, travel and other assorted test blanks are used for Quality Control testing.

3.6 Sample Types

3.6.1 Grab Samples

Sample containing water collected during a single sampling event (i.e., water taken from a given place at a given time).

3.6.2 Composite Samples

Sample containing a mixture of water collected from multiple locations or from different times at the same location.

3.6.3 Equipment Blanks

Equipment blanks are used to detect contamination from sampling equipment. They are prepared by rinsing precleaned equipment with laboratory-provided deionized water and collecting the rinsate into an appropriate container.

3.6.4 Field Blanks

Field blanks are used to detect contamination during sample collection and transport. They are prepared during a sampling event by filling the appropriate container with laboratory-provided deionized water. Field blanks are usually used in situations where there is reason to suspect that contamination will occur during sample collection and transport.

3.6.5 Travel (Trip) Blanks

Travel blanks detect sample contamination during transport. Travel blanks consist of pre-filled bottles provided by the analytical lab. They accompany empty sample bottles to the field site, where they are left intact and unopened inside the shipping cooler. The unopened travel blanks are then returned to the analytical lab to be analyzed along with collected samples.

3.6.6 Field Spikes

Field spikes are used to measure the performance of the complete analytical system, including sample handling, preservation and storage, as well as interference from the sample matrix. To generate a field spike, field personnel fill the usual sampling container with sample, leaving a small amount of space at

the top. They then add a specified amount of the chemical or compound of interest to the bottle and submit it with the rest of the samples. In general, field spikes are not recommended due to the logistical difficulties of transporting concentrated solutions in the field. If there is reason to doubt the performance of the sampling system, then a separate study involving field spikes should be carried out.

3.6.7 Standard Reference Samples

Standard reference samples, or blind QA samples, are samples of known concentration that are submitted to the analytical lab as a normal sample. The lab is not informed about the identity of the sample until after all analyses are complete.

3.6.8 Replicate Samples

Replicate samples are used to evaluate within-site and analytical variation. Replicate samples are collected by filling multiple containers at a single site. They are labelled and preserved individually and are submitted separately to the analytical laboratory.

3.6.9 Split Samples

Split samples are used to check analytical variation. A single sample (e.g. grab) is collected and is split into two sample containers. These are labelled and preserved individually and are submitted separately to the analytical laboratory or to two different laboratories.

3.7 Specific Work Instructions (SWI)

Detailed instructions in a standardized format provided to field personnel. The SWI describe all aspects of the work to be conducted, including personnel allocation, procedures to be used, time allocation and any additional information deemed necessary by the project or task manager.

3.8 Toxicity Analysis

Analytical procedure specifically designed to examine how the health of living organisms may be affected by exposure to a given substance or sample. Toxicity tests can be based on either: acute exposures (short-term exposures lasting only a small portion of the animals life cycle, e.g. 96 hours for rainbow trout); or, chronic exposures (longer-term exposures meant to represent a significant portion of the animal's life cycle, or a particularly sensitive portion of the animal's life cycle, e.g. 28 days for *Daphnia magna*). Responses measured in toxicity tests can be lethal (e.g. mortality), or sublethal (e.g., reduced growth or reproduction). Unlike other procedures, toxicity testing evaluates the sample as a whole, rather than describing its chemical make-up.

4 REFERENCES AND SUGGESTED READING

4.1 Sampling Methodology

Environment Canada. 1993. Quality Assurance in Water Quality Monitoring. Ecosystem Sciences and Evaluation Directorate Conservation and Protection. Ottawa, Ontario, Canada.

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5 DISCUSSION

5.1 General Safety

Refer to Golder Associates Ltd. Health and Safety Manual.

5.2 Sampling Procedures

Samples are collected as representative pieces of a larger puzzle. Ideally, they should describe all of the characteristics of the larger body from which they originate, which, by its very definition, is too large to analyze directly. As a result, it is very important to follow a well-organized sampling plan and to preserve sample integrity throughout the collection and transportation process.

5.2.1 General Practices

Usually, analytical laboratories will provide pre-cleaned sample containers, shipping containers, required forms for sample submission and specific sample shipping instructions. It is important to check with the lab that these arrangements have been made. Similarly, field crews should familiarize themselves with the SWI before initiating a sampling program. By reviewing the instructions, personnel can ensure that they have all of the equipment they require to fulfill the objectives of the sampling program. Field crews will also then be aware of the types of samples they are being asked to collect, be they grab samples, composite samples or QA/QC test blanks. Finally, sample crews should organize themselves such that samples will be collected and shipped during the early part of the work week (Monday to Wednesday) to help avoid delays caused by weekend shipping.

Sampling Locations

General sampling locations are described in the SWI. However, field crews will have a certain degree of freedom in choosing the exact locations from which to take the samples. When selecting these sites, personnel should consider the layout of the local environment, project objectives and personal safety. They should then choose areas that are both easily accessible and representative of the target waterbody or waterbodies.

Once sampling sites have been identified, they must be accurately described relative to permanent landmarks, such as groundwater wells, outfalls or distinctive landscape features; measuring the distance from permanent landmarks to each site with an appropriate compass heading is recommended. Ideally, one should try to use the Global Positioning System (GPS), but locations can also be recorded as the perpendicular distance from the shoreline and the distance upstream or downstream of a permanent landmark.

Sample Collection

- Start sampling at the least contaminated site (i.e., the reference site) and move from there to the more contaminated areas.

- If sampling equipment must be used, then it must be cleaned before and after use. This may involve rinsing with ambient water, cleaning with soap and water, acid washing, rinsing with organic solvents or pure water, or a combination of these. Refer to the SWI for details.

- Each sample bottle must be labelled at the time of collection with either waterproof, permanent marker or using pre-printed waterproof labels. See section 5.3.2 for details of label format.

- When sampling, it is important to rinse sample containers 3 times before actually taking a sample. Rinse each bottle by partially filling it with ambient water, loosely attaching the cap and shaking the bottle; drain the water and repeat the process. As a general rule, rinse plastic bottles unless instructed otherwise by the analytical laboratory. Bottles that already contain the preservatives and containers for the following analyses should *not* be rinsed prior to taking the sample:
  - volatile organic compounds (VOCs), including total volatile hydrocarbons (TVH), total extractable hydrocarbons (TEH), BTEX (benzene, toluene, ethylbenzene and xylene) and total petroleum hydrocarbons (TPH; includes TVH, TEH and BTEX); and
  - bacteriological testing (e.g., fecal coliforms).

- Carefully fill sample containers, without splashing, leaving only enough space for preservatives (if required - see Table 1). Be sure to keep hands and fingers downstream of bottle opening and sample upstream of bridges, boats and yourself to prevent sample contamination. If no preservatives need to be added, completely fill the bottles and cap tightly. There should be as little air in the containers as possible, as it can affect sample integrity.

- Whenever possible, fill sample containers directly from the source, without using an intermediate container to transfer the sample. This avoids potential sample contamination due to carry-over from one sample to the next. Also, take care to avoid contaminating sample waters through contact with rubber, oil, gasoline and other machinery fluids, metal-based paints, cigarette ash, paper tissues and other such material.

- Sample bottles should then be stored appropriately (Table 1). In most cases, this will involve keeping the sample cool ($4^{o}C$) and dark. Samples should never be allowed to freeze and should be shipped as soon as possible to the appropriate analytical lab, in coolers with reusable ice packs. If possible, avoid using bags of ice purchased from convenience stores; the water that leaks out of these bags as the ice melts may ruin sample labels.

- Chain-of-Custody and Analytical Request forms must accompany all samples (one set of forms per sample shipment). Prior to shipping, the person submitting the sample should inform the analytical lab by telephone or fax that the samples will be arriving. As well, he or she should check back later to confirm arrival of the samples and to explain analysis requests if needed.

5.2.2 Sampling for Metals

When collecting samples for a metals analysis, it is important that sample waters do not come into contact with any metal products. Samples for metals analysis also have other stringent collection and preservation requirements (Table 1). For example, waters collected for dissolved metal analysis have to be field-filtered using a 0.45 µm polycarbonate or cellulose acetate filter and then preserved with acid. Field crews need to be aware of these restrictions to ensure that samples are taken correctly and that they maintain their integrity until they can be analyzed. Special sampling and preservation instructions should be included in the SWI.

5.2.3 Sampling for Organic Chemicals

In addition to the general principles outlined above, there are specific protocols associated with sampling for organic measurements. As described above, sample bottles should *not* be rinsed prior to taking samples for certain organics analyses. It is also very important to completely fill each bottle, as certain organics will volatilize into the overlying air space and will be lost after opening the bottle. Finally, proper containers must be used when sampling for organics, since some bottles will release or absorb organic compounds when filled with water. Generally, glass containers are used, but certain tests may require other materials; be sure to obtain the appropriate sample bottles from the analytical laboratory and refer to the SWI.

5.3 Sample Documentation

The importance of proper sample documentation cannot be overemphasized. Lack of careful documentation can lead to misunderstandings and questionable test results. Components of proper documentation of field activities are described below.

5.3.1 Field Notebooks

Field notebooks must be kept, describing all field activities. Format of field notes and information to be recorded should follow Golder Associates' specific guidelines. During the field survey, field notes must be maintained in a permanent, safe location at the field site where samples are collected. If possible, new entries in the field note book should be photocopied at the end of each field day and copies should be stored in a safe place.

5.3.2 Sample Labels

Sample labels must contain the following information:

- Sample identifier (name of site or sample code);
- Date (written as day/month/year; month abbreviated as three letters) and time (24 hour clock) of collection;
- Initials of collector; and
- Analysis requested (this is usually done by the analytical laboratory in the form of a code on the sample bottle).

Fill out labels at the time of collection using waterproof ink and affix a label to each sample container. Plastic bottles may be labelled by writing directly on the bottle using a waterproof marker; however, this approach is not recommended if samples are transported over long distances (friction may rub label off) or if bags of ice are used to keep the samples cool (water may damage label information).

5.3.3 Custody Seals

If required for a project, numbered seals should be used to detect unauthorized tampering with samples in transit. Attach the seal in a way that it is necessary to break it to open the cooler containing the samples. The number on the custody seal should be recorded in the field note book and on the Chain-of-Custody and Analytical Request forms.

5.3.4 Chain-of-Custody Forms and Analytical Request Forms

Chain-of-Custody and Analytical Request forms must accompany all samples submitted for analysis. These forms are usually combined as a single document. An example of Golder Associates' combined Chain-of-Custody and Analytical Request Form is provided in Appendix 1.

The combined form must be filled out completely and the white and yellow copies should be sent along with the samples being submitted. Field personnel should retain the pink copy after it is signed by the shipper. Depending on the shipping container, these forms can either be enclosed inside the sealed container or attached firmly to the outside of the container. In either case, it is advisable to enclose the forms within a waterproof plastic bag to guard against damage. It is important that each person having custody or control of the samples identify themselves on this form. This means that the person collecting the sample, any intermediate persons involved in packaging, storing or transporting the sample and the person accepting the sample on behalf of the analytical lab must all be identified.

5.4 Sample QA/QC

The main goal of sample QA/QC is to monitor for various sources of contamination during sample collection, transport and analysis. This process will involve the use of field, travel and other test blanks. QA/QC programs are designed on a project-specific basis. Details of individual QA/QC programs are described in the SWI.

6 EQUIPMENT AND MATERIALS

6.1 Sampling

The following is a list of sampling equipment generally recommended for surface water sampling:

- Pre-cleaned sample bottles and required preservatives (usually supplied by the analytical laboratory)
- Coolers and reusable ice packs
- Waterproof labels and permanent markers
- Sampling equipment (e.g. Kemmerer or Van Dorn bottles)

6.2 Site Location and Sample Documentation

For proper sample site identification and sample documentation, field crews may need:

- Bound, water-proof field logbooks
- Maps
- Air photos
- Indelible ink pens and pencils
- Long tape measure
- Survey flagging tape
- Compass
- GPS unit
- Combined Analytical Request and Chain-of-Custody forms

6.3 Health and Safety

The following health and safety equipment is recommended for surface water sampling:

- Waders and waterproof gloves
- Heavy socks, warm pants, rain gear and other articles of clothing suitable for prolonged water work
- Extra set of clothes
- First aid kit
- Approved personal floatation device for deep water or boat work

TABLE 1

SUMMARY OF SAMPLE COLLECTION, PRESERVATION AND STORAGE REQUIREMENTS

PARAMETER	BOTTLE TYPE	ETL[1] LABEL	SAMPLE PRESERVATION	PRESERVATIVE CODE (ETL)[1]	HOLDING TIME	COMMENTS
Conventional Chemistry						
pH to TDS + DOC	500 mL plastic	"routine"	in the dark at 4°C	-	**48 hrs.**	Note short holding time
TOC	100 mL amber glass	unlabelled	1 mL H_2SO_4	Fluorescent Red	5 days	Do not triple rinse
Major Ions						
Calcium to Sulphate	in "routine" bottle	n/a	-	-	-	
Sulphide	100 mL plastic	"Sulphide"	1 mL NaOH+ 2 mL zinc acetate	Orange	5 days	
Nutrients						
Ammonia, TKN & Total P	500 mL plastic	"nutrients"	2 mL H_2SO_4	Purple	10 days	Indicate on label that sample is preserved
Nitrate + Nitrite & Dissolved P	in "routine" bottle	n/a	-	-	-	
Bacterial						
Biochemical Oxygen Demand	1 L plastic	unlabelled	in the dark at 4°C	-	**48 hrs.**	Note short holding time
Coliforms	300 mL sterilized glass	unlabelled	in the dark at 4°C	-	**48 hrs.**	Note short holding time
Toxicity						
Daphnia magna 48 h. Static Acute	1 L clear glass / plastic	unlabelled	in the dark at 4°C	-	5 days	
Rainbow trout 24 and 96h Static Acute	20 L collapsible carboy	unlabelled	in the dark at 4°C	-	5 days	
Algal Growth 72h Inhibition/Stimulation	1 L clear glass / plastic	unlabelled	in the dark at 4°C	-	3 days	
Ceriodaphnia dubia 7d Growth and Reproduction	20 L collapsible carboy	unlabelled	in the dark at 4°C	-	3 days	
Fathead Minnow 7d Survival/Growth	20 L collapsible carboy	unlabelled	in the dark at 4°C	-	3 days	
Bacterial Luminescence (Microtox IC50 and IC20)	1 L clear glass	unlabelled	in the dark at 4°C	-	48 hrs.	Note short holding time
Other						
Total Recoverable Hydrocarbons	1 L amber glass	"oil & grease"	2 mL H_2SO_4	Purple	5 days	Do not triple rinse
Naphthenic acids	1 L amber glass	unlabelled	0.5g ascorbic acid + 2 NaOH pellets		10 days	Do not triple rinse; preservative in bottle
Total Phenolics	100 mL amber glass	unlabelled	1 mL H_2SO_4	Fluorescent Red	**24 hrs.**	Note short holding time Do not triple rinse
Chlorophyll *a*	500 mL plastic	"nutrient"	in the dark at 4°C	-	**48 hrs.**	Note short holding time Indicate on label that sample is unpreserved
Total Metals						
Aluminum to Zinc + Sb, As & Se	500 mL plastic	"metals"	2 mL NO_3	Blue	6 months	
Mercury (Hg)	250 mL plastic	"mercury"	2 mL NO_3 + dichromate	Yellow	30 days	
Dissolved metals						
Aluminum to Zinc + Sb, As & Se	500 mL plastic	"metals"	filter, 2 mL NO_3	Blue	6 months	See dissolved metals sampling protocol
Mercury (Hg)	250 mL plastic	"mercury"	filter, 2 mL NO3 + dichromate	Yellow	30 days	See dissolved metals sampling protocol
PAHs						
Naphthalene....	2 L clear glass	unlabelled	in the dark at 4°C	-	14 days	Bottle may be 4 L Do not triple rinse
Phenolics						
Phenol....	in PAH bottle	unlabelled	-	-	-	
Volatile Organics						
Acetone...	40 mL amber glass	unlabelled	Na2S2O3, 2 crystals, dark, 4°C	-	14 days	Do not triple rinse; preservative in bottle

NOTE: 1ETL = Enviro-Test Laboratories

APPENDIX 1

GOLDER ASSOCIATES' COMBINED CHAIN-OF-CUSTODY

AND ANALYTICAL REQUEST FORM

GOLDER ASSOCIATES LTD.
CHAIN-OF-CUSTODY RECORD
AND ANALYTICAL REQUEST FORM

Page ____ of ____

Field Sampler: (Signature) _____

Phone No.: _____

Shipment Date: _____

Carrier: _____

Waybill No.: _____

Ship To:

Send Results To:

Project Name: _____

Project No: _____

P.O. No.: _____

Relinquished by: (Signature)	Received by: (Signature)	Date:	Time:
Relinquished by: (Signature)	Received at lab by: (Signature)	Date:	Time:
Relinquished by: (Signature)	Received at lab by: (Signature)	Date:	Time:
Relinquished from lab by: (Signature)	Received by: (Signature)	Date:	Time:

ANALYSIS REQUEST

Sample ID No.	Sample Description	Date/Time Sampled	Analysis Requested	Sample Condition Upon Receipt

Special Instructions/Comments:

Rush (surcharge): _____ Standard Turnaround Time: _____

WHITE COPY — RETURN TO GOLDER ASSOCIATES LTD.
YELLOW COPY — LABORATORY COPY
PINK COPY — RETAINED BY FIELD CREW LEADER

GOLDER ASSOCIATES LTD.
CHAIN-OF-CUSTODY RECORD
AND ANALYTICAL REQUEST FORM

Page ____ of ____

Field Sampler: (Signature) _____

Phone No.: _____

Shipment Date: _____

Carrier: _____

Waybill No.: _____

Sample ID No.	Sample Description	Date/Time Sampled	Analysis Requested	Sample Condition Upon Receipt

Special Instructions/Comments:

Rush (surcharge): _____ Standard Turnaround Time: _____

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APPENDIX B

GOLDER ASSOCIATES' TECHNICAL PROCEDURES TP-8.2-2
SURFACE WATER SAMPLING METHODS

1 PURPOSE

This technical procedure describes the methods to be used for sampling bottom sediment (referred to below as sediment) for analysis of physical, chemical or toxicological characteristics. It does not apply to collection of sediment for benthic community analysis, which is covered in TP 8.6 (Benthic Invertebrate Sampling).

2 APPLICABILITY

This technical procedure is applicable to any persons involved in the collection of sediment and is not restricted to any geographic area.

3 DEFINITIONS

3.1 Analytical Request Form

Standard form provided by analytical laboratories. This form is filled out by the person collecting samples and is used to indicate how each sample is to be analyzed. This form is often combined with the Chain-of-Custody Form in a single document.

3.2 Chain-of-Custody Form

Standard form used to track the movement of sample containers from the time they leave the field until they arrive at the specified laboratory. The Chain-of-Custody form provides a clear record of sample transport and handling, thereby reducing the risk of sample loss during transport. This form may be combined with the Analytical Request Form in a single document. Golder Associates' combined form is attached as Appendix 1.

3.3 Chemical Analysis

Analytical procedure used to measure the *amount* of a certain compound, or group of compounds, present in a sample.

3.4 Quality Assurance/Quality Control (QA/QC)

Quality Assurance refers to a detailed protocol used to produce high quality products, while Quality Control refers to the process by which this protocol is tested to ensure that final products are of the specified quality. With reference to sediment sampling, QA protocol includes the use trained personnel, proper sampling methods, clean containers and equipment, proper sample preservation and transportation and detailed documentation of the entire process; field, travel and other test blanks are used for Quality Control testing.

3.5 Sample Types

3.5.1 Grab Samples

Sample containing sediment collected during a single sampling event (i.e., sediment taken from a given place at a given time).

3.5.2 Composite Samples

Sample containing a mixture of sediment collected from multiple locations or from different times at the same location.

3.5.3 Replicate Samples

Replicate samples are used to evaluate within-site variation. Replicate samples are collected by filling multiple containers at a single site. They are labelled and preserved individually and are submitted separately to the analytical laboratory. Check the SWI for the number of replicate samples required per sampling site.

3.5.4 Split Samples

Split samples are used to check analytical variation. A single sample (e.g. grab) is collected and is split into two sample containers. These are labelled and preserved individually and are submitted separately to the analytical laboratory.

3.6 Sediment

Loose material on the bottom of waterbodies, including organic material (live plants or decaying plant material) and inorganic material of varying particle size.

3.7 Specific Work Instructions (SWI)

Detailed instructions in a standardized format provided to field personnel. The SWI describe all aspects of the work to be conducted, including personnel allocation, procedures to be used, time allocation and any additional information deemed necessary by the project or task manager.

3.8 Toxicity Analysis

Analytical procedure specifically designed to examine how the health of living organisms may be affected by exposure to a given substance or sample. Toxicity tests can be based on either: acute exposures (short-term exposures lasting only a small portion of the animals life cycle, e.g. 96 hours for rainbow trout); or, chronic exposures (longer-term exposures meant to represent a significant portion of

the animal's life cycle, or a particularly sensitive portion of the animal's life cycle, e.g. 28 days for *Daphnia magna*). Responses measured in toxicity tests can be lethal (e.g. mortality), or sublethal (e.g., reduced growth or reproduction). Unlike other procedures, toxicity testing evaluates the sample as a whole, rather than describing its chemical make-up.

4 REFERENCES AND SUGGESTED READING

Clesceri, L.S., A.E. Greenberg and R.R. Trussell. 1989. Standard Methods for the Examination of Water and Wastewater. American Public Health Association, Washington, D.C., U.S.A.

Environment Canada. 1993. Quality Assurance in Water Quality Monitoring. Ecosystem Sciences and Evaluation Directorate Conservation and Protection. Ottawa, Ontario.

5 DISCUSSION

5.1 General Safety

Refer to Golder Associates Ltd. Health and Safety Manual.

5.2 Methods

5.2.1 Sampling Site Selection and Identification

General sampling locations are described in SWI. However, field crews will have a certain degree of freedom in choosing the exact locations from which to take the samples. When selecting these sites, personnel should consider the layout of the local environment, project objectives and personal safety. They should then choose areas that are both easily accessible and representative of the target waterbody or waterbodies.

Once sampling sites have been identified, they must be accurately described relative to permanent landmarks, such as groundwater wells, outfalls or distinctive landscape features; measuring the distance from permanent landmarks to each site with an appropriate compass heading is recommended. Ideally, one should try to use the Global Positioning System (GPS), but locations can also be recorded as the perpendicular distance from the shoreline and the distance upstream or downstream of a permanent landmark.

5.2.2 Sampling Methods

To ensure the contaminant-free collection of representative sediment samples, consider the following points:

- collect as representative a sample as possible based on the local sediment conditions and safety;
- avoid obvious sources of contamination when collecting samples, unless those sources represent the impact being investigated;
- use an appropriate sampling device, cleaned consistently with the specific requirements of the sampling program (consult SWI);
- sampling equipment should be cleaned between sites as specified in the SWI; and
- only pre-cleaned sample containers provided by the analytical laboratory or those approved by the laboratory should be used.

Grab Samples (Ekman, Ponar, Peterson)

1. Label sample container with indelible ink marker.

2. Grab sampler should be rinsed twice with ambient water prior to sampling to ensure no sediment or other material are attached. This should be done with the jaws open. Be sure to check that sediments have not dried on to the sampler. If so, remove dry material to prevent contamination and rinse sampler again. Additional cleaning may be required, as specified in the SWI.

3. Using a graduated line attached to the top of the sampler, lower it **slowly** until it touches the bottom. If using the Ekman grab, be sure to retain the messenger (small weight used to trigger sampler) at the surface. Be careful not to touch the bottom too abruptly as surface sediments could be disturbed by the mouth of the sampler which would result in an inaccurate sample.

4. Making sure the graduated line is as vertical as possible, release the messenger. Maintain some tension of the line to ensure that the messenger falls freely (Note: when using the Ponar or Peterson grabs, which do not have a messenger, use the appropriate method to trigger the sampler).

5. Once you feel the messenger trigger the sampler, begin to slowly raise it off the bottom. It is important to raise the grab slowly otherwise fine sediments may be lost.

6. Once the grab reaches the surface, the spring loaded jaws should be pried open and the sample put into a flat bottomed pan or similar container. The entire sample, or the top layer of the sample can then be scooped into containers. Sample containers (bottles or bags) should be stored appropriately, as instructed by the analytical laboratory.

Core Samples

Sediment cores are used more frequently for metals analyses than the grab samplers. Any part of core samplers that comes into contact with the sample material must be made of plastic to avoid metal contamination of samples from the sampler itself. For metals analysis, clean the sampler using

laboratory soap and rinse it with ambient water prior to sampling and between samples. Cleaning requirements may vary depending on the analyses and should be determined prior to sampling (consult SWI).

1. Label sample container with indelible ink marker.

2. For the 5-cm mouth metal core sampler, insert the plastic sleeve and an 'eggshell' stopper into the mouth of the sampler and screw on the plastic nose cone until tight.

3. If sampling from a boat, slowly lower the sampler using a graduated line until it gently touches but does not penetrate the sediment. If sampling by hand, place and hold the core sampler at the desired location on the bottom.

4. For lake sampling, raise the sampler 1-1.5 metres above the sediment and drop it vertically to collect a sample. Maintain some tension on the line to ensure the sampler falls vertically.

5. Slowly raise the sampler until it reaches the boat. Before lifting the sampler from the water, plug the bottom opening with a rubber stopper to prevent loss of fine sediments.

6. Unscrew the bottom cone and remove the plastic tube containing the sample, while holding the corer in a vertical position. Decant the entire sample, or its desired portion, into an appropriate, pre-labelled container. Sample containers (bottles or bags) should be stored appropriately, as instructed by the analytical laboratory.

5.2.3 Sample Documentation

The importance of proper sample documentation cannot be overemphasized. Lack of careful documentation can lead to misunderstandings and questionable test results. Components of proper documentation of field activities are described below.

Field Notebooks

Field notebooks must be kept, describing all field activities. Format of field notes and information to be recorded should follow Golder Associates' specific guidelines. During the field survey, field notes must be maintained in a permanent, safe location at the field site where samples are collected. If possible, new entries in the field note book should be photocopied at the end of each field day and copies should be stored in a safe place.

Sample Labels

Sample labels must contain the following information:

- Sample identifier (name of site or sample code);
- Date (written as day/month/year; month abbreviated as three letters) and time (24 hour clock) of collection;
- Initials of collector; and
- Analysis requested (this is usually done by the analytical laboratory in the form of a code on the sample bottle).

Fill out labels at the time of collection using waterproof ink and affix a label to each sample container. Plastic bottles may be labelled by writing directly on the bottle using a waterproof marker; however, this approach is not recommended if samples are transported over long distances (friction may rub label off) or if bags of ice are used to keep the samples cool (water may damage label information).

Custody Seals

If required for a project, numbered seals should be used to detect unauthorized tampering with samples in transit. Attach the seal in a way that it is necessary to break it to open the cooler containing the samples. The number on the custody seal should be recorded in the field note book and on the Chain-of-Custody and Analytical Request forms

Chain-of-Custody Forms and Analytical Request Forms

Chain-of-Custody and Analytical Request forms must accompany all samples submitted for analysis. These forms are usually combined as a single document. An example of Golder Associates' combined Chain-of-Custody and Analytical Request Form is provided in Appendix 1.

The combined form must be filled out completely and the white and yellow copies should be sent along with the samples being submitted. Field personnel should retain the pink copy after it is signed by the shipper. Depending on the shipping container, these forms can either be enclosed inside the sealed container or attached firmly to the outside of the container. In either case, it is advisable to enclose the forms within a waterproof plastic bag to guard against damage. It is important that each person having custody or control of the samples identify themselves on this form. This means that the person collecting the sample, any intermediate persons involved in packaging, storing or transporting the sample and the person accepting the sample on behalf of the analytical lab must all be identified.

5.2.4 Sample Handling

Samples need to be treated or preserved according to their specific handling protocols as prescribed by the laboratory. Storage and shipping times are very important and must be considered, as many analytical parameters require that the sample needs to be in the laboratory for analysis within a specific time frame to ensure sample integrity. Refer to SWIs for specific project requirements or check with the analytical laboratory. Contact the laboratory in advance to secure recommended sample storage and

transportation times specific to the analytical parameters. Crew leader is to confirm shipment arrival at the laboratory and to explain analysis requests if needed.

6 EQUIPMENT

6.1 Sampling Equipment

The following is a list of the equipment recommended for sediment sampling:

- precleaned sample containers from analytical laboratory
- sampling equipment
- metal tray
- coolers and ice

6.2 Field Location Equipment and Logs

The following is recommended for the complete documentation of sediment samples:

- field record sheets
- maps of area for site locations
- indelible ink pens and felt tip markers and pencils
- 50 metre long tape measure
- survey flagging tape
- GPS unit
- survey lathe
- Analytical Request forms
- Chain-of-Custody forms

6.3 Health and Safety Equipment

- waders and waterproof gloves
- suitable clothing for prolonged water work: heavy socks, warm pants, rain gear, etc.
- first aid kit
- approved personal floatation device

APPENDIX I

SAMPLE CHAIN OF CUSTODY AND ANALYSIS REQUEST FORMS

GOLDER ASSOCIATES LTD. CHAIN-OF-CUSTODY RECORD AND ANALYTICAL REQUEST FORM

Page ____ of ____

Field Sampler: (Signature) _____

Phone No.: _____

Shipment Date: _____

Carrier: _____

Waybill No.: _____

Ship To:

Send Results To:

Project Name: _____

Project No: _____

P.O. No.: _____

Relinquished by: (Signature)	Received by: (Signature)	Date:	Time:
Relinquished by: (Signature)	Received at lab by: (Signature)	Date:	Time:
Relinquished by: (Signature)	Received at lab by: (Signature)	Date:	Time:
Relinquished from lab by: (Signature)	Received by: (Signature)	Date:	Time:

ANALYSIS REQUEST

Sample ID No.	Sample Description	Date/Time Sampled	Analysis Requested	Sample Condition Upon Receipt

Special Instructions/Comments:

Rush (surcharge): _____ Standard Turnaround Time: _____

WHITE COPY — RETURN TO GOLDER ASSOCIATES LTD.
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GOLDER ASSOCIATES LTD. CHAIN-OF-CUSTODY RECORD AND ANALYTICAL REQUEST FORM

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