GEOLOGICAL SURVEY OF CANADA
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J.M. Galloway[1], H. Sanei[1], R.T. Patterson[2], T. Mosstajiri[1], T. Hadlari[1], and H. Falck[3]

[1] Geological Survey of Canada (Calgary), 3303-33rd Street, N.W., Calgary AB T2L 2A7
[2] Department of Earth Sciences, Carleton University, Ottawa ON K1S 5B6
[3] Northwest Territories Geoscience Office, Yellowknife NT X1A 2R3

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ABSTRACT

We report on recent geoscience data collected by the Geological Survey of Canada in collaboration with Northwest Territories Geoscience Office and Carleton University. Fifty sediment-water interface samples from 19 lakes were collected between July and August 2009 along a 90 km east-west transect and analyzed for grain size, organic matter, nutrients, and metals. The work was undertaken to establish a dataset to contribute to the determination of natural variability of arsenic in freshwater sediments in the Yellowknife area, Northwest Territories. Geochemistry results of lake sediments are compared to previous work, bedrock geochemistry where available, and the Canadian Council of Ministers of the Environment Interim Sediment Quality Guidelines and Probable Effects Levels for the Protection of Aquatic Life. Concentrations of arsenic in bulk lake sediment samples are elevated above Interim Sediment Quality Quidelines and Probable Effects Levels in lakes located west of the city of Yellowknife. These lakes occur on granitoid bedrock, which contain low arsenic relative to other bedrock types in the study region. The spatial pattern of arsenic in lake sediments is consistent with aerial dispersion of emitted particulates from mine smelting point sources and transportation by prevailing winds west of the city of Yellowknife.

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1. INTRODUCTION

Particles and elements emitted from anthropogenic sources may be deposited close to their origin or transported large distances. Their spatial distribution in the environment is affected by prevailing wind, humidity, fog, precipitation, temperature, and landscape morphology (Schroeder et al. 1987; Schroeder and Lane 1988). Metals deposited in lakes may be scavenged from the water column to surface sediments by various geochemical processes (Murray 1975; Tessier et al. 1996). Lake sediments can also behave as a source of metals to the water column under certain redox conditions (Andrade et al. 2010). Thus, while concentrations of dissolved metal-species in sediment porewater and surface water are a measure of mobility, and potential accessibility to biota, total metal concentration of lake sediments can represent a source of metals to aqueous phases (Walker et al. 2005). Geochemical characterization of lacustrine sediments is therefore a useful tool for monitoring concentrations of elements of concern in the environment and assessing the potential for interaction with biota (Sanei et al. 2010). The spatial distribution of metals in lake sediments can also provide information on the source and transport mechanisms of elements of concern to lakes and provides a means to survey geochemical distributions in a region (Sanei et al. 2010).

Arsenic is a metalloid that is toxic to both plants and animals due to its affinity for proteins, lipids, and other cellular components (Harrington et al., 1980; Spehar et al. 1980). Adverse health effects to humans associated with chronic exposure to arsenic include cardiovascular and neurological effects and neoplasms. Arsenic is an element of concern near the City of Yellowknife, Northwest Territories (N.W.T.), due to historical release of thousands of kilograms of arsenic trioxide particulates to the atmosphere by nearly a century of gold mining activities (MacDonald 1997; SRK Consulting 2002). The concentration of arsenic in lake sediments near the City of Yellowknife is elevated relative to the rest of Canada due to bedrock geology (Webster, 1999; Ollson, 1999) and the anthropogenic releases of this element to the environment. Consequently, numerous studies have measured the concentration of arsenic and other metals in a variety of substrates, including water, lake sediments, soil, snow, trees, fungi, garden produce, and animals, in the Yellowknife region (Wageman et al., 1978; Hutchinson et al., 1982; Murdoch et al., 1989; Bright et al., 1996; Jackson et al., 1996; Koch et al., 2000; Risklogic, 2002; Andrade et al., 2010). However, only limited attention has been placed on sites outside of mine lease areas or known mine discharge pathways and consequently, little data on baseline sediment and water quality exists for the region surrounding the City of Yellowknife (Murdoch et al., 1989; Bright et al., 1996; Risklogic, 2002; Andrade et al., 2010). The objective of this study is to investigate the spatial pattern of arsenic in lake sediments in the Yellowknife area to contribute to an understanding of baseline geochemistry for the region and to provide data that may be used to define a zone of anthropogenic impact.

2. STUDY AREA

The City of Yellowknife and surrounding area is located in the southwestern Slave Geological province, District of Mackenzie. Elevation of the region ranges from 157 m above mean sea level (Great Slave Lake) and rises gradually to 350 to 400 m north of 63° (Fig. 1). Much of the terrain near Yellowknife is low relief and consists of rocky outcrops with glacial and glaciolacustrine sediments in topographic lows. The

Yellowknife River is the main component of the drainage system for the area. Its southern outlet flows into Yellowknife Bay, Great Slave Lake. Many lakes east of Yellowknife lie within the Cameron River-Prelude Lake drainage system. Drainage in the region is influenced by bedrock structure; numerous small elongate lakes have formed along fault and joints in the bedrock.

The study area occurs south of the treeline and within the Taiga Shield Ecozone (TSE). The climate of the TSE is continental. Mean annual precipitation is low (175 mm to 200 mm) and May to September is the period of maximum rainfall. Winter temperatures are cold (mean daily January temperature -17.5 °C to -27.5 °C). Mean daily July temperatures range from 7.5 °C to 17.5 °C (unknown observation period; Wiken, 1986). Prevailing wind direction changes seasonally. It is predominantly from the NW from January to March and from the SE from May to September (observation period 1971-2000; Environment Canada 2010). Vegetation in the study region consists of lichen woodlands dominated by black spruce (*Picea mariana* (P. Mill.) B.S.P.) with alder (*Alnus* P. Mill.), willow (*Salix* L.), and larch (*Larix* P. Mill.) in fens and bogs. Open mixed associations of white spruce (*Picea glauca* Moench), balsam fir (*Abies balsamea* (L.) P. Mill.), and trembling aspen (*Populus tremuloides* Michx.) also occur (Wiken, 1986).

The bedrock of the study area is composed of components of the southern Slave structural province of the Canadian Shield. In general, the bedrock consists of Archean felsic to mafic meta-volcanics of the Yellowknife Supergroup that include basalt, andesite, and pillowed flows that trend north-south through the central area of the study region. East of Yellowknife, Archean meta-sedimentary rocks predominate and consist of greywacke, slate, schist, and phyllite. Yellowknife Supergroup meta-volcanics and meta-sedimentary rocks are intruded by younger granitoid rocks in isolated areas. West of Yellowknife, granitoid intrusions, consisting of granite, granodiorite, and tonalite, compose the majority of the bedrock. The region is crosscut by early Proterozoic diabase and gabbro dykes and several major fault lines, such as the Kam Lake Fault and the West Bay Fault that run through the city of Yellowknife, separating the volcanic rocks from younger granitoids (Yamashita and Creaser, 1999; Yamashita et al., 1999; Cousens, 2000; Cousens et al., 2002).

The surficial geology consists of a mosaic of Glacial Lake McConnell sediments and glacial tills that infill the topographic lows of the abundant bedrock outcrops. Till consists of matrix-supported diamicton (Kerr and Wilson, 2000). Clasts consist of various lithologies and range in size from small pebbles to large boulders. Till in the Yellowknife area may be composed of up to 60% clasts, but most exposures contain approximately 20% to 40% (Kerr and Wilson, 2000). Till exposures are generally eroded, less than 2 m thick, and form a discontinuous cover in topographic lows or on bedrock outcrops. Glaciofluvial sediments are relatively uncommon in the study region, and where present consist of fine sand to cobbles in the forms of eskers, kames, and outwash (Kerr and Wilson, 2000). A number of surficial sedimentary deposits may be attributed to Glacial Lake McConnell, which formed in Great Slave Lake, Great Bear Lake, and Athabasca Lake basins during deglaciation between 11,800 and 8,300 years ago (Dyke and Prest, 1989; Smith, 1994; Kerr and Wilson, 2000). Sedimentary deposits of Glacial Lake McConnell consist of poorly to moderately sorted coarse to fine sand, silt, and clay that can be up to 20 m thick in some topographic lows (Kerr and Wilson, 2000). These sediments may overlie till, outwash, or bedrock and finer grained sediments deposited in deep water environments, and may be overlain by sand and gravel deposited in regressive fluvial or littoral successions.

Abundant gold mineralization in the Yellowknife Supergroup of the Slave Geological province led to the establishment of at least three major gold mines in the immediate vicinity of the City of Yellowknife: The Discovery Mine, Con Mine, and Giant Mine, that collectively operated from 1938 until 2004. The Discovery Mine, located approximately 81 km northeast of Yellowknife, operated between 1950 and 1969 and produced one million ounces of gold. Con Mine began operation in 1938, processed largely free milling ore on site from 1941 until the mine was closed in 2003. The refractory component of Con Mine ore was roasted until 1970 when it was suspended. Production from the refractory ore was resumed in 1992, when the construction of an autoclave was completed. Giant Mine began gold production in 1948 and roasting of ore commenced on site in January, 1949. Giant Mine produced 7.6 million ounces of gold until 1999 when the mine owner went into receivership and ownership was transferred to the Government of Canada. Mining continued until mid-2004 but ore processing was shifted to the Con Minesite. Due to the complex refractory mineralogy of ores in the Yellowknife Greenstone Belt, processing involved roasting of sulphide minerals, dominantly pyrite and arsenopyrite, to volatilize As and Sb and transform sulphide minerals into porous iron oxides of maghemite and hematite that are amenable to cyanidation. An Au-rich calcine, generally high in As, Sb, Cu, Pb, and Fe, was also produced. Roaster generated iron oxides produced at Giant Mine contain as much as 68.5 wt. % As that includes both As (III) and As (V) (Clark and Raven 2005). Roasting of ores at Giant and Con Mines released arsenic (predominantly As_2O_3) particulates and SO_x vapours directly to the atmosphere until gas cleaning technologies were applied at Giant Mine in 1951. However, during the first decade of ore processing at Giant Mine, millions of kgs of As_2O_3 were nonetheless emitted to the atmosphere (2.6 million kg/year; MacDonald 1997; SRK Consulting 2002). More stringent emission controls developed and implemented after 1958 decreased aerial emissions substantially, reducing release of arsenic to approximately 5700 kg/year and leading to the storage of 237,176 tonnes of arsenic trioxide by-product at Giant Mine (MacDonald 1997; SRK Consulting 2002). Overall, Giant Mine released approximately 19 million kg of As_2O_3 as aerial emissions since 1949; approximately 1 million kg was released from ore processing at Con Mine.

3. STUDY SITES

Nineteen lakes along a 90 km east-west transect through the City of Yellowknife were accessed from roadways for sediment collection (Fig. 1; Galloway et al., 2010). Sampling locations that had a vegetation buffer between the sampling site and the highway were preferentially selected and sample sites that were greater than 20 feet from shore were targeted to reduce effects of runoff on sedimentary variables. As the sample sites were also being used for a study on the occurrence and distribution thecamoebians (arcellaceans) in Yellowknife area lakes as part of a larger study, relatively shallow sample sites were targeted to reduce the influence of thermal stratification that can result in summer bottom water dysoxia or anoxia. One to three sites were sampled within each lake to assess inter-basin variability in study variables as part of a larger, ongoing study.

Fourteen study lakes (South Tibbitt and Prosperous lakes, and lakes 3 through 14) occur on meta-sedimentary rocks of the Yellowknife Supergroup. Study lake 15 occurs on meta-volcanic rocks of the Yellowknife Supergroup and study lakes 17, 18, and 19 occur on granitoid bedrock west of the City of Yellowknife.

4. METHODS

Surface sediments were collected between July and August 2009 from a small boat using an Ekman Grab sampler. The top 2 to 5 cm of sediment retrieved with the Ekman grab were sub-sampled for grain size, organic geochemical, element geochemical, and biological analyses. Water quality variables (dissolved oxygen, temperature, and conductivity) were measured at one metre intervals using a YSI multi-metre probe. Surface water pH was measured with a hand-held pH metre. All equipment was calibrated according to the manufacturer's instructions (see Galloway et al. (2010) for additional information on sampling).

Grain size was determined using a Beckman Coulter LS 13 320 Single Wavelength laser diffraction particle size analyzer with a measurement range between 0.4 and 2000 µm. Samples were pretreated with dilute hydrochloric acid, hydrogen peroxide and Calgon solution. The particle size analyzer yields the percentages of size fractions in a sample and the median and mean grain size diameter (the 50th percentile of the grain size distribution).

The type and quantity of organic matter in lake sediments was determined by thermal volatilization of the organic constituents using Rock-Eval™ 6 pyrolysis (Vinci Technologies, Rueil-Malmaison, France; Lafargue et al., 1998). Twenty milligram freeze-dried bulk samples were pyrolyzed and oxidized in an inert Helium atmosphere to determine the amount, in milligrams hydrocarbons per grams bulk sample (mg HC/g), of free hydrocarbons (S1), released at 300ºC; kerogen-derived hydrocarbons (S2), released near 650ºC; the amount of carbon dioxide released during pyrolysis of kerogen (S3); and, residual carbon (RC). The S2 carbon is generally derived from the highly aliphatic biomacromolecule structure of algal cell walls (Sanei et al., 2005). The temperature at which S2 reaches its maximum depends on the nature and maturity of kerogen, and is called T_{max}. S3 is an indication of the amount of oxygen in the kerogen. Following the pyrolysis stage, the sample is transferred to a second oven where residual carbon is oxidized. Total organic carbon (TOC), in weight percent (wt %), is determined from the sum of all organic carbon released during pyrolysis and oxidation. Analyses of standard reference material show that the accuracy and precision of Rock-Eval™ results to be greater than 5% relative standard deviation (IFP 160000, Institut Français du Pétrole and internal 9107 shale standard, Geological Survey of Canada, Calgary).

Concentrations of nutrients and metals in lake sediment samples were determined using an ICP-OES (Inductively Coupled Plasma – Optical Emission Spectrometer) with an aqua regia digestion at Caduceon Laboratories, Ottawa. Aqua regia digestion was selected to determine concentrations of elements that are bioavailable (e.g., are not in silicate mineral matrices).

The spatial distribution of arsenic was mapped in ArcGIS® 9.3.1 using the Inverse Distance Weighting (IDW) algorithm with a squared distance term for interpolating values between measurements. In IDW each interpolated value is a weighted average of surrounding data points and weights are computed as the inverse distance between a data location and the location being estimated (Burrough and McDonnell, 1998). Inverse distance weighting with a squared distance term produces results that are more consistent with original data than other similar methods (Burrough and McDonnell, 1998).

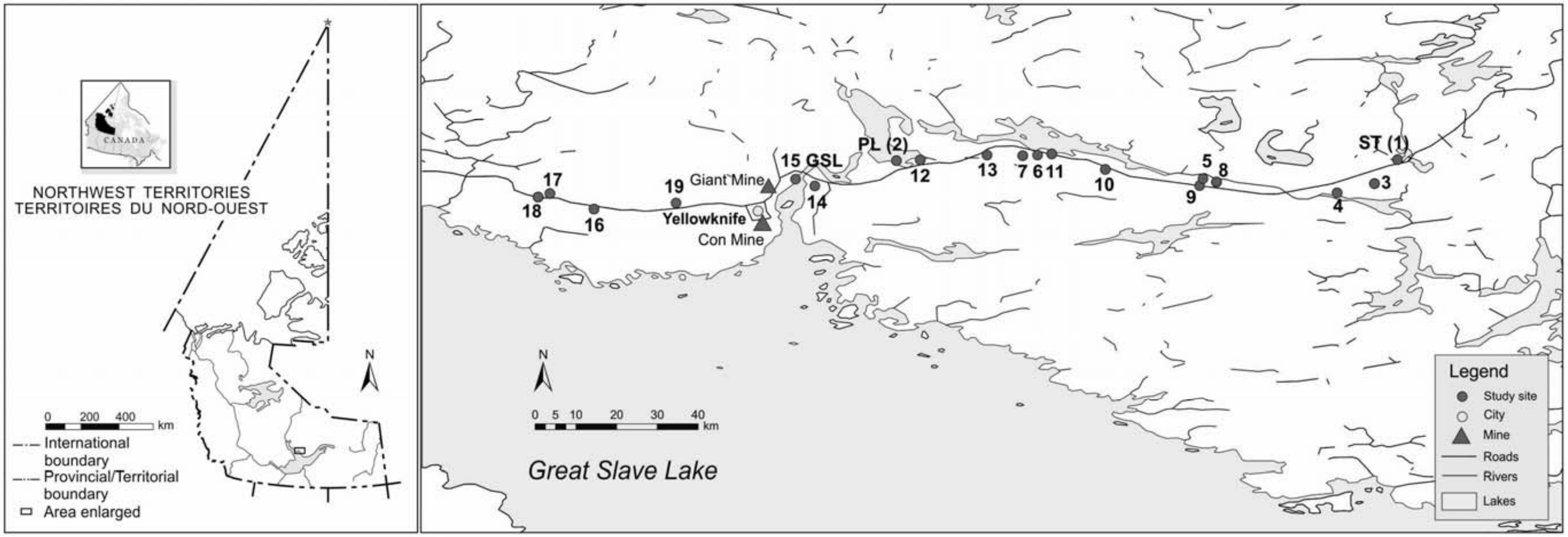

Fig. 1. Map showing the location of the study area in the Northwest Territories and the locations of the study lakes. GSL – Great Slave Lake; PL – Prosperous Lake; ST – South Tibbitt Lake

4. RESULTS

Fifty lake sediment-water interface sediment samples were collected from 19 lakes near Yellowknife. Study sites ranged from N 62°33.124' to N 62°28.007' in latitude and from W 113°21.522' to W 114° 43.603' in longitude (Fig. 1; Table 1a). Field information and physical limnological characteristics are presented in Galloway et al. (2010), but also included here (Tables 1a and b). All lakes were near neutral in pH, and ranged from 6.55 to 8.65. Lake depth at sampling sites ranged from <1 m to 7 m.

Table 1a. Metadata and physical limnological characteristics of lake sample sites in the Yellowknife area

Site name	GPS co-ordinates	Surface water pH	Ecosite characterization	Bedrock geology[a]	Distance from Giant Mine (km)[b]	Lake depth (m)	Substrate
Prosperous Site 1	N 62º 32.420' W 114º 08.737'	6.55	wetland, spruce forest	metasedimentary (ABa)	12.00	0.75	gyttja
Prosperous Site 2	N 62º 32.300' W 114º 09.444'	6.84	spruce forest	metasedimentary (ABa)	11.37	5	gyttja
South Tibbitt Site 1	N 62º 32.396', W 113º 21.755'	7.06	wetland, birch woodland, spruce forest	metasedimentary (Aa)	51.61	2	sand
South Tibbitt Site 2	N 62º 32.449' W 113º 21.522'	8.46	wetland, birch woodland, spruce forest	metasedimentary (Aa)	51.72	1.5	gyttja
Lake 3 Site 1	N 62º 30.143' W 113º 24.080'	8.24	wetland, spruce forest	metasedimentary (ABa)	49.44	4	gyttja
Lake 3 Site 2	N 62º 30.104' W 113º 23.942'	8.02	wetland, spruce forest	metasedimentary (ABa)	49.56	2	gyttja
Lake 4 Site 1 (Reid Lake)	N 62º 29.397' W 113º 27.334'	7.97	wetland, jackpine woodland	metasedimentary (ABa)	46.66	5	gyttja
Lake 5 Site 1	N 62º 30.483' W 113º 40.359'	7.66	wetland	metasedimentary (ABa)	35.47	1	gyttja
Lake 5 Site 2	N 62º 30.466' W 113º 40.531'	7.82	wetland	metasedimentary (ABa)	35.32	3	gyttja
Lake 6 site 1	N 62º 32.866' W 113º 57.681'	8.60	wetland, spruce forest	metasedimentary (ABa)	21.28	2	gyttja
Lake 6 Site 2	N 62º 32.783' W 113º 57.709'	8.65	wetland, spruce forest	metasedimentary (ABa)	21.22	2	gyttja
Lake 6 Site 3	N 62º 32.781' W 113º 57.432'	8.63	wetland, spruce forest	metasedimentary (ABa)	21.45	2	gyttja
Lake 7 Site 1	N 62º 32.836' W 113º 56.013'	8.12	wetland, spruce forest	metasedimentary (ABa)	21.65	1	gyttja with plant remains
Lake 7 Site 2	N 62º 32.990' W 113º 56.424'	7.81	wetland, spruce forest	metasedimentary (ABa)	22.38	4	gyttja

Table 1a: continued

Site name	GPS co-ordinates	Surface water pH	Ecosite characterization	Bedrock geology[a]	Distance from Giant Mine (km)[b]	Lake depth (m)	Substrate
Lake 7 Site 3	N 62º 32.910’ W 113º 56.204’	7.75	wetland, spruce forest	metasedimentary (ABa)	22.53	2	gyttja
Lake 8 Site 1	N 62º 30.25’ W 113º 38.984’	7.73	wetland, birch woodland, spruce forest	metasedimentary (ABa)	36.64	3	gyttja
Lake 8 Site 2	N 62º 30.314’ W 113º 39.041’	7.77	wetland, birch woodland, spruce forest	metasedimentary (ABa)	36.59	3	gyttja
Lake 8 Site 3	N 62º 30.269’ W 113º 38.980’	7.82	wetland, birch woodland, spruce forest	metasedimentary (ABa)	36.64	2	gyttja
Lake 9 dock	N 62º 31.352’ W 113º 49.625’	8.07	wetland, spruce forest	metasedimentary (ABa)	27.62	1	gyttja
Lake 10 Site 1	N 62º 31.468’ W 113º 49.573’	7.58	wetland, spruce forest	metasedimentary (ABa)	27.68	3	gyttja
Lake 10 Site 2	N 62º 31.483’ W 113º 49.594’	7.46	wetland, spruce forest	metasedimentary (ABa)	27.67	2	gyttja
Lake 10 Site 3	N 62º 31.470’ W 113º 49.544’	7.32	wetland, spruce forest	metasedimentary (ABa)	27.71	5	gyttja
Lake 11 Site 1	N 62º 32.898’ W 113º 54.608’	7.65	wetland, spruce forest	metasedimentary (ABa)	23.85	7	gyttja
Lake 11 Site 2	N 62º 32.773’ W 113º 54.276’	7.60	wetland, spruce forest	metasedimentary (ABa)	24.08	2	gyttja
Lake 11 Site 3	N 62º 32.946’ W 113º 54.658’	7.38	wetland, spruce forest	metasedimentary (ABa)	23.83	2	gyttja
Lake 12 Site 1	N 62º 32.335’ W 114º 07.283’	7.74	wetland, spruce forest	metasedimentary (ABa)	13.12	2	gyttja with plant remains
Lake 12 Site 2	N 62º 32.367’ W 114º 07.420’	7.82	wetland, spruce forest	metasedimentary (ABa)	13.03	3	gyttja
Lake 12 Site 3	N 62º 32.379’ W 114º 07.180’	7.70	wetland, spruce forest	metasedimentary (ABa)	12.23	4	gyttja

Table 1a: continued

Site name	GPS co-ordinates	Surface water pH	Ecosite characterization	Bedrock geology[a]	Distance from Giant Mine (km)[b]	Lake depth (m)	Substrate
Lake 13 (Pontoon Lake) Site 1	N 62º 33.124’ W 114º 01.608’	7.44	willow, spruce forest	metasedimentary (ABa)	18.20	4	clay with shell hash
Lake 13 (Pontoon Lake) Site 2	N 62º 32.995’ W 114º 01.336’	7.84	willow, spruce forest	metasedimentary (ABa)	18.34	3	clay with plant remains
Lake 13 (Pontoon Lake) Site 3	N 62º 32.837’ W 114º 00.829’	8.23	willow, spruce forest	metasedimentary (ABa)	18.67	5	gyttja
Lake 14 Site 1	N 62º 29.837’ W 114º 17.289’	7.96	spruce forest	metasedimentary (ABg)	3.74	3	gyttja
Lake 14 Site 2	N 62º 29.781’ W 114º 17.352’	7.97	wetland, spruce forest	metasedimentary (ABg)	3.69	1	gyttja
Lake 14 Site 3	N 62º 29.781’ W 114º 17.277’	7.90	wetland, spruce forest	metasedimentary (ABg)	3.75	2	gyttja
Lake 15 (Great Slave Lake) Site 1	N 62º 31.054’ W 114º 19.490’	8.30	wetland, spruce forest	volcanic (Aa)	2.81	1	clay
Lake 15 (Great Slave Lake) Site 2	N 62º 30.879’ W 114º 19.479’	7.85	wetland, spruce forest	volcanic (Aa)	2.58	1	clay
Lake 15 (Great Slave Lake) Site 3	N 62º 30.871’ W 114º 19.474’	7.86	wetland, spruce forest	volcanic (Aa)	2.58	1	clay
Lake 16 Site 1	N 62º 27.600’ W 114º 38.069’	7.88	wetland, spruce forest	granitoid (Ad)	-14.76	2	gyttja
Lake 16 Site 2	N 62º 27.668’ W 114º 38.227’	7.77	wetland, spruce forest	granitoid (Ad)	-14.86	3	gyttja
Lake 16 Site 3	N 62º 27.866’ W 114º 38.111’	7.75	wetland, spruce forest	granitoid (Ad)	-14.66	1	gyttja
Lake 17 Site 1	N 62º 29.182’ W 114º 42.412’	7.72	wetland, willow, spruce forest	granitoid (Ad)	-17.9	1	gyttja
Lake 17 Site 2	N 62º 29.160’ W 114º 42.434’	7.75	wetland, willow, spruce forest	granitoid (Ad)	-17.92	1	gyttja

Table 1a: continued

Site name	GPS co-ordinates	Surface water pH	Ecosite characterization	Bedrock geology[a]	Distance from Giant Mine (km)[b]	Lake depth (m)	Substrate
Lake 17 Site 3	N 62º 29.144’ W 114º 42.199’	7.81	wetland, willow, spruce forest	granitoid (Ad)	-17.85	1	gyttja
Lake 18 Site 1	N 62º 28.827’ W 114º 43.672’	7.54	wetland, spruce forest	granitoid (Ad)	-19.42	6	sandy mud
Lake 18 Site 2	N 62º 28.840’ W 114º 43.603’	7.44	wetland, spruce forest	granitoid (Ad)	-18.98	7	sandy mud
Lake 18 Site 3	N 62º 28.826’ W 114º 43.548’	7.34	wetland, spruce forest	granitoid (Ad)	-18.94	7	sandy mud
Lake 19 Site 1	N 62º 28.007’ W 114º 30.338’	7.75	willow, jackpine woodland	granitoid (Ad)	-8.27	2	sandy mud
Lake 19 Site 2	N 62º 28.211’ W 114º 30.273’	7.68	willow, jackpine woodland	granitoid (Ad)	-8.07	3	sandy mud
Lake 19 Site 3	N 62º 28.263’ W 114º 30.430’	7.88	willow, jackpine woodland	granitoid (Ad)	-8.15	4	sandy mud
Lake 19 Site 4	N 62º 28.228’ W 114º 30.748’	7.80	willow, jackpine woodland	granitoid (Ad)	-8.43	5	sand

[a] Henderson (1985) ABa: Archean Yellowknife Supergroup – Burwash Formation; Aa: Archean amphibolite; Ad: Archean Putonic Suite; ABg: Archean Yellowknife Supergroup – Duncan Lake Group

[b] Positive = east; Negative = west

km – kilometer; m - metre

Table 1b. Physical limnological characteristics of lakes sampled

Site name	Profile				
	Depth (m)	Dissolved oxygen (%)	Dissolved oxygen (mg/L)	Temperature (°C)	Conductivity (µS)
Prosperous Site 1	0	74.0	n/a	15.0	n/a
	1	76.0	n/a	14.4	n/a
Prosperous Site 2	0	105.7	n/a	13.3	n/a
	1	105.5	n/a	12.7	n/a
	2	106.2	n/a	10.9	n/a
	3	107.1	n/a	10.5	n/a
	4	104.2	n/a	8.9	n/a
	5	101.8	n/a	8.2	n/a
South Tibbitt Site 1	0	114.8	11.05	17.2	257.7
	1	113.1	10.86	17.1	257.7
	2	113.2	10.75	17.6	257.1
South Tibbitt Site 2	0	116.4	11.23	17.3	260.0
	1	116.5	10.90	17.5	260.7
	2	113.3	10.66	17.2	259.3
Lake 3 Site 1	0	107.6	10.29	18.3	235.0
	1	106.1	10.28	18.1	234.0
	2	114.0	10.67	18.0	234.4
	3	116.0	9.66	17.7	235.9
	4	35.7	2.32	16.3	245.9
Lake 3 Site 2	0	105.8	9.99	18.5	237.6
	1	105.1	9.98	18.4	236.4
	2	92.7	8.29	18.3	236.4
Lake 4 Site 1 (Reid Lake)	0	98.9	9.83	16.1	109.6
	1	101.9	10.21	15.7	109.5
	2	101.4	10.04	15.5	109.7
	3	101.1	10.16	15.2	134.1
	4	101.5	10.26	15.1	108.8
	5	101.3	10.43	15.0	108.4
Lake 5 Site 1	0	87.1	7.95	20.2	254.3
	1	88.5	8.32	19.4	247.2
Lake 5 Site 2	0	90.6	8.43	18.8	246.0
	1	89.0	8.38	18.3	243.8
	2	89.1	8.40	18.3	242.5
	3	87.6	n/a	17.3	235.8
Lake 6 site 1	0	106.9	9.96	18.8	266.6
	1	107.7	9.98	18.7	266.5
	2	109.7	10.59	18.6	267.8
Lake 6 Site 2	0	105.8	9.52	18.5	267.8
	1	108.2	10.13	18.5	268.0
	2	108.8	10.22	18.5	268.3

Table 1b: continued

Site name	Profile				
	Depth (m)	Dissolved oxygen (%)	Dissolved oxygen (mg/L)	Temperature (°C)	Conductivity (μS)
Lake 6 Site 3	0	109.5	10.17	19.2	200.1
	1	113.7	10.39	19.0	271.5
	2	105.6	9.86	18.7	269.3
Lake 7 Site 1	0	104.8	9.78	18.8	205.6
	1	111.0	10.24	18.9	206.4
Lake 7 Site 2	0	103.7	9.80	18.9	203.4
	1	105.4	9.79	18.1	204.1
	2	101.3	9.74	17.8	200.8
	3	103.7	9.80	17.2	202.7
	4	74.8	n/a	15.8	n/a
Lake 7 Site 3	0	106.0	9.75	18.9	209.9
	1	103.8	9.64	18.9	209.8
	2	104.9	9.69	18.6	208.7
Lake 8 Site 1	0	78.0	7.10	19.6	351.2
	1	77.4	7.06	19.4	350.8
	2	75.1	7.06	18.3	342.1
	3	56.3	5.12	17.9	345.4
Lake 8 Site 2	0	86.1	7.90	20.5	361.3
	1	85.5	7.62	19.9	360.4
	2	82.7	7.48	19.8	353.0
	3	41.4	2.20	18.1	339.4
Lake 8 Site 3	0	84.8	7.55	20.4	357.0
	1	79.7	7.31	19.9	356.0
	2	77.0	7.31	19.7	351.0
Lake 9 dock	0	114.1	10.66	19.2	107.4
	1	116.2	10.66	17.8	106.8
Lake 10 Site 1	0	91.6	7.98	21.8	111.4
	1	50.0	4.81	17.5	104.2
	2	12.8	1.50	13.9	92.7
	3	11.7	1.25	13.6	94.1
Lake 10 Site 2	0	88.5	7.76	21.8	117.2
	1	82.2	7.44	20.4	105.0
	2	15.5	1.19	13.2	90.0
Lake 10 Site 3	0	90.1	7.72	22.7	106.6
	1	21.3	2.17	16.6	104.6
	2	5.5	0.57	12.8	116.1
	3	2.1	0.21	10.8	98.7
	4	2.2	0.25	6.8	211.2
	5	1.4	0.17	5.7	213.2

Table 1b: continued

Site name	Profile				
	Depth (m)	Dissolved oxygen (%)	Dissolved oxygen (mg/L)	Temperature (°C)	Conductivity (µS)
Lake 11 Site 1	0	90.3	8.31	20.3	179.0
	1	97.5	8.85	19.6	178.4
	2	82.4	8.04	19.2	175.3
	3	62.7	6.12	17.4	166.6
	4	8.0	0.98	14.8	162.1
	5	2.1	0.22	14.3	174.2
	6	1.7	0.17	12.9	174.6
	7	1.0	0.10	12.6	196.8
Lake 11 Site 2	0	91.9	8.26	20.6	200.0
	1	95.1	8.70	19.4	200.0
	2	90.8	8.82	19.4	200.0
Lake 11 Site 3	0	90.1	8.14	20.4	200.0
	1	100.1	9.02	19.4	200.0
	2	99.6	9.19	18.9	200.0
Lake 12 Site 1	0	79.1	7.01	21.1	323.5
	1	80.0	7.40	20.9	322.8
	2	85.8	7.73	20.9	322.5
Lake 12 Site 2	0	80.2	7.09	21.2	336.0
	1	78.5	6.96	21.1	366.2
	2	80.1	7.19	20.4	330.0
	3	82.2	7.64	19.4	327.3
Lake 12 Site 3	0	80.1	7.23	20.7	331.5
	1	78.7	7.08	20.4	330.8
	2	78.2	7.08	20.2	329.6
	3	72.9	6.52	19.0	322.7
	4	45.6	4.61	18.4	316.0
Lake 13 (Pontoon Lake) Site 1	0	84.7	7.70	20.0	351.4
	1	85.0	7.67	20.0	351.5
	2	86.1	7.82	19.9	350.8
	3	85.3	7.77	19.9	350.5
	4	85.0	7.76	19.8	350.7
Lake 13 (Pontoon Lake) Site 2	0	93.1	8.45	20.0	351.4
	1	92.3	8.36	20.0	352.1
	2	91.6	8.36	19.8	351.3
	3	88.9	8.20	19.7	350.9
Lake 13 (Pontoon Lake) Site 3	0	94.0	8.54	19.9	352.3
	1	92.6	8.46	19.9	350.8
	2	92.2	8.40	19.6	350.3
	3	92.2	8.44	19.7	350.2
	4	93.0	8.46	19.6	350.0
	5	94.0	8.54	19.6	349.9

Table 1b: continued

Site name	Profile				
	Depth (m)	Dissolved oxygen (%)	Dissolved oxygen (mg/L)	Temperature (°C)	Conductivity (µS)
Lake 14 Site 1	0	64.9	5.69	21.4	283.7
	1	65.1	5.89	19.9	273.8
	2	63.2	5.79	19.5	273.5
Lake 14 Site 2	0	78.6	6.84	20.9	279.6
	1	83.2	7.60	19.1	255.3
Lake 14 Site 3	0	74.5	6.65	20.9	263.9
	1	71.3	6.42	20.4	273.1
	2	75.8	6.99	19.6	265.4
Lake 15 (Great Slave Lake) Site 1	0	57.2	5.39	18.0	50.6
	1	57.2	4.43	17.8	50.6
Lake 15 (Great Slave Lake) Site 2	0	78.1	7.37	18.6	51.1
	1	78.1	7.35	18.2	51.1
Lake 15 (Great Slave Lake) Site 3	0	66.6	6.14	19.3	28.7
	1	66.1	6.15	19.1	51.8
Lake 16 Site 1	0	57.6	5.21	20.1	129.2
	1	57.6	5.21	20.1	129.0
Lake 16 Site 2	0	61.2*	5.5	20.3	130.6
	1	60.8*	5.49	20.3	130.6
	2	60.7*	5.49	20.2	129.0
Lake 16 Site 3	0	66.6	6.01	20.2	143.7
	1	65.5	5.74	20.8	142.4
Lake 17 Site 1	0	46.2	4.36	18.1	66.3
	1	45.7	4.31	18.0	66.3
Lake 17 Site 2	0	20.1	1.88	18.5	67.2
	1	20.3	1.90	18.6	67.2
Lake 17 Site 3	0	23.2	2.16	18.5	37.1
	1	23.2	2.19	18.4	66.8
Lake 18 Site 1	0	18.1	1.67	19.5	123.5
	1	18.5	1.72	18.6	120.9
	2	10.2	1.01	18.0	121.9
	3	3.6	0.34	14.3	129.9
	4	2.2	0.21	12.8	122.8
	5	1.8	0.18	12.5	124.6
	6	2.4	0.22	14.5	135.3
Lake 18 Site 2	0	30.0	2.74	19.3	123.1
	1	28.6	2.66	18.8	120.9
	2	3.2	0.28	17.0	123.9
	3	1.6	0.16	14.3	127.1
	4	1.2	0.13	11.5	112.0
	5	1.1	0.12	9.3	98.0
	6	1.0	0.11	7.6	102.2
	7	1.3	0.16	6.5	168.1

Table 1b: continued

Site name	Profile				
	Depth (m)	Dissolved oxygen (%)	Dissolved oxygen (mg/L)	Temperature (°C)	Conductivity (μS)
Lake 18 Site 3	0	36.2	3.57	19.0	121.3
	1	34.1	3.17	18.7	121.2
	2	24.1	2.11	17.8	127.2
	3	1.8	0.17	13.6	127.7
	4	1.1	0.13	11.0	112.5
	5	1.2	0.13	11.5	114.2
	6	1.1	0.12	11.7	114.8
	7	1.2	0.14	11.7	116
Lake 19 Site 1	0	57.3	5.28	19.2	121.4
	1	57.4	5.29	19.2	124.8
	2	56.6	5.23	19.3	124.8
Lake 19 Site 2	0	58.3	5.39	19.0	127.9
	1	58.4	5.42	19.0	127.6
	2	58.8	5.46	18.9	127.2
	3	58.6	5.44	18.9	127.2
Lake 19 Site 3	0	59.5	5.48	19.3	128.6
	1	60.0	5.55	19.1	127.8
	2	59.8	5.54	19.0	127.5
	3	59.7	5.53	18.9	127.3
	4	55.2	5.03	18.9	127.0
Lake 19 Site 4	0	61.7	5.71	19.0	128.1
	2	61.8	5.70	19.1	128.1
	3	61.9	5.74	19.1	127.8
	4	61.9	5.73	19.0	127.8
	5	61.9	5.73	19.1	127.7

m – metre; % - percent; mg/L – milligram/litre; °C – degree Celsius; μS – microSiemens; n/a – not applicable

4.1 Grain size

Mean grain size of lake sediment samples ranged from 16.90 μm (Lake 14 Site 3) to 447.78 μm (Lake 19 Site 3) (Table 2). In general, the grain size is coarse; an average of 14.43% ± 8.49 standard deviation (SD) of the samples (*n*=50) fall within the clay size fraction (<4 μm), an average of 56.00% ± 18.40 SD of the samples fall within the silt size fraction (>4 μm, <63 μm), and an average of 29.58% ± 23.02 SD of samples fall within the sand size fraction (>63 μm).

Table 2. Grain size distribution and descriptive statistics of the sediments collected from lakes in the Yellowknife area

Site	Mean (µm)	Median (µm)	Mean /Median	Mode	SD	Variance	Skew-ness	Kurtosis	%Clay (<4µm)	%Silt (<63µm)	%Sand (>63µm)
Prosperous Site 1	22.72	10.83	2.10	18.00	32.64	1065.64	2.80	8.78	26.63	64.68	8.69
Prosperous Site 2	53.32	39.44	1.35	66.45	50.06	2506.19	1.20	0.97	11.51	55.35	33.14
South Tibbitt Site 1	29.46	14.63	2.01	16.40	41.38	1712.53	2.81	8.82	17.43	70.71	13.25
South Tibbitt Site 2	32.93	20.69	1.59	23.82	37.83	1431.13	2.49	7.07	10.15	77.17	12.68
Lake 3 Site 1	30.73	17.01	1.81	18.00	37.48	1404.38	2.23	5.33	16.67	69.93	13.40
Lake 3 Site 2	28.60	15.76	1.81	18.00	36.60	1339.24	2.53	7.09	17.39	71.20	11.40
Lake 4 Site 1 (Reid Lake)	155.80	117.20	1.33	127.65	142.05	20178.00	1.64	2.54	4.31	20.10	75.59
Lake 5 Site 1	64.80	50.31	1.29	96.50	55.58	3089.23	0.83	-0.19	8.55	48.97	42.47
Lake 5 Site 2	52.39	33.42	1.57	45.76	52.00	2703.73	1.29	1.00	9.18	59.78	28.26
Lake 6 Site 1	29.50	17.56	1.68	41.68	33.53	1124.01	1.96	4.31	19.97	67.47	12.57
Lake 6 Site 2	33.28	21.27	1.57	37.97	34.69	1203.65	1.72	2.99	13.94	70.39	15.67
Lake 6 Site 3	35.84	21.55	1.66	37.97	39.16	1533.58	1.73	1.16	15.44	66.63	17.93
Lake 7 Site 1	35.88	15.85	2.26	16.40	49.77	2477.13	2.23	2.84	16.66	66.56	16.77
Lake 7 Site 2	50.27	31.27	1.61	37.97	50.13	2513.29	1.36	1.16	9.05	62.36	28.59
Lake 7 Site 3	38.47	15.69	2.45	74.49	4.54	5548.72	0.54	24.91	16.30	70.28	13.42
Lake 8 Site 1	38.70	19.96	1.94	18.00	45.57	2076.53	1.76	2.58	15.51	64.27	20.22
Lake 8 Site 2	49.89	22.35	2.23	18.00	73.65	5424.98	3.84	22.33	11.70	64.84	23.46
Lake 8 Site 3	34.60	22.70	1.52	28.70	37.82	1430.59	2.32	5.92	8.51	78.24	13.25
Lake 9 dock	31.55	17.80	1.77	18.00	37.68	1420.05	2.30	5.66	11.83	74.59	13.58
Lake 10 Site 1	39.94	17.18	2.23	19.76	55.04	3830.00	2.17	4.57	19.16	61.49	19.35
Lake 10 Site 2	57.82	34.24	1.69	45.76	61.67	3803.41	1.35	1.04	12.83	54.43	32.73
Lake 10 Site 3	122.50	67.75	1.81	185.00	141.42	21178.00	1.62	2.21	8.86	39.78	51.36
Lake 11 Site 1	37.19	19.05	1.95	18.00	44.89	2015.11	1.85	3.03	16.20	64.96	18.84
Lake 11 Site 2	85.16	50.53	1.69	168.90	101.50	10302.00	2.50	7.96	7.98	48.28	43.74
Lake 11 Site 3	46.56	28.20	1.65	37.97	49.07	2407.52	1.57	2.04	10.50	63.90	25.60
Lake 12 Site 1	79.72	60.31	1.31	168.87	69.57	4840.60	0.66	-0.68	9.75	41.36	48.89
Lake 12 Site 2	108.17	37.32	2.90	203.51	150.42	22625.70	2.14	4.90	18.40	38.90	42.69
Lake 12 Site 3	61.85	45.71	1.35	127.65	53.31	2841.87	0.91	-0.06	4.47	53.96	39.57
Lake 13 Site 1 (Pontoon L)	80.33	50.18	1.60	87.90	96.94	9396.00	2.88	10.65	6.33	51.10	42.57
Lake 13 Site 2 (Pontoon L)	98.55	48.82	2.02	185.40	124.10	15408.00	2.08	4.43	8.41	47.47	44.13
Lake 13 Site 3 (Pontoon L)	68.52	98.06	1.43	153.80	62.10	3857.00	0.96	0.00	7.59	50.37	42.04
Lake 14 Site 1	26.87	17.85	1.51	34.59	28.48	811.21	2.02	5.10	17.36	73.08	9.56
Lake 14 Site 2	44.45	30.00	1.48	41.68	44.69	1996.84	1.48	1.96	12.00	65.68	22.32
Lake 14 Site 3	16.90	7.11	2.38	4.88	24.39	595.08	2.94	2.94	37.48	57.91	4.62
Lake 15 Site 1 (Great Slave)	32.41	21.99	1.47	31.51	35.00	1225.26	2.19	5.58	33.03	54.25	12.73
Lake 15 Site 2 (Great Slave)	36.76	24.43	1.50	37.97	37.48	1404.68	1.65	2.67	31.77	49.99	18.24

Table 2: continued

Site	Mean (µm))	Median (µm))	Mean/Median	Mode	SD	Variance	Skewness	Kurtosis	%Clay (<4µm)	%Silt (<63µm)	%Sand (>63µm)
Lake 15 Site 3 (Great Slave)	54.52	36.78	1.48	37.97	52.80	2787.37	1.44	1.67	8.56	60.51	30.93
Lake 16 Site 1	27.08	22.03	1.23	34.59	24.33	592.14	2.36	8.57	10.21	84.30	5.49
Lake 16 Site 2	36.93	22.19	1.66	45.76	40.26	1620.70	1.70	2.85	15.31	65.56	19.12
Lake 16 Site 3	28.42	11.19	2.54	18.00	39.04	1524.11	1.90	2.90	29.91	55.31	14.78
Lake 17 Site 1	65.68	20.86	3.15	37.97	111.72	12481.00	2.81	8.12	18.24	56.73	25.01
Lake 17 Site 2	88.65	70.09	1.26	96.50	94.58	8946.29	2.26	7.64	13.67	33.21	53.12
Lake 17 Site 3	38.48	15.69	2.45	19.76	74.49	5548.72	4.54	24.92	16.30	70.28	13.42
Lake 18 Site 1	20.53	7.66	2.68	7.08	34.68	1202.63	3.10	10.26	33.73	58.14	8.13
Lake 18 Site 2	21.77	10.75	2.03	11.29	33.05	1092.10	3.22	11.62	22.34	69.86	7.80
Lake 18 Site 3	24.24	12.17	1.99	14.94	32.93	1084.41	2.58	7.17	22.76	68.08	9.16
Lake 19 Site 1	136.58	137.58	0.99	153.83	48.71	2372.98	-0.32	0.21	1.40	4.92	93.68
Lake 19 Site 2	83.57	83.01	1.01	105.93	52.39	2744.23	0.25	-0.67	4.54	32.16	63.30
Lake 19 Site 3	447.78	407.39	1.10	567.76	309.90	96035.30	0.70	-0.07	0.97	5.40	93.63
Lake 19 Site 4	388.96	376.27	1.33	471.14	176.60	31186.30	0.41	-0.08	0.49	1.30	98.08

µm – micron; % - percent; SD – standard deviation

4.2 Organic geochemistry (Rock Eval™ analysis)

Lake sediment samples have, on average, a high TOC content (mean 16.91% ± 11.57 SD, *n*=50; Table 3). The majority of organic carbon in the samples consists of labile, predominantly algal-derived S2 kerogen (mean 56.56 mg HC/g ± 41.81 SD, *n*=50). Residual carbon composes, on average, 9.92 mg HC/g ± 6.78 SD of the TOC of the samples.

Table 3. Organic carbon parameters of sediments collected from lakes in the Yellowknife area

Site	S1 (mg HC/g)	S2 (mg HC/g)	S3 (mg HC/g)	T_{max} (°C)	TOC (%)	RC (%)
Prosperous Site 1	1.06	6.80	4.12	422	2.57	1.71
Prosperous Site 2	0.71	4.43	4.19	419	2.11	1.49
South Tibbitt Site 1	37.06	86.68	33.45	423	22.28	10.60
South Tibbitt Site 2	40.37	110.78	35.87	424	27.79	13.67
Lake 3 Site 1	43.47	112.23	36.86	419	28.25	13.72
Lake 3 Site 2	41.00	119.26	37.70	421	29.16	14.21
Lake 4 Site 1 (Reid Lake)	1.32	4.08	2.41	324	1.23	0.67
Lake 5 Site 1	17.68	89.20	33.14	416	26.40	16.00
Lake 5 Site 2	17.55	84.68	33.37	417	24.17	14.20
Lake 6 Site #1	47.92	77.92	36.65	421	24.27	12.26
Lake 6 Site #2	43.05	109.89	32.78	426	25.84	11.72
Lake 6 Site #3	40.23	110.65	30.47	425	25.77	11.90
Lake 7 Site #1	25.20	113.11	40.50	331	32.89	19.56
Lake 7 Site #2	25.30	104.12	37.97	326	29.44	17.00
Lake 7 Site #3	20.79	109.62	43.38	416	33.58	20.76
Lake 8 Site #1	23.73	117.45	38.50	341	33.11	19.52
Lake 8 Site 2	23.21	116.42	40.92	408	34.58	21.15
Lake 8 Site 3	18.59	106.59	40.50	411	33.39	21.16
Lake 9 dock	9.04	43.13	15.55	421	12.38	7.30
Lake 10 Site 1	1.49	10.98	7.82	421	5.06	3.65
Lake 10 Site 2	0.89	6.22	5.09	417	3.00	2.17
Lake 10 Site 3	3.10	14.96	8.88	407	5.98	4.04
Lake 11 Site 1	16.08	75.58	29.65	420	23.40	14.42
Lake 11 Site 2	18.43	96.69	34.92	421	28.66	17.48
Lake 11 Site 3	21.00	90.06	46.60	326	32.57	21.18
Lake 12 Site 1	7.39	16.91	8.79	310	5.58	3.16
Lake 12 Site 2	12.76	23.47	11.79	297	6.99	3.46
Lake 12 Site 3	37.90	71.61	27.51	327	19.97	9.69
Lake 13 Site 1 (Pontoon L)	17.13	78.55	32.14	329	24.23	14.80
Lake 13 Site 2 (Pontoon L)	15.41	79.19	34.46	420	25.74	16.27
Lake 13 Site 3 (Pontoon L)	16.66	78.50	32.95	417	24.86	15.40
Lake 14 Site 1	1.21	7.76	5.58	410	3.37	2.36
Lake 14 Site 2	7.65	35.36	15.72	329	11.99	7.65
Lake 14 Site 3	4.05	21.61	10.16	416	7.51	4.88
Lake 15 Site 1 (Great Slave)	0.76	3.86	3.36	416	1.70	1.15
Lake 15 Site 2 (Great Slave)	0.17	1.09	1.70	415	0.70	0.51
Lake 15 Site 3 (Great Slave)	0.55	2.45	2.37	412	1.03	0.67
Lake 16 Site 1	10.35	47.40	20.17	421	15.56	9.79
Lake 16 Site 2	7.12	36.27	14.15	424	10.75	6.47
Lake 16 Site 3	13.68	58.02	25.79	324	18.79	11.63
Lake 17 Site 1	16.78	84.14	35.76	416	27.05	17.00
Lake 17 Site 2	12.88	64.30	23.89	423	18.76	11.23
Lake 17 Site 3	13.19	73.27	32.90	419	25.56	16.84
Lake 18 Site 1	6.06	34.88	23.28	318	15.13	10.59
Lake 18 Site 2	2.10	16.45	11.05	422	6.86	4.79
Lake 18 Site 3	12.46	42.33	24.28	316	16.26	10.53
Lake 19 Site 1	1.90	3.60	2.02	316	1.15	0.59
Lake 19 Site 2	5.33	21.36	8.87	420	6.80	4.15
Lake 19 Site 3	0.80	2.65	2.11	311	1.00	0.61
Lake 19 Site 4	0.39	1.41	1.34	302	0.52	0.31

mg/g HC - milligram per gram hydrocarbon; % - percent; TOC – total organic carbon; RC – residual carbon

4.3 Inorganic geochemistry

The inorganic geochemistry results are presented in Table 4 (Appendix) and are compared with the Canadian Council of Ministers of the Environment Interim Sediment Quality Guidelines (ISQG) and Probable Effects Levels (PEL; CCME 2002; Table 5). Arsenic exceeds the ISQG in 78% of samples (*n*=39/50) and in 74% of lakes (*n* =14/19), but exceeds the PEL in only 44% of samples (*n* =22/50) and in 47% of lakes (*n* =9/19). Cadmium exceeds the ISQG in 24% of samples (*n* =12/50) and in 32% of lakes (*n* =6/19), but does not exceed the PEL in any samples. Chromium exceeds the ISQG in 8% of samples (*n* =4/50) and in 21% of lakes (*n* =4/19). Copper exceeds the ISQG in 4% of samples (*n* =2/50) and in 5% of lakes (*n* =1/19). Zinc exceeds the ISQG in 6% of samples (*n* =3/50) and in 11% of lakes (*n* =2/19). Lead does not exceed the ISQG in any samples. Chromium, copper, lead, and zinc do not exceed the PEL in any samples.

Table 5. Comparison of metal concentrations in Yellowknife lake sediment samples with CCME (2002) Interim Sediment Quality Guidelines (ISQG) and Probable Effects Level (PEL) for the Protection of Aquatic Life

Metal	ISQG (mg/kg or µg/g)	Number of samples in exceedance (*n*=50)	Number of lakes with samples in exceedance (*n*=19)	PEL (mg/kg or µg/g)	Number of samples in exceedance (*n*=50)	Number of lakes with samples in exceedance (*n*=19)
Arsenic	5.9	39	14	17	22	9
Cadmium	0.6	12	6	3.5	0	0
Chromium	37.3	4	4	90	0	0
Copper	37.3	2	1	197	0	0
Lead	35	0	0	91.3	0	0
Mercury	0.17	n/a	n/a	0.486	n/a	n/a 0
Zinc	123	3	2	315	0	0

mg/kg – milligram/kilogram; µg/g – microgram/gram; n/a – not applicable

5. DISCUSSION

Arsenic concentrations in the Yellowknife lake sediment samples (mean 27.66 µg/g ± 35.19 SD; median 13.00 µg/g, range <5.00 µg/g to 155.00 µg/g in Lake 16, Site 3; Appendix – Table 4) are broadly comparable to the concentrations found in the regional geology (2-100 µg/g; Boyle, 1960; Ootes et al., 2006), and are therefore expected to exceed CCME (2002) ISQG (5.9 µg/g) and PEL (17 µg/g) due to weathering of bedrock. Arsenic concentrations in Yellowknife lake sediments are also comparable to Canadian averages for this element in uncontaminated soils (4 to 150 µg/g; Wang and Mulligan, 2006) and are within the range of arsenic concentrations in soils in the communities of N'Dilo and Dettah (2.5-900 µg/g; Risklogic, 2002). However, it may not be appropriate to compare lake sediment arsenic concentrations to surface soils or bedrock because complex geochemical processes occur during transport and sedimentation of arsenic in lacustrine systems that can result in sequestration of arsenic from aqueous solution by sorption or precipitation (Murray 1975; Tessier et al. 1996; Andrade et al. 2010). Arsenic concentrations in Yellowknife lake sediments are elevated compared to "background" arsenic concentrations in lake sediments outside of the city of Yellowknife or in known control lakes (5-38 µg/g; Wageman et al., 1978; 115 µg/g Risklogic, 2002) and pre-1947 sediments in Back Bay and Yellowknife Bay, Great Slave Lake (15-25 µg/g; Murdoch et al., 1989; Table 6).

Table 6. Arsenic concentrations in soils and sediments of the Yellowknife area

Impact or Control	Location and substrate	Mean µg/g	Range µg/g	*n*	Date sampled	Source
Control	Regional geology	n/a	2-100	not known	n/a	Boyle 1960; Ootes et al. 2006
	Sediment pre-1947 Back Bay	n/a	20-25	3*	Pre-1947	Murdoch et al. 1989
	Sediment pre-1957 Yellowknife Bay	n/a	15-18	3*	Pre-1947	Murdoch et al. 1989
	Lake sediments outside of Yellowknife (Grace, Likely, Chitty, Indin lakes)	n/a	5-38	not known	1970's	Wagemann et al. 1978
	Soil outside Yellowknife city limit (N'dilo, Dettah)	115	2.5-900	928	1987-2001	Risklogic 2002
Impact	Sediment post-1947 Back Bay	n/a	54-1230	3*	Post-1947	Murdoch et al. 1989
		275.5	2-2550	39	1992-1993	Jackson et al. 1996
		n/a	650-1100	1	2003-2005	Andrade et al. 2010
	Sediment post-1947 Yellowknife Bay	n/a	12-890	3*	Post-1947	Murdoch et al. 1989
	Sediment lakes near Con Mine (Kam and Keg lakes)	n/a	6.3-3500	7	1972-1875	Wageman et al. 1978
	Soil inside Yellowknife city limit	122	3.5-1570	401	1987-2001	Risklogic 2002
	Soil of Con Trailer Court	404	4-4950	70	1987-2001	Risklogic 2002

µg/g – microgram/gram; n/a – not applicable; * - sediment core(s)

The atmospheric emissions of arsenic from the Giant Mine ore roaster resulted in widespread distribution of this element to the surrounding region (CPHA, 1977; Hocking et al., 1978). However, a zone of influence has not been defined. Previous sampling surveys for arsenic have been focused on sites with a known discharge of mine effluent (e.g., Back Bay, Great Slave Lake, Andrade et al., 2010), or areas of human inhabitation (e.g., the Giant Mine Townsite, the Con Mine Trailer Court; Hutchinson et al., 1982; the City of Yellowknife, references summarized in Risklogic, 2002). Thus, it appears that the City of Yellowknife represents a general zone of impact (Risklogic, 2002) but this delineation may be a function of sampling intensity.

This study shows that lake sediment arsenic concentrations tend to be higher in sites located near and west of the city of Yellowknife (Fig. 2) despite the fact that these lakes occur on granitoid bedrock with lower arsenic concentrations relative to the metavolcanics and metasedimentary rocks that underlie the eastern portions of the City of

Yellowknife and lakes east of the city (Boyle, 1960; Ootes et al., 2006). The spatial pattern of arsenic in lake sediment samples is consistent with aerial dispersion of emitted matter from smelting and mining sources and transportation by prevailing winds west of the City of Yellowknife. Climate normals show that predominant wind direction in late spring and summer months (May to September) is from the southeast to the northwest. Alternatively, arsenic may be relatively high in Glacial Lake McConnell sediments that occur to the west of the City of Yellowknife. However, the spatial extent of Glacial Lake McConnell sediments has not been fully mapped, nor are we aware of a detailed geochemical study of them. This, and detailed geochemical analysis of granitoid bedrock west of the City of Yellowknife using modern analytical methods, are areas identified for future research.

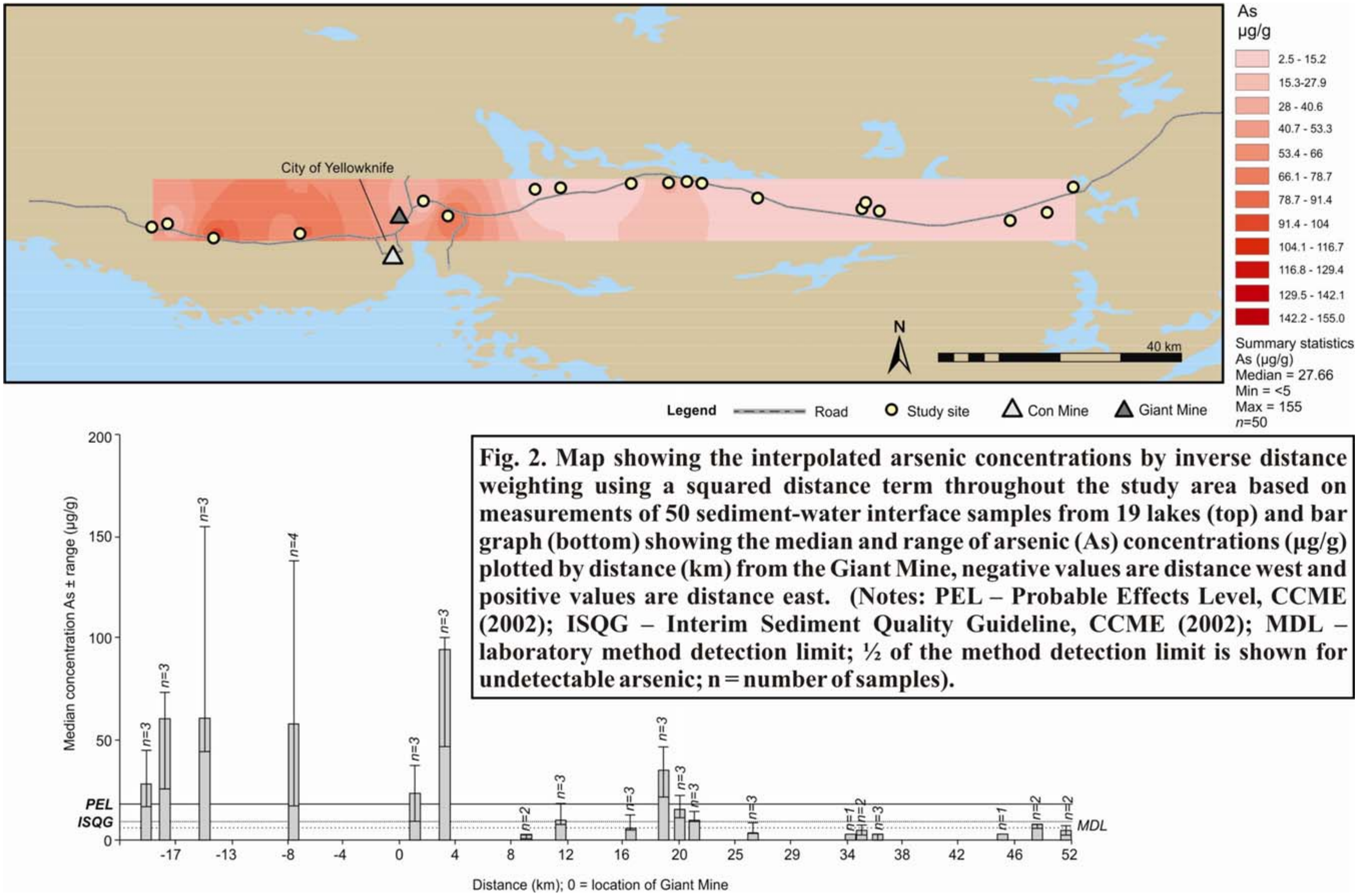

Fig. 2. Map showing the interpolated arsenic concentrations by inverse distance weighting using a squared distance term throughout the study area based on measurements of 50 sediment-water interface samples from 19 lakes (top) and bar graph (bottom) showing the median and range of arsenic (As) concentrations (µg/g) plotted by distance (km) from the Giant Mine, negative values are distance west and positive values are distance east. (Notes: PEL – Probable Effects Level, CCME (2002); ISQG – Interim Sediment Quality Guideline, CCME (2002); MDL – laboratory method detection limit; ½ of the method detection limit is shown for undetectable arsenic; n = number of samples).

6. CONCLUSIONS

Fifty sediment-water interface samples were collected from 19 lakes along an east to west transect, spanning 90 km through the City of Yellowknife. Cadmium, chromium, copper, lead, and zinc are mostly below CCME (2002) ISQG and PEL for sediments of freshwater lakes. Arsenic exceeds ISQG in 39 of 50 samples (in 14 lakes) and exceeds the PEL in 22 samples (in 9 lakes). In lakes west of the City of Yellowknife, arsenic is elevated relative to local bedrock geology and “background” levels defined as concentrations of arsenic in lake sediments outside of the City of Yellowknife and in pre-1947 sediments of Back Bay, Great Slave Lake. The spatial distribution of arsenic along a 90 km east-west transect is consistent with aerial emission from mining activities near the City of Yellowknife and dispersion with prevailing winds. Additional research is required to constrain the source of arsenic in lakes west of Yellowknife.

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APPENDIX

Table 4: Total bulk concentrations of nutrients and major, minor, and trace elements in sediments collected from lakes in the Yellowknife area

Element	**Nitrate**	**Nitrite**	**TP**	**Al**	**Sb**	**As**	**Ba**	**Be**	**Bi**
Unit	µg/g	µg/g	µg/g	µg/g	µg/g	µg/g	µg/g	µg/g	µg/g
MDL	1	1	0.01	10	5	5	1	0.2	5
Reference method	EPA 300.0	EPA 300.0	EPA 365.4	EPA 6010	EPA 6010	EPA 6010	EPA 6010	EPA 6010	EPA 6010
Prosperous Site 1	< 1	1	713	10200	< 5	< 5	115	0.5	< 5
Prosperous Site 2	< 1	5	601	9240	< 5	7	98	0.5	< 5
South of Tibbitt Site 1	< 10	< 10	1040	4970	< 5	7	109	0.3	< 5
South of Tibbitt Site 2	< 10	< 10	1100	4950	< 5	< 5	113	0.3	< 5
Lake 3 Site 1	< 20	< 20	810	2810	< 5	8	95	< 0.2	< 5
Lake 3 Site 2	< 20	30	856	3030	< 5	6	84	< 0.2	< 5
Lake 4 Site 1 (Reid Lake)	< 3	5	465	4230	< 5	< 5	44	< 0.2	< 5
Lake 5 Site 1	< 8	10	856	3270	< 5	< 5	61	< 0.2	< 5
Lake 5 Site 2	< 10	< 10	1100	3800	< 5	7	72	< 0.2	< 5
Lake 6 Site 1	< 40	< 40	1230	4780	< 5	21	81	0.3	< 5
Lake 6 Site 2	< 30	< 30	926	4970	< 5	34	72	0.3	< 5
Lake 6 Site 3	< 20	< 20	852	4800	< 5	46	82	0.3	< 5
Lake 7 Site 1	< 30	< 30	876	3920	< 5	22	70	< 0.2	< 5
Lake 7 Site 2	< 30	30	1270	4030	< 5	15	70	< 0.2	< 5
Lake 7 Site 3	< 10	< 10	760	3470	< 5	11	67	< 0.2	< 5
Lake 8 Site 1	< 10	< 10	887	2900	< 5	< 5	64	< 0.2	< 5
Lake 8 Site 2	< 80	< 80	1170	2850	< 5	< 5	69	< 0.2	< 5
Lake 8 Site 3	< 400	< 400	715	2690	< 5	< 5	61	< 0.2	< 5
Lake 9 dock	< 10	< 10	655	8430	< 5	< 5	112	0.5	< 5
Lake 10 Site 1	< 5	< 5	727	12200	< 5	< 5	186	0.7	< 5
Lake 10 Site 2	< 7	< 7	679	12200	< 5	< 5	199	0.7	< 5
Lake 10 Site 3	< 8	8	868	13000	< 5	6	191	0.7	< 5
Lake 11 Site 1	< 20	40	1080	5570	< 5	14	84	0.3	< 5
Lake 11 Site 2	< 30	< 30	845	4670	< 5	9	71	0.2	< 5
Lake 11 Site 3	< 10	< 10	743	3540	< 5	10	80	< 0.2	< 5
Lake 12 Site 1	< 30	< 30	1410	5070	< 5	10	111	0.3	< 5

Table 4: continued

Element	Nitrate	Nitrite	TP	Al	Sb	As	Ba	Be	Bi
Lake 11 Site 2	< 30	< 30	845	4670	< 5	9	71	0.2	< 5
Lake 11 Site 3	< 10	< 10	743	3540	< 5	10	80	< 0.2	< 5
Lake 12 Site 1	< 30	< 30	1410	5070	< 5	10	111	0.3	< 5
Lake 12 Site 2	< 20	< 20	850	4280	< 5	8	96	0.2	< 5
Lake 12 Site 3	< 60	< 60	1040	6550	< 5	18	152	0.4	< 5
Lake 13 Site 1 (Pontoon L)	1	< 1	547	6730	< 5	6	98	0.3	< 5
Lake 13 Site 2 (Pontoon L)	2	< 1	510	8070	< 5	6	162	0.3	< 5
Lake 13 Site 3 (Pontoon L)	1	< 1	841	5060	< 5	12	87	0.3	< 5
Lake 14 Site 1	< 1	< 1	660	12600	< 5	46	172	0.5	< 5
Lake 14 Site 2	< 1	< 1	937	13600	5	94	189	0.6	< 5
Lake 14 Site 3	< 1	< 1	953	15400	< 5	100	197	0.6	< 5
Lake 15 Site 1 (Great Slave)	< 1	< 1	740	9770	6	36	77	0.4	< 5
Lake 15 Site 2 (Great Slave)	< 1	< 1	535	8130	5	23	68	0.3	< 5
Lake 15 Site 3 (Great Slave)	< 1	< 1	561	7080	< 5	10	55	0.3	< 5
Lake 16 Site 1	1	< 1	714	8870	< 5	60	114	0.4	< 5
Lake 16 Site 2	< 1	< 1	611	15300	< 5	43	191	0.6	< 5
Lake 16 Site 3	< 1	< 1	942	5880	< 5	155	96	0.3	< 5
Lake 17 Site 1	< 1	< 1	768	2790	< 5	44	70	< 0.2	< 5
Lake 17 Site 2	< 1	< 1	628	3610	< 5	28	72	< 0.2	< 5
Lake 17 Site 3	< 1	< 1	606	3780	< 5	16	85	0.2	< 5
Lake 18 Site 1	1	2	752	6940	< 5	25	97	0.3	< 5
Lake 18 Site 2	< 1	< 1	635	15000	< 5	60	159	0.5	< 5
Lake 18 Site 3	2	27	992	6110	< 5	73	89	0.2	< 5
Lake 19 Site 1	1	< 1	297	1660	< 5	23	25	< 0.2	< 5
Lake 19 Site 2	< 1	< 1	556	3790	< 5	138	61	0.3	< 5
Lake 19 Site 3	< 1	< 1	291	2940	< 5	91	39	< 0.2	< 5
Lake 19 Site 4	< 1	< 1	224	1280	< 5	17	11	< 0.2	< 5

µg/g - microgram/gram; MDL - method detection limit; TP - total Phosphorous

Table 4: continued

Element	**Cd**	**Ca**	**Cr**	**Co**	**Cu**	**Fe**	**Pb**	**Mg**	**Mn**	**Mo**
Unit	µg/g	µg/g	µg/g	µg/g	µg/g	µg/g	µg/g	µg/g	µg/g	µg/g
MDL	0.5	10	1	1	1	10	5	10	1	1
Reference method	EPA 6010	EPA 6010	EPA 6010	EPA 6010	EPA 6010	EPA 6010	EPA 6010	EPA 6010	EPA 6010	EPA 6010
Prosperous Site 1	< 0.5	3180	37	10	17	18700	13	6810	232	< 1
Prosperous Site 2	< 0.5	3520	33	13	19	19000	12	6080	547	< 1
South of Tibbitt Site 1	< 0.5	19300	13	8	24	12600	7	3940	429	1
South of Tibbitt Site 2	< 0.5	13000	15	8	21	9240	< 5	4400	299	< 1
Lake 3 Site 1	< 0.5	12200	12	6	26	3580	6	3070	216	1
Lake 3 Site 2	< 0.5	12400	12	5	25	3270	7	3250	194	< 1
Lake 4 Site 1 (Reid Lake)	< 0.5	1570	14	5	7	8090	< 5	2680	192	< 1
Lake 5 Site 1	< 0.5	7970	9	4	15	6090	< 5	3000	136	< 1
Lake 5 Site 2	< 0.5	10600	11	5	18	8820	5	3980	262	1
Lake 6 Site 1	< 0.5	11900	18	6	31	6040	7	4860	208	1
Lake 6 Site 2	0.8	9740	16	5	28	6770	8	3720	165	1
Lake 6 Site 3	0.9	10400	15	6	30	7480	7	3370	175	1
Lake 7 Site 1	< 0.5	11500	12	4	22	4950	< 5	3170	190	< 1
Lake 7 Site 2	< 0.5	10900	12	3	22	4790	< 5	3340	162	< 1
Lake 7 Site 3	< 0.5	14800	12	4	18	6140	< 5	2680	186	< 1
Lake 8 Site 1	< 0.5	11800	9	3	14	5960	< 5	3070	282	< 1
Lake 8 Site 2	< 0.5	13700	9	3	15	4210	< 5	3640	252	< 1
Lake 8 Site 3	< 0.5	12300	8	3	16	4320	< 5	2780	220	< 1
Lake 9 dock	< 0.5	5220	26	7	19	13100	9	4740	503	< 1
Lake 10 Site 1	< 0.5	4670	35	13	26	18800	11	6590	201	< 1
Lake 10 Site 2	< 0.5	4190	37	13	25	22000	11	7500	251	< 1
Lake 10 Site 3	< 0.5	4830	39	11	32	22400	12	8000	224	< 1
Lake 11 Site 1	< 0.5	10500	17	7	34	10300	< 5	3770	141	< 1

Table 4: continued

Element	Cd	Ca	Cr	Co	Cu	Fe	Pb	Mg	Mn	Mo
Lake 11 Site 2	< 0.5	11000	16	6	25	7950	< 5	3260	174	< 1
Lake 11 Site 3	< 0.5	14500	11	5	25	6270	< 5	3330	202	< 1
Lake 12 Site 1	< 0.5	7650	14	5	15	10900	5	4260	471	< 1
Lake 12 Site 2	< 0.5	7280	12	4	12	9050	< 5	3570	192	< 1
Lake 12 Site 3	< 0.5	9910	19	7	21	18400	6	5800	574	1
Lake 13 Site 1 (Pontoon L)	< 0.5	9960	19	6	13	11700	< 5	4470	283	< 1
Lake 13 Site 2 (Pontoon L)	< 0.5	62200	21	6	10	13100	6	6360	503	< 1
Lake 13 Site 3 (Pontoon L)	< 0.5	10100	16	5	15	8690	< 5	3820	284	< 1
Lake 14 Site 1	0.7	3990	36	10	23	22400	9	7410	233	< 1
Lake 14 Site 2	1.3	6500	35	12	29	22900	11	8040	306	1
Lake 14 Site 3	1.4	6230	40	13	29	25600	13	9330	274	1
Lake 15 Site 1 (Great Slave)	< 0.5	2890	30	8	37	18000	10	5900	316	< 1
Lake 15 Site 2 (Great Slave)	< 0.5	2290	26	7	44	14700	9	4890	174	< 1
Lake 15 Site 3 (Great Slave)	< 0.5	2280	23	6	10	13300	7	4310	226	< 1
Lake 16 Site 1	0.8	8120	26	8	18	13200	7	5330	314	< 1
Lake 16 Site 2	< 0.5	5900	42	12	21	21200	10	8690	303	< 1
Lake 16 Site 3	1.8	6960	17	6	15	11500	< 5	4010	387	1
Lake 17 Site 1	0.7	8770	8	4	11	6480	< 5	1910	319	< 1
Lake 17 Site 2	< 0.5	6670	10	4	10	5930	< 5	2300	171	< 1
Lake 17 Site 3	< 0.5	10600	10	4	14	6550	< 5	2680	316	< 1
Lake 18 Site 1	< 0.5	18600	18	6	18	11200	< 5	11600	211	< 1
Lake 18 Site 2	0.7	16100	40	12	24	22400	11	16100	279	< 1
Lake 18 Site 3	1.1	8130	15	5	20	8890	< 5	4760	199	1
Lake 19 Site 1	< 0.5	1070	6	2	4	3900	< 5	1000	68	< 1
Lake 19 Site 2	1.6	3400	19	8	12	13600	< 5	1860	241	5
Lake 19 Site 3	1	1940	10	6	8	11800	< 5	1820	312	2
Lake 19 Site 4	< 0.5	910	4	1	2	3920	< 5	910	71	< 1

μg/g - microgram/gram; MDL - method detection limit; TP - total Phosphorous

Table 4: continued

Element	**P**	**K**	**Si**	**Ag**	**Na**	**Sr**	**Tin**	**Sn**	**W**
Unit	µg/g	µg/g	µg/g	µg/g	µg/g	µg/g	µg/g	µg/g	µg/g
MDL	5	30	1	0.2	20	1	10	1	200
Reference method	EPA 6010	EPA 6010	EPA 6010	EPA 6010	EPA 6010	EPA 6010	EPA 6010	EPA 6010	EPA 6010
Prosperous Site 1	26	2080	127	< 0.2	360	21	< 10	604	< 200
Prosperous Site 2	25	2370	140	< 0.2	320	22	< 10	562	< 200
South of Tibbitt Site 1	72	1320	70	< 0.2	900	64	< 10	120	< 200
South of Tibbitt Site 2	90	1270	279	< 0.2	730	58	< 10	142	< 200
Lake 3 Site 1	53	640	77	< 0.2	420	54	< 10	75	< 200
Lake 3 Site 2	79	730	99	< 0.2	580	54	< 10	80	< 200
Lake 4 Site 1 (Reid Lake)	22	900	82	< 0.2	200	8	< 10	223	< 200
Lake 5 Site 1	30	850	98	< 0.2	520	39	< 10	126	< 200
Lake 5 Site 2	83	1090	71	< 0.2	510	48	< 10	124	< 200
Lake 6 Site 1	101	1590	145	< 0.2	860	48	< 10	143	< 200
Lake 6 Site 2	96	1180	87	< 0.2	580	42	< 10	131	< 200
Lake 6 Site 3	44	940	99	< 0.2	530	44	< 10	112	< 200
Lake 7 Site 1	110	860	93	< 0.2	480	57	< 10	103	< 200
Lake 7 Site 2	194	1060	126	< 0.2	660	52	< 10	107	< 200
Lake 7 Site 3	57	590	138	< 0.2	280	58	< 10	84	< 200
Lake 8 Site 1	100	610	120	< 0.2	400	56	< 10	89	< 200
Lake 8 Site 2	161	810	177	< 0.2	1190	69	< 10	64	< 200
Lake 8 Site 3	47	500	122	< 0.2	1160	56	< 10	70	< 200
Lake 9 dock	35	1860	189	< 0.2	220	29	< 10	422	< 200
Lake 10 Site 1	30	2440	241	< 0.2	520	38	< 10	488	< 200
Lake 10 Site 2	13	3130	263	< 0.2	410	37	< 10	653	< 200
Lake 10 Site 3	45	3570	282	< 0.2	610	44	< 10	598	< 200
Lake 11 Site 1	66	970	133	< 0.2	320	48	< 10	174	< 200

Table 4: continued

Element	P	K	Si	Ag	Na	Sr	Tin	Sn	W
Lake 11 Site 2	55	750	149	< 0.2	230	47	< 10	131	< 200
Lake 11 Site 3	101	660	184	< 0.2	520	66	< 10	79	< 200
Lake 12 Site 1	55	1620	162	< 0.2	990	53	< 10	192	< 200
Lake 12 Site 2	36	1210	153	< 0.2	640	44	< 10	166	< 200
Lake 12 Site 3	56	2760	207	< 0.2	950	63	< 10	293	< 200
Lake 13 Site 1 (Pontoon L)	441	1850	276	< 0.2	1020	28	< 10	380	< 200
Lake 13 Site 2 (Pontoon L)	460	2080	208	< 0.2	560	112	< 10	395	< 200
Lake 13 Site 3 (Pontoon L)	619	1430	224	< 0.2	1800	37	< 10	212	< 200
Lake 14 Site 1	950	2640	263	< 0.2	570	26	< 10	613	< 200
Lake 14 Site 2	829	3400	259	< 0.2	720	44	< 10	596	< 200
Lake 14 Site 3	750	3550	341	< 0.2	550	40	< 10	641	< 200
Lake 15 Site 1 (Great Slave)	671	2200	265	0.2	1200	16	< 10	498	< 200
Lake 15 Site 2 (Great Slave)	487	1520	289	< 0.2	930	12	< 10	442	< 200
Lake 15 Site 3 (Great Slave)	528	1430	328	< 0.2	810	11	< 10	395	< 200
Lake 16 Site 1	541	1850	217	< 0.2	450	39	< 10	406	< 200
Lake 16 Site 2	535	3420	442	< 0.2	330	33	< 10	661	< 200
Lake 16 Site 3	665	1640	163	0.4	540	31	< 10	242	< 200
Lake 17 Site 1	406	550	133	< 0.2	430	42	< 10	111	< 200
Lake 17 Site 2	324	680	177	< 0.2	430	34	< 10	167	< 200
Lake 17 Site 3	349	680	149	< 0.2	470	52	< 10	156	< 200
Lake 18 Site 1	468	1420	154	< 0.2	560	40	< 10	280	< 200
Lake 18 Site 2	595	3430	228	< 0.2	600	35	< 10	652	< 200
Lake 18 Site 3	660	1270	173	< 0.2	530	36	< 10	204	< 200
Lake 19 Site 1	271	140	188	< 0.2	120	3	< 10	67	< 200
Lake 19 Site 2	498	370	175	< 0.2	360	11	< 10	152	< 200
Lake 19 Site 3	411	270	200	< 0.2	950	6	< 10	101	< 200
Lake 19 Site 4	264	90	132	< 0.2	180	2	< 10	56	< 200

µg/g - microgram/gram; MDL - method detection limit; TP - total Phosphorous

Table 4: continued

Element	**V**	**Yt**	**Zn**	**Zi**
Unit	µg/g	µg/g	µg/g	µg/g
MDL	1	0.5	1	0.1
Reference method	EPA 6010	EPA 6010	EPA 6010	EPA 6010
Prosperous Site 1	36	8.3	68	3
Prosperous Site 2	35	8.9	50	1.6
South of Tibbitt Site 1	14	3.9	72	0.7
South of Tibbitt Site 2	14	4.1	75	2.5
Lake 3 Site 1	7	1.8	124	< 0.1
Lake 3 Site 2	7	2.1	131	0.6
Lake 4 Site 1 (Reid Lake)	13	3.4	22	0.7
Lake 5 Site 1	9	2.5	43	2
Lake 5 Site 2	13	2.9	67	1.7
Lake 6 Site 1	15	2.8	88	0.4
Lake 6 Site 2	14	3.1	109	< 0.1
Lake 6 Site 3	13	3.1	95	0.5
Lake 7 Site 1	11	2.3	73	1
Lake 7 Site 2	12	2.3	59	1.1
Lake 7 Site 3	8	2.6	44	2.3
Lake 8 Site 1	7	2.5	36	1.2
Lake 8 Site 2	7	2	48	1.1
Lake 8 Site 3	6	2.4	31	1
Lake 9 dock	21	6.9	45	2.4
Lake 10 Site 1	37	9.6	56	1.8
Lake 10 Site 2	41	10.2	57	6.6
Lake 10 Site 3	42	8.9	69	1.9
Lake 11 Site 1	15	4.1	45	0.4

Table 4: continued

Element	V	Yt	Zn	Zi
Lake 11 Site 2	12	3.7	40	1
Lake 11 Site 3	10	2.7	38	0.2
Lake 12 Site 1	15	3.6	57	3.1
Lake 12 Site 2	12	3.3	40	3.3
Lake 12 Site 3	23	4.7	72	4.3
Lake 13 Site 1 (Pontoon L)	21	4.8	42	3.6
Lake 13 Site 2 (Pontoon L)	23	4.8	36	1.7
Lake 13 Site 3 (Pontoon L)	16	3.3	53	1
Lake 14 Site 1	37	6.8	62	6
Lake 14 Site 2	40	7.6	69	3.9
Lake 14 Site 3	44	8.1	74	5.8
Lake 15 Site 1 (Great Slave)	30	6.9	71	0.7
Lake 15 Site 2 (Great Slave)	26	6.3	51	2.5
Lake 15 Site 3 (Great Slave)	23	5.3	35	1.4
Lake 16 Site 1	24	6.1	69	4.1
Lake 16 Site 2	40	7.8	90	3.6
Lake 16 Site 3	18	4.1	95	2
Lake 17 Site 1	7	2.3	42	1.8
Lake 17 Site 2	9	2.9	42	1.9
Lake 17 Site 3	9	3.6	51	2.3
Lake 18 Site 1	20	5	112	0.7
Lake 18 Site 2	43	7.5	121	3.7
Lake 18 Site 3	18	4.4	215	0.6
Lake 19 Site 1	6	2.6	10	0.3
Lake 19 Site 2	19	6.5	34	2
Lake 19 Site 3	11	3.6	27	0.4
Lake 19 Site 4	5	1.5	11	< 0.1

µg/g - microgram/gram; MDL - method detection limit; TP - total Phosphorous