

## **Part 2 - Other Issues**

*The Review Board identified a number of areas where additional information would be helpful in assessing the likelihood of significant impacts on the environment. The Developer should provide any additional information that is available on the items listed below. The remainder of this section provides the relevant sections of the terms of reference and the Review Board's questions in relation to those sections.*

### **IR Number: 1-2-10**

**Source:** Mackenzie Valley Review Board  
**To:** Tyhee  
**Issue:** Additional Items

### **Terms of Reference**

*The conformity check also revealed these general information gaps not directly associated with line items in the terms of reference.*

### **Request**

- 1) *The Tailings Alternatives Assessment is illegible in key sections of the document. Resubmit this document in the original PDF form or some other legible form.*
- 2) *Tyhee refers to various studies that are currently not available to the Review Board and parties. These are a basis for a number of important assumptions about baseline conditions, and for Tyhee's impact predictions on water quality. These studies, or relevant excerpts of them, should be compiled and submitted.*

### **Tyhee NWT Corp Response**

1) Tyhee submitted a revised format in the form of links to the TAA and the Review Board responded on October 12, 2011 as follows: *"Since the TAA is legible and downloadable it is satisfactory for the purposes of the Review Board's information request IR#1-2-10.1 regarding the TAA".*

2) Based on the October 11, 2011 email from Mr. Paul Mercredi, it became clear that the MVEIRB wanted copies of the specific references used in the regional water quality section of the DAR. These references are:

Puznicki, W.S. 1996. An Overview of Lake Water Quality in the Slave Structural Province, Northwest Territories. Prepared by and available from INAC, Yellowknife.

Pienitz, R., et al. 1997. Physical and Chemical Limnology of 24 lakes located between Yellowknife and Contwoyto Lake, Northwest Territories. This is a publically available Canadian Journal of Fisheries and Aquatic Science paper.

Ruhland, K., et al. 2003. Limnological Characteristics of 56 Lakes in the Central Canadian Arctic Treeline Region. This is a publically available Journal of Limnology publication.

The referenced documents are attached to this response.

**AN OVERVIEW OF LAKE WATER QUALITY IN  
THE SLAVE STRUCTURAL PROVINCE AREA  
NORTHWEST TERRITORIES**

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IN THE SLAVE STRUCTURAL PROVINCE AREA  
NORTHWEST TERRITORIES**

February 1996

Prepared for the Department of Indian and Northern Affairs

By

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## SUMMARY

The Central Arctic Study measured the current lake water chemistry in the Slave Province area of the Northwest Territories, Canada.

The Department of Indian Affairs and Northern Development is committed by the Arctic Environmental Strategy, Action on Water, to develop a better understanding of water quality in the Northwest Territories.

Lake water information in the Slave Province is sparse and limited. Most existing studies are a result of impact assessments for individual developments, especially mines.

The Central Arctic Study was implemented during the 1993 open water season in the area between the north shore of Great Slave Lake (south boundary) and the Coronation Gulf (north boundary), and between Camsell River (west boundary) and Artillery Lake (east boundary). The study provided information to support future studies and enable assessments of any changes caused by current and potential developments. Visual displays of the current water quality conditions in the Slave Structural Province area were made possible through the use of GIS technology. The visual displays permit the portrayal of the distribution of concentration, identification of anomalous areas that occur naturally or as result of impacts, and distinguishing of differences in geology particularly between the Bear and Slave Provinces.

## ACKNOWLEDGMENTS

I would like to thank Mr. Brian Latham, Head of Water Management and Planning, Water Resources Division, Department of Indian and Northern Affairs for giving me the opportunity to conduct this study. His support, guidance and patience throughout the study was well appreciated. I would also like to thank the following groups, organizations and individuals: Juanetta Peddle and Murray Swyripa, DIAND Water Resources, for contract evaluation; Patsy Cross, HBT AGRA Limited; DIAND Water Lab staff, with special thanks to Kathleen Puznicki; Dave Taylor, Helmutt Epp and Norman Mair, GNWT Remote Sensing; Bill Padgham, Valerie Jackson and Pattie Beales, DIAND Geology, special thanks to Valerie for use of her field camp; DIAND Drafting Services; DIAND Yellowknife District; Martin Erving, Energy Mines and Petroleum Resources, map of mineral potential in the Slave Geological Province, Rob Johnstone, for use of his fuel cache; Lou Covello, Covello, Bryan & Associates, for use of Damotti lake Camp; Metall Mining Corporation, for use of their Izok lake camp; Peter Klewchuck, Consolidated Ramrod Gold Corporation, for use of Damotti lake Camp; and field samplers, Sara Bunge, Natasha Thorpe and Scott Wytrychowski.

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# INTRODUCTION

## BACKGROUND

The north is divided into seven distinct geological subdivisions termed "structural provinces". Each is distinct with respect to structural style and orogenic history. The oldest of these structural provinces is the Slave (Figure 1). The Slave Structural Province consists of Archean age rocks and contains numerous gold and volcanic base metal deposits thereby making it very attractive to the mining industry. The recent discovery of significant amounts of diamonds has led to the probability of one or more sites being developed. This area also invites other types of industry and activity such as hydro-electric power and exploration camps. Winter ice roads enable transport of various materials including hazardous chemicals. Such activities might have an impact on the surrounding environment.

The waters in the Slave Province are not only the way of life for the people who reside there but also the key to all life within it. Water quality information in the Slave Province is sparse and limited. Most of the studies in the area are a result of the establishment of individual developments, especially mines. A broad overall look at the current water quality in the Slave Province is required, with emphasis on areas that are devoid of data. The information collected would provide support for future studies and be used to assess any changes caused by current and future potential development within the water basins.

The Department of Indian and Northern Affairs' Arctic Environmental Strategy, Action on Water, is committed to developing a better understanding of water quality in the north. *The Northwest Territories Waters Act*, part of the Department's mandate, is designed to ensure the protection and conservation of N.W.T. water resources for all Canadians, and residents of the N.W.T. in particular. *The DIAND Act*, requires the department to support knowledge of the Canadian north through scientific investigation and technology.

## OBJECTIVES

The objectives of this study are:

- to measure the current lake water quality in the Slave Structure Province area (snap shot) with emphasis on areas that were devoid of data;
- to identify impacted areas;
- to identify anomalous areas (areas of high concentrations) that could support future studies; and



- to illustrate the results graphically using GIS (geographic information system).

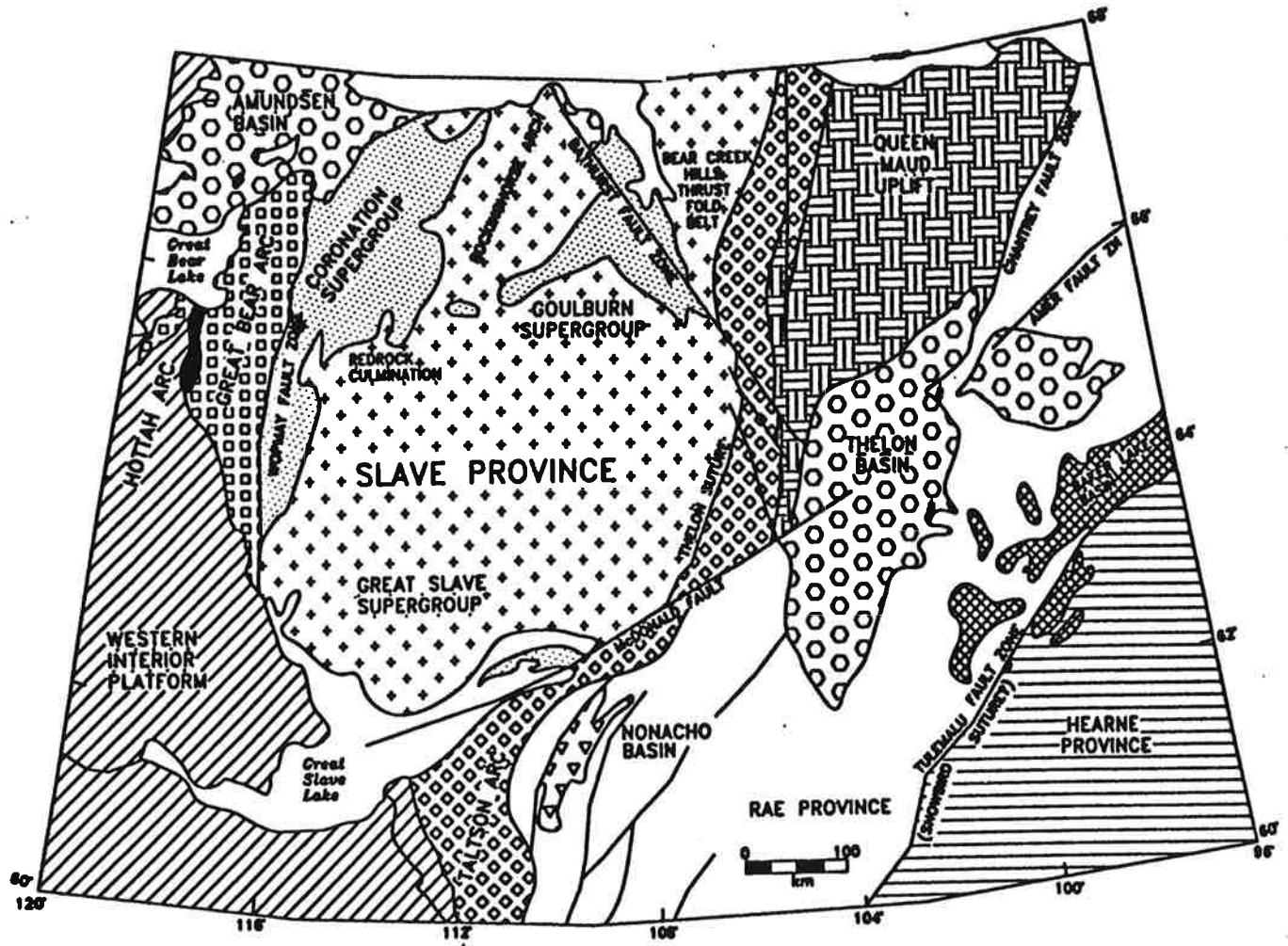


FIGURE 1. SLAVE STRUCTURAL PROVINCE



## STUDY AREA

The study area (Figure 2) includes most of the Slave and Bear Provinces encompassing an area of approximately 275,000 km<sup>2</sup>, and is geographically defined as follows:

The western boundary includes the most westerly part of the north arm of Great Slave Lake northwest along the series of lakes that form the Camsell River system to the east shore of Great Bear Lake near Sawmill Bay (approximately 65°40'N, 118°40'W) then along the east shore to Hornby Bay then northeast to the south west shore of the Coronation Gulf at Richardson Bay (67°55'N, 115°30'W) located slightly west of Coppermine. The north boundary is the south shore of the Coronation Gulf between Richardson Bay and Bathurst Inlet (approximately 67°45' north latitude) . The eastern boundary follows south along the west shore of Bathurst Inlet (66°10'N - 107°05'W) down to Artillery Lake (63°28'N, 107°40'W) including Clinton Colden Lake and then follows along the west shore of Artillery Lake to the Lockhart River and along the Lockhart River to McLeod Bay (62°48'N, 108°55'W) of Great Slave Lake. The south boundary follows along the north shore of Great Slave Lake (62°00') from the eastern edge of McLeod Bay to the most westerly part of the north arm including Marion Lake (63°05'N, 116°20'W).

The study area is divided diagonally from northwest to southeast by the approximate limit of trees known as the tree line, as well as the line of continuous permafrost. The area above the tree line is referred to as the tundra or barrenlands, and the area below the tree line as the taiga or boreal forest. In general, the climate is cold and dry. Most precipitation occurs in the winter in the form of snow. Lakes break-up in early to mid-June and freeze by mid- to late September. These lakes are drained into seven main basins (Figure 3).





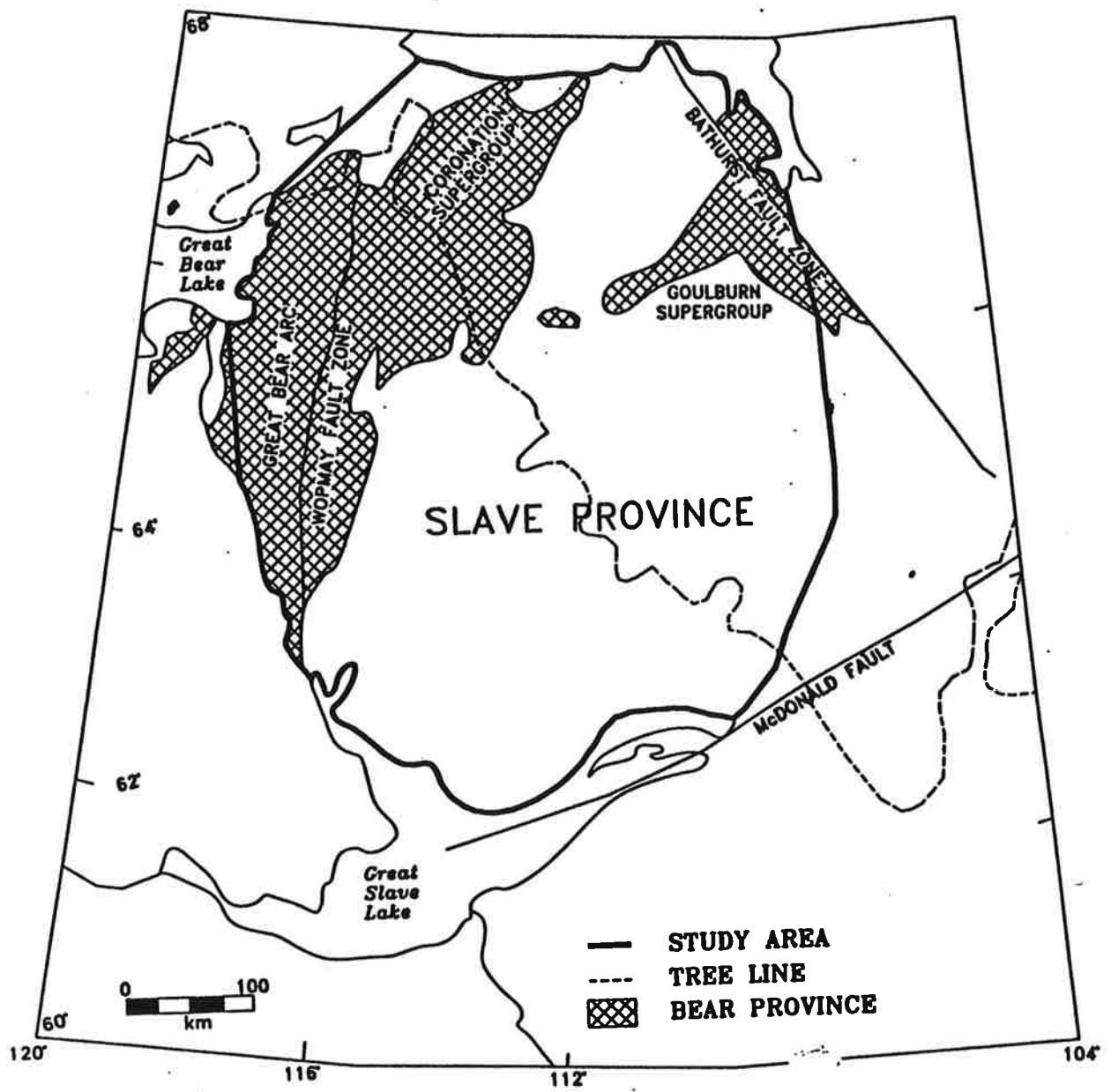


FIGURE 2. STUDY AREA



# METHODOLOGY

## STUDY DESIGN

In 1993 HBT Agra Limited was contracted to identify impacts affecting water quality in the Slave Structural Province and design a baseline water quality sampling program (HBT Agra Limited. 1993. Water Quality in the Slave Structural Province). The study design included sampling locations, sampling methods, parameters and protocols. Due to circumstances beyond control of the study, it was not always practical or feasible to adhere strictly to the all methods outlined in the report.

## LAKE SELECTION

Lakes were selected to ensure thorough coverage and address most concerns within the study area. Selection of lakes involved two processes.

### Development Impact

From a development perspective, mining and recreation are the most active sources of impacts within the study area. Lakes with past, present or future mining developments were selected to fill data gaps within the study area. Some of the larger lakes with existing operational developments such as Contwoyto Lake (ECHO BAY's Lupin Mine) have been excluded from the study since these lakes will have or have undergone extensive water quality programs. However, some lakes in the surrounding area were tested. In terms of recreation, lodges and outfitters provide services for sport hunting, fishing, canoeing, and eco-tours attracting tourist and outdoor enthusiasts alike. Within the study area, recreation is second to mining in terms of impacts.

### Random Selection

To ensure thorough coverage of the study area, lakes were also selected randomly using uniform spacing. Lakes chosen randomly were selected by placing a 25 kilometer spacing grid on the NTS map sheets and selecting the lake closest to the grid points of intersection. The only requirement the lake had to meet was to be large enough to accommodate the takeoff and landing of a Cessna 185 float plane.



## FIELD

### Lake Sampling

All lakes were sampled during the open water season (July - September 1993-94) and as close to the lake centers as possible whenever permissible. However, due to irregularity of some lake shapes, sampling in more than one location within a lake was required. All samples were collected using a three liter horizontal Van Dorne water sampler. The samples were collected at four meter depths to avoid contamination at or near the lake surface such as dust particles, leaves and detritus. At each sampling site, measurements of pH, conductivity, lake depth, and water temperature were recorded. Appendix A, lists the equipment used in the field.

Table 1, lists the suite of samples collected at each sampling site based on the method of selection.

**TABLE 1**

### Sample Suite

Method	Sample Type	Bottle Type
Development Impact	Mining	- Physicals and Major Ions, - Metals, - Nutrients, - Cyanide, - Mercury
	Lodges and Outfitters	- Physicals and Major Ions, - Metals, - Nutrients, - Bacteriological
Random Selection	Random Selection	- Physicals and Major Ions, - Metals, - Nutrients



## **SAMPLE NUMBERING AND LOCATION**

Sample numbering is unique, and descriptive in that it incorporates the project initials, the National Topographical System (NTS) map sheet number (Figure 3), the order in which the site was established and sample type. An example of one sample number is CA85I11DW1-2T. Appendix B, gives a more detailed explanation of interpreting sample numbers.

The rationale for using this type of numbering system is:

- the sample number is the sample location;
- quick and easy reference of sample location ( $\pm 2\text{km}$ ); and
- easy management and analysis of a large number of samples and data points.

At each sampling site, measurements of latitude and longitude were recorded via global positioning system (GPS). The GPS serves three purposes;

- records the exact sample location;
- simplifies navigation to the same sampling location; and
- geographical data points could be displayed utilizing state of the art geographical information system (GIS).

## **QUALITY CONTROL (QC) / QUALITY ASSURANCE (QA)**

To ensure sample integrity, field quality control and quality assurance tests were conducted on a regular basis. All sample bottles were new and certified precleaned to EPA recommended inorganic quality standards. Conductivity and pH measuring devices were calibrated daily. For quality assurance and quality control purposes, field blanks (F), travel blanks (TR), duplicate (D), triplicate (T), vertical variability (V), or horizontal variability (H) samples were also collected. These samples are identified as having an extension to the sample numbers. For example, CA85I11AW1-2T is a Qa/Qc sample and is the second sample of a triplicate.

Field blanks and/or travel blanks, were performed daily and submitted as 10%-15% of the samples. Duplicate or triplicate samples were collected on a daily basis as well as horizontal and vertical variability samples as an additional 10%-15% over and above the field and travel blanks. Appendix C, defines these Qa/Qc samples.

All samples were collected on the upstream or outer side of the pontoons of the float plane to minimize any possibility of contamination.

The three liter horizontal Van Dorne Beta water sampler used in this study was new, and designed specifically for sampling trace metal and trace organic





parameters. The sampler was rinsed with 5% nitric acid and Type I water prior to its use each day.

## LABORATORY

All samples were analyzed at the DIAND Water Laboratory in Yellowknife. Appendix D, lists the methods of analysis. The following parameters were tested for and reported as follows:

Physicals & Major Ions (parts per million - ppm or  $\text{mg}\cdot\text{L}^{-1}$  unless otherwise stated)

pH (pH units), specific conductivity ( $\mu\text{S}\cdot\text{cm}^{-1}$ ), turbidity (NTU - nephelometric turbidity units), colour (TCU - True colour units), filterable residue (total dissolved solids), non filterable residue (suspended solids), calcium, magnesium, total hardness ( $\text{CaCO}_3$ ), total alkalinity ( $\text{CaCO}_3$ ), sodium, potassium, chloride, and sulphate.

Nutrients (parts per million - ppm or  $\text{mg}\cdot\text{L}^{-1}$ )

Ammonia (nitrogen), nitrate and nitrite, total phosphorous, and reactive silica.

Cyanide (parts per million - ppm or  $\text{mg}\cdot\text{L}^{-1}$ )

Total cyanide.

Bacteriological (colony counts per 100 mL -  $\text{counts}\cdot 100\text{ mL}^{-1}$ )

Total coliform, and faecal coliform.

Mercury (parts per billion - ppb or  $\mu\text{g}\cdot\text{L}^{-1}$ )

Total mercury

Metals (parts per billion - ppb or  $\mu\text{g}\cdot\text{L}^{-1}$ )

Aluminum, antimony, arsenic, barium, beryllium, bismuth, cadmium, cerium, cesium, chromium, cobalt, copper, dysprosium, erbium, europium, gadolinium, gallium, germanium, gold, hafnium, holmium, indium, iridium, iron, lanthanum, lead, lutetium, lithium, manganese, molybdenum, neodymium, nickel, niobium, osmium, palladium, platinum, praseodymium, rhenium, rubidium, ruthenium, samarium, scandium, selenium, silver, strontium, tantalum, tellurium, terbium, thallium, thorium, thulium, tin, titanium, tungsten, uranium, vanadium, ytterbium, yttrium, zinc, zirconium.



## DATA HANDLING

This report contains both field and laboratory data collected over a two year period during the open water season. Data collected in the first year were entered into separate spreadsheets according to the category in which the data was received from the laboratory. In the second year of the study, depending on category, the data were either combined with 1993 data or entered as a separate spreadsheet. Bacteriological, mercury and cyanide parameters were not tested for in 1994. Although both field and laboratory data are stored in spreadsheet format, only certain laboratory data (as outlined below) were imported into SPANS MAP. SPANS MAP was then used to generate the maps portraying the elements various levels of concentration.

Field and laboratory data are handled separately and are stored in separate spreadsheet format as follows.

### FIELD DATA

Field data consist of lake depth, sample depth, water temperature, pH and conductivity. In the first year of sampling (1993), the data are stored in a single LOTUS spreadsheet. After the second year of sampling, the field data were combined with the 1993 data to form one large spreadsheet. The combined data were sorted in alphabetical order according to sample identification. These data were collected primarily for field notes purposes and in the case of pH and conductivity, for comparison to laboratory measurements.

### LABORATORY DATA

All laboratory data were received in electronic format to minimize error in data entry. The data were sorted by matching the laboratory identification number with the sample identification number. Due to the large number of samples and parameters tested for, it was impossible to store all data into one spreadsheet. Therefore, separate spreadsheets were generated to categorize the data as it was received from the laboratory. Elements in the metals category were received as analysed using two methods: quantitative and total quantitative. According to the laboratory, quantitative or routine metal data are the more accurate because elements are calibrated against more than one standard. Total quantitative or exotic metals is the least accurate in that these elements are measured against one standard and estimated against others (accuracy  $\pm 20\%$ ). All spreadsheets exist as separate files and are categorized as follows:



- Regular analysis
- QA/QC analysis
- Rerun analysis

## **Regular Analysis**

Regular analysis consists of Routine Analysis, Routine Metals and Exotic Metals.

### Routine Analysis

Routine analysis consists of physical and major ions, bacteriological, nutrients, cyanide and mercury.

### Routine Metals

Routine metals (quantitative) - iron, lithium, beryllium, aluminum, vanadium, chromium, manganese, cobalt, nickel, copper, zinc, selenium, rubidium, strontium, silver, cadmium, indium, cesium, barium, thallium, lead, bismuth and uranium.

### Exotic metals

Exotic metals (total quantitative)- accurate to 20 % - scandium, titanium, gallium, germanium, yttrium, zirconium, niobium, molybdenum, ruthenium, palladium, tin, antimony, tellurium, lanthanum, cerium, praseodymium, neodymium, samarium, europium, gadolinium, terbium, dysprosium, holmium, erbium, thulium, ytterbium, lutetium, hafnium, tantalum, tungsten, rhenium, osmium, iridium, platinum, gold and thorium.

## **QA/QC Analysis**

Qa/Qc samples consists of field blanks, travel blanks, duplicate, triplicate, horizontal and vertical variability samples and are treated as follows:

### Field and Travel Blank Samples

Field (F), and travel (TR) blank data are combined as one spreadsheet. 1994 data are combined with 1993 data in ascending order of sampling dates. These data are not included in the main spreadsheet. No corrections were applied to these data.



### Duplicate and Triplicate Samples

All duplicate (D), and triplicate (T) sample data appear in the main spreadsheets as individual entries. No corrections were applied to these data.

### Horizontal and Vertical Variability Samples

All data collected for horizontal variability (H), and vertical variability (V) samples appear in the main spreadsheets. No corrections were applied to these data.

### **Rerun Analysis**

All rerun data collected consist of sampling sites of 1993 that were revisited in 1994 and tested for the same physical and major ions, nutrients, and metal parameters. Bacteriological samples were not collected in 1994 due to the extended holding time of samples in the field. Mercury and cyanide samples were not collected in 1994 because the levels measured in 1993 were not significant to warrant further testing, considering that these sites (mining development impact), were selected based on the assumption they contained the highest values. Rerun sites were selected randomly and consisted primarily of elevated results in at least one parameter. Also included in this survey were several other sites selected randomly for comparison purposes. The purpose of this survey was to confirm as well as increase the confidence in data generated by the laboratory. The data collected in this survey are not included in the main spreadsheet. The rerun spreadsheet contains the 1994 sample sets paired up with the 1993 sample sets. No corrections were applied to these data.





## RESULTS

Table #2 illustrates the 1993 sampling frequency. The number of sampling days in 1993 totaled 38.

Table #3 illustrates the 1994 sampling frequency. The number of sampling days in 1994 totaled 15.

The data are available on computer diskette from the author.

The data presented on the following pages are grouped according to their major category and presented in the following format:

Maps portraying varying levels of concentration are produced for each detectable element. These maps were produced by importing Lotus and Quattro Pro spreadsheet data into a Spans Universe (georeferenced window) created specifically for this study. The levels of concentration, where applicable, range between detection limits and the Canadian Water Quality Guidelines.

Units of measurement are dependent upon the parameter and method of analysis. Parameters reported as ppm are parts per million ( $\text{mg}\cdot\text{L}^{-1}$ ), those reported as ppb are parts per billion ( $\mu\text{g}\cdot\text{L}^{-1}$ ). For a more thorough description see laboratory section in methodology.



# TABLE 2

1993 SAMPLING FREQUENCY

1993										
Sample Type	Mining		Lodges & Outfitters		Random		Blanks		Total	
	# of lakes	# of sample sets	# of lakes	# of sample sets	# of lakes	# of sample sets	# of lakes	# of sample sets	# of lakes	# of sample sets
SINGLE	27	27	20	20	159	159			206	206
HORIZONTAL					12	35			12	35
VERTICAL	1	3	1	3	46	114			48	120
TRIPLICATE			1	3	23	69			24	72
DUPLICATE			1	2	1	2			2	4
FIELD BLANK								26		26
TRAVEL BLANK								37		37
TOTAL	28	30	23	28	241	379		63	292	500



# TABLE 3

## 1994 SAMPLING FREQUENCY

1994										
Sample Type	Mining		Lodges & Outfitters			Random		Blanks		Total
	# of lakes	# of sample sets	# of lakes	# of sample sets	# of lakes	# of sample sets	# of lakes	# of sample sets	# of lakes	# of sample sets
SINGLE					64	64			64	64
HORIZONTAL					9	29			9	29
VERTICAL					6	18			6	18
TRIPLICATE					3	9			3	9
DUPLICATE										
FIELD BLANK								13		13
TRAVEL BLANK								2		2
RETESTED	6	6	3	3	23	23			32	32
TOTAL	6	6	3	3	105	143		15	114	167



A brief description contains background information, some common minerals in which the elements are found in, major uses, hazards, guidelines and discussions of distribution of each element appears on facing pages. Sources of Information for these descriptions were selected as follows :

## **BACKGROUND**

U.S. Bureau of Mines. 1970.

Clesceri, L.S. et al. 1989.

Weast, Robert C. (Ed.), 1974.

Van Loon, Jon C. (Ed.). 1982.

Fairbridge, R.W. 1972.

## **COMMON MINERALS, MAJOR USES AND HAZARDS**

Fairbridge, R.W. 1972.

U.S. Bureau of Mines. 1970.

## **GUIDELINES**

Health and Welfare Canada. 1989.

Water Quality Branch. Canadian Water Quality Guidelines 1990.





## **PHYSICALS AND MAJOR IONS**

In general, most of the physical parameters and major ions within the study area fall within the Canadian Water Quality Guidelines or are characteristic of most Canadian surface freshwaters. However, specific sites exist where concentration values are somewhat uncharacteristic. Concentration levels tend to be relatively higher in the Bear Province than in Slave Province. More specifically along the Camsell River and the area above the mouth of the North Arm of Great Slave Lake. The anomalous area above the mouth of the North Arm of Great Slave Lake is identified as being impacted by previous mining activity as well as currently operating lodges and outfitters (Acres International Limited, 1993).



## Alkalinity

**Symbol:** None

**Background:** Alkalinity is a quantitative measure of the capacity of water to neutralize a strong acid to a designated pH. The alkalinity of natural waters is attributed primarily to the presence of bicarbonates, carbonates, hydroxides, silicates, borates, and phosphate. Alkalinity is dependent on many variables such as pH, mineral composition, temperature, ionic strength, and the overall buffering capacity of the water. Dissolved gases such as carbon dioxide ( $\text{CO}_2$ ), hydrogen sulphide ( $\text{H}_2\text{S}$ ), and ammonia ( $\text{NH}_3$ ) may affect alkalinity values as well. Alkalinity is reported as hydroxide, carbonate, or bicarbonate alkalinity, depending on certain specific relationships to be determined in making the measurements. According to the Canadian Water Quality Guidelines, the alkalinity for most surface fresh waters is in the range of  $30\text{-}500 \text{ mg}\cdot\text{L}^{-1} \text{ CaCO}_3$ .

<b>Common Minerals:</b>	Bicarbonates	$-\text{HCO}_3^{-1}$	Silicates	$-\text{SiO}_2$
	Carbonates	$-\text{CO}_3^{-1}$	Borates	$-\text{H}_3\text{BO}_3$
	Hydroxides	$-\text{OH}$	Phosphates	$-\text{PO}_4$

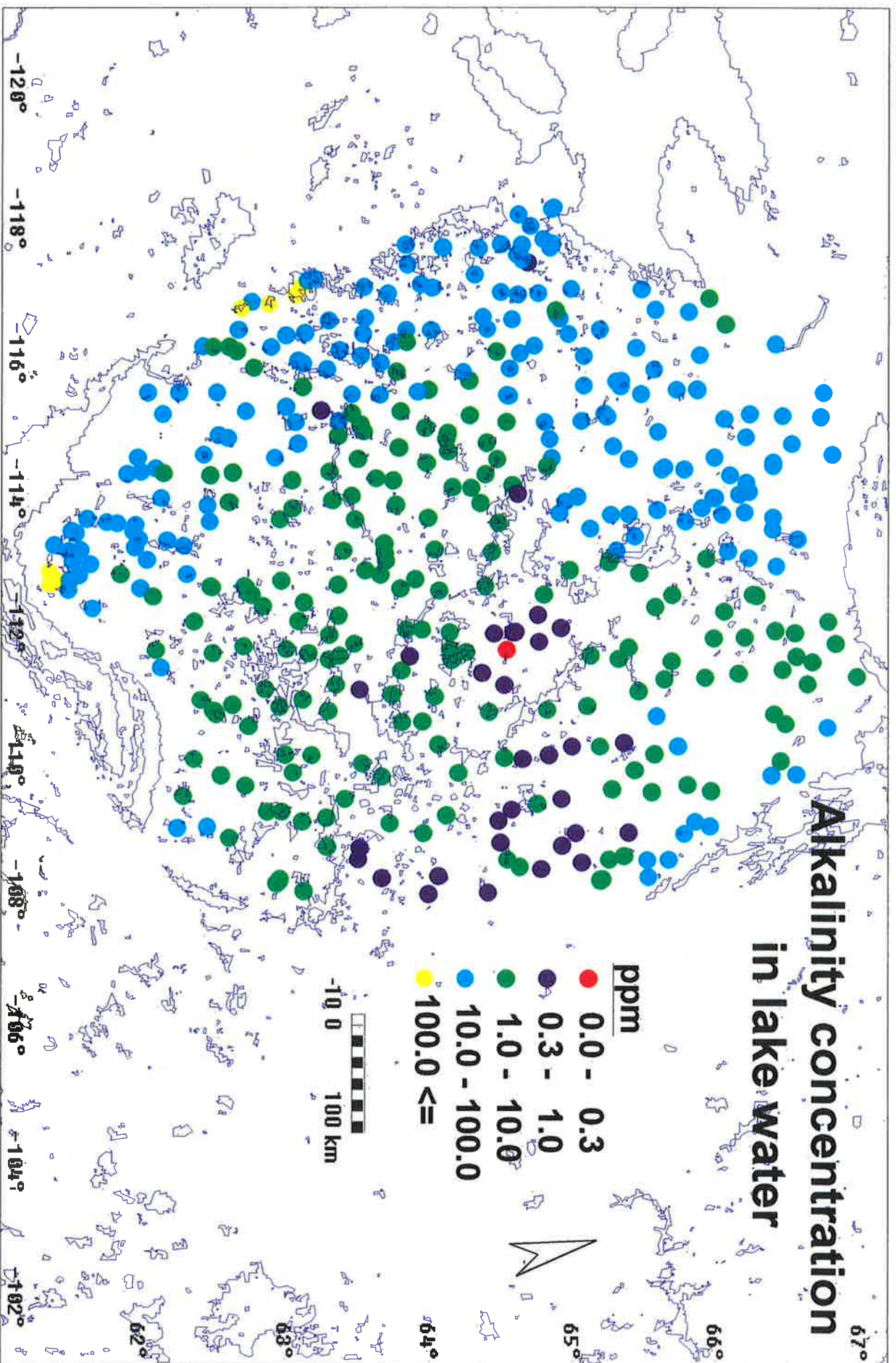
**Major Uses:** Alkalinity is used in determining how a given source of water may be used, too high or too low has undesirable effects.

<b>Hazards:</b>	high alkalinity	-	high mineralization
		-	hard water
		-	gastrointestinal discomfort
	low alkalinity	-	iron pick up (red water)
		-	high acidity
		-	corrosion

**Guidelines:** As of 1994 there were no Canadian Water Quality guidelines specifically for alkalinity. However, guidelines exist for contributing elements such as pH and ammonia.

### **Discussion:**

The maximum measured alkalinity value of  $140 \text{ mg}\cdot\text{L}^{-1}$  is well within the  $30\text{-}500 \text{ mg}\cdot\text{L}^{-1}$  range characteristic of most freshwaters. Elements contributing to alkalinity likely exists as carbonates, more commonly known as limestones and dolomites. These elements are associated mostly with sedimentary type rocks characteristic of the Bear Province. This is in support with higher alkalinity values measured in the Bear Province and along the north shore of Great Slave Lake. High alkalinity values observed in the southern portion of the Slave Province occur in an area identified to contain previous mining activity as well as currently operating lodges and outfitters (Acres International Limited, 1993). In lakes retested, it appears that where alkalinity values decreased, sulfate concentrations increased. Alkalinity values increased in 28 of 32 lakes retested in 1994.



## Calcium

**Symbol:** Ca

**Background:** Calcium is one of the most abundant metals in natural surface and ground waters existing primarily as bicarbonates and, to a lesser degree, as sulphates and chlorides. Dissolved readily from rocks, and leached from soils, it is one of the primary contributors to water hardness. Calcium is an essential nutritional element for animal life and aids in maintaining the structure of plant cells and soils. According to the Chemical Analysis of Inorganic Constituents of Water, the concentration of calcium in natural fresh waters is less than  $10 \text{ mg}\cdot\text{L}^{-1}$ . However, waters in close proximity of carbonate rocks may contain concentrations ranging from 30-100  $\text{mg}\cdot\text{L}^{-1}$ . Maximum limits for drinking water have been considered unnecessary by the department of National Health and Welfare, Canada.

<b>Common minerals:</b>	Calcite	$\text{CaCO}_3$
	Dolomite	$\text{CaMg}(\text{CO}_3)_2$
	Anorthite	$\text{CaAl}_2\text{Si}_2\text{O}_8$
	Fluorite	$\text{CaF}_2$
	Apatite	$\text{Ca}_5(\text{F,Cl,OH,})(\text{PO}_4)_3$
	Calcium Hydroxide	$\text{CaOH}$
	Calcium Chloride	$\text{CaCl}_2$

**Major Uses:** Cement, blast furnaces, steel works, agricultural products, water treatment, paper making, sugar refining, sanitation, and petroleum refining to name a few.

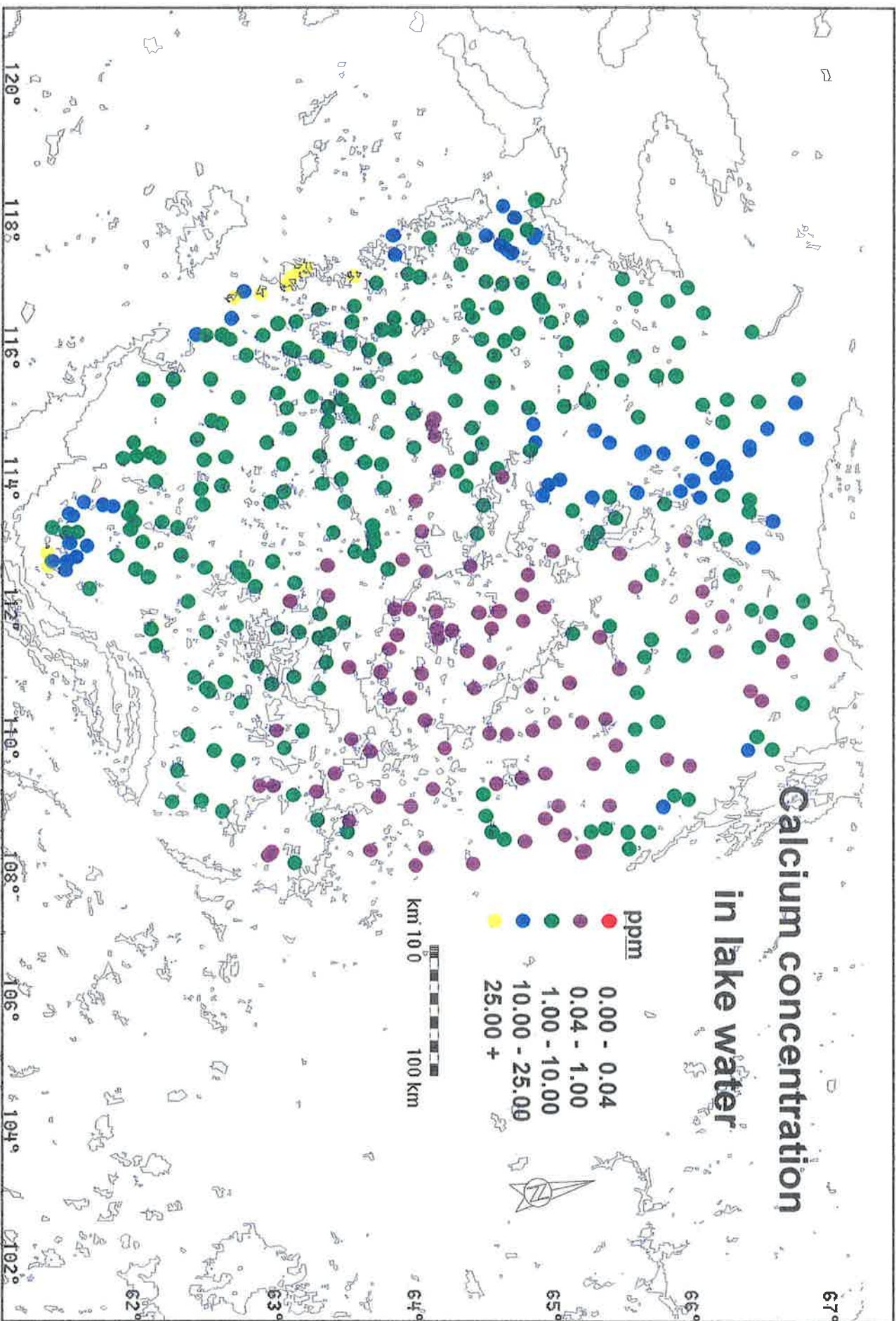
**Hazards:** Most of the hazards associated with calcium result from the dust and noise created from mining and quarrying of calcium ores, primarily limestone.

**Guidelines:** As of 1994 there were no Canadian Water Quality guidelines.

### **Discussion:**

Calcium concentrations in the Slave Province are characteristic of most natural freshwaters, being less than  $10 \text{ mg}\cdot\text{L}^{-1}$  in the absence of carbonate rocks. The anomalous area observed in the southern portion of the Slave Province has been identified to contain previous mining activity as well as currently operating lodges and outfitters (Acres International Limited, 1993). Concentrations observed in the Bear Province are higher than those in the Slave. The presence of sedimentary rocks, particularly limestones and dolomites, are reflected in the relatively higher calcium values. Concentrations were higher in 20 of 32 lakes resampled in 1994. Lower water levels in 1994 may be contributing to this slight increase in concentration. The maximum value measured for calcium is  $36.20 \text{ mg}\cdot\text{L}^{-1}$  from sample # CA85N14CW1- 3H.





## Chloride

**Symbol:** Cl<sup>-</sup>

**Background:** Chloride finds its way into natural surface and ground waters through the weathering and leaching of rocks and soils. The concentration of chloride in natural waters generally bears a strong correlation with the sodium content and specific conductance. Chloride can also be used as an index of pollution from primary sources such as industrial and municipal outlets. According to the Chemical Analysis of Inorganic Constituents of Water, the concentration of chloride of surface waters in humid regions is normally below 10 mg·L<sup>-1</sup>, whereas waters in semi-arid and arid regions may contain up to several hundred mg·L<sup>-1</sup>.

<b>Common Minerals:</b>	Halite (common table salt)	NaCl
	Carnallite	KMg(H <sub>2</sub> O) <sub>6</sub> Cl <sub>3</sub>
	Bischoffite	Mg(H <sub>2</sub> O) <sub>6</sub> Cl <sub>2</sub>
	Cerargyrite	AgCl
	Sal Ammoniac	NH <sub>4</sub> Cl

**Major Uses:** Table salt (NaCl), soda ash, glass, germicides, and numerous inorganic and organic chemicals.

**Hazards:** Chloride by itself is not considered potentially hazardous. However, some of its compounds to some degree are.

**Guidelines:** As outlined in the Canadian Water Quality Guidelines (1990).

### Drinking Water

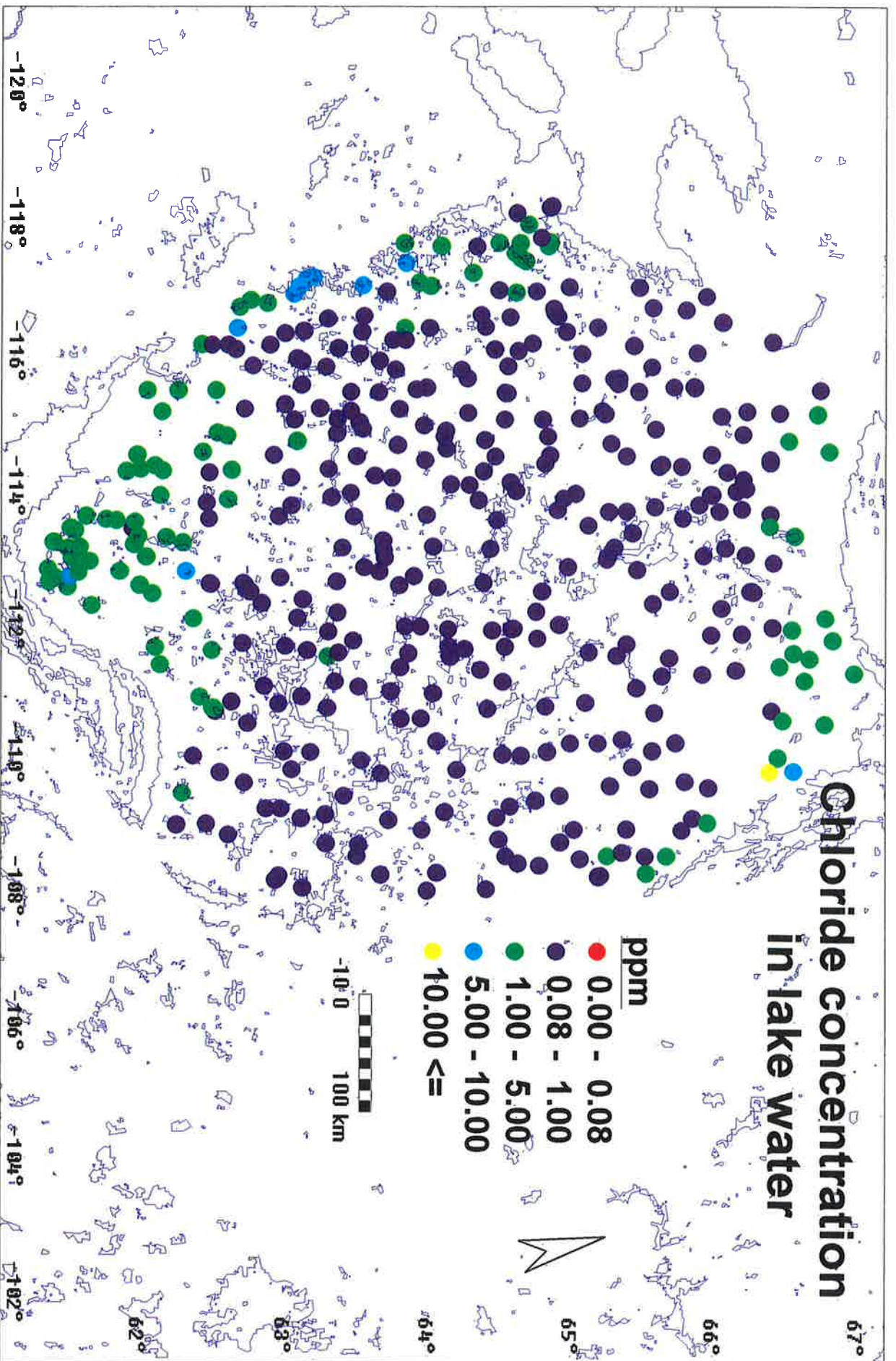
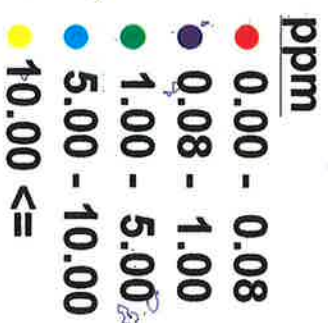
≤ 250 mg·L<sup>-1</sup>

### **Discussion:**

In all but one sample, chloride concentrations are below 10 mg·L<sup>-1</sup>. Sample CA76N2DW1 had a concentration of 62.4 mg·L<sup>-1</sup>. Although blatantly higher, it is still within the drinking water guideline of 250 mg·L<sup>-1</sup>. This sample location, near Bathurst Inlet, is believed to be influenced by saline water. Chloride concentrations are relatively higher in the Bear Province particularly along the Camsell River system. The higher chloride concentrations observed in the southern portion of the Slave Province occur in an area identified to contain previous mining activity as well as currently operating lodges and outfitters (Acres International Limited, 1993). Chloride concentrations were higher in 17 of 32 lakes tested in 1994.



# Chloride concentration in lake water



## Color

**Symbol:** None

**Background:** The color of water results from its optical properties causing changes in the spectral composition of transmitted visible light. Although color may be of natural origin such as from humus or peat materials, it may result from turbidity, inorganic compounds, or from certain classes of organic compounds. Colour is pH dependent. It is also an important factor controlling aquatic plant and animal life. It is possible, to remove or treat some of the undesirable constituents that contribute to the color of water. Color is measured in units known as True Color Units.

**Common Minerals:** Depending on chemical and physical or mechanical properties, practically any rock, mineral, soil, algae, or organic material could potentially contribute to color.

**Major Uses:** Color measurements are useful in assessing water quality. Color may be an indication of occurring pollution or biological processes. The origin or source contributing to the color of water could be an indication of pollution. Color could be an important factor in determining water use.

**Hazards:** None

**Guidelines:** As outlined in the Canadian Water Quality Guidelines (1990).

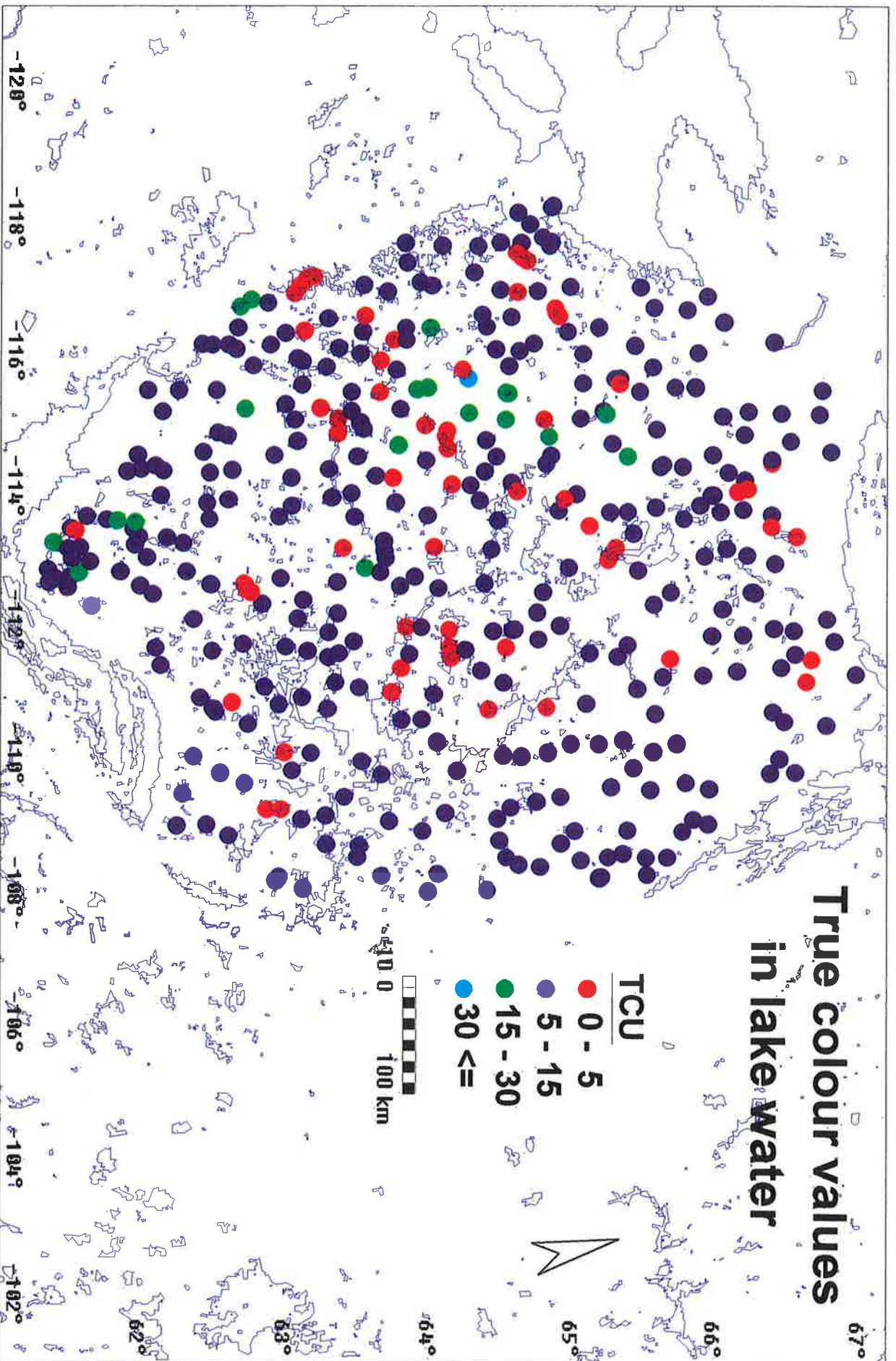
### Drinking Water

≤15 TCU

### **Discussion:**

The Canadian Water Quality Guideline maximum value of 15 TCU for drinking water is equaled or exceeded in 19 of 374 lakes. Of these 19 lakes, most are shallow and located in low swampy areas. These lakes are also recorded in the field notes as being tea stained. These high color values probably result from contact with humic or peat materials. In the case of sample CA85N7CW1, the high color value (25 NTU) is probably attributed to the high turbidity associated with this sample. Depth seems to be the factor for higher color and turbidity values within the study area. Color values were higher in 6 of 32 lakes retested in 1994.





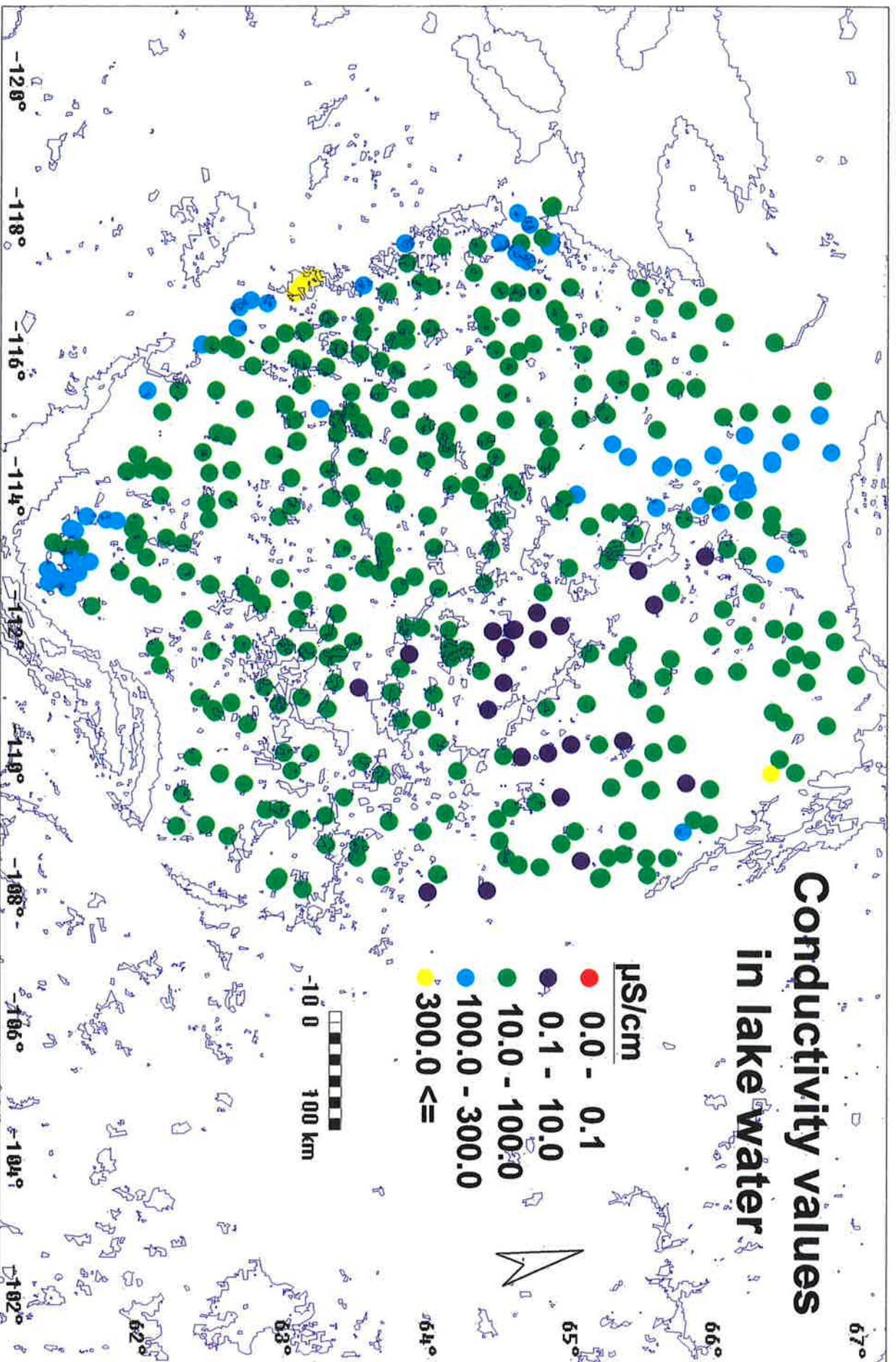
## Specific Conductance

<b>Symbol:</b>	None
<b>Background:</b>	Specific conductance is the ability of a solution to conduct an electrical current by the migration of solute ions and is dependent on the nature and number of the ionic species in that solution. The specific conductance of a sample correlates with the concentration of dissolved minerals or total dissolved solids of the sample. Conductivity is a useful indicator of the degree of mineralization in a sample. The Chemical Analysis of Inorganic Constituents of Water states that the conductivity range for most natural surface waters is between 50 and 1500 $\mu\text{S}\cdot\text{cm}^{-1}$ .
<b>Common Minerals:</b>	Practically all minerals could potentially in some way contribute to the specific conductance of surface waters.
<b>Major Uses:</b>	As an indicator of the degree of mineralization. Conductivity could also be used to determine movement within a given body of water, and corrosion rates.
<b>Hazards:</b>	These depend on the contributing elements and variables.
<b>Guidelines:</b>	Although there are no water quality guidelines specifically for specific conductance, guidelines do exist for associating or contributing elements such as major ions.

### **Discussion:**

Conductivity values are well within the 50 - 1500  $\mu\text{S}\cdot\text{cm}^{-1}$  range characteristic of most natural surface waters. Laboratory measurements were slightly higher than most field measurements. The maximum laboratory measurement of 357  $\mu\text{S}\cdot\text{cm}^{-1}$  from sample site CA76N2DW1 is probably attributed to the presence of sodium and chloride ions. This sample location, near Bathurst Inlet, is believed to be influenced by saline water. Higher conductivity measurements are observed throughout the Bear Province. The area of the Slave Province showing similarly high concentrations are in the area identified as being impacted by previous mining activity as well as currently operating lodges and outfitters (Acres International Limited, 1993). In lakes retested in 1994, conductivity values measured in the laboratory were higher in 28 of 32 lakes compared to 24 of 32 lakes measured in the field.





## Filterable Residue

<b>Symbol:</b>	None
<b>Background:</b>	The physical, chemical, and biological characteristics of water are determined by the types and amounts of particulate matter and dissolved substances present. Filterable residue or total dissolved solids is defined as that portion of the sample that passes through a 0.45 $\mu\text{m}$ glass fibre filter. Filterable residue bears some relationship with turbidity.
<b>Common Minerals:</b>	Sodium salts Potassium salts Calcium salts Magnesium salts as well as, living and dead organic matter, plants, silt, and eroded soil.
<b>Major Uses:</b>	Filterable and non-filterable residue may be used in determining suitability of a water body and /or if treatment is required.
<b>Hazards:</b>	Suspended solids may act as carriers of toxic chemicals including heavy metals and trace organics. High suspended solids render water aesthetically unsatisfactory for recreational uses and causes serious problems if used for certain domestic and industrial purposes.
<b>Guidelines:</b>	As outlined in the Canadian Water Quality Guidelines (1990).

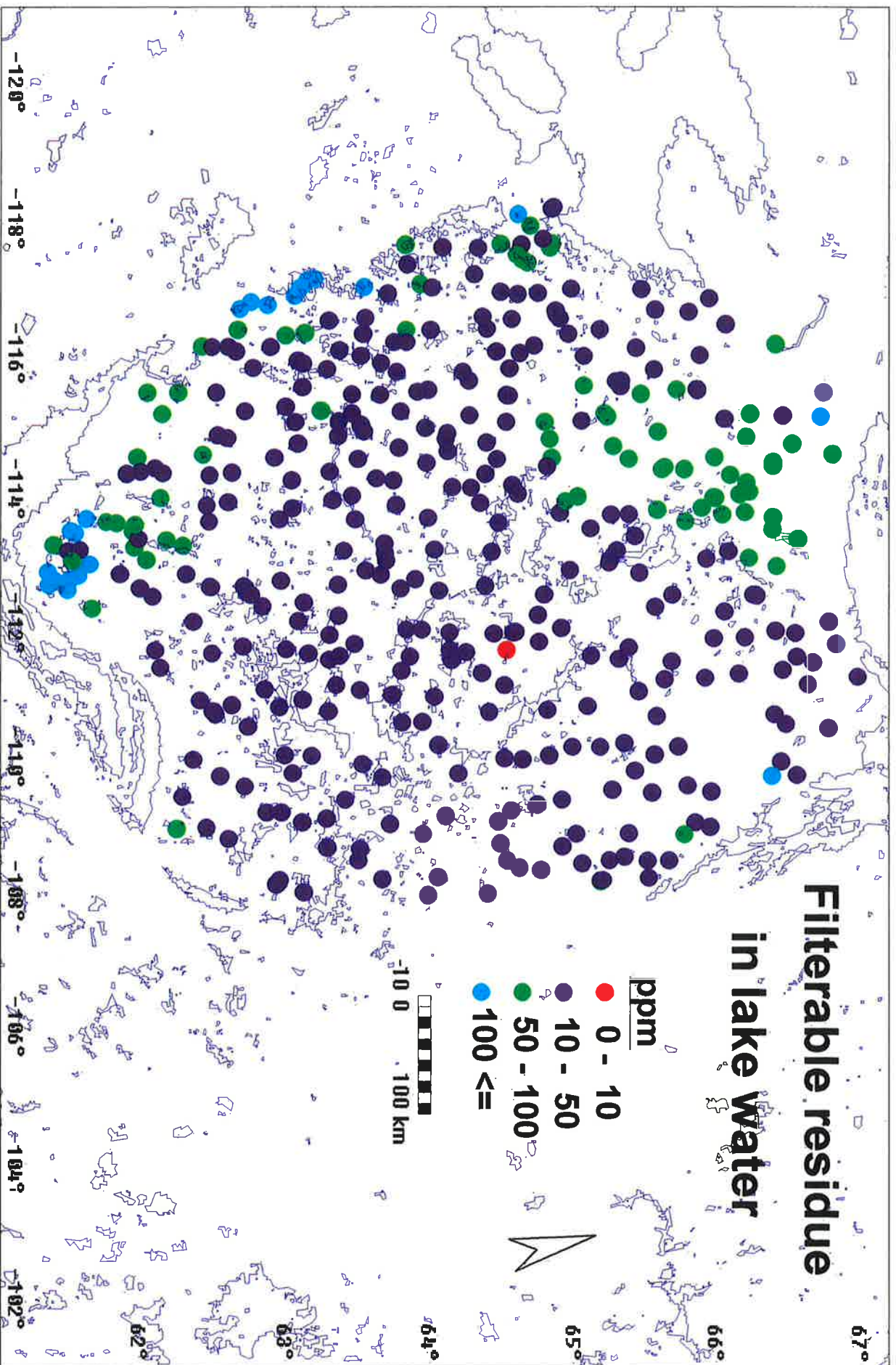
### Drinking Water

$\leq 500 \text{ mg}\cdot\text{L}^{-1}$

### **Discussion:**

All values measured for filterable residue are within the Canadian Drinking Water Quality Guidelines of  $\leq 500 \text{ mg}\cdot\text{L}^{-1}$ . The highest concentration was  $201 \text{ mg}\cdot\text{L}^{-1}$  from sample CA85N14AW2-2H. Relatively higher concentration are observed in the Bear Province. These high values are attributed to dissolved salts particularly calcium, magnesium and sodium. The presence of these parameters also reflect on other parameters such as conductivity, alkalinity, hardness and pH. Filterable residue were higher in 23 of 32 lakes retested in 1994.





## **Non Filterable Residue**

<b>Symbol:</b>	None
<b>Background:</b>	The physical, chemical, and biological characteristics of water are determined by the types and amounts of particulate matter and dissolved substances present. Non filterable residue (suspended solids) are the particles that do not pass through a 0.45 $\mu\text{m}$ glass fibre filter.
<b>Common Minerals:</b>	Sodium salts Potassium salts Calcium salts Magnesium salts as well as, living and dead organic matter, plants, silt, and eroded soil.
<b>Major Uses:</b>	Filterable and non-filterable residue may be used in determining suitability of a water body and /or if treatment is required.
<b>Hazards:</b>	Suspended solids may act as carriers of toxic chemicals including heavy metals and trace organics. High suspended solids render water aesthetically unsatisfactory for recreational uses and causes serious problems if used for certain domestic and industrial purposes.
<b>Guidelines:</b>	As outlined in the Canadian Water Quality Guidelines (1990).

### **Freshwater Aquatic Life**

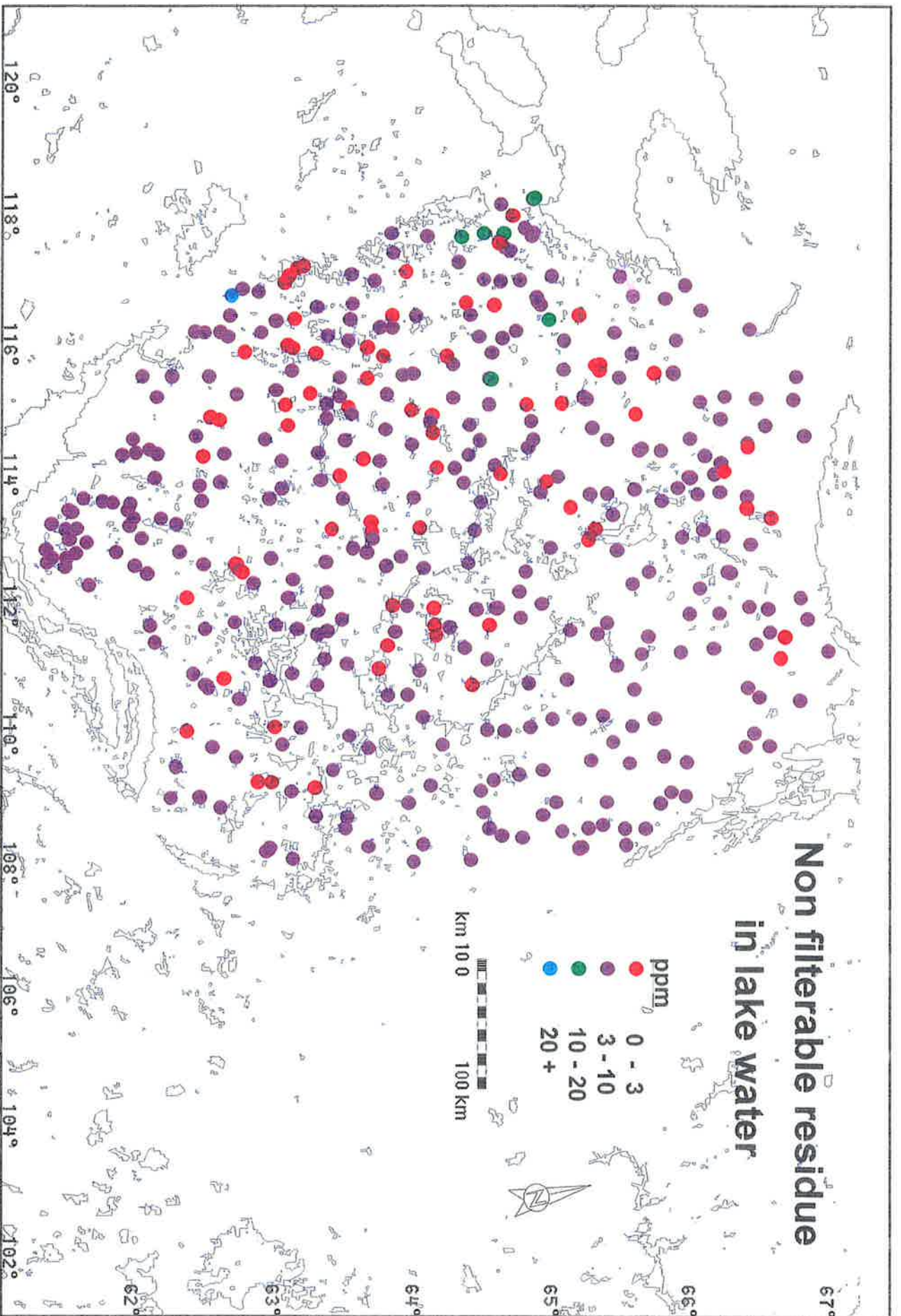
$\leq 10 \text{ mg}\cdot\text{L}^{-1}$  when background concentrations are  $\leq 100 \text{ mg}\cdot\text{L}^{-1}$ .

10% of background concentrations when background concentrations are  $> 100 \text{ mg}\cdot\text{L}^{-1}$ .

### **Discussion:**

Eight of the measured values of non filterable residue are greater than  $10 \text{ mg}\cdot\text{L}^{-1}$ . Sample CA85N7CW1 exceeds  $20 \text{ mg}\cdot\text{L}^{-1}$  with a value of  $47 \text{ mg}\cdot\text{L}^{-1}$ . This high value is probably attributed to calcium and magnesium salts which also tested relatively higher. This is also reflected in turbidity, colour, filterable residue, water hardness, conductivity and alkalinity. Non filterable residue values are higher in the Bear province specifically near Great Bear Lake. Non filterable residue values were lower in 30 of 32 lakes tested in 1994.





## Total Hardness

**Symbol:** None

**Background:** Water hardness is attributed primarily by the presence of dissolved calcium and magnesium salts. Although these salts are found in the form of bicarbonates, sulphates and, to a lesser extent, chlorides and nitrates. Hardness is expressed as an equivalent of calcium carbonate. Water in areas of carbonate bedrock are generally hard, while waters draining igneous rocks are relatively soft. Very soft water has an approximate hardness range between 0 and 30 mg·L<sup>-1</sup> CaCO<sub>3</sub>, soft water between 31 and 60, moderately hard between 61 and 120, hard water between 121 and 180, over 180 mg·L<sup>-1</sup> CaCO<sub>3</sub> is considered very hard water.

**Common Minerals:**

Aluminum Silicates	
Calcium carbonate (limestone)	CaCO <sub>3</sub>
Calcium, magnesium carbonate (dolomite)	CaMg(CO <sub>3</sub> ) <sub>2</sub>

**Major Uses:** Hardness is useful in assessing water quality. It is useful in determining suitability of water source or if treatment is required.

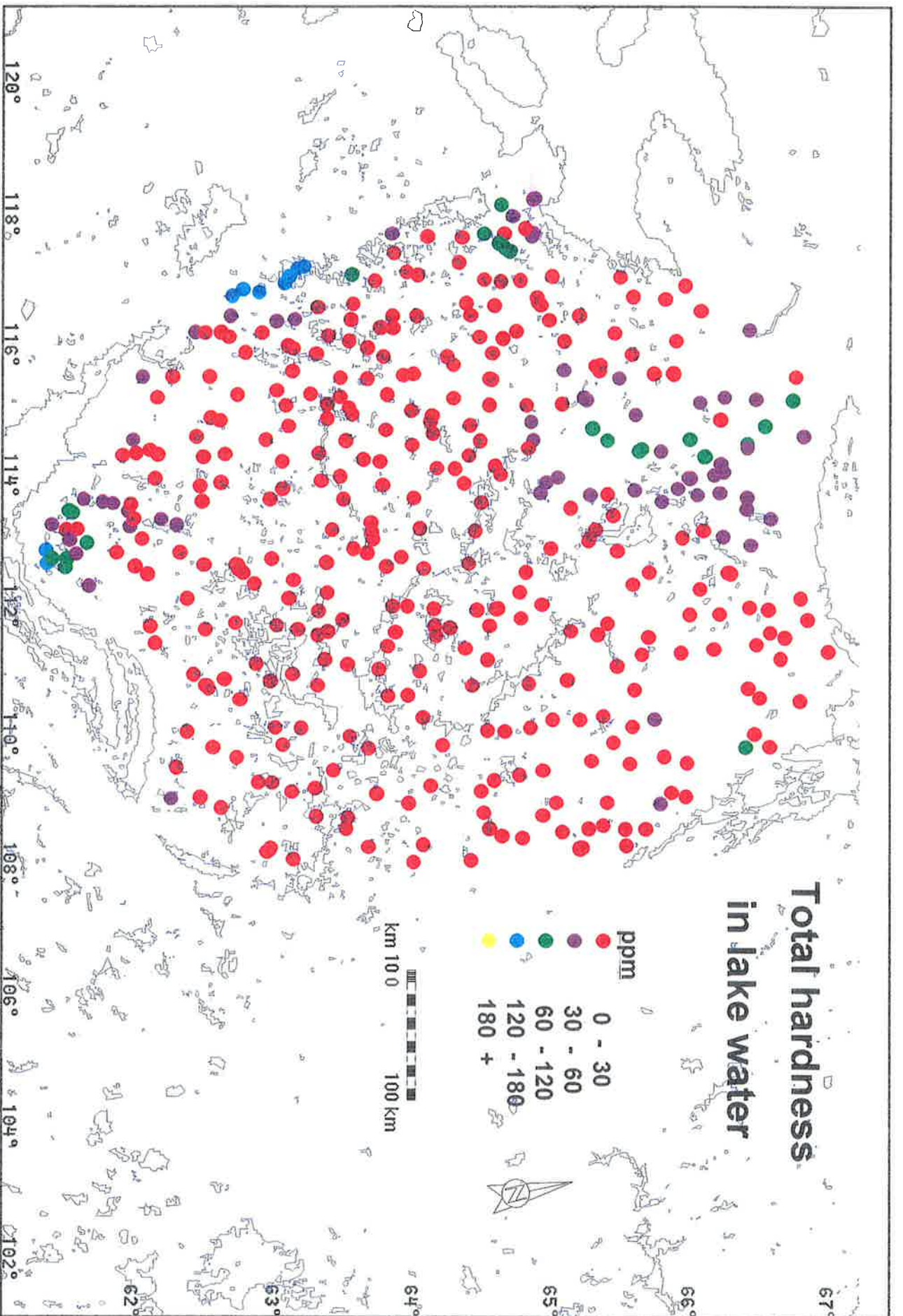
**Hazards:**

Hard water	-	forms scale deposits
	-	influence the toxicity of numerous heavy metals.
Soft water	-	corrosive to water pipes

**Guidelines:** A hardness of 120 mg·L<sup>-1</sup> CaCO<sub>3</sub> or less is considered satisfactory for most domestic, agricultural, and industrial uses.

### **Discussion:**

In 11 of 374 lakes tested, water hardness ranged between 120 -180 mg·L<sup>-1</sup> considered satisfactory for most domestic, agricultural and domestic uses. Most of the moderately hard and hard waters are located in the Bear Province, while the softer waters are in the Slave. This holds true for the general geology of the area. Hardness values increased slightly in 20 of 32 lakes retested in 1994. In all but three lakes the increase was due primarily to the presence of calcium. The increase may also be attributed to lower water levels. The maximum value for hardness was 179 mg·L<sup>-1</sup> for sample CA85N10BW1 probably due to the presence of magnesium.



## Potassium

**Symbol:** K

**Background:** Potassium is the seventh most abundant element of the earth's crust constituting 2.5%. However, due to reconstitution into insoluble secondary minerals formed in the process of weathering, most natural waters contain low concentrations. Potassium enters surface waters through weathering and leaching of feldspars, micas, clay minerals, potassium-bearing soils, industrial discharges, and agricultural run-offs. Potassium is an essential nutritive element for both plant and animal life. According to the Canadian Water Quality Guidelines, the concentration of potassium in natural surface waters is generally below  $10 \text{ mg}\cdot\text{L}^{-1}$ .

**Common Minerals:**

Feldspars  $XZ_4O_8$   
where  $X = \text{Ba, Ca, K, Na, NH}_4, \text{Sr}$   
 $Z = \text{Al, B, Si}$

Micas  $XY_{2-3}Z_4O_{10}(\text{OH},\text{F})_2$  or  $XY_3\text{Si}_4\text{O}_{12}$   
where  $X = \text{Ba, Ca, Cs}(\text{H}_3\text{O})\text{K, Na, (NH}_4)$   
 $Y = \text{Al, Cr}^{+3}, \text{Fe}^{+2}, \text{Fe}^{+3}, \text{Li, Mg, Mn}^{+2}, \text{Mn}^{+3}, \text{V}^{+3}, \text{Zn}$   
 $Z = \text{Al, Be, Fe}^{+3}, \text{Si}$

Clay minerals

**Major Uses:** Fertilizers, dyes, drugs, detergents, soap, glass, and analytical reagents.

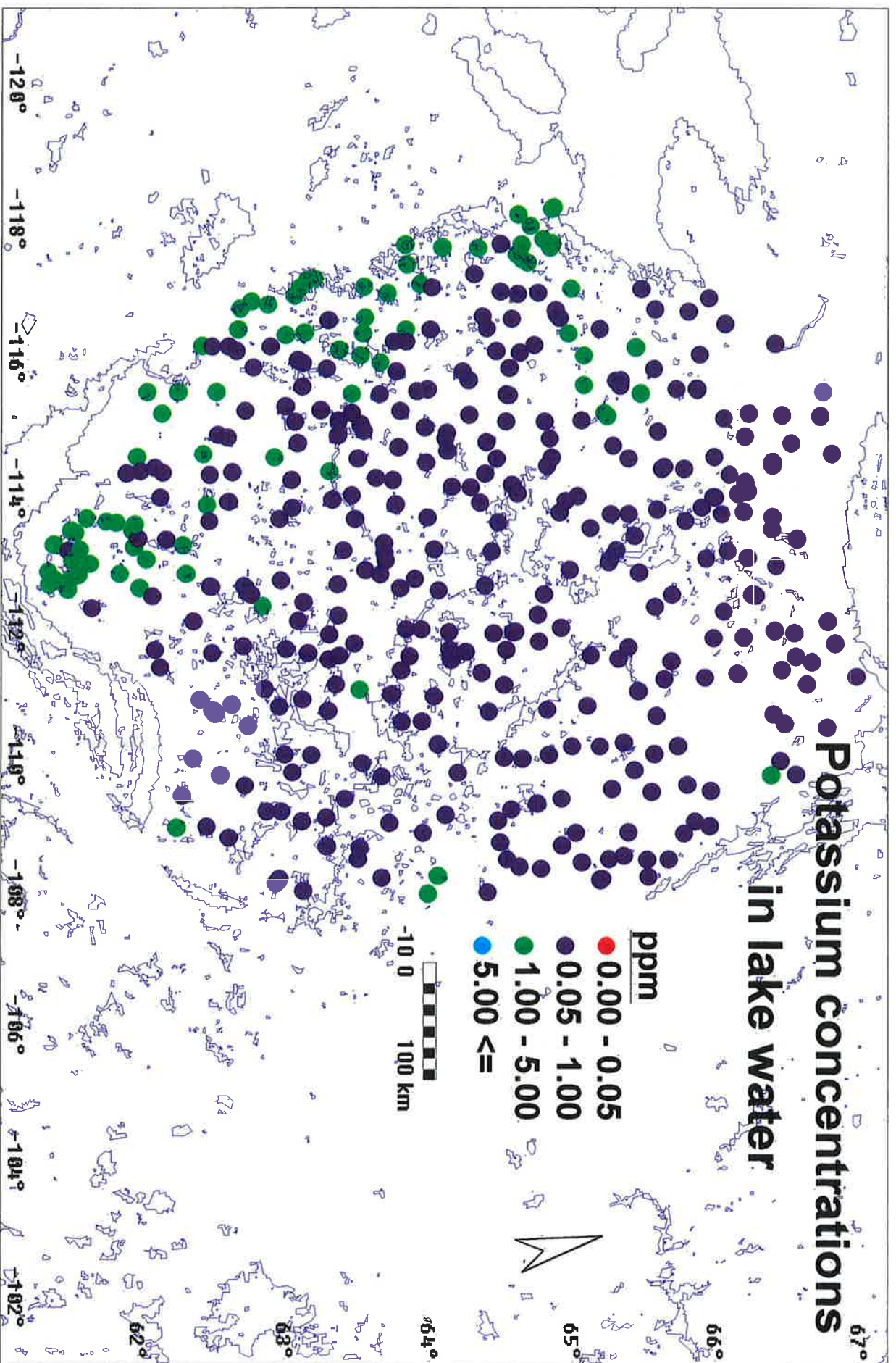
**Hazards:** Refining of potassium requires large tailing disposal areas. These tailings consist largely of sodium chloride salt. Areas covered with this waste are incapable of supporting any plant life.

**Guidelines:** As of 1994 there were no Canadian water quality guidelines.

**Discussion:**

Potassium concentrations are characteristic of most natural surface freshwaters measuring less than  $10 \text{ mg}\cdot\text{L}^{-1}$  with most values being less than  $1 \text{ mg}\cdot\text{L}^{-1}$ . Concentrations are higher in the Bear Province than in the Slave Province. In lakes retested in 1994, potassium concentrations were higher in 17 of 32 lakes. It appears that where potassium concentrations decrease reactive silica concentrations increase and vice versa. Potassium is also a nutritive element and appears to be affected by the presence or lack of nutrients.





## Magnesium

**Symbol:** Mg

**Background:** Magnesium is a common constituent of natural water second only to calcium in contributing to water hardness. Magnesium enters a water system primarily through the dissolution of ferromagnesium minerals from igneous rocks and dolomitic sedimentary rocks. Because magnesium salts are highly soluble, the metal tends to stay in solution. According to the Canadian Water Quality Guidelines, the concentration of magnesium in most surface fresh waters ranges between 1-100 mg·L<sup>-1</sup>.

<b>Common Minerals:</b>	Brucite	Mg(OH) <sub>2</sub>
	Magnesite	MgCO <sub>3</sub>
	Serpentine	H <sub>4</sub> Mg <sub>3</sub> Si <sub>2</sub> O <sub>9</sub>
	Enstatite	MgSiO <sub>3</sub>
	Olivine	(Mg,Fe) <sub>2</sub> SiO <sub>4</sub>
	Kieserite	MgSO <sub>4</sub> ·H <sub>2</sub> O
	Dolomite	CaCO <sub>3</sub> ·MgCO <sub>3</sub>

**Major Uses:** Iron and steel industry, soil conditioner, aggregate in concrete, rayon, fertilizer, insulation, pulp and paper processing, uranium processing, rubber, chemicals, glass, ink and pharmaceuticals. Magnesium is essential for human life.

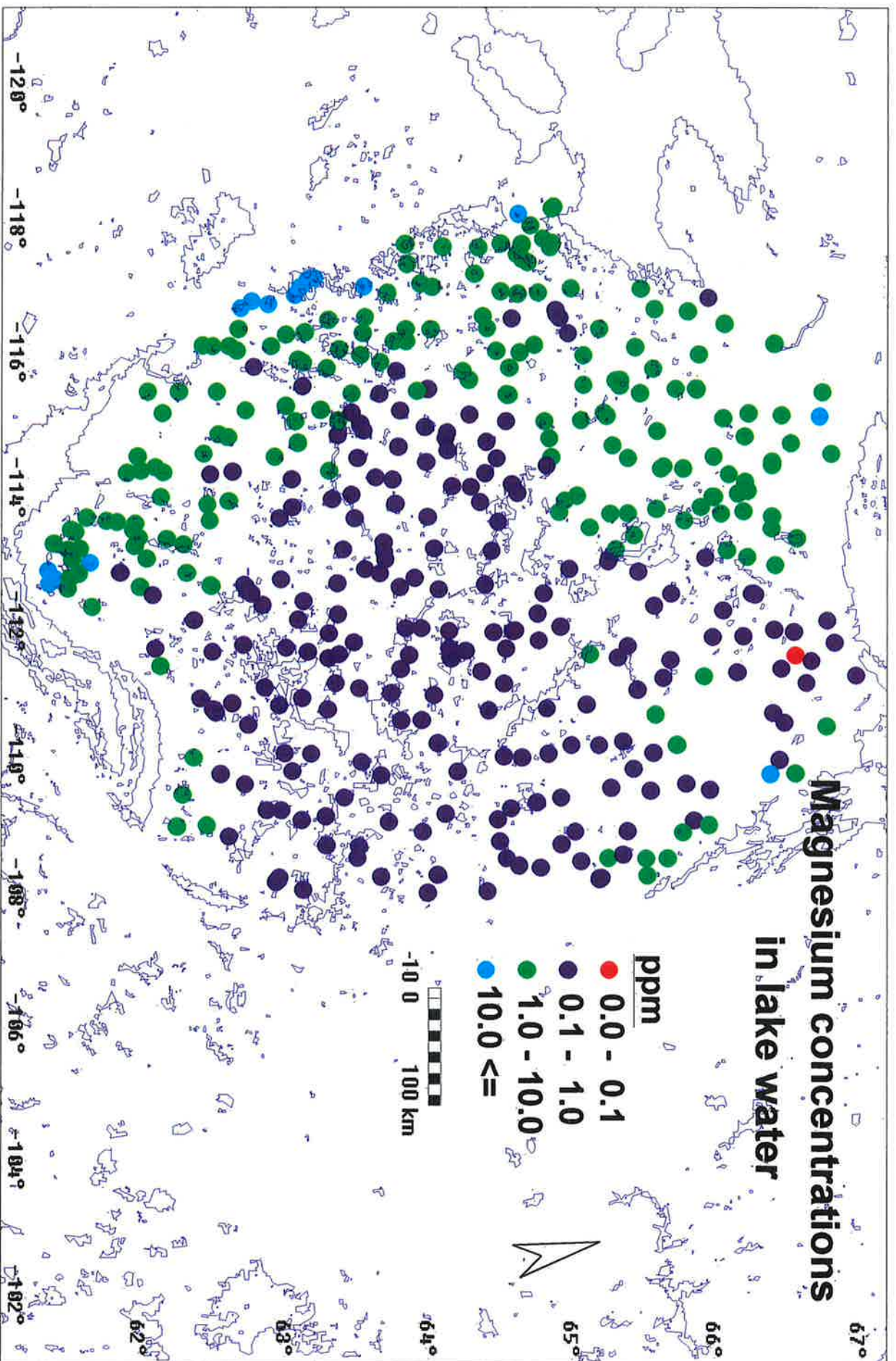
**Hazards:** In general, there are no major concern with regard to public health or the aquatic environment. However, magnesium imparts an unpleasant bitterish taste to water when present in large concentrations.

**Guidelines:** As of 1994 there were no Canadian water quality guidelines.

### **Discussion:**

Magnesium concentrations are within the 1-100 mg·L<sup>-1</sup> range characteristic for most surface freshwaters. Concentrations being lower than calcium concentrations are typical of most natural waters. Concentrations are higher in the Bear Province particularly along the Camsell River. The relatively high concentrations observed in the southern portion of the Slave Province occur in an area identified to contain previous mining activity as well as currently operating lodges and outfitters (Acres International Limited, 1993). Concentrations were higher in 11 of 32 lakes retested in 1994. It is uncertain whether low water levels in 1994 had any affect on magnesium concentrations. The maximum magnesium concentration measured was 34.40 mg·L<sup>-1</sup> from sample number CA85N10BW1. The distribution pattern appears to reflect the geology of the study area.





## Sodium

**Symbol:** Na

**Background:** Practically all sodium compounds are water-soluble making it present in all natural waters. Sodium finds its way into aquatic environment through the weathering of natural sources such as igneous rocks, clay minerals, feldspars, and halite (common table salt) as well as run-off from salted roads. Typically, highly mineralized water usually contains high concentrations of sodium. Sodium is frequently associated with calcium in silicate minerals rather than other alkali elements. According to the Canadian Water Quality Guidelines the mean concentration of sodium for North American river waters is estimated at  $9 \text{ mg}\cdot\text{L}^{-1}$ . Water containing up to about  $1000 \text{ mg}\cdot\text{L}^{-1}$  may generally be physiologically tolerable.

<b>Common Minerals:</b>	Halite	NaCl
	Villaumite	NaF
	Cryolite	$\text{Na}_3\text{AlF}_6$
	Natron	$\text{Na}_2\text{CO}_3\cdot 10\text{H}_2\text{O}$
	Trona	$\text{Na}_2\text{CO}_3\cdot\text{NaHCO}_3\cdot 2\text{H}_2\text{O}$
	Gay-Lussite	$\text{CaCO}_3\cdot\text{Na}_2\text{CO}_3\cdot 5\text{H}_2\text{O}$
	Anorthoclase	$(\text{Na},\text{K})\text{AlSi}_3\text{O}_8$
	Plagioclase group	$\text{NaAlSi}_3\text{O}_8$ to $\text{CaAl}_2\text{Si}_2\text{O}_8$

**Major Uses:** Pulp and paper industry, de-icer for roads, chemicals, water softener, food, glass, soap and detergents, and rayon to name a few.

**Hazards:** Sodium contributes to corrosion and incrustation in pipes as well as adversely affecting soil structure and permeability. Excessive amounts of sodium in drinking water would affect mainly the taste of the water.

**Guidelines:** As outlined in the Canadian Water Quality Guidelines (1990).

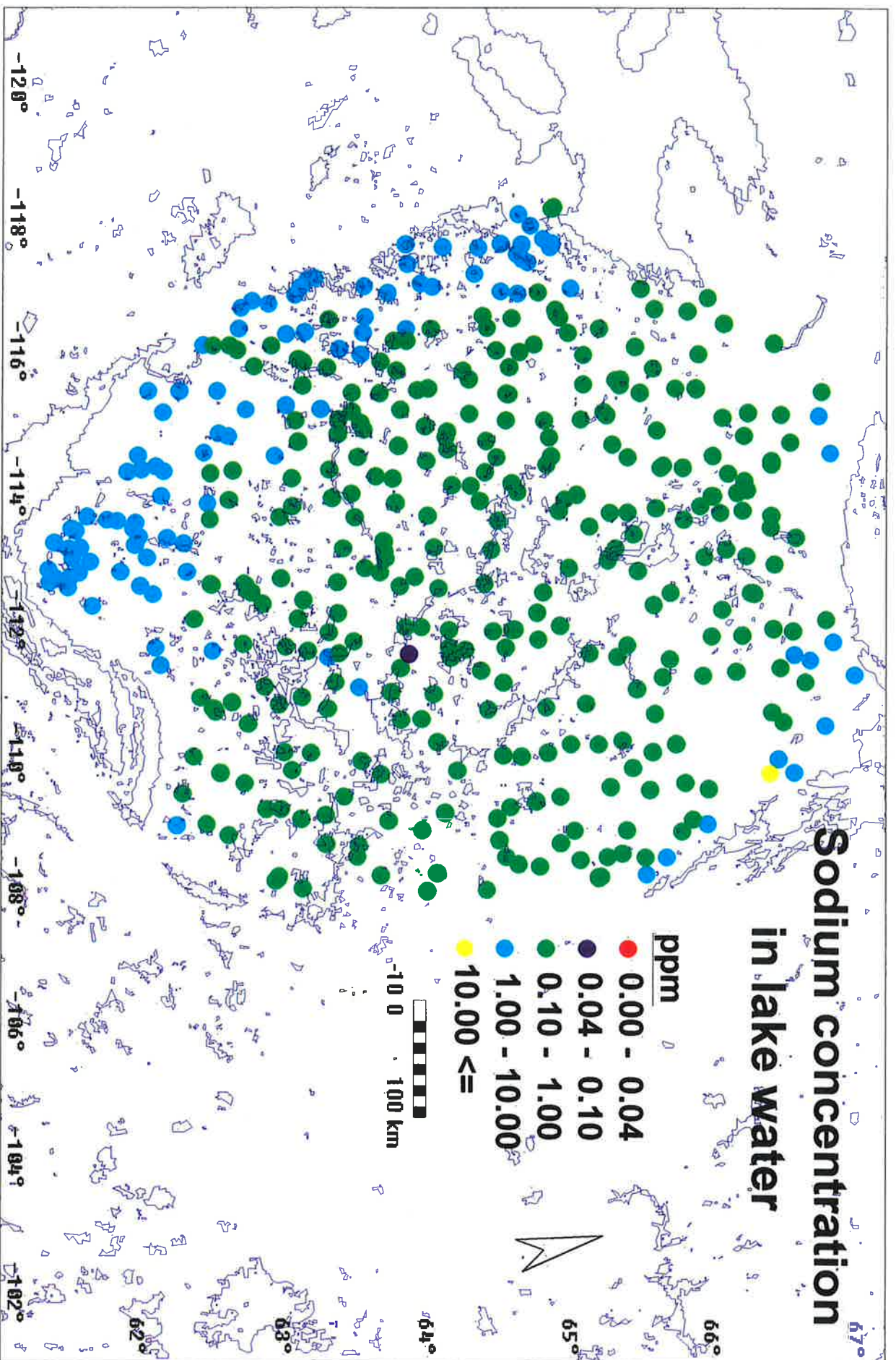
### Drinking Water

$< 200 \text{ mg}\cdot\text{L}^{-1}$

### **Discussion:**

With the exception of sample CA76N2DW1, samples measured less than the North American mean of  $9 \text{ mg}\cdot\text{L}^{-1}$ . Sample CA76N2DW1 not only measured the highest concentration of  $32.40 \text{ mg}\cdot\text{L}^{-1}$  but also measured a high chloride concentration of  $62.4 \text{ mg}\cdot\text{L}^{-1}$  as well. This site is believed to be influenced by saline water from Bathurst Inlet. In terms of distribution, higher concentrations are observed in the Bear Province. The area of higher concentration in the Slave Province occur in an area identified to contain previous mining activity as well as currently operating lodges and outfitters (Acres International Limited, 1993). Sodium concentrations were lower in 26 of 32 lakes retested in 1994.





## pH

**Symbol:** pH

**Background:** pH is the measure of the negative logarithm to the base 10 of the hydrogen ion concentration. It is a measure of the intensity factor of acidity. The scale of pH ranges in values between 0 and 14 with 7 being neutral. pH values increasingly less than 7 are considered acidic and those values increasingly greater than 7 are considered basic. pH governs the solvent properties of water and determines the extent and type of physical, biological and chemical reactions likely to occur within a water system or between the water and surrounding rocks and soils. According to the Canadian Water Quality Guidelines the pH for most natural fresh waters ranges between values of 4 and 9.

**Common Minerals:** pH is a measure of the physical state of a given body of water. Although not a product or byproduct of any particular minerals or mineral groups, it is influenced by their presence.

**Major Uses:** pH is useful in assessing water quality. Used in calculating carbonate, bicarbonate, and carbon dioxide concentrations, it is also a key factor in determining water use and treatment.

**Hazards:** Waters with abnormally low pH values (acidic) have the potential of being corrosive as well as having adverse effects on aquatic life. Waters with abnormally high pH values (alkaline), could inhibit encrustation and scaling.

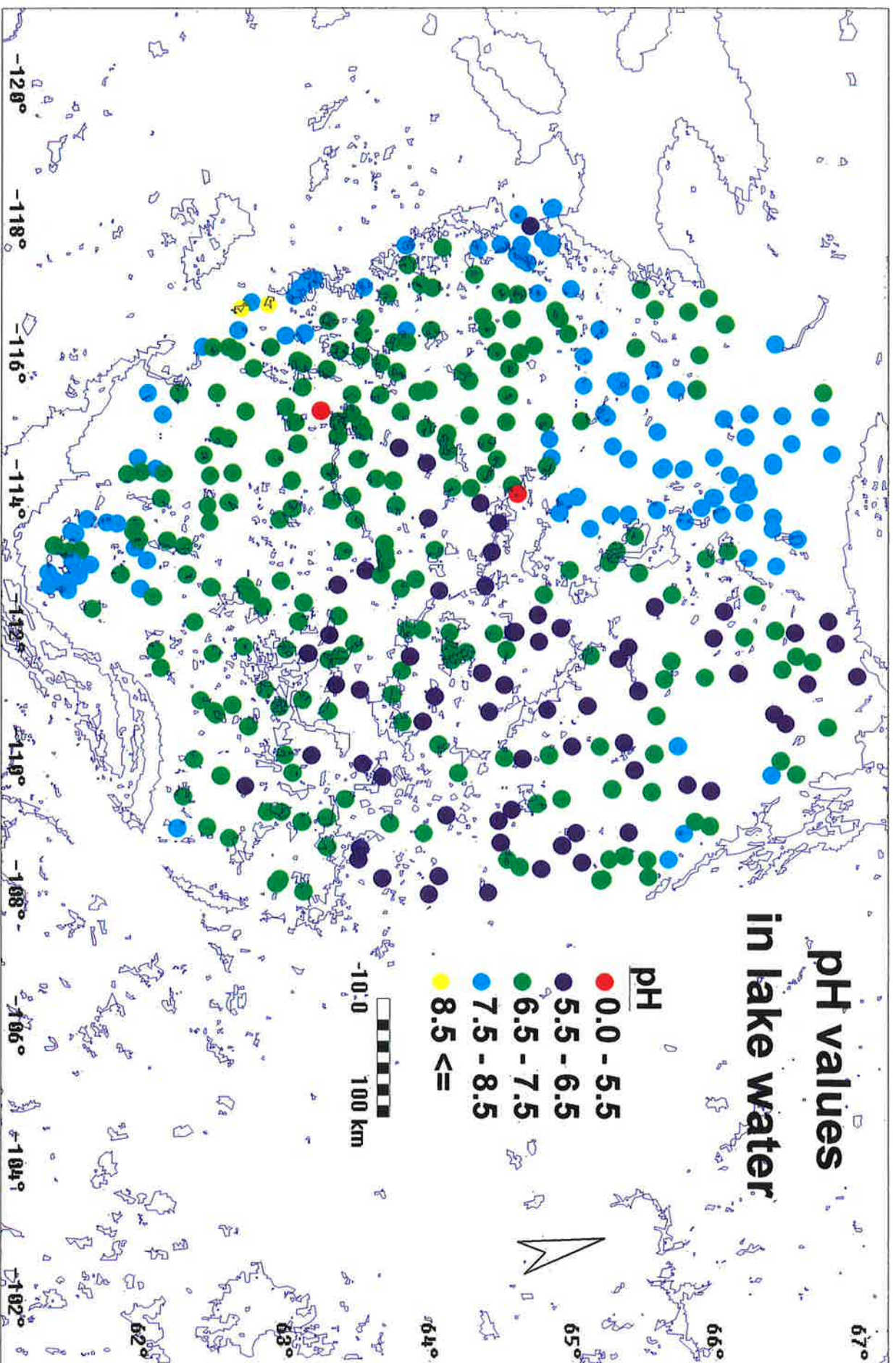
**Guidelines:** As outlined in the Canadian Water Quality Guidelines (1990).

<u>Drinking Water</u>	<u>Freshwater Aquatic Life</u>	<u>Recreation</u>
6.5 - 8.5	6.5 - 9.0	5.0 - 9.0

### **Discussion:**

pH values fall within the characteristic values set by the Canadian Water Quality Guidelines of pH 4.0 to pH 9.0. Lakes with higher pH values (more alkaline waters) are observed throughout the Bear Province. The higher values observed in the Slave Province specifically in the southern area is identified as impacted by previous mining activity and lodges and outfitters (Acres International Limited, 1993). Field measurements are slightly higher than laboratory. Laboratory pH values were also higher in 26 of 32 lakes re-tested in 1994 compared to 19 of 32 field measurements. Overall, the pH values of lakes tested in the study area have slightly increased in value or have become slightly more alkaline.





## Sulphate

**Symbol:**  $\text{SO}_4^{-2}$

**Background:** Sulphate is a stable, highly oxidized, soluble form of sulphur. As one of the secondary contributors to water hardness, sulphate finds its way into water sources through the weathering and leaching of sulphide-bearing rocks and minerals, industrial effluents, and air-borne pollutants. Sulphate is generally found bound to alkali and alkaline earth metals. According to the Canadian Water Quality Guidelines the concentration of sulphate for most natural surface fresh waters ranges between 10 - 80  $\text{mg}\cdot\text{L}^{-1}$ . However, it is not uncommon to have values in the thousands for industrial waste waters.

<b>Common Minerals:</b>	Gypsum	$\text{CaSO}_4\cdot 2\text{H}_2\text{O}$
	Anhydrite	$\text{CaSO}_4$
	Barite	$\text{BaSO}_4$
	Thenardite	$\text{Na}_2\text{SO}_4$

**Note:** Sulphate combines to form many complex compound groups too numerous to mention.

**Major Uses:** Chemicals, dyes, fertilizers, glass, paper, soaps and detergents, textiles, pharmaceuticals, sewage treatment, and wood preservatives. Sulphates serve as an oxygen source for bacteria under anaerobic conditions which convert it to hydrogen sulphide gas.

**Hazards:** Most of the hazards associated with sulphate result from sulphur products. Hydrogen sulphide gas, produced from the anaerobic uptake of sulphate, is extremely dangerous. The roasting of sulphur bearing ores produce sulphur dioxide and sulphur trioxide gas which, when in contact with precipitation, is returned to earth's surface in the form of acid rain.

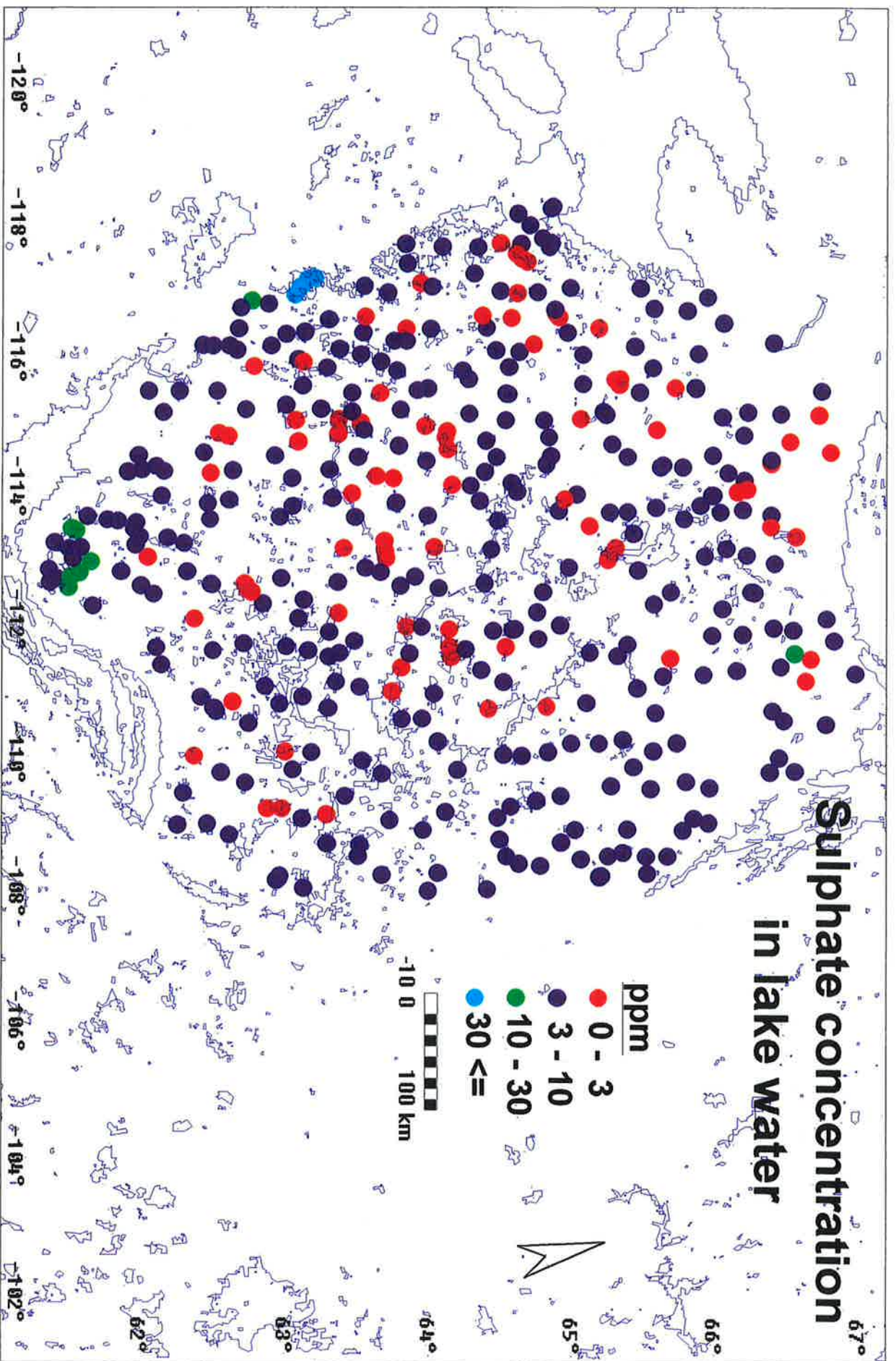
**Guidelines:** As outlined in the Canadian Water Quality Guidelines (1990).

**Drinking Water**  
 $\leq 500 \text{ mg}\cdot\text{L}^{-1}$

### **Discussion:**

Sulphate concentrations are within the 10-80  $\text{mg}\cdot\text{L}^{-1}$  range characteristic of most natural surface freshwater. Concentrations were greater than 10  $\text{mg}\cdot\text{L}^{-1}$  in 14 lakes. The maximum concentration of 45  $\text{mg}\cdot\text{L}^{-1}$  was recorded at site CA85N14AW1. Relatively higher concentrations are observed in the Bear Province than in the Slave Province. The higher concentrations in the Slave Province occur in an area noted to contain previous mining activity as well as currently operating lodges and outfitters (Acres International Limited, 1993). Sulphate concentrations decreased or stayed unchanged in 29 of 32 lakes retested in 1994.





## Turbidity

**Symbol:** None

**Background:** Turbidity is an expression of the optical properties of the water which causes incident light to be scattered and or absorbed instead of being transmitted straight through it. Turbidity results from the presence of mineral and organic particulate matter, usually in a finely divided state and held in suspension by turbulent flow and by Brownian movement. The optical properties of the suspension depends on the size and number of particles as well as their distribution, shape, and refractive indices of the particles and the liquid itself. The amount of suspended material in natural water may stem from natural erosion, runoff, biological activities such as algal blooms and as a result from human activities. According to Health and Welfare Canada, the maximum acceptable concentration for turbidity is 1 NTU (nephelometric turbidity unit) for water entering a distribution system. A maximum of 5 (NTU) may be permitted if it can be demonstrated that disinfection is not compromised by the use of this less stringent value.

**Common Minerals:** Practically any mineral that can be weathered. However not all particles that contribute to turbidity will consist of minerals.

**Major Uses:** Useful in assessing water quality.

**Hazards:** High turbidity not only detracts from the aesthetic characteristics of water but may also render the water unsuitable for domestic, industrial, agriculture, and recreational uses. High turbidity reduces photosynthesis, a key element in the primary production of a water body, increases water temperature, and is abrasive to water pumps, pipes and turbines.

**Guidelines:** As outlined in the Canadian Water Quality Guidelines (1990).

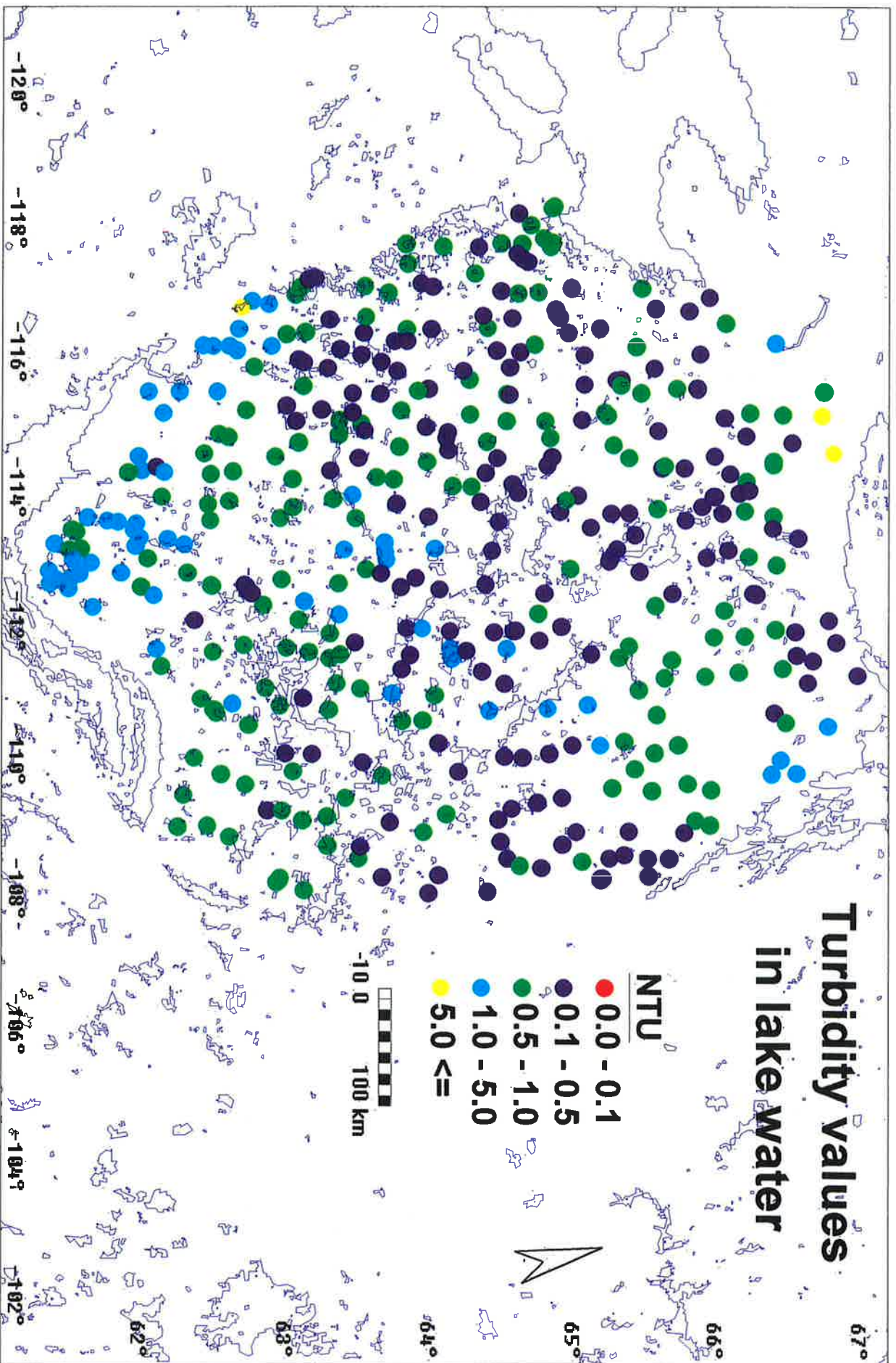
### Drinking Water

1 - <5 NTU

### **Discussion:**

Turbidity values exceed Health and Welfare Canada's maximum acceptable concentration for drinking water of 1NTU in 60 of 374 lakes tested with three exceeding 5 NTU. Lakes exceeding 5 NTU are relatively shallow at 1.2 - 4.3 metres. High concentrations in filterable residue indicate that the material contributing to turbidity must be of a fine enough material to pass through a 0.45  $\mu\text{m}$  filter. This is also verified with high concentrations in conductivity, alkalinity, calcium and magnesium. High turbidity values could be a function of lake turnover, a process that occurs when water temperature near the surface reaches 4°C, at that temperature the water layer begins to sink due to obtaining its maximum density. The layer of water below is replaced at the surface. The majority of higher turbidity values are observed in the Slave Province. Turbidity values were lower in 18 of 32 lakes retested in 1994.





## Arsenic

**Symbol:** As

**Background:** Arsenic, although found mostly in arsenopyrite (associated with high temperature gold-quartz veins and sulphide deposits) is also found in combination with heavy metals such as copper, iron, nickel, and cobalt. It is also a by-product of the smelting and processing of base metal ores. Arsenic finds its way into the environment through several processes such as weathering of arsenic containing rocks, combustion of fossil fuels, processing of sulphide minerals and human activities. In most natural waters, arsenic prevails in inorganic forms. The most toxic forms of arsenic result from the biological methylation of inorganic arsenic. According to the Canadian Water Quality guidelines, the concentration of arsenic for most surface fresh waters range between  $0.5$  and  $50 \mu\text{g}\cdot\text{L}^{-1}$ , however, levels as high as  $12,600 \mu\text{g}\cdot\text{L}^{-1}$  have been reported in the Yellowknife area.

<b>Common Minerals:</b>	Realgar	AsS
	Arsenopyrite	FeAsS
	Dimorphite	As <sub>4</sub> S <sub>3</sub>
	Skutterudite	CoAs <sub>3</sub>
	Lautite	CuAsS

**Major Uses:** Pesticides, pigments, medicinal purposes, glass making, lead and copper alloys, and in manufacturing semiconductors. Arsenic is a pathfinder element for many precious and base metals.

**Hazards:** The main hazard associated with arsenic is its toxic properties. Arsenic released to the environment poses a threat to the public and the environment. A pollutant to air, land and water it requires strict regulatory monitoring.

**Guidelines:** As outlined in the Canadian Water Quality Guidelines (1990).

### Drinking Water

$0.025 \text{ mg}\cdot\text{L}^{-1}$

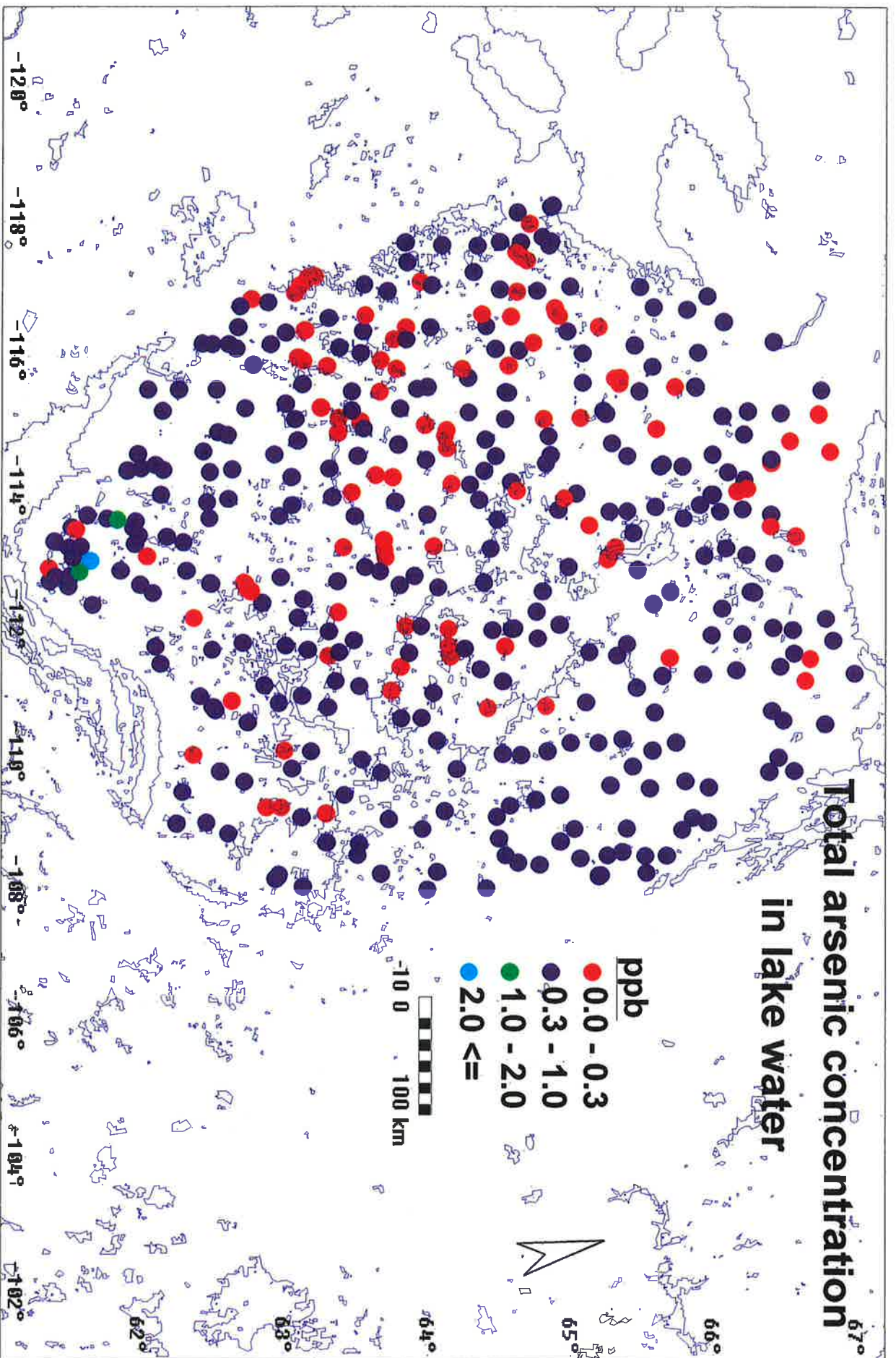
### Freshwater Aquatic Life

$0.05 \text{ mg}\cdot\text{L}^{-1}$

### **Discussion:**

Arsenic concentrations are within the  $0.5$  and  $50 \mu\text{g}\cdot\text{L}^{-1}$  range characteristic of most natural surface freshwater. The maximum measured concentration of  $2.60 \mu\text{g}\cdot\text{L}^{-1}$  was obtained from site CA85I7CW1. This site also contains the highest concentration of manganese and rubidium metals. There is no notable distribution pattern of arsenic concentration that differentiates the Slave Province from the Bear Province. Arsenic concentrations measured lower or equal to in 30 of 32 lakes retested in 1994.





## **NUTRIENTS**

Nutrient samples were collected and analysed for in all lakes during the 1993 and 1994 sampling seasons. Ammonia, total phosphorus and nitrate and nitrite concentrations display no noticeable distribution patterns. However, the distribution of reactive silica concentrations are noticeably higher in the Bear Province than in the Slave Province. The higher concentrations observed in the Slave Province occur in the area identified as impacted by previous mining activity and lodges and outfitters (Acres international Limited, 1993). In general, lakes retested in 1994 showed an increase in ammonia values while phosphorous decreased and nitrates and nitrites remained the same.

## Ammonia

**Symbol:**  $\text{NH}_3$

**Background:** Ammonia occurs naturally in surface and waste waters as the most reduced inorganic form of nitrogen. It includes dissolved ammonia ( $\text{NH}_3$ ) and the ammonium ion ( $\text{NH}_4^+$ ). Nitrogen is reduced to ammonia ion by nitrogen-fixing bacteria living in a symbiotic association with plants, soil or water. Ammonia is an essential component of the nitrogen cycle, linked to the origin and evolution of life on earth. According to the Canadian Water Quality Guidelines, the concentration of ammonia for most natural surface fresh waters is generally below  $0.1 \text{ mg}\cdot\text{L}^{-1}$  (as nitrogen).

**Common Minerals:** Sodium nitrate (soda niter)  $\text{NaNO}_3$   
Potassium nitrate (saltpetre)  $\text{KNO}_3$

**Major Uses:** Fertilizers, chemicals, explosives, plastics, adhesives, cleaners, dyes, pesticides, deicer, paper and textiles to name a few.

**Hazards:** Most of the hazards associated with ammonia are from the very soluble, highly volatile and hazardous liquid form of anhydrous ammonia compound. However, since nitrogen is one of the main components of ammonia, and considered a nutrient, it also acts as an indicator of the extent of eutrophication of a lake. Eutrophication could either occur naturally over geological time or it may be accelerated by human activities, such as waste disposal or land drainage, leading to an increase in algae and a decrease in diversity.

**Guidelines:** As outlined in the Canadian Water Quality Guidelines (1990).

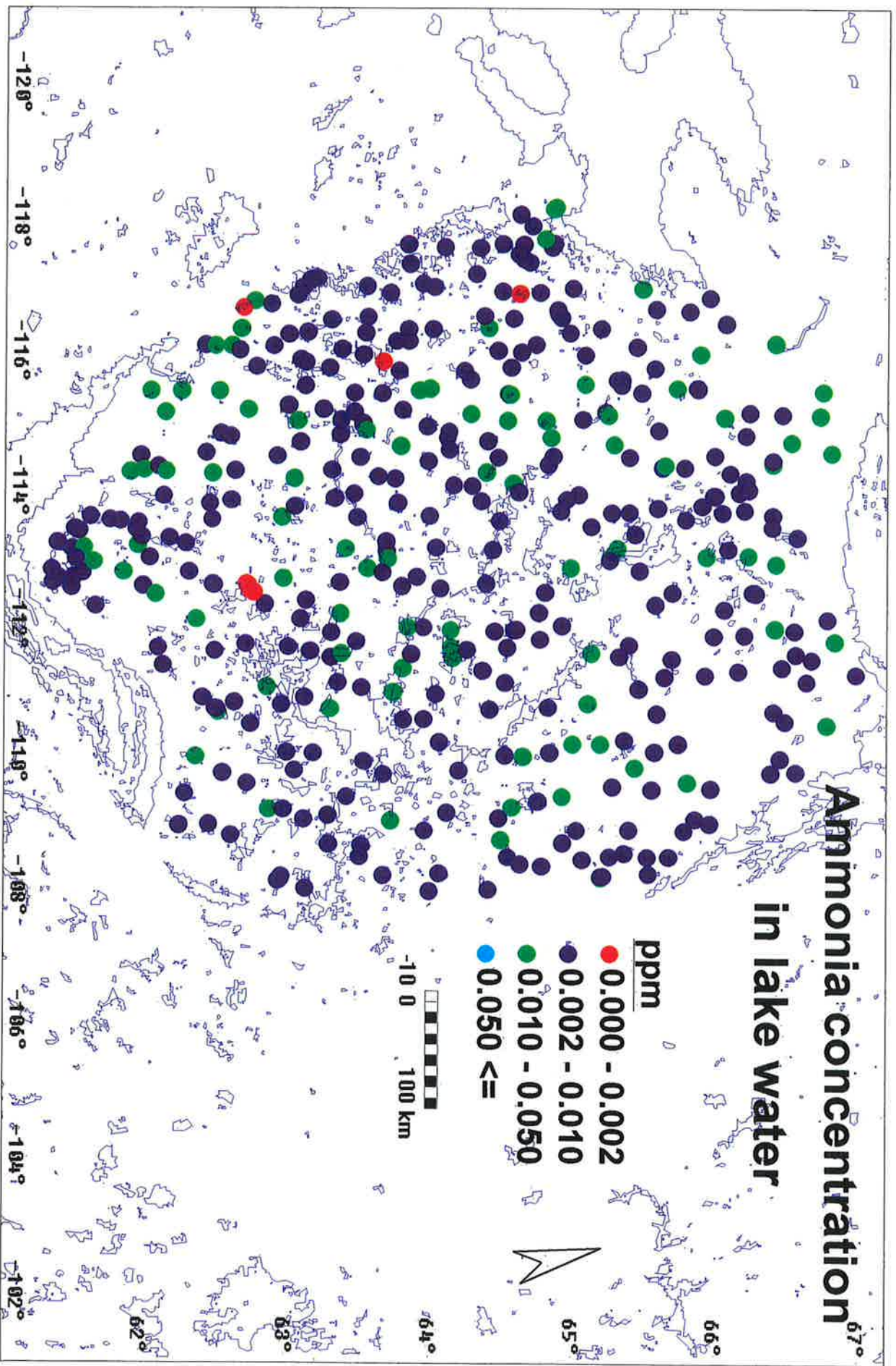
### Freshwater Aquatic Life

1.37 -  $2.20 \text{ mg}\cdot\text{L}^{-1}$

### **Discussion:**

Ammonia concentrations are less than  $0.1 \text{ mg}\cdot\text{L}^{-1}$  as nitrogen, characteristic of most surface freshwater. Concentrations are evenly distributed between the Slave and Bear Provinces. The concentrations do not appear to be influenced by the surrounding geology. The maximum ammonia concentration measured  $0.049 \text{ mg}\cdot\text{L}^{-1}$  as nitrogen at site CA85N7DW1. Ammonia values were slightly higher in 20 of 32 lakes retested in 1994.





## Phosphorous

**Symbol:** P

**Background:** Phosphorous does not occur as abundantly in nature as does carbon and nitrogen. However, it is the main nutrient that triggers eutrophication. In natural waters, phosphorus occurs in numerous forms such as particulate phosphorous, reactive phosphate, hydrolysable phosphate and organic phosphate, but the principal form is inorganic orthophosphate. In shallow warm waters during the summer, orthophosphate phosphorous is absorbed by plankton and algae resulting in a depletion of orthophosphate phosphorous. In deeper and colder waters, phosphate is increased due to the decomposition and liberation of orthophosphates from decaying organic debris. Phosphorous can also be precipitated as apatite, a calcium fluorophosphate mineral. According to the Canadian Water Quality Guidelines the concentration of phosphorous for most surface fresh waters of lakes are uniformly low in phosphorous.

<b>Common Minerals:</b>	Apatite	$\text{Ca}_5[(\text{F}, \text{Cl}, \text{OH}) (\text{PO}_4)_3]$
	Viviannite	$\text{Fe}_3^{+2}[\text{PO}_4]_2 \cdot 8\text{H}_2\text{O}$
	Pyromorphite	$\text{Pb}_5[\text{Ce}(\text{PO}_4)_3]$
	Monazite	$\text{Ce}[\text{PO}_4]$
	Zenotime	$\text{Y}[\text{PO}_4]$

**Major Uses:** Fertilizers, soaps and detergents, plating and polishing, animal and fowl feed, water softeners, matches, toothpaste, plastics, and dyes to name a few.

**Hazards:** The main hazards associated with phosphorous are a result of the mining process where slime pits are formed. These slime pits require many years to settle before being reclaimed. Another hazard is the release of dangerous fluorine gas, resulting from the processing of phosphate ores containing fluorine.

**Guidelines:** As of 1994, there were no Canadian water quality guidelines.

### **Discussion:**

Low phosphorous concentrations are characteristic of most natural surface waters. Concentrations are relatively higher in the Slave Province than in the Bear. Specific sites containing higher concentrations exist in the Bear Province particularly along the Camsell River system. The higher concentrations observed in the Slave Province occur in an area noted to contain previous mining activity as well as currently operating lodges and outfitters (Acres International Limited, 1993). The highest concentration measured was  $0.096 \text{ mg} \cdot \text{L}^{-1}$  for sample CA85111CW1. Values were lower in 23 of 32 lakes retested in 1994.

## Nitrates and Nitrites

**Symbol:**  $\text{NO}_3^- + \text{NO}_2^-$

**Background:** Nitrates and nitrites are inorganic forms of nitrogen resulting from the biological transformation process of the nitrogen cycle known as nitrification. Nitrification is the microbial oxidation of ammonia to nitrate and nitrite. Since the rate of nitrification is temperature dependent, the nitrifying bacteria prefer temperatures of 30°C, and a pH of approximately 8.0. According to the Canadian Water Quality Guidelines, the concentrations of nitrate and nitrite for most surface freshwaters ranges from 0.01-0.35 mg·L<sup>-1</sup> in Atlantic Canada, to 0.01-2.20 mg·L<sup>-1</sup> in Western Canada.

**Common Minerals:**

Sodium nitrate (soda niter)	$\text{NaNO}_3$
Potassium nitrate (saltpetre)	$\text{KNO}_3$

**Major Uses:** Most of the uses of nitrate and nitrite are in the form of either elemental nitrogen ( $\text{N}_2$  gas) or fixed nitrogen. For commercial purposes gas is extracted from the atmosphere and fixed through a process to produce nitrogen compounds which in turn are processed into fertilizers, explosives, chemicals etc..

**Hazards:** Most of the hazards associated with nitrates and nitrites result from the processing of nitrogen either through fixation or mining. Large quantities of nitrogen and nitrogen compounds such as anhydrous ammonia, fertilizers, and sewage entering an aquatic system can have deleterious effects.

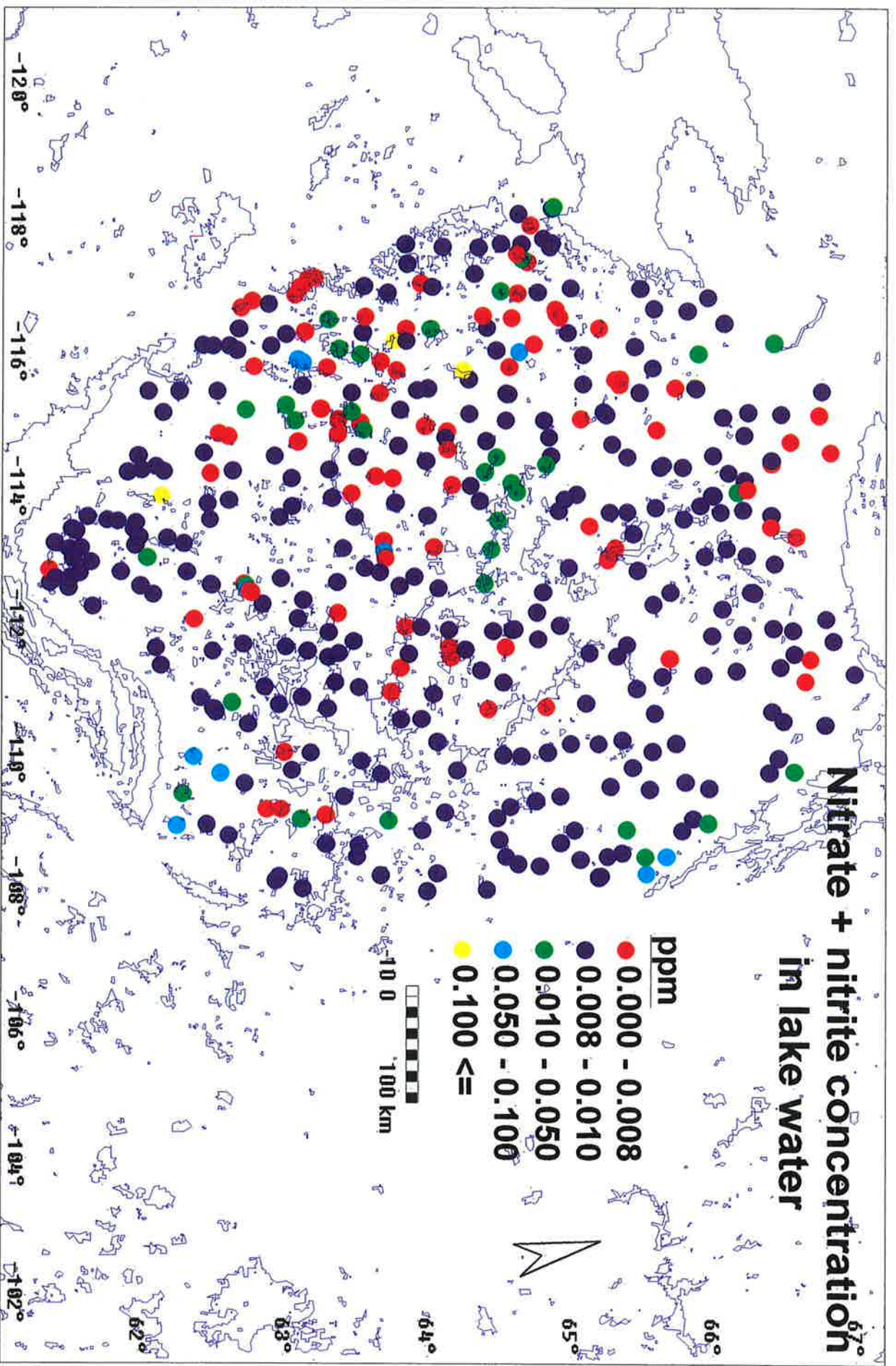
**Guidelines:** As of 1994 there were no Canadian water quality guidelines specifically for nitrates and nitrites. However guidelines exist for nitrate and nitrite independently.

### **Discussion:**

Nitrate and nitrite values are within the 0.01-2.20 mg·L<sup>-1</sup> range characteristic of most surface freshwaters. Concentrations appear to be higher in the Bear Province than in the Slave Province, more specifically, where the Slave Province makes contact with the Bear Province. Samples CA76M6BW1-1V and CA86H14CW1-2V have high nitrate and nitrite values of 0.449 mg·L<sup>-1</sup> and 0.360 mg·L<sup>-1</sup> respectively. The relatively high values measured from these two vertical variability samples could indicate lake turnover or lake stratification. In lakes retested in 1994 nitrate and nitrite values remained relatively unchanged.



# Nitrate + nitrite concentration in lake water



## Reactive Silica

**Symbol:**  $\text{SiO}_2$

**Background:** Silica is the second most abundant element in the earth's crust next to oxygen. Silica is classified as a nutrient and as such is involved in a cycling process. Although it is a major constituent in many plants, it should not be considered limiting to plant growth except where diatoms are present. The most common form of silica is silica oxide. Silica oxide combines with metals to form many complex silicate minerals, particularly igneous rocks. Degradation of silica containing rocks results in the presence of silica in natural waters as suspended particles (colloidal or polymeric state), and as silicic acids or silicate ions. According to the Canadian Water Quality Guidelines, the silica content for most natural surface fresh waters normally ranges between 1-30  $\text{mg}\cdot\text{L}^{-1}$ , however, it is not unusual for concentrations to be as high as 100  $\text{mg}\cdot\text{L}^{-1}$ .

<b>Common Minerals:</b>	Quartz	$\text{SiO}_2$
	Chalcedony	$\text{SiO}_2$
	Cristobalite	$\text{SiO}_2$
	Silica gel	$\text{SiO}_2$

**Hazards:** There are no hazards associated with silica other than the fact that it forms difficult to remove silica and silicate scales in water.

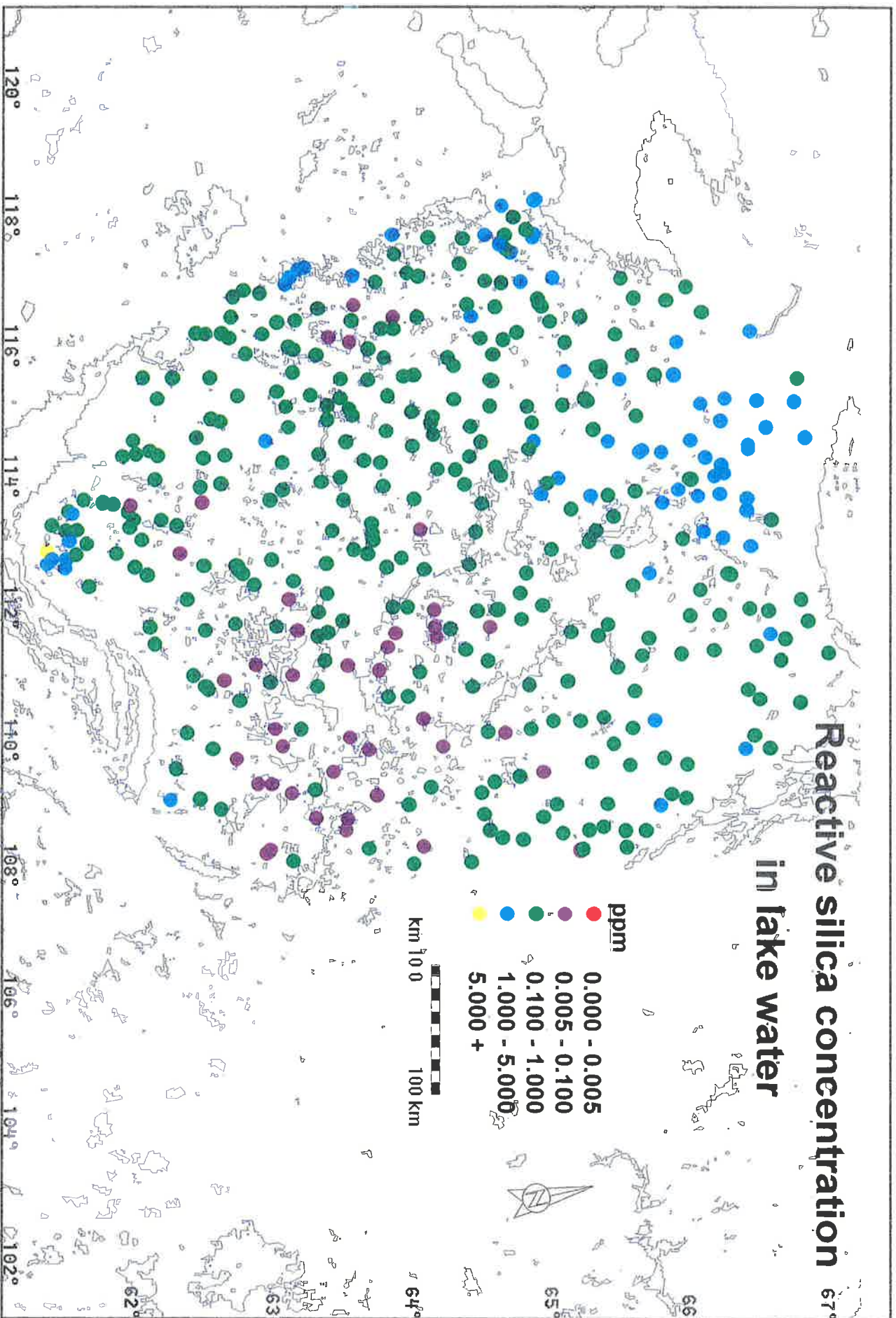
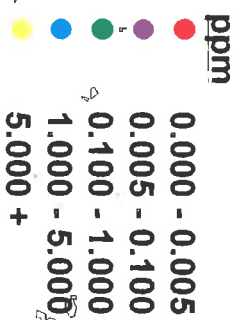
**Guidelines:** As of 1994 there were no Canadian water quality guidelines.

### **Discussion:**

Reactive silica concentrations are within the 1-30  $\text{mg}\cdot\text{L}^{-1}$  range characteristic of most surface freshwaters. Concentrations are relatively higher in the Bear Province than in the Slave Province, typical of the geological patterns. The higher concentrations observed in the Slave Province occur in an area noted to contain previous mining activity as well as currently operating lodges and outfitters (Acres International Limited 1993). The maximum reactive silica concentration measured 5.4  $\text{mg}\cdot\text{L}^{-1}$  at site CA85I2BW1. In lakes retested in 1994 reactive silica concentrations were slightly lower in 21 of 32 lakes. It appears that in lakes where silica concentrations increased in 1994, potassium concentrations decreased.



# Reactive silica concentration in lake water



## **CYANIDE**

Total cyanide was tested for in 28 lakes during the 1993 sampling season from lakes known to have contained previous mining activity. There are no noticeable patterns that indicate any differences between the Slave and Bear Provinces. Cyanide was not tested for in lakes during the 1994 sampling season, primarily because there were no significant levels observed in 1993 to warrant further testing especially considering that the lakes being tested were in an area known to be impacted by the mining industry (Acres International Limited, 1993).

## Cyanide

**Symbol:**  $\text{CN}^-$

**Background:** Cyanide can exist in water in several forms such as molecular cyanide (HCN), free cyanide ion ( $\text{CN}^-$ ), simple cyanide and complex cyanide. Molecular cyanide is defined as cyanide in the form of an unchanged undissociated molecule. Free cyanide is defined as the summation of molecular HCN and the cyanide ion in aqueous solution irrespective of their sources in water. Simple cyanide is defined as those cyanide compounds that readily dissociate in water to produce cyanide ions. Complex cyanide is defined as metal cyanides such as nickel, copper and iron cyanides. Total cyanide is defined as the summation of the CN group in all the different forms of cyanide that exist in aqueous solution.

The most important factor that governs the formation of a predominant cyanide species is the pH of the aquatic environment. In most natural waters cyanide exists in a simple form as HCN (hydrogen cyanide). Although many plants contain cyanogenic glycosides, and release hydrogen cyanide upon hydrolysis, the main source of cyanide is from industrial effluents from the processing of metals and ores. According to the Canadian Water Quality Guidelines, the concentration of total cyanide for fresh waters have been reported as high as  $30\text{-}60\ \mu\text{g}\cdot\text{L}^{-1}$ .

<b>Common Minerals:</b>	Hydrogen cyanide	HCN
	Potassium cyanide	KCN
	Sodium cyanide	NaCN

**Major Uses:** Extraction of gold and silver from low grade ores, steel production, electroplating, and pesticides.

**Hazards:** Cyanide is highly toxic to all forms of life. Many studies have shown that free cyanide concentration in the range of  $50\text{ - }100\ \mu\text{g}\cdot\text{L}^{-1}$  as cyanide is fatal to most sensitive fish and that levels above  $200\ \mu\text{g}\cdot\text{L}^{-1}$  are fatal to most species.

**Guidelines:** As outlined in the Canadian Water Quality Guidelines (1990).

### Drinking Water

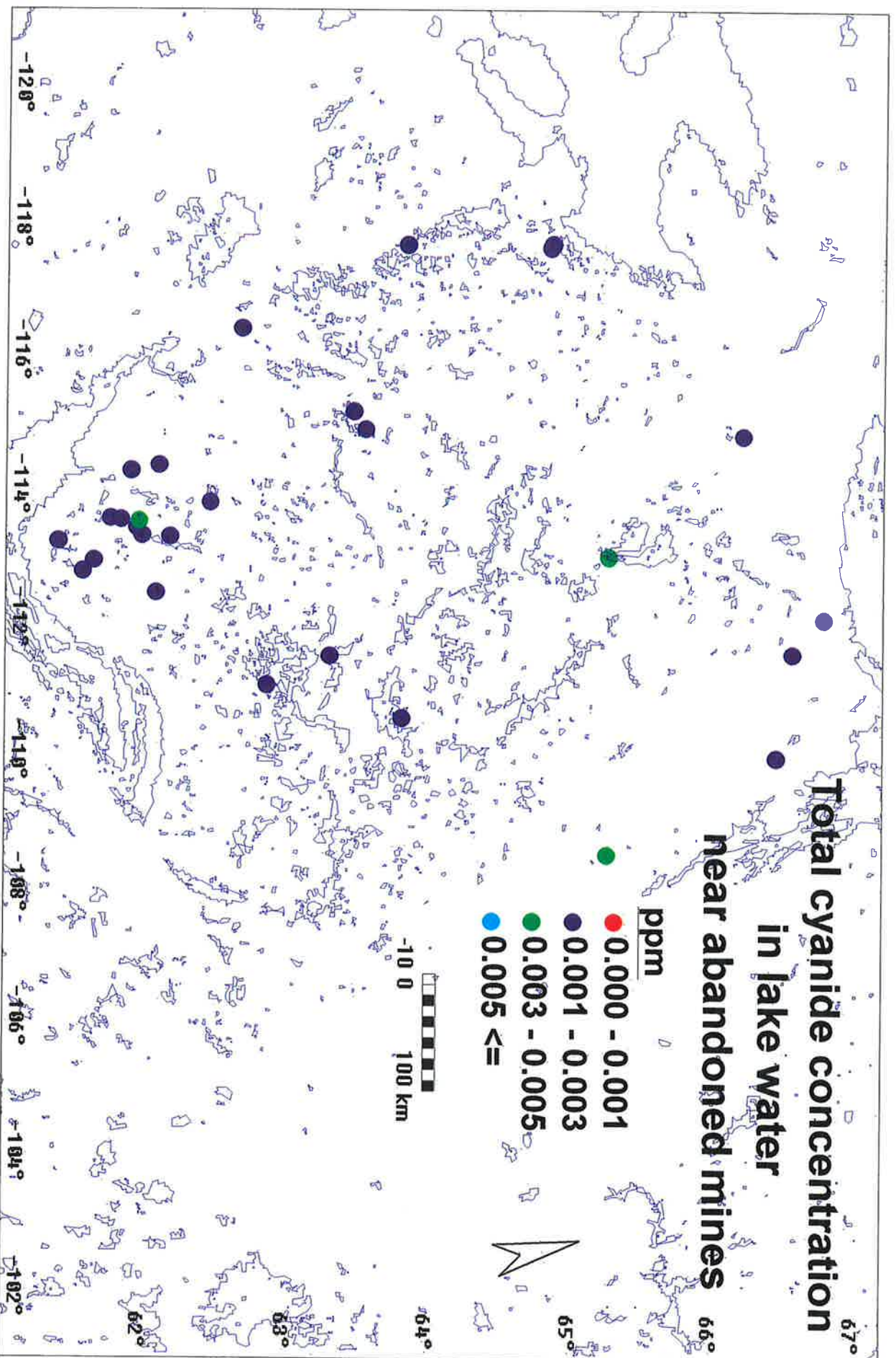
$0.2\ \text{mg}\cdot\text{L}^{-1}$  (total CN)

### Freshwater Aquatic life

$0.005\ \text{mg}\cdot\text{L}^{-1}$  (free CN)

### **Discussion:**

The highest concentration of  $0.004\ \text{mg}\cdot\text{L}^{-1}$  was observed at eight of the 28 sites. This concentration is well within acceptable limits as set out in the Canadian Water Quality Guidelines of  $0.2\ \text{mg}\cdot\text{L}^{-1}$  total cyanide for drinking water and  $0.005\ \text{mg}\cdot\text{L}^{-1}$  free cyanide for the protection of freshwater aquatic life. Cyanide was not tested for in 1994.



## **BACTERIOLOGICAL**

Bacteriological samples were collected from 23 lakes in 1993. Lakes tested are situated primarily in the Slave Province. All lakes tested contained some form of seasonal camp or outlet providing service for public. Sample site CA85I3DW1 measured the highest faecal coliform counts per 100 mL at 15. Samples of cyanide and mercury were also collected at this site because it was believed that this lake was possibly impacted by previous mining activity. Bacteriological samples were not collected in 1994 primarily due to the extended holding time of samples in the field. For accurate analyses it is crucial that the samples not be delayed for testing after sampling.



## Total Coliform

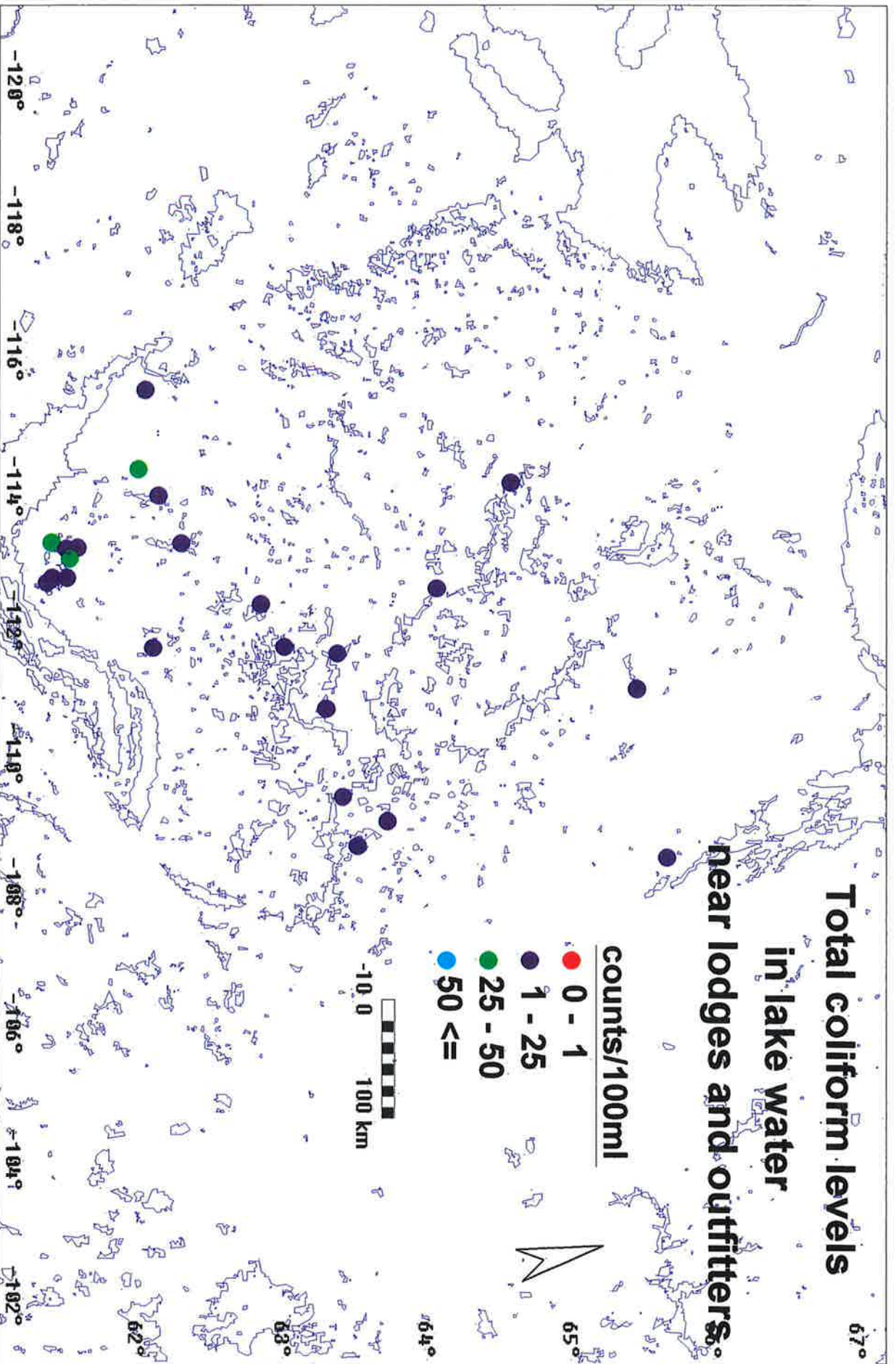
<b>Symbol:</b>	None
<b>Background:</b>	Coliforms are defined as all the aerobic and facultative anaerobic gram-negative non-spore-forming, rod shaped bacteria which ferment lactose with gas formation within 48 hours at 35°C.
<b>Common Minerals:</b>	Coliform is not associated with any minerals.
<b>Major Uses:</b>	Coliforms are used to indicate the presence of human or animal faeces. It is also a measure of the number of bacteria present in a given amount of water.
<b>Hazards:</b>	Certain types of coliforms present in water could indicate that it is unsafe for human consumption as well as pose a health risk.
<b>Guidelines:</b>	As outlined in the Canadian Water Quality Guidelines (1990).

### Drinking Water

10 counts·100 mL<sup>-1</sup>

### **Discussion:**

The maximum allowable concentration of 10 counts ·100 mL<sup>-1</sup> total coliform for drinking water, as set by the Canadian Water Quality Guidelines, is exceeded in 11 of 23 lakes. The maximum value of 55 counts ·100mL<sup>-1</sup> total coliform was detected at sample site CA85I7AW2-1V. Also noted at this site is a sulphate concentration of 10 mg·L<sup>-1</sup>. This is the highest concentration of sulphate amongst those lakes tested as Lodges and Outfitters. There is a possibility that this is a result of sulfate reducing bacteria. These bacteria contribute greatly to corrosion, odour and taste problems in water. Total coliform was not tested for in 1994.



## Faecal Coliform

<b>Symbol:</b>	None
<b>Background:</b>	Faecal coliform is defined as those coliform which ferment EC (Escherichia coli) medium with gas formation within 48 hours at 44.5°C.
<b>Common Minerals:</b>	Coliform is not associated with any minerals.
<b>Major Uses:</b>	Coliforms are used to indicate the presence of human or animal faeces. It is also a measure of the number of bacteria present in a given amount of water.
<b>Hazards:</b>	Certain types of coliforms present in water could indicate that it is unsafe for human consumption as well as pose a health risk.
<b>Guidelines:</b>	Recreation values are based on the geometric mean of not fewer than five samples taken over a 30-day period. There are no guidelines for freshwater aquatic life.

### Drinking Water

0 counts · 100 mL<sup>-1</sup>

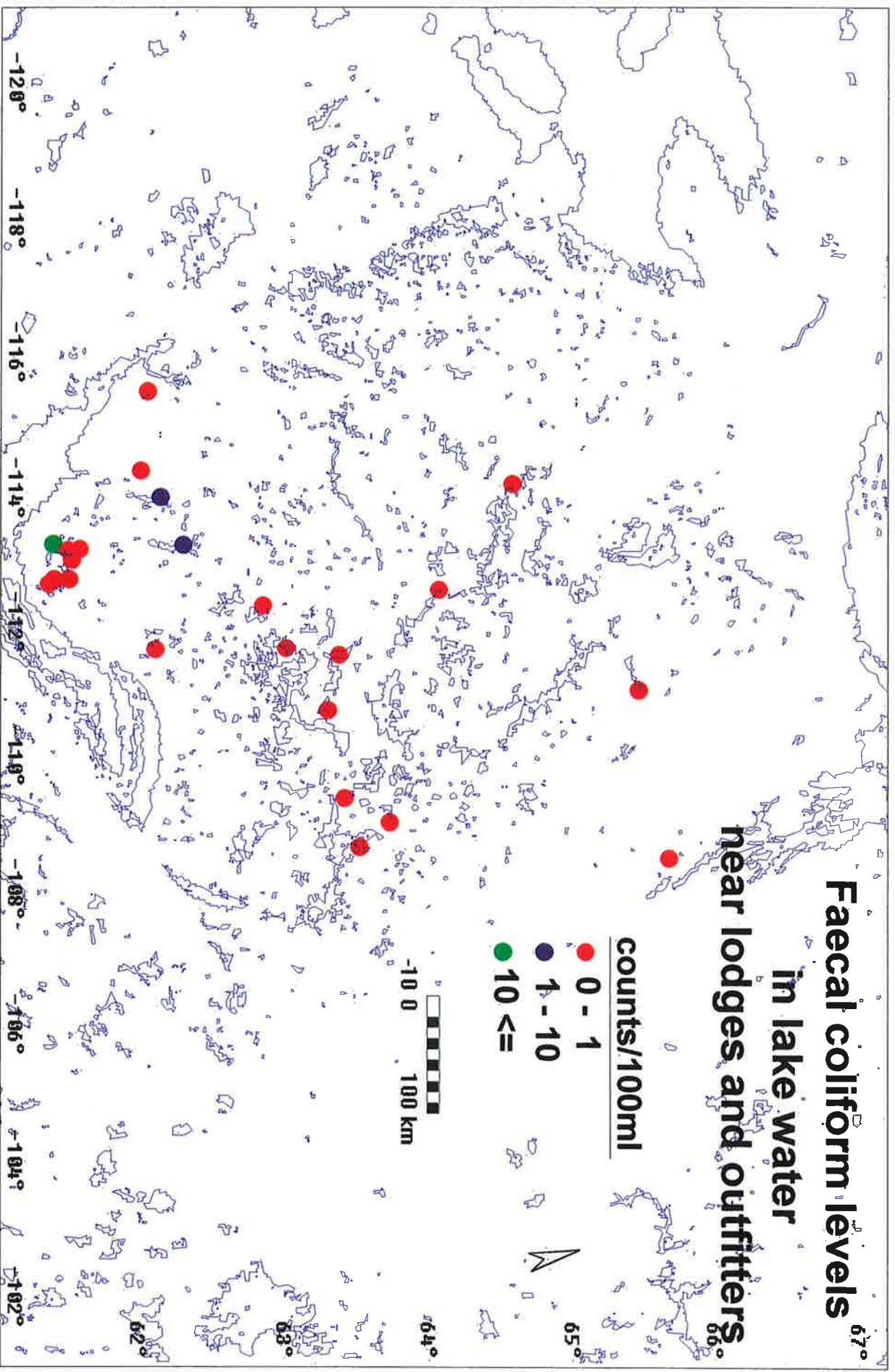
### Recreation

< 200 counts · 100mL<sup>-1</sup>

### **Discussion:**

Faecal coliform exceeded the guidelines for drinking water in 4 of 27 lakes. Three of these four lakes measured 1 count · 100 mL<sup>-1</sup>. Sample site CA85I3DW1 measured the highest faecal coliform value at 15 counts · 100 mL<sup>-1</sup>. This sample site is located in the southern portion of the Slave Province identified as containing previous mining activity as well as currently operating lodges and outfitters (Acres International Limited, 1993). Faecal coliform was not tested for in 1994.





## MERCURY

Mercury was tested for in 28 lakes during the 1993 sampling season from lakes known to have contained previous mining activity. According to the Canadian Water Quality Guidelines, the concentration for most surface fresh waters is generally less than  $0.05 \mu\text{g}\cdot\text{L}^{-1}$  with higher concentrations expected in organic rich material. All lakes tested are characteristic of most surface freshwaters. There are no noticeable patterns in concentrations that would suggest that there are measurable differences between the Slave and Bear Provinces. Mercury was not tested for in lakes sampled during the 1994 sampling season, primarily because there were no significant levels to warrant further testing.

## Mercury

**Symbol:** Hg

**Background:** Mercury, also known as quick-silver, is the only metal that is liquid at ordinary temperatures. Mercury does not react with air, ammonia, carbon dioxide, nitrous oxide, or oxygen. However, it does combine readily with the halogens (fluorine, chlorine, bromine, iodine, astatine) and sulphur. Mercury is found in rocks of all geological ages and all classes. The common host rocks are limestone, calcareous shale, sandstone, serpentine, chert, andesite, basalt, and rhyolite. Although mercury is known in 25 minerals, it is recovered almost entirely from cinnabar. Mercury can exist in soluble and insoluble forms and in three oxidation states elemental, mercurous, and mercuric. Chemical speciation is dependant upon redox potential, pH, and certain types of ligands present. In the aquatic environment, it is the highly toxic methyl mercury that is of most concern. According to the Canadian Water Quality Guidelines, the concentration of mercury for most surface fresh waters are generally low ( $< 0.05 \mu\text{g}\cdot\text{L}^{-1}$ ). However, higher concentrations are more likely to be expected in organic material, sediment, and fish.

<b>Common Minerals:</b>	Cinnabar	HgS
	Tetrahedrite	$\text{Cu}_{12}\text{Sb}_4\text{S}$
	Sphalerite	ZnS
	Wurtzite	$(\text{Fe}, \text{Zn})\text{S}$

**Major Uses:** Recovery of gold and silver by amalgamation, vermilion, felt, paints, dental supplies, manufacture of alkalies and chlorine, electrical applications, and mechanical measuring devices.

**Hazards:** Mercury is highly toxic. Handling or exposure to mercury vapors can result in poisoning.

**Guidelines:** As outlined in the Canadian Water Quality Guidelines (1990).

### Drinking Water

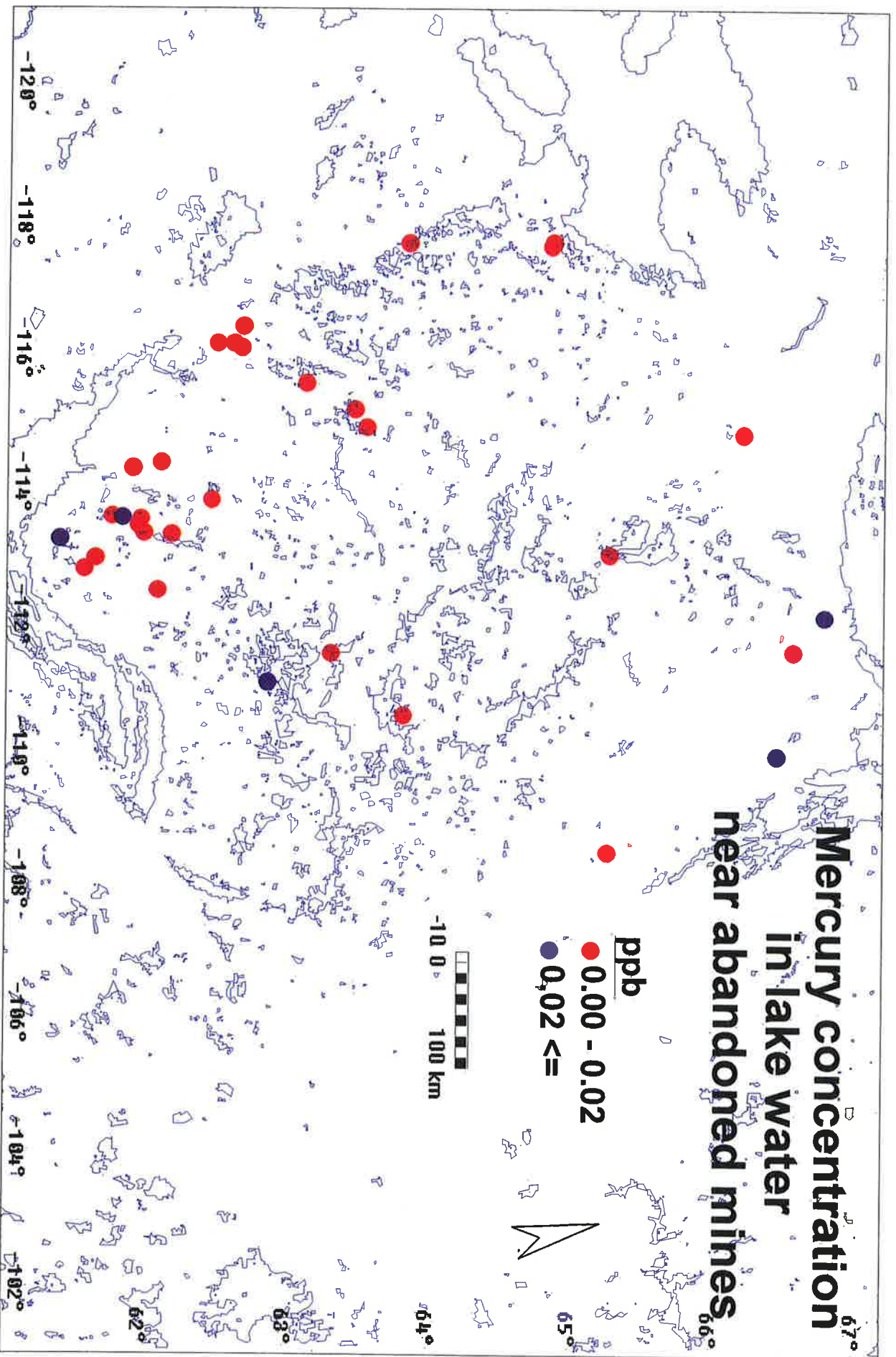
$1.0 \mu\text{g}\cdot\text{L}^{-1}$  (total)

### Freshwater Aquatic Life

$0.10 \mu\text{g}\cdot\text{L}^{-1}$  (total)

### **Discussion:**

The maximum value of  $0.04 \mu\text{g}\cdot\text{L}^{-1}$  measured at site CA85I3DW1 is well within water quality guidelines. This sample site also contains a high total coliform and faecal coliform count of 30 and 15 counts  $\cdot 100 \text{ mL}^{-1}$  respectively. This is a very shallow lake with a depth of 2.4 metres, weedy and stained.



## **METALS**

All sample sites were analysed for 60 metal parameters. Of the 60 parameters only 27 (aluminum, antimony, arsenic, barium, cadmium, cerium, chromium, copper, cobalt, gallium, iron, lanthanum, lead, lithium, manganese, molybdenum, nickel, rubidium, scandium, strontium, tin, titanium, uranium, vanadium, yttrium, zinc, zirconium) were detectable. Although most metals are insoluble in water, low concentrations could be expected in areas of high mineralization. Distribution patterns of concentration typically reflect the geology or degree of mineralization as well as areas of impact.

Metal parameters not detected are not portrayed on the following pages.

Please refer to the discussion of accuracy of Exotic Metals in the Data Handling - Laboratory Data Section.