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CHRISTINA LAKE REGIONAL PROJECT

WATER QUALITY
ENVIRONMENTAL SETTING REPORT

Prepared For:
MEG Energy Corp.

Prepared By:
Golder Associates Ltd.

March 2005 **04**

MEG Energy Corp. is proposing the development of the Christina Lake Regional Project including facility construction and operation of a modified Steam Assisted Gravity Drainage oil sands project. The operation is designed to produce up to 25,000 barrels per day of bitumen near Christina Lake in northeastern Alberta The MEG oil sands lease is located approximately 150 km south of Fort McMurray on the north side of Christina Lake. Facilities will be constructed in Townships 76, 77 and 78, Ranges 4, 5 and 6, W4M, in the area north and east of Christina Lake.

The water quality of several waterbodies in the area of the Christina Lake Regional Project was summarized to characterize pre-development baseline water quality. Samples were collected from 12 waterbodies and 3 watercourses. Samples from Christina Lake, Unnamed Waterbodies 6, 7 and 12, and Unnamed Watercourses 1, 6 and 10 were analyzed for a detailed list of water quality parameters. Samples from Unnamed Waterbodies 2, 5, 8, 9, 11, 13, 15 and 16 were analyzed to evaluate acid sensitivity. Historical data from Alberta Environment for Christina Lake and the Christina River were used to supplement data collected during these baseline surveys.

Waterbodies and watercourses in the Local Study Area and the Regional Study Area generally have high concentrations of humic material originating from surrounding muskeg and peat bogs, resulting in elevated colour values. Concentrations of total suspended solids are usually low in these waters. Major ion concentrations are generally low to moderately low as indicated by conductance values and total dissolved solids concentrations. These waters are often soft, but have alkalinity levels indicating that they are not susceptible to acid deposition. Nutrient concentrations are variable indicating the trophic status of waterbodies and watercourses likely range from oligotrophic to eutrophic.

Metal concentrations were generally below guidelines, with the exception of total iron and manganese, both of which often had concentrations above aesthetic human health guidelines. Occasionally, total chromium and total aluminium concentrations were greater than guidelines protective of aquatic life. Concentrations of organic compounds were usually below detection limits; however, late summer concentrations of total phenolics were often greater than the aquatic life guideline. These exceedances can be attributed to natural factors and do not indicate that water quality has been compromised.

Some seasonal variability was observed in the waterbodies sampled, although the available data are insufficient for a detailed assessment of seasonal patterns in water quality. Dissolved oxygen concentration was lower during spring and pH was slightly elevated in late summer. Late summer colour values tended to be slightly higher than values measured during the spring. Conductance values measured during spring were generally higher than summer values. Occasionally, total metal concentrations were higher in the spring; however, seasonal variation in metals was generally low.

ACKNOWLEDGEMENTS

This Water Quality Environmental Setting Report was prepared for MEG Energy Corp. (MEG) by Golder Associates Ltd. (Golder). John Gulley is the Project Director, Tod Collard is the Project Manager and Zsolt Kovats is the Water Quality Component Lead.

The field surveys were carried out by Cam Davis, Gina Hoar, Jeanette Davis and Rick Hunt. Jody Janvier of Janvier, Alberta, assisted with the field work. This report was prepared by Darrell Jobson and Zsolt Kovats. Maps were prepared by Paul St. Rose and Joel Farah. This report was reviewed by Robert Mugo and Tod Collard, and was formatted by Tammy Toby.

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1 INTRODUCTION

1.1 PROJECT DESCRIPTION

MEG Energy Corp. (MEG) is a Calgary-based, private energy company focused on the development and recovery of bitumen, shallow gas reserves and the generation of power in northeast Alberta. MEG is proposing to develop the Christina Lake Regional Project (the Project) on part of the 52 sections of oil sands leases that it holds in the area of Christina Lake, Alberta. The Project would be located within the Regional Municipality of Wood Buffalo in northeastern Alberta, approximately 15 km southeast of local Secondary Highway 881 and 20 km northeast of Conklin.

MEG is proposing to develop their oil sands lease area by building and operating the Project utilizing a steam assisted gravity drainage (SAGD) oil recovery technology. The Project would consist of a central processing facility, SAGD wells, co-generation facilities and additional infrastructure. The proposed central processing facility and the co-generation unit would be located adjacent to MEG's approved Pilot facilities located in NE¼ 9 and SE¼ 16, Township 77, Range 5, W4M. The Project would be designed and built to produce 22,000 barrels per day of bitumen (approximately 3,500 cubic metres per day). This production, which would be in addition to the 3,000 barrels of bitumen per day from the pilot operation, would result in a total production of 25,000 barrels of bitumen per day (approximately 4,000 cubic metres per day).

1.2 STUDY OBJECTIVES

This report presents water quality data for waterbodies and watercourses in the vicinity of the proposed Project facilities. Included are results from the 2004 baseline surveys, and historical water quality data from Alberta Environment (AENV) for Christina Lake and the Christina River. Baseline water quality data are required to complete the Environmental Impact Assessment (EIA) for the Project.

The water quality data collected for this baseline assessment were used to characterize existing water quality in selected waterbodies and watercourses within the Local Study Area (LSA). Historical data were used to summarize water quality in the Regional Study Area (RSA).

1.3 STUDY AREAS

1.3.1 Regional Study Area

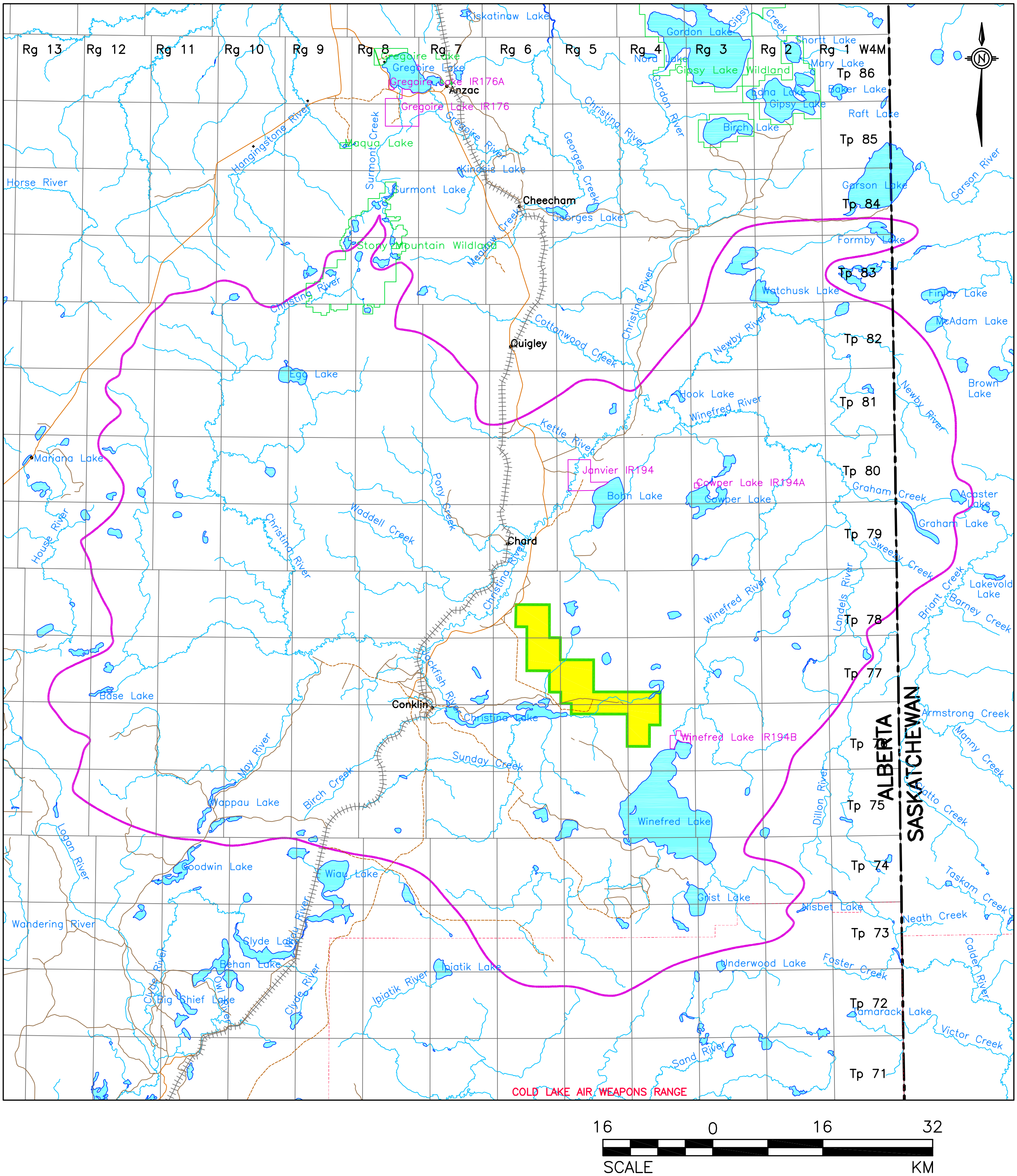
The Aquatic Resources RSA includes waterbodies and watercourses of regional significance in the vicinity of the Project (i.e., Christina, Cowper, Bohn and Winefred lakes, Christina and Winefred rivers), their entire drainage areas with exception of the Christina River, as well as surface waters that may be affected by nearby developments and the Project. The RSA includes the area considered relevant for assessing the cumulative effects of the Project and nearby developments.

The RSA boundaries were defined as follows (Figure 1-1):

- north: drainage divides of Kettle River and Newby River, and the headwaters of the Christina River;
- east: drainages for Newby River and Winefred River (crossing over the Alberta/Saskatchewan boundary);
- south: drainage divides of Christina Lake and Winefred Lake; and
- west: drainage divide of the Christina River.

1.3.2 Local Study Area

The Aquatic Resources LSA was selected based on the Project lease area, local drainage basins and the requirements of aquatics components including water quality, hydrology, and fish and fish habitat. The LSA was delineated by watershed boundaries of waterbodies and watercourses that may be directly or indirectly affected by the Project. The Aquatic Resources LSA encompasses portions of the upper watershed areas of the Christina River drainage, upstream of, and including, Christina Lake (Figure 1-2). The LSA boundaries are the north, west and south shorelines of Christina Lake, and the drainage basins of two small watercourses draining to the eastern basin of the lake. This area encompasses several small waterbodies and their tributaries.



LEGEND

(yellow)	MEG OIL SANDS LEASE
(magenta)	REGIONAL STUDY AREA

REFERENCE

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PROJECT

CHRISTINA LAKE REGIONAL PROJECT

TITLE

AQUATIC RESOURCES REGIONAL STUDY AREA

MEG ENERGY CORP.

PROJECT 04-1334-001.6100			FILE No. Aquatics_RSA	
DESIGN	KM	03/12/04	SCALE AS SHOWN	REV. 0
CADD	PSR	18/01/05		
CHECK	KM	18/01/05	**FIGURE: 1-1**	
REVIEW				

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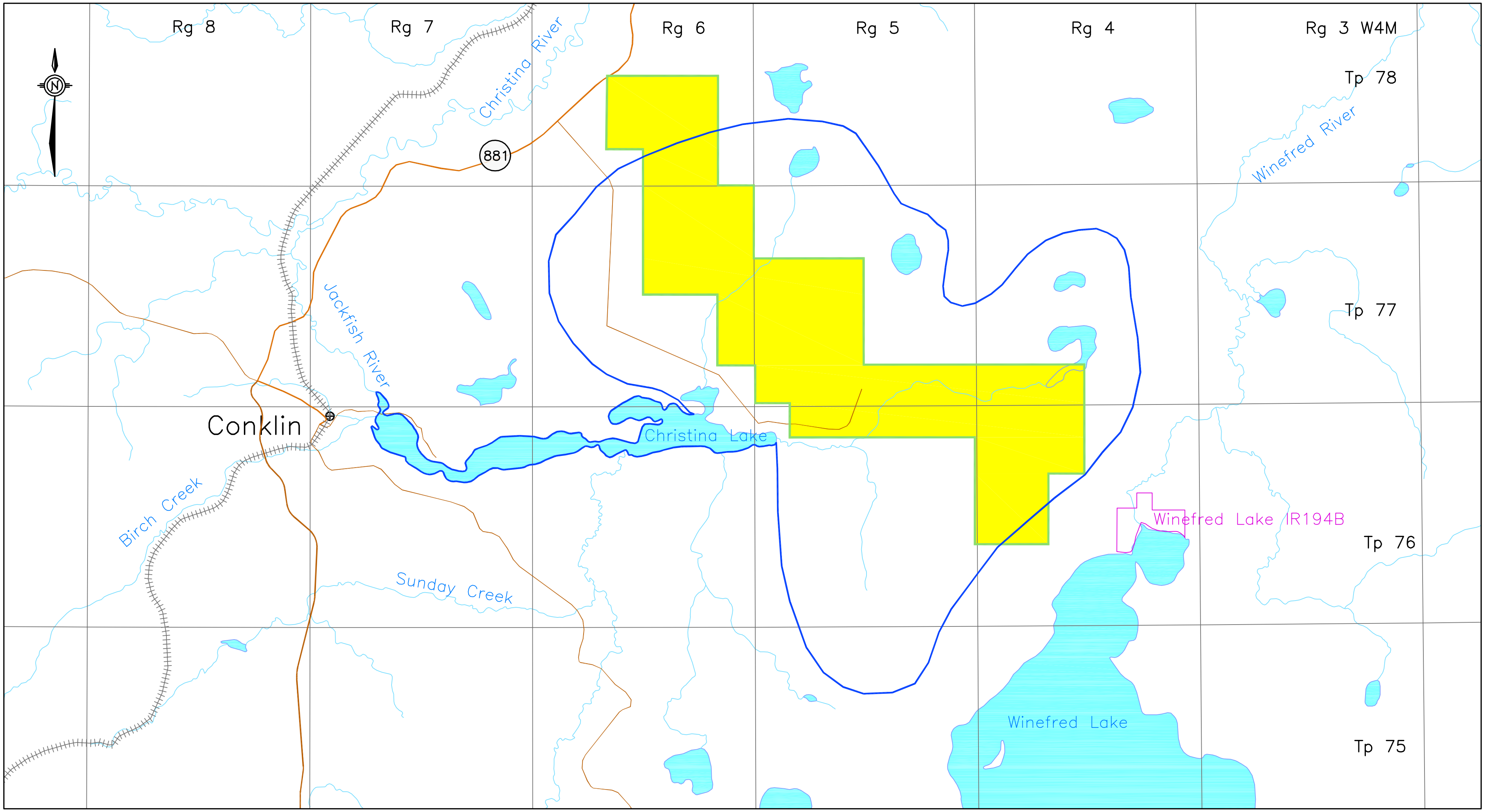

LEGEND

- MEG OIL SANDS LEASE
- LOCAL STUDY AREA

REFERENCE

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DATUM: NAD 83 PROJECTION: UTM ZONE 13
OIL & GAS AND ENVIRONMENTAL DATA PROVIDED BY VERITAS GeoSERVICES LTD., CURRENT AS OF MAY 2001.

5 0 5
SCALE KILOMETRES

PROJECT

CHRISTINA LAKE REGIONAL PROJECT

TITLE

AQUATIC RESOURCES
LOCAL STUDY AREA

MEG ENERGY CORP.

PROJECT 04-1334-001.6100			FILE No. Aquatic Res_LSA	
DESIGN	KM	02/12/04	SCALE 1:250000	REV. 0
CADD	PSR	18/01/05	**FIGURE: 1-2**	
CHECK	KM	18/01/05		
REVIEW				

2 METHODS

2.1 2004 BASELINE PROGRAM

2.1.1 Timing and Location of Sampling

Water quality samples were collected in the LSA from May 13 to 21, 2004 (spring survey) and August 24 to 30, 2004 (late summer survey). Surface waters in the immediate vicinity of the planned Project facilities include Christina Lake and a number of unnamed waterbodies and watercourses (Figure 1-1). Christina Lake and a representative set of smaller waterbodies (Unnamed Waterbodies 6, 7 and 12) located close to proposed Project facilities were selected for analysis of detailed water chemistry. Most of the remaining small waterbodies in the LSA (Unnamed Waterbodies 2, 5, 8, 9, 11, 13, 15 and 16) were sampled for parameters relevant for evaluating acid sensitivity.

The unnamed watercourses in Christina Lake's eastern drainage basin (Unnamed Watercourses 1, 6 and 10) convey most of the drainage from the Project area to Christina Lake. These watercourses were also analyzed for detailed water chemistry.

2.1.2 Sampling Methods and Water Quality Parameters

Water samples were collected, preserved, stored and shipped in accordance with Golder Technical Procedure 8.3-1 (available upon request). Composite water quality samples were collected from five random locations in waterbodies, while grab samples were collected in watercourses. Filled sample bottles were shipped on ice in coolers to the appropriate analytical laboratories (Alberta Research Council in Vegreville, Alberta, for low level mercury and silver, Enviro-Test Laboratories in Edmonton, Alberta, for all other parameters).

Samples collected to evaluate acid sensitivity were analyzed for conventional parameters (except total suspended solids [TSS] and chlorophyll *a*) and major ions (Table 2-1). Samples from the four remaining waterbodies and the watercourses were analyzed for all parameters listed in Table 2-1.

Table 2-1 Water Quality Parameters Analyzed in the 2004 Field Program

Group	Parameters
conventional parameters	pH, conductance, total dissolved solids (TDS), total suspended solids (TSS), hardness, alkalinity, dissolved organic carbon (DOC), total organic carbon (TOC), colour, chlorophyll *a*
major ions	bicarbonate, calcium, chloride, magnesium, potassium, sodium, sulphate, sulphide
nutrients	ammonia, nitrate plus nitrite, total Kjeldahl nitrogen (TKN), total nitrogen (TN), dissolved phosphorus, total phosphorus (TP)
organics	naphthenic acids, total phenolics, recoverable hydrocarbons (mineral oil and grease)
total and dissolved metals	aluminum, antimony, arsenic, barium, beryllium, boron, cadmium, chromium, cobalt, copper, iron, lead, lithium, manganese, mercury, molybdenum, nickel, selenium, silver, strontium, thallium, titanium, uranium, vanadium, zinc

Field water quality parameters (water temperature, conductivity, dissolved oxygen (DO) concentration and pH) were measured for all collected water quality samples. Field measurements were made using a field-calibrated multi-meter (YSI 556). Locations of all sampling sites were identified and recorded using a Garmin Global Positioning System (GPS) unit.

2.2 HISTORICAL DATA

Historical data for waterbodies and watercourses in the LSA and RSA were obtained from Alberta Environment's (AENV) Water Data System (WDS; AENV 2004), formerly known as NAQUADAT.

Data from AENV were evaluated for inclusion in the data summary. Waterbodies and watercourses with a sufficient amount of data, collected over a reasonable period, were included in the data summary. This was generally considered to be two or more sampling times per season over two or more years. Available information for the LSA and RSA include data for Christina Lake from 1980 through 1988 (Table 2-2), and for the Christina River from 1978 and 1979 (Table 2-2).

Table 2-2 Location of Historical Sampling Sites for Stations with Water Data System Data

Station	WDS Station Number	Station Description
Christina Lake	AB07CE0240	Christina Lake profile at centre
	AB07CE0250	Christina Lake euphotic composite
	AB07CE0260	Christina Lake profile at centre
	AB07CE0270	Christina Lake grab 200 m from shore
	AB07CE0590	Christina Lake Section 32, Township 76, Range 7, W4M
	AB07CE0600	Christina Lake Section 32, Township 76, Range 7, W4M
Christina River	AB07CE0050	Christina River above confluence with Clearwater River

2.3 DATA SUMMARY METHODS

The water quality data collected during the 2004 baseline program (i.e., spring and late summer water quality samples) are presented in table format in Section 3. Seasonal summary statistics (i.e., the median, minimum and maximum value for each parameter) were calculated for historical data from Christina Lake and the Christina River. The 2004 baseline data are presented with the historical data to allow for direct comparisons.

Seasons were defined as follows:

- spring: April, May;
- summer: June, July, August;
- fall: September, October; and
- winter: November, December, January, February, March.

To provide an indication of baseline water quality, water quality data were compared with guidelines for the protection of freshwater aquatic life and human health. Guidelines developed by regulatory agencies (Table 2-3) were used in these comparisons including AENV (1999), the Canadian Council of Ministers of the Environment (CCME 1999 with 2002 updates) and the United States Environmental Protection Agency (U.S. EPA 1999). In cases where a number of guidelines were available for a parameter, the most stringent guideline was used in these comparisons, as recommended by AENV (1999). Water quality guidelines have been developed for numerous substances, typically based on measured responses of standard test species (fish and invertebrates) to known concentrations of chemicals. Guidelines for nutrients (e.g., TP and TN), which are non-toxic, correspond to levels below which the harmful effects of nutrient enrichment (e.g., algal blooms) are unlikely. Chronic guidelines provide protection from long-term, sub-lethal effects (e.g., reduced growth or impaired reproduction). Acute guidelines are intended to protect aquatic organisms from short-term, lethal effects.

Concentrations of parameters measured to evaluate water quality may be affected by a number of factors. Natural conditions associated with surficial geology, interactions between surface water and groundwater, physical features of the waterbody and its drainage basin, local weather and seasonal hydrological changes and a number of other factors can influence baseline water quality. For example, many elements can be tightly bound to suspended sediments from spring runoff resulting in elevated concentrations of metals (e.g., aluminum, iron and manganese) and nutrients (e.g., TP) in surface water. These parameters are generally not available for aquatic organisms. Consequently, it is not uncommon to measure water quality parameters above regulatory guidelines in remote areas that are not directly affected by human activities.

Chemical concentrations that are slightly higher than water quality guidelines under baseline conditions are generally not considered to be of concern to aquatic life. Laboratory testing used to develop guidelines tends to be conservative and frequently incorporates a safety factor. Moreover, aquatic species are adapted to the natural levels of chemicals present in the waters they inhabit. Therefore, concentrations of water quality parameters that are greater than guidelines do not necessarily indicate that water quality has been compromised by human activities or natural factors.

Likewise, water quality parameters above human health guidelines (e.g., certain metals) do not necessarily indicate a danger to human health. For example, iron and manganese are frequently above human health guidelines; however, these guidelines are aesthetic and are intended to indicate the suitability of water for industrial or domestic uses (e.g., laundry use) rather than to identify health concerns.

Definitions and qualitative scales for selected parameters used to describe waterbodies in this report are summarized in Table 2-3.

Table 2-3 Water Quality Guidelines for the Protection of Aquatic Life and Human Health

Parameter	Units	Guidelines for the Protection of:			Guideline Source		
		Aquatic life		Human Health	Aquatic life		Human Health
		Acute	Chronic		Acute	Chronic	
pH	-	6.5 - 8.5	6.5 - 8.5	5 – 9	AENV[(a)]	AENV	U.S. EPA[(b)]
dissolved oxygen	mg/L	5 (1-day minimum)	6.5 (7-day mean)	-[(c)]	AENV	AENV	-
Major Ions							
chloride	mg/L	860	230	-	U.S. EPA	U.S. EPA	-
sulphide[(d)]	mg/L	-	0.002 - 0.117	-	-	U.S. EPA	-
Nutrients							
ammonia[(e)]	mg/L	0.9 - 36.7	0.45 - 6.95	-	U.S. EPA	U.S. EPA	-
nitrate	mg/L	-	-	1.4	-	-	U.S. EPA
nitrite	mg/L	-	0.06	-	-	CCME[(f)]	-
total nitrogen[(g)]	mg/L	-	1	-	-	AENV	-
total phosphorus	mg/L	-	0.05	-	-	AENV	-
Total Metals							
aluminum	mg/L	0.75	0.1	0.1	U.S. EPA	CCME	HC 2002[(k)]
antimony	mg/L	-	-	0.0008	-	-	U.S. EPA
arsenic	mg/L	0.34	0.005	0.025	U.S. EPA	CCME	HC 2002
boron	Mg/L			5			HC 2002
barium	mg/L	-	-	1	-	-	HC 2002
cadmium[(h)]	mg/L	0.0006 - 0.003	0.0001 - 0.00035	0.005	U.S. EPA	U.S. EPA	HC 2002
chromium VI[(i)]	mg/L	0.016	0.001	0.05	U.S. EPA	CCME	HC 2002
copper[(h)]	mg/L	0.004 - 0.019	0.002 - 0.003	0.188	U.S. EPA	CCME	U.S. EPA
iron	mg/L	-	0.3	0.043	-	CCME	U.S. EPA
lead[(h)]	mg/L	0.015 - 0.124	0.001 - 0.004	0.01	U.S. EPA	CCME	HC 2002
manganese	mg/L	-	-	0.0072	-	-	U.S. EPA
mercury[(j)]	mg/L	0.0016	0.0001	0.001	U.S. EPA	CCME	HC 2002
molybdenum	mg/L	-	0.073	-	-	CCME	-
nickel[(h)]	mg/L	0.155 - 0.620	0.017 - 0.069	0.088	U.S. EPA	U.S. EPA	U.S. EPA
selenium	mg/L	-	0.001	0.01	-	CCME	HC 2002
silver[(h)]	mg/L	0.0004 - 0.0072	0.0001	-	U.S. EPA	CCME	-
thallium	mg/L	-	0.0008	0.0002	-	CCME	U.S. EPA
zinc[(h)]	mg/L	0.04 - 0.158	0.030	1.069	U.S. EPA	CCME	U.S. EPA
Organics							
phenolics	mg/L	-	0.005	-	-	AENV	-

(a) AENV (1999).
(b) U.S. EPA (1999 with 2002 updates).
(c) - = No guideline available.
(d) Total sulphide concentration equivalent to 0.002 mg/L undissociated H_2S based on pH; the range is shown for minimum and maximum pH values (6 and 9) in the data summarized in this document.
(e) Guidelines are pH (acute and chronic) and temperature (chronic) dependent and were calculated for each sample using the U.S. EPA method described in AENV (1999), updated according to U.S. EPA (1999 with 2002 updates); the range is shown for minimum and maximum pH values (6 and 9) in the data summarized in this document and a temperature of 10^{o}C.
(f) CCME (1999 with 2002 updates).
(g) Total Kjeldahl nitrogen + nitrate + nitrite were compared with the total nitrogen guideline to identify guidelines being exceeded.
(h) Guidelines are hardness dependent and were calculated for each sample; the range is shown for minimum and maximum hardness values (27 and 139 mg/L) in the data summarized in this document.
(i) The guideline for chromium VI was applied to total chromium because CCME (1999 with 2002 updates) states that up to 60% of the total chromium in surface waters can exist as chromium VI.
(j) U.S. EPA (1999 with 2002 updates) acute and CCME (1999 with 2002 updates) chronic guidelines are shown, because Alberta mercury guidelines have not been finalized.
(k) Health Canada (2001).

The pH is a measure of hydrogen ion activity (or concentration) in a solution and is expressed as the negative logarithm (-log) of hydrogen ion concentration. The greater the hydrogen ion activity in water the more acidic it is. Because it is expressed as the -log, the greater the hydrogen ion activity, the lower the pH value. Solutions with low hydrogen ion activity are alkaline (basic) and have a high pH. Neutral waters have a pH of 7. Most aquatic organisms can tolerate waters with a pH between 6 and 9, as commonly found in many of the natural surface waters in Canada. Acidic deposition can lower the pH of a waterbody. Likewise, during spring freshet, the pH of surface waters can drop to values approximating the pH of precipitation (e.g., 5.1 to 5.4) (Schindler 1996).

Major ion concentrations in surface waters can be measured by hardness, total dissolved solids (TDS) and electrical conductivity. Hardness is the sum of calcium and magnesium concentrations. A scale of water hardness, expressed as mg/L equivalent to calcium carbonate is provided in Table 2-4. The toxicity of many metals decreases as hardness increases. The concentration of total dissolved solids is another measure of ion concentration. This is the amount of dissolved salts remaining after filtered water is evaporated at 180°C. Waters high in TDS are sometimes referred to as saline, and concentrations greater than 1,000 mg/L are usually considered to be harmful to aquatic life (Table 2-5; Hart et al. 1990; Mitchell and Prepas 1990).

Table 2-4 Qualitative Scale of Water Hardness Based on Concentration of Calcium Carbonate

Hardness Scale	Calcium Carbonate (mg/L)
very soft (low)	0-30 (*<28*)
soft	31-60
moderately soft (relatively low)	61-120 (*28-120*)
hard	121-180
very hard	>180

Note: Italics indicate Mitchell and Prepas (1990) definition of hardness.
Source: McNeely et al. (1979); Mitchell and Prepas (1990).

Table 2-5 Qualitative Scale of Salinity Based on Concentration of Total Dissolved Solids

Salinity Scale	Total Dissolved Solids (mg/L)
freshwater	<500
slightly saline	500-1,000
moderately saline	1,000-5,000
saline	>5,000

Source: Mitchell and Prepas (1990).

Conductance is a measure of how much electricity can pass through one cm of a water sample. This indicates the concentration of dissolved charged particles in the water. The concentration of TDS and conductance are strongly related; however, in freshwaters TDS is generally lower than conductivity (Mitchell and Prepas 1990). Descriptive scales for conductivity and TDS are provided in Table 2-6.

Table 2-6 Qualitative Scale of Total Dissolved Solids and Electrical Conductivity

Description	Total Dissolved Solids (mg/L)	Conductivity (µS/cm)
low	≤100	≤165
moderately low	100-200	166-330
moderate	201-300	331-500
moderately high	301-400	501-665
high	401-500	666-830
very high	>500	>830

Source: CCME (2003).

Water transparency is measured by turbidity and colour. Nephelometric turbidity units (NTU) is a measure of how much light is scattered by suspended particles in a water sample. Particles can include silt, clay, organic matter, plankton and microscopic organisms. Turbidity in natural waters can be highly variable, from not very turbid (less than 33 NTU; Mitchell and Prepas 1990) to very high (in the range of several hundred NTU; McNeely et al. 1979). For this report, turbidity is classified as follows:

- low: less than 30 NTU;
- moderate: between 30 and 100 NTU; and
- high: greater than 100 NTU.

Colour, which reflects the amount of humic material in water, is measured in true colour units (TCU). Filtered water samples are compared to a mixture of platinum (Pt) and cobalt compounds to determine the degree of colour (1 mg/L Pt is equal to 1 TCU). A scale of true colour is presented in Table 2-7. Waters in boreal forest regions dissolve humic material as they flow through peat bogs and muskeg, and typically have high colour values (Mitchell and Prepas 1990). Turbidity and colour often display seasonal variation related to hydrologic regime (e.g., elevated values during spring melt and summer) and local rainstorm events.

Table 2-7 Colour Scale of Surface Waters

Colour Scale	True Colour Units (as mg/L platinum)
very clear	<4
coloured	4-55
highly coloured	>55

Note: True colour units are expressed as mg/L of platinum (1 mg/L platinum = 1 true colour unit).
Source: Mitchell and Prepas (1990).

The capacity of a water sample to neutralize acids is termed alkalinity. This provides an indication of a waterbody's sensitivity to acid deposition or its acid neutralizing capacity (ANC). Saffran and Trew (1996) presented a scale of surface water sensitivity to acidification based on alkalinity (see Table 2-8).

Table 2-8 Scale of Acid Sensitivity Based on Alkalinity in Lakes

Acid Sensitivity	Alkalinity	
	(mg/L as $CaCO_3$)	(μeq/L)
high	0-10	0-200
moderate	>10-20	>200-400
low	>20-40	>400-800
least	>40	>800

Source: Saffran and Trew (1996).

Generally accepted categories of acid sensitivity for streams based on alkalinity and the acid neutralizing capacity is provided in Table 2-9.

Table 2-9 Acid Sensitivity Scale Based on Values of Acid Neutralizing Capacity and Alkalinity in Streams

Acid Sensitivity	Acid Neutralizing Capacity (μeq/L)	Alkalinity (mg/L as $CaCO_3$)
acidic	<0	<0
highly sensitive	0-50	0-2.5
sensitive	51-200	2.6-10
not sensitive	>200	>10

Source: Boward et al. (1999).

The concentration of all solid particles in the water column is termed the total suspended solids (TSS). High TSS values can cause stress to aquatic life. Negative effects from TSS depend on TSS concentration and length of exposure. Concentrations of TSS below 25 mg/L are generally not considered harmful to aquatic life (EIFAC 1965; U.S. EPA 1973; DFO and DOE 1983). Aquatic organisms can withstand low levels of TSS for long periods and higher levels for shorter periods (Newcombe and MacDonald 1991). In this report, TSS is characterized by the following concentrations:

- low: less than 10 mg/L;
- moderate: between 10 and 25 mg/L; and
- high: greater than 25 mg/L.

Particulate and dissolved organic carbon comprise total organic carbon (TOC). Natural waters can have concentrations that vary from 1 to 30 mg/L (McNeely et al. 1979). Naturally occurring “brown water” lakes and ponds, common in boreal forest areas, generally have higher TOC concentrations. The majority of TOC is derived from humic substances and partly degraded plant and animal materials. In this report, TOC is characterized by the following concentrations:

- low: less than 5 mg/L;
- moderate: between 5 and 20 mg/L; and
- high: greater than 20 mg/L.

The main nutrients of concern in most surface waters include nitrogen and phosphorus. Both are required for plant growth in very small amounts. Total Kjeldahl nitrogen (TKN) is a measure of ammonia and organic nitrogen and is a good indicator of biologically available nitrogen. Total Kjeldahl nitrogen concentrations in rivers that are not influenced by excessive organic inputs typically range from 0.1 to 0.5 mg/L (McNeely et al. 1979). In this report, TKN is characterized by the following concentrations:

- low: less than 0.1 mg/L;
- moderate: between 0.1 and 0.5 mg/L; and
- high: greater than 0.5 mg/L.

Biological productivity of waterbodies and watercourses can be described in terms of trophic classification (Table 2-10). The trophic status is affected by the amount of available nutrients concentrations. Phosphorus is frequently the limiting nutrient (i.e., the nutrient in shortest supply). Trophic status can also be measured in terms of chlorophyll *a* concentration (Table 2-11).

Table 2-10 General Relationship of Surface Water Productivity to Average Concentration of Epilimnetic Total Phosphorus

Trophic Status	Total Phosphorus (mg/L)	
	Waterbodies[a]	Watercourses[b]
Ultra-oligotrophic (very nutrient-poor)	<0.004	n/a
Oligotrophic (nutrient-poor)	0.004-0.01	<0.025
Mesotrophic (containing a moderate level of nutrients)	0.01-0.02	0.025-0.075
Meso-eutrophic (containing moderate to high level of nutrients)	0.02-0.035	n/a
Eutrophic (nutrient rich)	0.035-0.1	>0.075
Hypereutrophic (very nutrient rich)	>0.1	n/a

Source: CCME (2003)
[a] Vollenweider and Kerekes (2002)
[b] Dodds et al. (1982)
n/a=not applicable

Table 2-11 General Relationship of Waterbody Productivity to Maximum Concentration of Epilimnetic Chlorophyll *a*

Trophic Status	Chlorophyll *a* (μg/L)
Oligotrophic	<8
Oligo-mesotrophic	occasionally >8
Mesotrophic	8-25
Eutrophic	26-75
Hypereutrophic	>75

Source: Mitchell and Prepas (1990).

Metals naturally occur in surface waters in small quantities (i.e., usually less than 1 mg/L). Aquatic organisms can show effects associated with high metal concentrations; however, the level at which metals are toxic varies. Metal toxicity is also inversely related to water hardness and therefore, certain metal guidelines are expressed in hardness. Usually, most metals are associated with TSS and therefore tend to settle out of the water column, rendering them biologically unavailable. Total metal concentrations (dissolved metals plus metals associated with suspended particles) and dissolved metals are both reported. In this report, total metal concentrations are discussed relative to the aquatic life and drinking water guidelines. There are no regulatory guidelines for dissolved metal concentrations.

Phenolic compounds from natural and human sources are also found in surface waters. Naturally occurring phenols are released by plants and decaying vegetation and wild animal wastes, and concentrations are usually variable. Human sources of phenols include coal and wood distilleries, oil refineries, chemical plants, and domestic animal and human wastes. Phenols can cause water to have an undesirable taste, even at low concentrations, and can persist for a long time. In this report, aquatic life and drinking water guidelines are used to discuss relative concentrations of total phenolics.

2.4 QUALITY ASSURANCE AND QUALITY CONTROL (QA/QC)

Field blanks were used to evaluate the effects of collection, handling and analysis of samples on data quality. One field blank was collected during each sampling trip, by filling a set of sample bottles with deionized water provided by the analytical laboratory. Field blanks were analyzed for the detailed parameter list shown in Table 2-1. Concentrations greater than five times the analytical detection limit in the field blanks were considered to indicate the possibility of contamination. This assessment criterion is based on the Practical Quantitation Limit defined by the U.S. EPA (1985) and is also used by the Oil Sands Regional Aquatics Monitoring Program (RAMP) (Golder 2003) to evaluate data quality.

Quality assurance for water quality data manipulation and data summary calculations consisted of:

- checking the data in the Project database against the raw data obtained from databases or analytical laboratories;
- logic checks on selected parameters; and
- verifying the accuracy of calculations performed to generate summary statistics.

A subset of the data transferred from electronic files was checked against the original files. Logic checks included verifying values outside of expected ranges. Calculations of summary statistics were verified by recalculating minimum and maximum concentrations, sample sizes and medians for a subset of the data. Any errors found were corrected in the final data tables.

Concentrations of dissolved metals that were 20% greater than their corresponding total concentration were assessed to determine if the difference was a result of laboratory error. Effects of analytical variability are proportionally higher at concentrations near detection limits. When concentrations were greater than five times the detection limit, the difference was considered to be due to analytical error.

3 RESULTS

3.1 CHRISTINA LAKE

The water quality sample collected from Christina Lake during the late summer of 2004 had a pH value within guideline levels (Table 3-1). Historical pH values were generally within guideline levels; however, a minimum winter value was below the aquatic life guideline of 6.5 in 1986. Christina Lake had a late summer dissolved oxygen (DO) level within guidelines protective of aquatic life. Historical DO values are unavailable for this waterbody.

Water in Christina Lake is coloured, which is typical of waterbodies in boreal areas. This usually results from elevated concentrations of humic matter contributed by surrounding muskeg and peat bogs. Total suspended sediment concentration was low in late summer 2004, as was the single historical value measured during spring.

Major ion concentrations in late summer of 2004 were low to moderately low, as reflected in the concentration of total dissolved solids (TDS) and conductance. Historically, conductance and TDS ranged from low to moderately low, with lowest values measured during spring. Alkalinity values in Christina Lake are indication of high buffering capacity and are therefore not acid sensitive.

Total organic carbon concentration in Christina Lake was elevated, which is typical of waterbodies in boreal forests. The concentration of TOC in the late summer of 2004 was in the moderate range. Total Kjeldahl nitrogen concentration was moderate in 2004, although one historical concentration measured during spring is considered high. Total nitrogen concentration was not above guidelines in 2004, which is similar to historical data. Based on total phosphorus concentrations, the trophic level in this waterbody varies between mesotrophic and meso-eutrophic. However, in late summer of 2004, chlorophyll *a* was characteristic of oligotrophic waterbodies.

Most total metal concentrations were below water quality guidelines. Manganese was above the guideline value set to protect human health. A single historical spring season value was also above guidelines for both manganese and chromium. Dissolved metal concentrations were measured in Christina Lake in 2004 (Table 3-2); however, historical dissolved metals data were not available.

Concentrations of general organics in Christina Lake during late summer of 2004 were below detection limits. A historical concentration of total phenols, measured during spring, was greater than the chronic guideline for the protection of aquatic life.

Table 3-1 Water Quality of Christina Lake in Late Summer of 2004 and Historical Water Quality Data

Parameter	Units	Christina Lake	Christina Lake (Historical Data)											
			Winter (1986)				Spring (1980,1988)				Summer (1983)			
		Late Summer (2004)	median	min	max	n	median	min	max	n	median	min	max	n
Field measured														
pH	-	8	6.5	**6.0** [(a,c)]	7.3	31	7.7	7.6	7.8	2	8.1	7.6	8.2	3
conductance	μS/cm	137	193	184	223	31	143	139	146	2	220	-	-	1
temperature	°C	15.3	-	-	-	-	-	-	-	-	-	-	-	-
dissolved oxygen	mg/L	9.6	-	-	-	-	-	-	-	-	-	-	-	-
Conventional Parameters														
colour	TCU	30	-	-	-	-	17	-	-	1	-	-	-	-
conductance	μS/cm	182	-	-	-	-	-	-	-	-	-	-	-	-
dissolved organic carbon	mg/L	15	-	-	-	-	11	-	-	1	-	-	-	-
hardness	mg/L	86	114	105	117	3	66	62	70	2	98	-	-	1
pH	-	8.1	-	-	-	-	-	-	-	-	-	-	-	-
total alkalinity	mg/L	92	116	113	124	3	76	69	83	2	115	-	-	1
total dissolved solids	mg/L	130	124	119	130	3	86	76	97	2	117	-	-	1
total organic carbon	mg/L	15	-	-	-	-	-	-	-	-	-	-	-	-
total suspended solids	mg/L	3	-	-	-	-	4	-	-	1	-	-	-	-
chemical oxygen demand	mg/L	-	-	-	-	-	34.1	-	-	1	-	-	-	-
Major Ions														
bicarbonate	mg/L	113	142	138	151	3	93	85	101	2	140	-	-	1
calcium	mg/L	23	31	29	32	3	17	16	18	2	26	-	-	1
carbonate	mg/L	<5	-	-	-	-	-	-	-	-	-	-	-	-
chloride	mg/L	2	<1	<1	<1	3	2	<1	2	2	<1	-	-	1
magnesium	mg/L	7	9	8	9	3	6	5	6	2	8	-	-	1
potassium	mg/L	1	1	1	1	3	1	1	1	2	1	-	-	1
sodium	mg/L	6	7	7	8	3	5	4	5	2	7	-	-	1
sulphate	mg/L	3	<5	<5	<5	3	<5	<5	<5	2	<5	-	-	1

Table 3-1 Water Quality of Christina Lake in Late Summer of 2004 and Historical Water Quality Data (continued)

Parameter	Units	Christina Lake	Christina Lake (Historical Data)											
			Winter (1986)				Spring (1980,1988)				Summer (1983)			
		Late Summer (2004)	median	min	max	n	median	min	max	n	median	min	max	n
sulphide	mg/L	0.007	-	-	-	-	-	-	-	-	-	-	-	-
Nutrients and Chlorophyll *a*														
nitrate + nitrite	mg/L	<0.1	0.1	0.1	0.2	3	0.1	-	-	1	<0.05	-	-	1
ammonia	mg/L	<0.05	-	-	-	-	-	-	-	-	-	-	-	-
total Kjeldahl nitrogen	mg/L	0.5	0.5	0.4	0.5	3	0.7	-	-	1	0.5	-	-	1
total nitrogen	mg/L	0.6	0.6	0.5	0.6	3	0.7	-	-	1	0.6	-	-	1
total phosphorus	mg/L	0.014	0.016	0.016	0.034	3	0.033	-	-	1	0.016	-	-	1
dissolved phosphorus	mg/L	0.005	-	-	-	-	-	-	-	-	-	-	-	-
chlorophyll *a*	mg/L	6	-	-	-	-	-	-	-	-	-	-	-	-
General Organics														
naphthenic acids	mg/L	<1	-	-	-	-	-	-	-	-	-	-	-	-
total phenolics	mg/L	0.004					**0.009** [c]	-	-	1	-	-	-	-
total recoverable hydrocarbons	mg/L	<0.5	-	-	-	-	-	-	-	-	-	-	-	-
Total Metals														
aluminum	mg/L	<0.02	-	-	-	-	-	-	-	-	-	-	-	-
antimony	mg/L	0.0006	-	-	-	-	-	-	-	-	-	-	-	-
arsenic	mg/L	0.0005	-	-	-	-	0.0005	-	-	1	-	-	-	-
barium	mg/L	0.021	-	-	-	-	0.019	-	-	1	-	-	-	-
beryllium	mg/L	<0.001	-	-	-	-	-	-	-	-	-	-	-	-
boron	mg/L	0.02	-	-	-	-	-	-	-	-	-	-	-	-
Cadmium	mg/L	<0.0002	-	-	-	-	<0.001 [d>c]	-	-	1	-	-	-	-
chromium	mg/L	0.0008	-	-	-	-	**0.002** [c]			1	-	-	-	-
cobalt	mg/L	<0.0002	-	-	-	-	<0.001	1	-	-	-	-	-	-
copper	mg/L	0.002	-	-	-	-	0.002	1	-	-	-	-	-	-
iron	mg/L	0.04	-	-	-	-	-	-	-	-	-	-	-	-

Table 3-1 Water Quality of Christina Lake in Late Summer of 2004 and Historical Water Quality Data (continued)

Parameter	Units	Christina Lake	Christina Lake (Historical Data)											
			Winter (1986)				Spring (1980,1988)				Summer (1983)			
		Late Summer (2004)	median	min	max	n	median	min	max	n	median	min	max	n
lead	mg/L	0.0001	-	-	-	-	-	-	-	-	-	-	-	-
lithium	mg/L	<0.006	-	-	-	-	-	-	-	-	-	-	-	-
manganese	mg/L	**0.01** [e]		-	-	-	**0.048** [e]	1	-	-	-	-	-	-
mercury	mg/L	<0.0000006	<0.0001 [d>e]	<0.0001 [d>e]	<0.0001 [d>e]	3	<0.0001 [d>e]	-	-	1	-	-	-	-
molybdenum	mg/L	0.0003	-	-	-	-	<0.001	-	-	1	-	-	-	-
nickel	mg/L	0.0007	-	-	-	-	0.002	1	-	-	-	-	-	-
selenium	mg/L	<0.0004	-	-	-	-	<0.0002	1	-	-	-	-	-	-
silver	mg/L	0.000008	-	-	-	-	-	-	-	-	-	-	-	-
strontium	mg/L	0.06	-	-	-	-	-	-	-	-	-	-	-	-
thallium	mg/L	<0.0001	-	-	-	-	-	-	-	-	-	-	-	-
titanium	mg/L	<0.005	-	-	-	-	-	-	-	-	-	-	-	-
uranium	mg/L	<0.0001	-	-	-	-	-	-	-	-	-	-	-	-
vanadium	mg/L	<0.0002	-	-	-	-	<0.002	1	-	-	-	-	-	-
zinc	mg/L	<0.004	-	-	-	-	0.017	1	-	-	-	-	-	-

Bolded concentrations are higher than water quality guidelines.

[a] = There were no summer data for general organics or total metals.

[b] = Concentration higher than the relevant acute aquatic life guideline or beyond the recommended pH or DO concentration range.

[c] = Concentration higher than the relevant chronic aquatic life guideline or beyond the recommended pH or DO concentration range.

[d>] = Analytical detection limit was higher than the relevant water quality guideline(s).

[e] = Concentration higher than the relevant human health guideline or beyond the recommended pH or DO concentration range.

- = no data / no guideline.

The human health guideline is based on the more conservative of: U.S. EPA (1999 with 2002 updates) adjusted for increased fish consumption using a rate of 45 g/day (Richardson 1997) and Health Canada (2001).

Table 3-2 Dissolved Metal Concentrations in Christina Lake in Late Summer of 2004

Parameter	Units	Christina Lake Late Summer (2004)
Dissolved Metals		
aluminum	mg/L	<0.01
antimony	mg/L	0.0007
arsenic	mg/L	0.0005
barium	mg/L	0.021
beryllium	mg/L	<0.001
boron	mg/L	0.02
cadmium	mg/L	<0.0001
chromium	mg/L	0.0007
cobalt	mg/L	<0.0001
copper	mg/L	<0.0006
iron	mg/L	0.02
lead	mg/L	0.0004
lithium	mg/L	0.005
manganese	mg/L	<0.001
mercury	mg/L	<0.0001
molybdenum	mg/L	0.0005
nickel	mg/L	0.0012
selenium	mg/L	<0.0004
silver	mg/L	<0.0002
strontium	mg/L	0.06
thallium	mg/L	0.00005
titanium	mg/L	0.0004
uranium	mg/L	<0.0001
vanadium	mg/L	0.0003
zinc	mg/L	0.003

3.2 SMALL WATERBODIES

Field measured water quality parameters in the three unnamed waterbodies sampled for detailed waterbody chemistry (Unnamed Waterbodies 6, 7 and 12) were generally within ranges typical of surface waters in northeastern Alberta (Table 3-3). Spring season DO values were just below the aquatic life guideline of 6.5 mg/L. Measured pH values were slightly lower in summer while DO was higher.

Colour was elevated in all waterbodies in the LSA. This is indicative of high concentrations of humic substances from peat bogs and muskeg found in many boreal forest areas. Unnamed Waterbody 6 was highly coloured in spring 2004 and Unnamed Waterbody 7 had high colour values in late summer 2004. The concentrations of TSS was low in all of these waterbodies.

During spring and late summer of 2004, major ion concentrations were low, as reflected in conductivity and TDS concentrations. Hardness ranged from very soft to soft. Alkalinity values were high enough to indicate a low sensitivity to acid deposition. The spring sulphide concentration in Unnamed Waterbody 7 was greater than the chronic guideline for the protection aquatic life. This concentration may be artificially high as the concentration of sulphide in the field blank from the spring was also higher than expected (Section 3.5).

Total organic carbon concentrations were variable, ranging from moderate to high, with the highest values occurring in late summer. Total Kjeldahl nitrogen concentrations were high in all samples. Total nitrogen concentration in Unnamed Waterbody 7 was greater than the chronic guideline to protect aquatic life during both spring and late summer of 2004. Total nitrogen concentrations in the other waterbodies were at the guideline value. The range of total phosphorus in Unnamed Waterbodies 7 and 12 is characteristic of mesotrophic to meso-eutrophic waterbodies, while concentrations at Unnamed Waterbody 6 are considered eutrophic. Chlorophyll *a* in Unnamed Waterbody 6 was higher than in the other two waterbodies and is characteristic of mesotrophic waterbodies.

Concentrations of total metals were generally below guideline levels. Exceptions included chromium, iron and manganese. Total chromium was greater than the chronic guideline protective of aquatic organisms in Unnamed Waterbodies 7 and 12. Total iron and manganese concentrations were greater than human health guidelines in all of the waterbodies sampled.

Naphthenic acid and total recoverable hydrocarbon concentrations were generally at or below detection levels except in Unnamed Waterbody 7 during late summer. Concentrations of total phenolics measured during spring were lower than the detection limit; however, in the late summer, concentrations were greater than the guideline protective of aquatic life.

Table 3-3 Water Quality of Waterbodies Sampled for Detailed Water Quality Parameters in the Christina Lake Regional Project Local Study Area in 2004

Parameter	Units	Unnamed Waterbody 6		Unnamed Waterbody 7		Unnamed Waterbody 12	
		Spring	Late Summer	Spring	Late Summer	Spring	Late Summer
Field measured							
pH	-	7.5	7.0	7.3	6.8	7.5	6.9
conductance	µS/cm	57	43	69	52	64	66
temperature	°C	12.1	13.1	13.6	13.6	11.8	13.1
dissolved oxygen	mg/L	**6.3** (a)	8.3	**6.3** (a)	7.8	**6.4** (a)	7.4
Conventional Parameters							
colour	TCU	70	50	50	60	30	50
conductance	µS/cm	58	55	69	68	68	85
dissolved organic carbon	mg/L	17	20	23	34	10	17
hardness	mg/L	30	27	37	37	33	44
pH	-	7.7	7.6	7.8	7.6	7.8	7.9
total alkalinity	mg/L	27	25	32	30	33	42
total dissolved solids	mg/L	70	50	80	80	60	40
total organic carbon	mg/L	18	21	27	35	11	17
total suspended solids	mg/L	4	<3	<3	3	4	<3
Major Ions							
bicarbonate	mg/L	32	30	39	37	41	51
calcium	mg/L	8	7	9	8	9	12
carbonate	mg/L	<5	<5	<5	<5	<5	<5
chloride	mg/L	2	2	2	2	2	1
magnesium	mg/L	2	2	4	4	3	4
potassium	mg/L	1	1	1	0.2	1	0.2
sodium	mg/L	2	2	2	2	2	1
sulphate	mg/L	2	1	2	1	1	1
sulphide	mg/L	0.004	<0.003	**0.005** (a)	0.003	0.005	<0.003

Table 3-3 Water Quality of Waterbodies Sampled for Detailed Water Quality Parameters in the Christina Lake Regional Project Local Study Area in 2004 (continued)

Parameter	Units	Unnamed Waterbody 6		Unnamed Waterbody 7		Unnamed Waterbody 12	
		Spring	Late Summer	Spring	Late Summer	Spring	Late Summer
Nutrients and Chloropyll *a*							
nitrate + nitrite	mg/L	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
ammonia	mg/L	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
total kjeldahl nitrogen	mg/L	0.9	0.9	1.3	1.6	0.9	0.8
total nitrogen	mg/L	1	1	**1.4** [(a)]	**1.7** [(a)]	1	0.9
total phosphorus	mg/L	0.041	0.041	0.017	0.028	0.021	0.02
dissolved phosphorus	mg/L	0.012	0.012	0.006	0.009	0.007	0.006
chlorophyll *a*	mg/L	10	17	5	2	3	<1
General Organics							
naphthenic acids	mg/L	<1	1	1	2	<1	1
total phenolics	mg/L	<0.001	**0.015** [(a)]	<0.001	**0.018** [(a)]	<0.001	**0.012** [(a)]
total recoverable hydrocarbons	mg/L	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Total Metals							
aluminum	mg/L	0.03	0.02	0.03	<0.02	0.02	<0.02
antimony	mg/L	0.0009	0.0007	0.0011	0.0007	0.001	0.0007
arsenic	mg/L	<0.0004	0.0005	<0.0004	0.0006	<0.0004	<0.0004
barium	mg/L	0.007	0.01	0.002	0.004	0.002	0.004
beryllium	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
boron	mg/L	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
cadmium	mg/L	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002
chromium	mg/L	<0.0008	<0.0008	**0.0012** [(a)]	<0.0008	**0.0019** [(c)]	<0.0008
cobalt	mg/L	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002
copper	mg/L	<0.001	<0.001	<0.001	<0.001	0.002	<0.001
iron	mg/L	**1.51** [(a,b)]	**0.32** [(a,b)]	**0.07** [(b)]	0.04	**0.1** [(b)]	**0.08** [(b)]
lead	mg/L	0.0001	<0.0001	0.0002	0.0002	0.0003	0.0002
lithium	mg/L	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006

Table 3-3 Water Quality of Waterbodies Sampled for Detailed Water Quality Parameters in the Christina Lake Regional Project Local Study Area in 2004 (continued)

Parameter	Units	Unnamed Waterbody 6		Unnamed Waterbody 7		Unnamed Waterbody 12	
		Spring	Late Summer	Spring	Late Summer	Spring	Late Summer
manganese	mg/L	**0.044** (b)	**0.049** (b)	0.006	**0.016** (b)	**0.011** (b)	**0.035** (b)
mercury	mg/L	<0.0000006	<0.0000006	0.0000006	<0.0000006	0.0000011	<0.0000006
molybdenum	mg/L	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
nickel	mg/L	0.0024	0.0002	0.0003	0.0002	<0.0002	0.0014
selenium	mg/L	<0.0004	<0.0004	<0.0004	<0.0004	0.0005	<0.0004
silver	mg/L	0.0000054	0.0000038	<0.000005	<0.0000005	<0.000005	0.0000029
strontium	mg/L	0.02	0.03	0.01	0.02	0.01	0.02
thallium	mg/L	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
titanium	mg/L	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
uranium	mg/L	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
vanadium	mg/L	0.0006	<0.0002	0.0002	<0.0002	0.0006	<0.0002
zinc	mg/L	0.023	0.007	0.008	0.005	0.016	0.01
Dissolved Metals							
aluminum	mg/L	<0.01	<0.01	0.01	<0.01	0.01	<0.01
antimony	mg/L	0.0011	0.0006	0.001	0.0006	0.0011	0.0005
arsenic	mg/L	0.0005	0.0005	0.0005	0.0006	<0.0004	<0.0004
barium	mg/L	0.006	0.008	0.002	0.003	0.002	0.002
beryllium	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
boron	mg/L	0.01	0.01	0.01	0.01	0.01	0.01
cadmium	mg/L	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
chromium	mg/L	0.0006	<0.0004	0.0006	<0.0004	0.0007	<0.0004
cobalt	mg/L	0.0001	<0.0001	0.0003	<0.0001	0.0002	<0.0001
copper	mg/L	<0.0006	<0.0006	<0.0006	<0.0006	<0.0006	<0.0006
iron	mg/L	1.14	0.14	0.05	0.03	0.06	0.06
lead	mg/L	<0.0001	0.0004	<0.0001	0.0001	0.0001	0.0001
lithium	mg/L	0.002	0.003	0.002	0.003	0.001	0.003

Table 3-3 Water Quality of Waterbodies Sampled for Detailed Water Quality Parameters in the Christina Lake Regional Project Local Study Area in 2004 (continued)

Parameter	Units	Unnamed Waterbody 6		Unnamed Waterbody 7		Unnamed Waterbody 12	
		Spring	Late Summer	Spring	Late Summer	Spring	Late Summer
manganese	mg/L	0.003	0.018	0.003	0.006	0.002	0.001
mercury	mg/L	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
molybdenum	mg/L	<0.0001	0.0002	<0.0001	<0.0001	<0.0001	<0.0001
nickel	mg/L	0.0001	0.0006	0.0002	<0.0001	<0.0001	0.0001
selenium	mg/L	0.0008	<0.0004	<0.0004	<0.0004	<0.0004	<0.0004
silver	mg/L	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002
strontium	mg/L	0.02	0.02	0.02	0.02	0.02	0.02
thallium	mg/L	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005
titanium	mg/L	0.0011	<0.0003	<0.0003	<0.0003	0.0003	0.0004
uranium	mg/L	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
vanadium	mg/L	0.0003	<0.0001	0.0002	<0.0001	0.0002	<0.0001
zinc	mg/L	0.012	0.004	0.004	0.004	0.005	0.003

Bolded concentrations are higher than water quality guidelines.

[(a)] = Concentration higher than the relevant chronic aquatic life guideline or beyond the recommended pH or DO concentration range.

[(b)] = Concentration higher than the relevant human health guideline or beyond the recommended pH or DO concentration range.

- = no data / no guideline.

The human health guideline is based on the more conservative of: U.S. EPA (1999 with 2002 updates) adjusted for increased fish consumption using a rate of 45 g/day (Richardson 1997) and Health Canada (2001).

3.3 WATERCOURSES

Field measured parameters in the three unnamed watercourses were within water quality guidelines (Table 3-4). Historical pH values in the Christina River were also within guidelines. Values for DO were unavailable.

Most of the watercourses in the LSA are considered highly coloured. Historically, water colour in the Christina River ranged from coloured to highly coloured. Concentrations of TSS in the unnamed watercourses are considered low. In the Christina River, historical TSS values were variable, ranging from low to high. Summer and fall concentrations were generally higher than winter values.

Major ion concentrations were variable in 2004, based on conductance and TDS concentration. Conductance and TDS were generally low or moderately low in the unnamed watercourses. Historical conductance values in the Christina River ranged from moderate to very high in the winter, while summer and fall values ranged from moderately low to moderate. Historical winter TDS concentrations were moderate to very high, while summer and fall concentrations were lower ranging from moderately low to moderate. Sulphide concentration was above the guideline in all watercourses sampled during the spring. These concentrations may be artificially high, as the concentration of sulphide in the spring field blank was also elevated (Section 3.5). Sulphide in Unnamed Watercourse 6 was above the aquatic life guideline in late summer. Hardness values in these watercourses were generally variable, ranging from very soft in Unnamed Watercourse 1 in spring, to hard in Unnamed Watercourse 6 in late summer of 2004. Alkalinity values measured in these watercourses are not indicative of sensitivity to acid deposition.

Total organic carbon concentrations ranged from moderate to high. The TKN concentrations in Unnamed Watercourse 1 were below detection limits in spring 2004. Historical TKN concentrations in the Christina River were high. Total nitrogen concentrations in the unnamed watercourses were below guidelines; however, historical concentrations in the Christina River were often greater than chronic guidelines protective of aquatic life. Concentrations of total phosphorus were greater than the guideline in Unnamed Watercourses 6 and 10 during 2004. The trophic level in these two watercourses ranged between oligotrophic and eutrophic based on total phosphorus concentrations. Historically, concentrations of total phosphorus in the Christina River were often greater than the guideline and were characteristic of mesotrophic to eutrophic watercourses.

Most total metal concentrations were below detection limits in the unnamed watercourses; however, three metals were greater than guidelines during 2004.

Table 3-4 Water Quality of Watercourses in the Christina Lake Regional Project Local Study Area in 2004 and Historical Data for Christina River

Parameter	Units	Unnamed Watercourse 1		Unnamed Watercourse 6		Unnamed Watercourse 10	Christina River (Historical Data)											
							Winter (1978-79)				Summer (1978)				Fall (1978)			
		Spring	Late Summer	Spring	Late Summer	Spring	median	min	max	n	median	min	max	n	median	min	max	n
Field measured																		
pH	-	7.3	7.2	7.6	7.5	6.9	7.9	7.5	8.5	5	8.0	7.8	8.2	3	7.9	7.5	8.3	2
conductance	µS/cm	103	93	184	242	99	680	400	850	5	190	175	444	3	131	63	200	2
temperature	°C	5.2	13.8	8.2	12.4	6.1	-	-	-	-	-	-	-	-	-	-	-	-
dissolved oxygen	mg/L	9.3	10.2	9.1	7.9	9.6	-	-	-	-	-	-	-	-	-	-	-	-
Conventional Parameters																		
colour	TCU	50	60	60	60	100	35	35	60	5	50	35	50	3	105	80	130	2
conductance	µS/cm	55	118	184	301	100	-	-	-	-	-	-	-	-	-	-	-	-
dissolved organic carbon	mg/L	14	30	15	21	18	17	16	21	5	24	20	33	3	20	19	21	2
hardness	mg/L	29	61	86	139	57	-	-	-	-	90	80	101	2	-	-	-	-
pH	-	7.6	7.9	8.1	8.1	7.7	-	-	-	-	-	-	-	-	-	-	-	-
total alkalinity	mg/L	26	61	91	159	50	169	133	191	5	105	87	144	3	83	66	99	2
total dissolved solids	mg/L	80	130	140	70	130	448	264	561	5	170	125	266	3	131	130	132	2
total organic carbon	mg/L	15	32	17	21	21	17	16	27	5	25	20	34	3	23	20	27	2
total suspended solids	mg/L	4	5	4	9	4	6	4	128	5	32	15	60	3	80	16	144	2
Major Ions																		
bicarbonate	mg/L	32	74	111	194	61	-	-	-	-	-	-	-	-	-	-	-	-
calcium	mg/L	8	16	23	37	15	44	30	46	5	27	21	36	3	20	18	22	2
carbonate	mg/L	<5	<5	<5	<5	<5	-	-	-	-	-	-	-	-	-	-	-	-
chloride	mg/L	<1	1	4	8	1	125	56	165	5	33	22	64	3	11	9	13	2
magnesium	mg/L	2	5	7	11	5	14	10	15	5	8	7	12	3	6	5	7	2
potassium	mg/L	1	0.1	1	1	2	1	1	2	5	1	1	1	3	1	1	1	2
sodium	mg/L	2	3	10	17	2	79	40	110	5	27	20	50	3	18	11	24	2
sulphate	mg/L	1	2	3	4	2	-	-	-	-	-	-	-	-	-	-	-	-
sulphide	mg/L	**0.014** [(b)]	0.004	**0.025** [(b)]	**0.011** [(b)]	**0.005** [(b)]	-	-	-	-	-	-	-	-	-	-	-	-
Nutrients and Chlorophyll *a*																		
nitrate + nitrite	mg/L	<0.1	<0.1	<0.1	<0.1	<0.1	0.3	0.1	0.6	5	0.003	<0.003	0.01	3	0.03	0.1	0.05	2
ammonia	mg/L	<0.05	<0.05	0.17	<0.05	<0.05	0.1	0.013	0.176	5	0.03	<0.002	0.05	3	0.059	-	-	1
total Kjeldahl nitrogen	mg/L	<0.2	0.6	0.5	0.8	0.8	1.2	0.5	2.2	5	1.1	0.8	1.2	3	1.3	1	1.7	2
total nitrogen	mg/L	0.3	0.7	0.6	0.9	0.9	**1.4** [(b)]	**1.1** [(b)]	**2.3** [(b)]	5	**1.1** [(b)]	0.8	**1.1** [(b)]	3	**1.4** [(b)]	**1.1** [(b)]	**1.7** [(b)]	2
total phosphorus	mg/L	0.02	0.026	**0.184** [(b)]	**0.059** [(b)]	**0.054** [(b)]	**0.073** [(b)]	**0.065** [(b)]	**0.17** [(b)]	5	**0.064** [(b)]	0.03	**0.086** [(b)]	3	**0.098** [(b)]	**0.054** [(b)]	**0.142** [(b)]	2
dissolved phosphorus	mg/L	0.01	0.015	0.032	0.032	0.01	-	-	-	-	-	-	-	-	-	-	-	-
chlorophyll *a*	mg/L	3	<1	4	5	2	-	-	-	-	-	-	-	-	-	-	-	-
General Organics																		
naphthenic acids	mg/L	<1	<1	<1	<1	<1	-	-	-	-	-	-	-	-	-	-	-	-
total phenolics	mg/L	<0.001	**0.008** [(b)]	<0.001	**0.008** [(b)]	<0.001	-	-	-	-	-	-	-	-	-	-	-	-

Table 3-4 Water Quality of Watercourses in the Christina Lake Regional Project Local Study Area in 2004 and Historical Data for Christina River (continued)

Parameter	Units	Unnamed Watercourse 1		Unnamed Watercourse 6		Unnamed Watercourse 10	Christina River (Historical Data)											
							Winter (1978-79)				Summer (1978)				Fall (1978)			
		Spring	Late Summer	Spring	Late Summer	Spring	median	min	max	n	median	min	max	n	median	min	max	n
total recoverable hydrocarbons	mg/L	<0.5	<0.5	<0.5	<0.5	<0.5	-	-	-	-	-	-	-	-	-	-	-	-
Total Metals																		
aluminum	mg/L	0.09	0.10	**0.12** [b]	0.03	0.04	-	-	-	-	-	-	-	-	-	-	-	-
antimony	mg/L	0.0017	0.0008	0.0013	0.0007	0.0011	-	-	-	-	-	-	-	-	-	-	-	-
arsenic	mg/L	<0.0004	0.0008	<0.0004	0.0009	<0.0004	-	-	-	-	-	-	-	-	-	-	-	-
barium	mg/L	0.007	0.015	0.022	0.032	0.007	-	-	-	-	-	-	-	-	-	-	-	-
beryllium	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001	-	-	-	-	-	-	-	-	-	-	-	-
boron	mg/L	<0.02	<0.02	0.02	0.04	<0.02	-	-	-	-	-	-	-	-	-	-	-	-
cadmium	mg/L	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	-	-	-	-	-	-	-	-	-	-	-	-
chromium	mg/L	<0.0008	<0.0008	<0.0008	<0.0008	<0.0008	-	-	-	-	-	-	-	-	-	-	-	-
chromium VI	mg/L	-	-	-	-	-	< 0.003 [d>b]	< 0.003 [d>b]	**0.006** [b]	5	**0.004** [b]	< 0.003 [d>b]	**0.005** [b]	3	**0.012** [b]	**0.006** [b]	**0.018** [a,b]	2
cobalt	mg/L	0.0004	0.0003	0.0003	<0.0002	<0.0002	-	-	-	-	-	-	-	-	-	-	-	-
copper	mg/L	<0.001	0.001	<0.001	0.001	0.001	-	-	-	-	-	-	-	-	-	-	-	-
iron	mg/L	**0.35** [b,c]	**0.36** [b,c]	**0.92** [b,c]	**0.6** [b,c]	**0.18** [c]	-	-	-	-	-	-	-	-	-	-	-	-
lead	mg/L	<0.0001	0.0004	0.0001	0.0002	0.0002	-	-	-	-	-	-	-	-	-	-	-	-
lithium	mg/L	<0.006	<0.006	<0.006	0.011	<0.006	-	-	-	-	-	-	-	-	-	-	-	-
manganese	mg/L	**0.029** [c]	**0.024** [c]	**0.074** [c]	**0.036** [c]	**0.022** [c]	-	-	-	-	-	-	-	-	-	-	-	-
mercury	mg/L	<0.0000006	<0.0000006	0.0000008	<0.0000006	0.0000022	<0.0001 [d>c]	<0.0001 [d>c]	<0.0001 [d>c]	5	<0.0001 [d>b]	<0.0001 [d>c]	**0.0003** [b,c]	3	<0.0001 [d>c]	<0.0001 [d>c]	<0.0001 [d>c]	2
molybdenum	mg/L	0.0001	0.0004	0.0004	0.0004	0.0002	-	-	-	-	-	-	-	-	-	-	-	-
nickel	mg/L	0.001	0.001	0.0004	0.0007	0.0006	-	-	-	-	-	-	-	-	-	-	-	-
selenium	mg/L	<0.0004	<0.0004	<0.0004	<0.0004	<0.0004	-	-	-	-	-	-	-	-	-	-	-	-
silver	mg/L	<0.000005	0.0000013	<0.000005	<0.0000005	0.0000052	-	-	-	-	-	-	-	-	-	-	-	-
strontium	mg/L	0.02	0.05	0.06	0.12	0.02	-	-	-	-	-	-	-	-	-	-	-	-
thallium	mg/L	<0.0001	0.0001	<0.0001	<0.0001	<0.0001	-	-	-	-	-	-	-	-	-	-	-	-
titanium	mg/L	<0.005	<0.005	<0.005	<0.005	<0.005	-	-	-	-	-	-	-	-	-	-	-	-
uranium	mg/L	<0.0001	0.0003	<0.0001	0.0001	<0.0001	-	-	-	-	-	-	-	-	-	-	-	-
vanadium	mg/L	0.0002	0.0005	0.0005	0.0003	0.0002	<0.001	<0.001	<0.001	5	<0.001	<0.001	0.001	3	0.005	<0.001	0.01	2
zinc	mg/L	0.017	0.005	0.011	0.007	0.021	-	-	-	-	-	-	-	-	-	-	-	-
Dissolved Metals																		
aluminum	mg/L	0.01	<0.01	<0.01	<0.01	0.02	-	-	-	-	-	-	-	-	-	-	-	-
antimony	mg/L	0.0011	0.0006	0.0009	0.0006	0.0011	-	-	-	-	-	-	-	-	-	-	-	-
arsenic	mg/L	0.0005	0.0007	0.0006	0.0009	<0.0004	0.0006	0.003	0.0015	5	0.0009	0.0002	0.0011	3	0.0008	0.0006	0.001	2
barium	mg/L	0.006	0.015	0.021	0.032	0.006	-	-	-	-	-	-	-	-	-	-	-	-
beryllium	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001	-	-	-	-	-	-	-	-	-	-	-	-
boron	mg/L	0.01	0.01	0.03	0.05	0.01	0.16	0.01	0.16	4	0.1	0.08	0.12	3	0.13	0.1	0.15	2
cadmium	mg/L	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	-	-	-	-	-	-	-	-	-	-	-	-

Table 3-4 Water Quality of Watercourses in the Christina Lake Regional Project Local Study Area in 2004 and Historical Data for Christina River (continued)

Parameter	Units	Unnamed Watercourse 1		Unnamed Watercourse 6		Unnamed Watercourse 10	Christina River (Historical Data)											
		Spring	Late Summer	Spring	Late Summer	Spring	Winter (1978-79)				Summer (1978)				Fall (1978)			
							median	min	max	n	median	min	max	n	median	min	max	n
chromium	mg/L	<0.0004	0.0006	<0.0004	0.0012	<0.0004	-	-	-	-	-	-	-	-	-	-	-	-
cobalt	mg/L	0.0002	<0.0001	0.0002	0.0001	0.0003	-	-	-	-	-	-	-	-	-	-	-	-
copper	mg/L	0.001	<0.0006	0.0013	<0.0006	0.0008	-	-	-	-	-	-	-	-	-	-	-	-
iron	mg/L	0.24	0.17	0.61	0.23	0.12	-	-	-	-	-	-	-	-	-	-	-	-
lead	mg/L	0.0001	0.0002	<0.0001	0.0004	0.0002	-	-	-	-	-	-	-	-	-	-	-	-
lithium	mg/L	0.003	0.005	0.006	0.011	0.002	-	-	-	-	-	-	-	-	-	-	-	-
manganese	mg/L	0.003	0.022	0.01	0.017	0.004	-	-	-	-	-	-	-	-	-	-	-	-
mercury	mg/L	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	-	-	-	-	-	-	-	-	-	-	-	-
molybdenum	mg/L	<0.0001	0.0001	0.0003	0.0007	0.0001	-	-	-	-	-	-	-	-	-	-	-	-
nickel	mg/L	0.0003	0.0006	0.0004	0.001	0.0014	-	-	-	-	-	-	-	-	-	-	-	-
selenium	mg/L	0.0005	<0.0004	0.0005	<0.0004	<0.0004	<0.0002	<0.0001	<0.0002	5	<0.0002	<0.0002	0.0003	3	-	<0.0002	<0.1	2
silver	mg/L	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	-	-	-	-	-	-	-	-	-	-	-	-
strontium	mg/L	0.02	0.05	0.06	0.12	0.02	-	-	-	-	-	-	-	-	-	-	-	-
thallium	mg/L	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	-	-	-	-	-	-	-	-	-	-	-	-
titanium	mg/L	<0.0003	0.001	0.0006	0.0009	0.0007	-	-	-	-	-	-	-	-	-	-	-	-
uranium	mg/L	<0.0001	<0.0001	<0.0001	0.0001	<0.0001	-	-	-	-	-	-	-	-	-	-	-	-
vanadium	mg/L	0.0003	0.0003	0.0004	0.0003	0.0003	-	-	-	-	-	-	-	-	-	-	-	-
zinc	mg/L	0.002	0.004	0.003	0.003	0.013	-	-	-	-	-	-	-	-	-	-	-	-

Bolded concentrations are higher than water quality guidelines.

(a) = Concentration higher than the relevant acute aquatic life guideline or beyond the recommended pH or DO concentration range.

(b) = Concentration higher than the relevant chronic aquatic life guideline or beyond the recommended pH or DO concentration range.

(c) = Concentration higher than the relevant human health guideline or beyond the recommended pH or DO concentration range.

(d>) = Analytical detection limit was higher than the relevant water quality guideline(s).

- = No data / no guideline.

The human health guideline is based on the more conservative of: U.S. EPA (1999 with 2002 updates) adjusted for increased fish consumption using a rate of 45 g/day (Richardson 1997) and Health Canada (2001).

Total aluminum was greater than the chronic guideline for aquatic life in Unnamed Watercourse 6 in the spring sample. Total iron and manganese concentrations were greater than human health guidelines in all samples collected from the unnamed watercourses. Historical chromium VI concentrations were frequently above the chronic aquatic life guideline. The analytical detection limit for historical mercury data was higher than the current water quality guideline. The historical summer maximum concentration, which was above the chronic aquatic life guideline, is considered unreliable, because sample collection and analysis methods were not consistent with the ultra-low techniques necessary to quantify mercury concentrations in surface waters.

Concentrations of naphthenic acids and total recoverable hydrocarbons in the unnamed watercourses were below detection limits in all samples collected in 2004. Spring values for total phenolics were also below detection limits; however, late summer concentrations were above guidelines protective of aquatic life. There were no historical data for organic parameters from the Christina River.

3.4 WATERBODIES SAMPLED TO EVALUATE ACID SENSITIVITY

Field measured pH values were generally within water quality guidelines in these waterbodies (Table 3-5). However, in late summer, pH at Unnamed Waterbody 13 was above the guideline protective of aquatic life. This was also reflected in laboratory measured pH. Dissolved oxygen concentrations were variable and spring concentrations were often below aquatic life guideline ranges.

Alkalinity values in these waterbodies indicated that they were generally not sensitive to acid deposition. Unnamed Waterbody 5 had the lowest alkalinity (i.e., 21 mg/L in late summer); however, acid sensitivity in this waterbody is still considered low. Colour ranged from coloured to highly coloured. Major ion concentrations were low to moderately low based on conductance and TDS concentrations. Hardness values were variable, and ranged between very soft to moderately soft.

Table 3-5 Water Quality of Waterbodies Monitored for Acid Sensitivity in the Christina Lake Regional Project Local Study Area in 2004

Parameter	Units	Unnamed Waterbody 2		Unnamed Waterbody 5		Unnamed Waterbody 8		Unnamed Waterbody 9		Unnamed Waterbody 11		Unnamed Waterbody 13		Unnamed Waterbody 15	Unnamed Waterbody 16
		Spring	Late Summer	Spring	Late Summer	Spring	Late Summer	Spring	Late Summer	Spring	Late Summer	Spring	Late Summer	Late Summer	Late Summer
Field measured															
pH	-	7.5	7.6	7.0	7.3	7.6	7.3	7.4	6.9	8.0	8.1	7.9	**9.0** [a,b]	7.6	6.7
conductance	µS/cm	93	66	50	38	108	99	127	91	95	78	159	140	108	52
temperature	°C	12	15.4	12.8	15.2	14	14.9	14.2	15.5	15	15	15.5	15.7	14.8	14.4
dissolved oxygen	mg/L	**3.8** [a,b]	9.9	**2.4** [a,b]	11.2	6.6	9.1	**6.3** [b]	7.7	**3.8** [a,b]	10.8	**4.2** [a,b]	11.3	9.6	8.6
Conventional Parameters															
colour	TCU	-	30	-	60	40	60	60	100	-	40	50	60	55	160
conductance	µS/cm	92	87	51	50	107	130	130	120	91	103	156	190	143	67
dissolved organic carbon	mg/L	12	15	17	23	-	34	27	40	17	25	16	27	33	32
hardness	mg/L	45	42	27	27	55	70	72	69	52	54	83	103	77	37
pH	-	8.0	7.9	7.7	7.5	8.0	8.0	8.1	7.9	8	8	8.2	**8.7** [a,b]	8.1	7.6
total alkalinity	mg/L	47	43	24	21	54	64	65	57	46	50	82	101	72	29
total dissolved solids	mg/L	49	60	26	70	100	120	140	140	50	110	110	160	140	100
Major Ions															
bicarbonate	mg/L	57	52	30	26	66	78	79	70	56	61	100	112	87	36
calcium	mg/L	12	11	7	7	14	18	19	17	13	14	22	26	19	10
carbonate	mg/L	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	6	<5	<5
chloride	mg/L	<1	<1	<1	2	1	1	1	2	1	1	1	1	1	2
magnesium	mg/L	4	4	2	2	5	6	6	6	5	5	7	9	7	3
potassium	mg/L	1	0.4	1	0.3	1	<0.1	1	0.1	0.4	0.3	2	<0.1	<0.1	0.2
sodium	mg/L	3	2	1	1	3	3	4	2	2	1	4	4	3	1
sulphate	mg/L	1	1	1	1	1	2	2	2	1	2	2	2	2	2

Bolded concentrations are higher than water quality guidelines.

[a] = Concentration higher than the relevant acute aquatic life guideline or beyond the recommended pH or DO concentration range.

[b] = Concentration higher than the relevant chronic aquatic life guideline or beyond the recommended pH or DO concentration range.

- = no data / no guideline.

3.5 QUALITY ASSURANCE AND QUALITY CONTROL

Concentrations of water quality parameters in the field blanks were generally less than five times the detection limit, with some exceptions (Table 3-6). Conductance was greater than five times the detection limit in both spring and late summer, but was well below all measured concentrations in samples collected from surface waters in 2004. Sulphide concentration was greater than five times the detection limit in spring blank. These concentrations may indicate sample contamination during sampling, sample handling or analysis, or a problem with the quality of the deionized water provided by the analytical laboratory.

Total metal concentrations greater than five times the detection limit included iron, lead and nickel (Table 3-6). Nickel was the only dissolved metal with a concentration greater than five times the detection limit. These concentrations may indicate sample contamination during sampling, sample handling or analysis. Concentrations of lead and nickel (total and dissolved) measured in surface water samples were usually below those measured in the blanks, suggesting the measured levels in the blanks were isolated occurrences likely originating from using poor quality deionized water. Iron concentrations were considerably higher in surface water samples compared to the blanks, indicating that the elevated levels in the blanks are unlikely to influence the results of the assessment for this metal.

Overall, relatively few parameters were measured in the blanks at concentrations greater than five times the detection limit, and the concentrations measured in the blanks do not compromise the interpretation of baseline study data. Therefore, the quality of water chemistry data collected during the baseline surveys is considered adequate to address the objectives of the study.

Table 3-6 Concentrations of Parameters in Field Blanks that are at Least Five Times Greater than the Detection Limit

Parameter	Units	Detection Limit	Five Times Detection Limit	Field Blank (spring)	Field Blank (late summer)
Conventional Parameters					
conductance	μS/cm	0.2	1	1.1	1.3
Major Ions					
sulphide	mg/L	0.003	0.015	0.037	-[(a)]
Total Metals					
iron	mg/L	0.005	0.025	0.077	-
lead	mg/L	0.0001	0.0005	-	0.0006
nickel	mg/L	0.0002	0.001	0.0021	0.0042
Dissolved Metals					
nickel	mg/L	0.0001	0.0005	-	0.0006

(a) - = concentration is less than five times the detection limit.

Dissolved metal concentrations that were 20% greater than the corresponding total metal concentration and greater than five times the detection limit are listed in Table 3-7. In Unnamed Watercourse 6, dissolved boron was more than 20% greater than the total boron concentration and more than five times the detection limit; however, the total boron concentration was at the detection level. This difference may be an artifact of low resolution in total boron analysis and the large differences in detection limits between total and dissolved concentrations. Strontium concentrations in Unnamed Watercourses 7 and 12 may be explained by laboratory procedures. Resolution in strontium analysis is often compromised by the difficulty in preventing contamination from ubiquitous strontium molecules in the environment (Tony Ciarla 2003: Pers. Comm.).

Table 3-7 Results of Dissolved Versus Total Metal Comparisons

Parameter	Units	Detection Limit	Five Times Detection Limit	Spring 2004 (a)		
				Unnamed Watercourse 6	Unnamed Waterbody 7	Unnamed Waterbody 12
total boron	mg/L	0.02	0.1	0.02	-[(b)]	-
dissolved boron	mg/L	0.002	0.01	**0.03**	-	-
total strontium	mg/L	0.0002	0.001	-	0.01	0.01
dissolved strontium	mg/L	0.0001	0.0005	-	**0.02**	**0.02**

Notes: Both dissolved and total concentrations are shown for each metal. Concentrations of dissolved metals that are 20% or greater than the corresponding total concentration and greater than five times the detection limit are bolded.

(a) There were no late summer dissolved metal concentrations that exceeded the assessment criteria.

(b) Concentration of dissolved metal was less than total metal.

4 CLOSURE

We trust the above meets your present requirements. If you have any questions or require additional details, please contact the undersigned.

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5 GLOSSARY AND ACRONYMS

5.1 GLOSSARY OF TERMS

Acute	The development of adverse effects after a brief exposure to a given substance. In aquatic toxicity tests, an effect observed in 96 hours or less is typically considered acute. When referring to aquatic toxicology or human health, an acute effect is not always measured in terms of lethality.
Alkalinity	A measure of water's capacity to neutralize an acid. It indicates the presence of carbonates, bicarbonates and hydroxides, and less significantly, borates, silicates, phosphates and organic substances. It is expressed as an equivalent of calcium carbonate. The composition of alkalinity is affected by pH, mineral composition, temperature and ionic strength. However, alkalinity is normally interpreted as a function of carbonates, bicarbonates and hydroxides. The sum of these three components is called total alkalinity.
Brown-water system	Freshwaters with elevated colour and dissolved organic carbon concentrations. According to the Atlas of Alberta Lakes, freshwater lakes with colour levels >55 mg/L are considered highly coloured (i.e., brown-water systems).
Chlorophyll *a*	One of the green pigments in plants. It is a photo-sensitive pigment that is essential for the conversion of inorganic carbon (e.g., carbon dioxide) and water into organic carbon (e.g., sugar). The concentration of chlorophyll *a* in water is an indicator of algal concentration.
Chronic	The development of adverse effects after extended exposure to a given substance. In chronic toxicity tests, the measurement of a chronic effect can be reduced growth, reduced reproduction or other non-lethal effects, in addition to lethality. Chronic should be considered a relative term depending on the life span of the organism.
Concentration	Quantifiable amount of a substance in environmental media.
Conductivity	A measure of a waterbody's capacity to conduct an electrical current. It is the reciprocal of resistance. This measurement relates to the total concentration of dissolved ionic matter in the water.
Detection limit	The lowest concentration that can be reported by an analytical laboratory with a specified confidence level.

Dissolved organic carbon (DOC)	The dissolved portion of organic carbon water; made up of humic substances and partly degraded plant and animal materials.
Epilimnetic	Localized in the surface layer of a waterbody.
Eutrophic	Trophic state classification for lakes characterized by high productivity and nutrient inputs (particularly total phosphorus).
Dissolved oxygen (DO)	The concentration of free (not chemically combined) molecular oxygen (a gas) dissolved in water; usually expressed in milligrams per litre (mg/L).
Hardness	Calculated mainly from the calcium and magnesium concentrations in water; originally developed as a measure of the capacity of water to precipitate soap; the hardness of water is environmentally important since it is inversely related to the toxicity of some metals (e.g., copper, nickel, lead, cadmium, chromium, silver and zinc).
Hypereutrophic	Trophic state classification for lakes characterized by very high productivity and nutrient inputs (particularly total phosphorus).
Mesotrophic	Trophic state classification for lakes characterized by moderate productivity and nutrient inputs (particularly total phosphorus).
Nutrients	Environmental substances (elements or compounds), such as nitrogen or phosphorus, that are necessary for the growth and development of plants and animals.
Oligotrophic	Trophic state classification for lakes characterized by low productivity and low nutrient inputs (particularly total phosphorus).
Organics	Chemical compounds, naturally occurring or otherwise, that contain carbon, with the exception of carbon dioxide (CO_2) and carbonates (e.g., $CaCO_3$).
pH	The negative logarithm of hydrogen ion concentration. The pH scale is presented from 1 (most acidic) to 14 (most alkaline). A difference of one pH unit represents a ten-fold change in hydrogen ion concentration.
Phosphorus	The key nutrient influencing plant growth in lakes; total phosphorus includes the amount of phosphorus in solution (reactive) and in particulate form.

QA/QC	Quality Assurance/Quality Control refers to a set of practices that ensure the quality of a product or a result. For example, “Good Laboratory Practice” is part of QA/QC in analytical laboratories and involves such things as proper instrument calibration, meticulous glassware cleaning and an accurate sample information system.
TOC	Total organic carbon has a direct relationship with both biochemical and chemical oxygen demands, and varies with the composition of organic matter present in the water. Organic matter in soils, aquatic vegetation and aquatic organisms are major sources of organic carbon.
Total alkalinity	A measure of the ability of water to resist changes in pH caused by the addition of acids or bases and therefore, the main indicator of susceptibility to acid rain; in natural waters it is due primarily to the presence of bicarbonates, carbonates and to a much lesser extent occasionally borates, silicates and phosphates; it is expressed in units of milligrams per litre (mg/L) of $CaCO_3$ (calcium carbonate). Alkalinity is determined from a discernable inflection point in the measured titration curve.
Total dissolved solids (TDS)	The amount of dissolved substances found in a water sample.
Total suspended solids (TSS)	The amount of suspended substances in a water sample.
Turbidity	An indirect measure of suspended particles, such as silt, clay, organic matter, plankton, and microscopic organisms, in water.

5.2 ACRONYMS AND ABBREVIATIONS

<	Less than
>	Greater than
µS/cm	Micro Siemens/centimetre
AENV	Alberta Environment
ANC	Acid neutralizing capacity
bpd	barrels per day
^{o}C	degrees Celsius
$CaCO_3$	Calcium carbonate
CO_2	Carbon Dioxide
CCME	Canadian Council of Ministers of the Environment
DFO	Fisheries and Oceans Canada
DO	Dissolved oxygen
DOC	Dissolved organic carbon
DOE	Department of Environment
e.g.	For example
EIA	Environmental Impact Assessment
EIFAC	European Inland Fisheries Advisory Commission
GPS	Global Positioning System
HC	Health Canada
H_2S	Hydrogen Sulphide
i.e.	That is
km	Kilometre
-log	Negative Logarithm
LSA	Local Study Area
max.	Maximum
MEG	MEG Energy Corp.
mg/L	milligram/litre
min.	Minimum
µeq/L	Microequivalents/litre
n	Number
NTU	Nephelometric turbidity unit
Pt	Platinum
QA/QC	Quality Assurance/Quality Control

RAMP	Regional Aquatics Monitoring Program
RSA	Regional Study Area
SAGD	Steam Assisted Gravity Drainage
TCU	True colour unit
TDS	Total dissolved solids
TKN	Total Kjeldahl nitrogen
TN	Total nitrogen
TOC	Total organic carbon
TP	Total phosphorus
TSS	Total suspended solids
U.S. EPA	United States Environmental Protection Agency
WDS	Water Data System

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