SURFACE WATER QUALITY
BASELINE REPORT
FOR THE CANADIAN NATURAL
KIRBY IN SITU OIL SANDS EXPANSION PROJECT

Submitted to:
Canadian Natural Resources Limited

December 2011 **10-1346-0052**

EXECUTIVE SUMMARY

Canadian Natural Resources Limited (Canadian Natural) is applying for approval of the Kirby In Situ Oil Sands Expansion Project (the Kirby Expansion Project or the Project). The submission contains the following:

- application to the Energy Resources Conservation Board (ERCB) under the *Oil Sands Conservation Act*;
- application to Alberta Environment and Water (AEW) under the *Environmental Protection and Enhancement Act* (EPEA); and
- application to AEW under the *Water Act.*

The above submissions are collectively referred to as the Application.

The Project is located in Townships 73, 74 and 75, Ranges 7, 8 and 9 West of the Fourth Meridian (W4M). The proposed development will include the use of in situ Steam Assisted Gravity Drainage (SAGD) well pairs and expansion phases of the two approved on-site steam generation and oil/water treatment plants.

This Surface Water Quality Baseline Report provides information required to complete the Environmental Impact Assessment (EIA) for the Project. It presents the results of the 2011 baseline water and sediment quality surveys in the Local Study Area (LSA), and historical water quality data in the LSA and the Regional Study Area (RSA). The main objective of this document is to describe existing water quality and sediment quality in the area associated with the Project.

Water quality samples were collected within the LSA in winter, summer and fall 2011 and sediment quality samples were collected in fall 2011. Wiau Lake, two unnamed lakes and six unnamed tributaries were sampled in the three seasons. Results from these surveys were supplemented with historical data. These data were used to summarize water and sediment quality of waterbodies and watercourses in the Project Area.

Water quality samples were analyzed for detailed water chemistry, including conventional parameters, total and dissolved metals, and selected organics. Sediment samples were analyzed for carbon content, particle size distribution, moisture content, metals and selected organics.

With few exceptions, dissolved oxygen and pH values were within water quality guideline ranges in waterbodies and watercourses in the LSA and RSA. Exceptions tended to occur in the winter when gas exchange is limited by ice formation.

EXECUTIVE SUMMARY

Major ion concentrations and hardness increased in the winter due to “freeze out” of dissolved matter resulting from ice formation. The Total Organic Carbon (TOC) concentrations ranged from moderate to high, with higher values observed during winter. Colour varied from coloured to highly coloured indicating a high dissolved humic matter content. Alkalinity values suggested that these waterbodies and watercourses are not sensitive to acid deposition.

Parameters associated with ionic concentrations (conductivity, hardness, alkalinity) peaked in the winter, probably associated with exclusion of dissolved matter during ice formation. Total suspended solids concentrations were generally higher during the spring as a result of sediment input by runoff during the spring freshet.

Nutrient concentrations were generally higher in spring and summer and decreased over the winter in the waterbodies. Based on total phosphorus concentrations, trophic status of waterbodies and watercourses in the LSA and RSA displayed a wide range, from oligo-mesotrophic to eutrophic. Based on the chlorophyll *a* levels, trophic status ranged from oligotrophic to mesotrophic in most of the waterbodies and watercourses, with the exception of Lac la Biche where the trophic status was categorized as hypereutrophic.

Total metal concentrations were generally below water quality guidelines, with exception of aluminum, arsenic, cadmium, chromium, copper, iron, lead, mercury, selenium, silver, thallium and zinc. Concentrations above guidelines generally appeared to be more frequent in spring than in other seasons, likely reflecting suspended sediment input during spring freshet.

Naphthenic acids concentrations were usually below the detection limits and total recoverable hydrocarbons were typically at or below the detection limit. Total phenolics concentrations did not show evidence of a seasonal trend and the values were consistently above guidelines throughout the year. These elevated concentrations can be attributed to natural factors and do not indicate that water quality has been compromised.

The inorganic fraction of the bottom sediments in most watercourses and waterbodies was dominated by the sand fraction. The TOC content ranged from low to high. With few exceptions, metal concentrations in sediments were below guidelines. Total arsenic, total cadmium, total mercury and total zinc concentrations were above the Interim Sediment Quality Guideline (ISQG) in some samples, while concentrations of other metals, when detectable, were below the ISQG.

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1 INTRODUCTION

Canadian Natural Resources Limited (Canadian Natural) is applying for approval of the Kirby In Situ Oil Sands Expansion Project (the Kirby Expansion Project or the Project). The applications to the Energy Resources Conservation Board (ERCB) under the Oil Sands Conservation Act, and Alberta Environment and Water (AEW) under Environmental Protection and Enhancement Act (EPEA) and Water Act as well as the Environmental Impact Assessment (EIA) are herein collectively referred to as the Application.

The proposed Project will involve bitumen production from oil sands formations within a Lease Area located in Townships 73, 74 and 75, Ranges 7, 8 and 9, West of the Fourth Meridian (W4M) and within the Regional Municipality of Wood Buffalo (RMWB). Minor portions of the proposed Project facilities will extend beyond the Lease Area boundary. The footprint includes water source and disposal wells and pipelines that extend west of the Lease Area into Lac La Biche County.

The Lease Area consists of 110.75 sections (29,143 ha) of land on which Canadian Natural fully or partially holds the oil sands exploration and development rights. To facilitate description of the expansion plans and facility locations, the Lease Area has been divided into two geographic areas, referred to as the North Expansion Area and the South Expansion Area, which are generally divided by Provincial Highway 881. The Project will be accessed via an all-weather gravel road which intersects with Highway 881, at a location approximately 35 km by road south of Conklin and 110 km by road northeast of Lac La Biche.

Canadian Natural currently has ERCB commercial scheme approvals for the following two projects:

- The Canadian Natural Kirby In Situ Oil Sands Project, hereafter referred to as Kirby South 2010 (or KS1) was approved in 2010 for bitumen production of 45,000 bbl/d (7,150 m^3/d) using Steam Assisted Gravity Drainage (SAGD) technology.

The Enerplus Resources Fund (Enerplus) Kirby Oil Sands Project Phase 1, hereafter referred to as Kirby North 2010, was approved in 2010 for bitumen production of 10,000 bbl/d (1,590 m^3/d), also using SAGD technology. The Kirby North 2010 oil sands leases and nearby Enerplus oil sands leases were acquired by Canadian Natural in 2010.

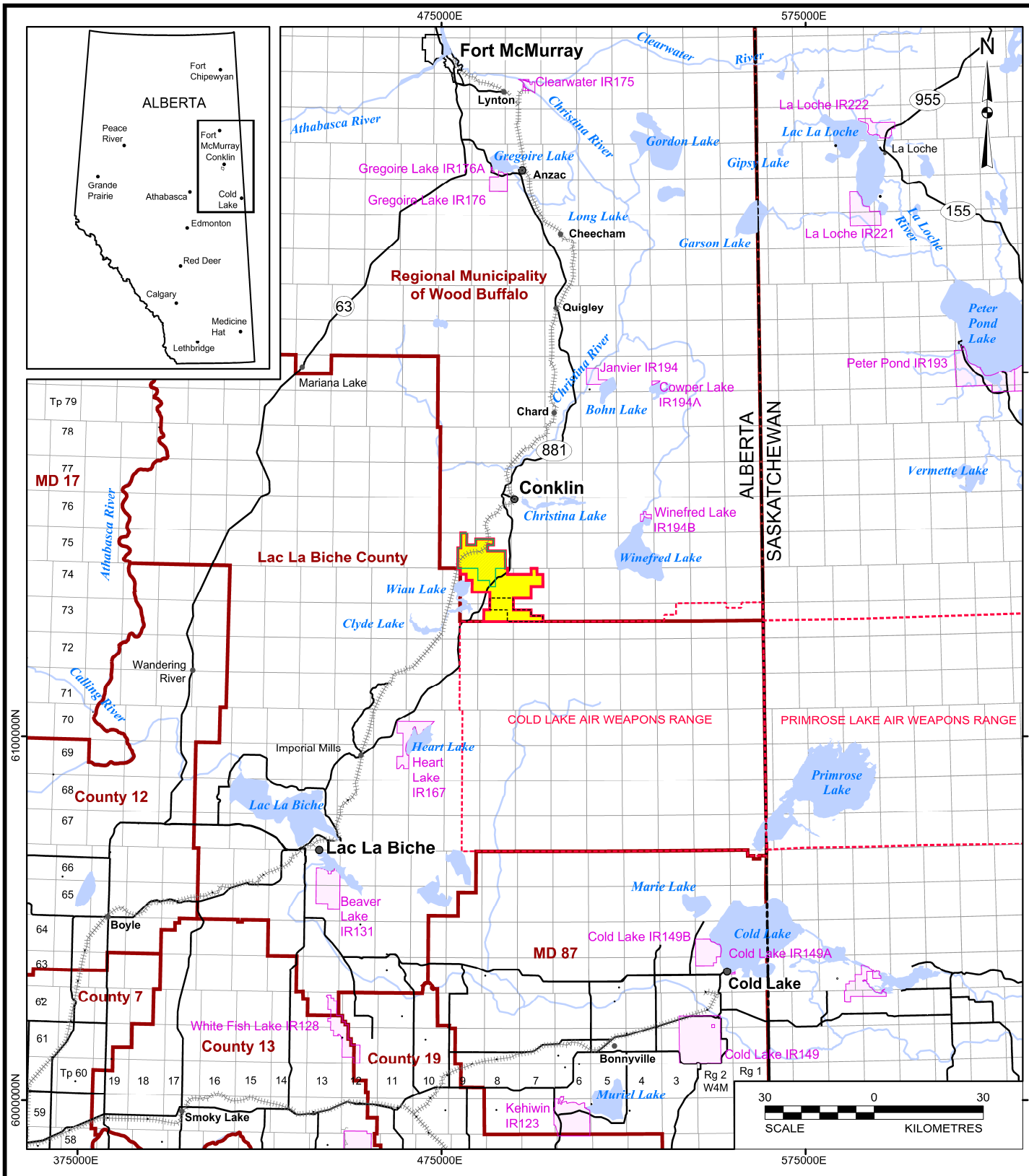
The Kirby Expansion Project will occur in three phases, as described below:

- Kirby North Phase 1 (KN1) will involve the expansion of the approved Kirby North Central Processing Facility (CPF) and development of facilities to increase bitumen production and processing capacity in the North Expansion Area from the approved 10,000 bbl/d (1,590 m^3/d) to 50,000 bbl/d (7,950 m^3/d);
- Kirby North Phase 2 (KN2) will further expand the Kirby North CPF, facilities, and bitumen production and processing capacity within the North Expansion Area from the 50,000 bbl/d (7,950 m^3/d) to 80,000 bbl/d (12,720 m^3/d).; and
- Kirby South Phase 2 (KS2) will involve expansion of the approved Kirby South CPF and development of facilities to allow an increase in South Expansion Area bitumen production and processing capacity by 15,000 bbl/d (2,384 m^3/d) from the approved 45,000 bbl/d (7,150 m^3/d) to a total of 60,000 bbl/d (9,540 m^3/d) bitumen.

As a result of the expansion, the Kirby North CPF will have a design capacity of 80,000 bbl/d (12,720 m^3/d) and the Kirby South CPF will have a design capacity of 60,000 bbl/d (9,540 m^3/d), for to a total bitumen production capacity within the Lease Area of 140,000 bbl/d (22,260 m^3/d). In addition, the Project will increase the combined life of Kirby lease developments from 20 years to approximately 30 years. The layout of surface facilities associated with the Project is shown on Figure 1.

The baseline studies for the two existing permitted areas were based on the available information up to 2008 for the Kirby North 2010 Project Area and up to 2006 for the Kirby South 2010 Project Area. The baseline hydrology in this section uses the available regional data primarily up to 2010 and will be used as the basis for assessment of the potential effects of the Project within the aquatics Regional Study Area (RSA) and Local Study Area (LSA).

This baseline report presents surface water quality and sediment data for waterbodies and watercourses in the vicinity of the Project to characterize baseline (existing) water and sediment quality. Water and sediment quality data from 1998 to 2011 baseline surveys in the LSA, and historical water quality data collected in the RSA and the LSA are included in this report.



LEGEND

- COLD LAKE / PRIMROSE LAKE AIR WEAPONS RANGE BOUNDARY
- RAILWAY
- ROAD
- KIRBY EXPANSION PROJECT LEASE AREA*
- APPROVED KIRBY SOUTH 2010 PROJECT AREA
- APPROVED KIRBY NORTH 2010 PROJECT AREA

Note

*Includes Oil Sands Leases fully and partially held by Canadian Natural

REFERENCE

ALBERTA NTDB DATA SUPPLIED BY GEOMATICS CANADA, AUGUST 2001. NAD 83 ZONE 12. SHEETS 74D, E AND 74L IN NAD 27 ZONE 12. SASKATCHEWAN NTDB DATA SUPPLIED BY ISC, AUG. 2001. NAD 83 ZONE 13. ALL DATA CONVERTED TO NAD 83 UTM ZONE 12.

PROJECT

KIRBY IN SITU OIL SANDS EXPANSION PROJECT

TITLE

PROJECT LOCATION

Canadian Natural

PROJECT	10.1346.0052.8700		FILE No.	10134600528750A001	
DESIGN	BB	17/11/11	SCALE	1:1,500,000	REV. 0
CADD	PSR	05/12/11			
CHECK	TGC	07/12/11			
REVIEW	SM	08/12/11			

FIGURE: 1

L:\2010\1346\10-1346-0052\Baseline\Fig 1_10134600523000A001 Project Location.dwg Dec 08, 2011 - 12:41pm

1.1 STUDY AREAS

1.1.1 Aquatics Regional Study Area

The aquatic RSA was established based on potential effects from construction and operation of the Project on flows and water levels in watersheds in which the Project is located, including surface water/groundwater interactions. This RSA also contains other projects and activities that are considered in the Baseline and Planned Development cases.

The aquatic RSA is shown in Figure 2 and includes the following three basins:

- Christina River basin (drainage area of 9,821 km^2 at the Winefred River confluence): The Christina River basin has been subdivided into three sub-basins:
  - The Christina River at Chard sub-basin with a drainage area of 4,784 km^2. This sub-basin was selected to correspond to the drainage measured at the Water Survey of Canada (WSC) Station 07CE002 such that an assessment of flow characteristics and drainage area can be made. The Christina River flows in a northerly direction to the Christina River at the north end of the RSA.
  - The Pony Creek and Kettle River sub-basin with a drainage area of 782 km^2. This sub-basin was selected to correspond to the drainage at the WSC Pony Creek Station 07CE003 (effective drainage area of 278 km^2) that is representative of a smaller drainage area upstream of Pony creek confluence.
  - The Winefred River sub-basin with a drainage area of 4,255 km^2. This sub-basin drains to the north into the Christina River at the north end of the RSA.
- Lac la Biche basin (effective drainage area of 4,476 km^2): Lac la Biche drainage basin is about 17 times the size of Lac la Biche and is mostly located to the east and north of the lake. The major inflow is the Owl River and its tributaries: the Logan, Clyde and Piche rivers and Gull Creek. The outflow is the La Biche River, which eventually joins the Athabasca River in northerly direction.
- Sand River basin (effective drainage area of 4,974 km^2 at the WSC Station 06AB001): Sand River basin consists of Ipiatik River, Caribou Lake, Wolf River and Punk Creek sub-basins.

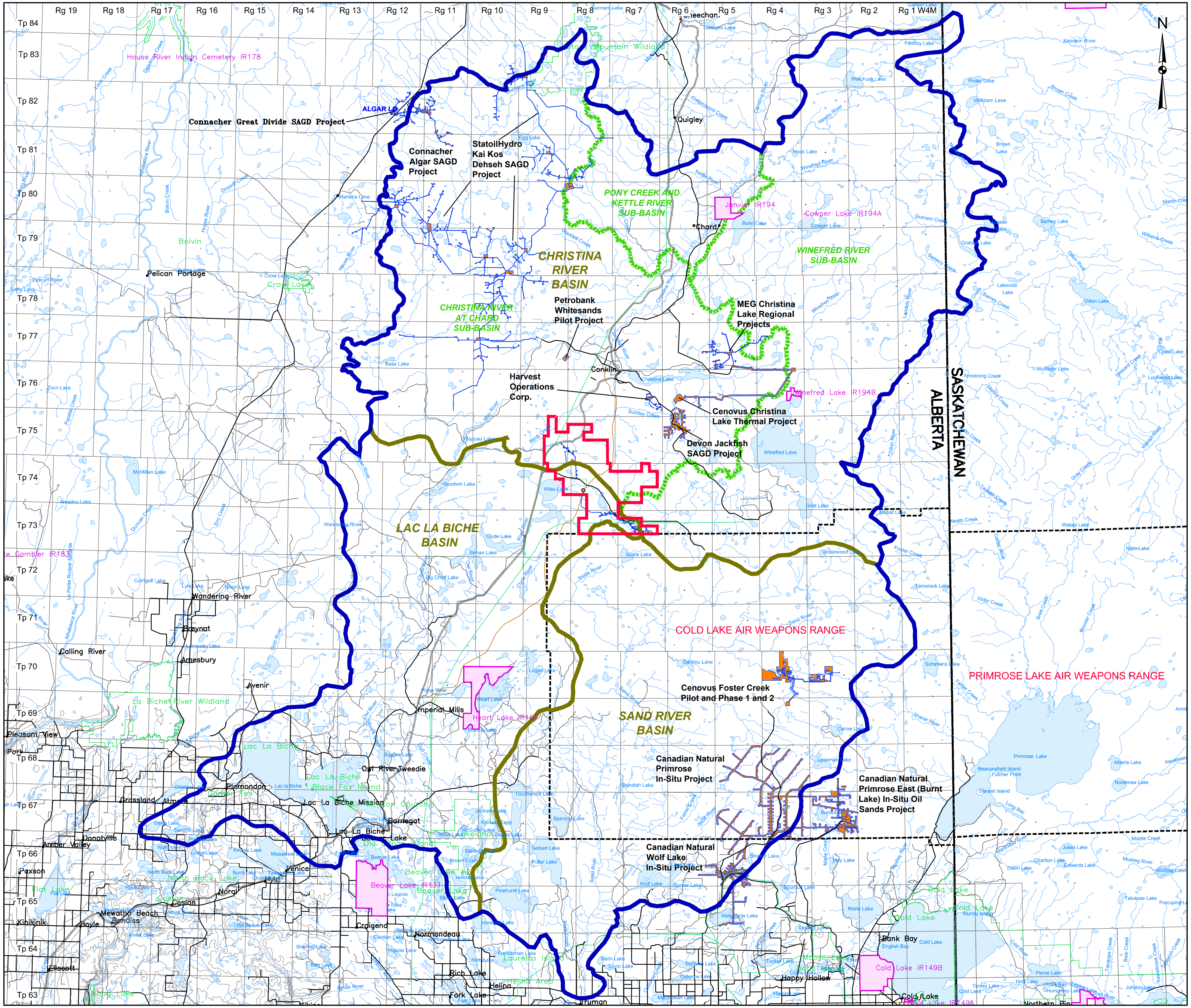
The total area of the aquatic RSA is approximately 19,271 km^2. Most of the RSA lies within Alberta, with only 2% extending into Saskatchewan. The portion in Saskatchewan lies within the Winefred River watershed, as shown in Figure 2.

The Lease Area is at a watershed divide between the three basins described above. Portions of the Lease Area and lands where Project facilities are proposed beyond the Lease Area (i.e., principally the disposal and source water pipelines that extend to the west and east respectively) drain into the three basins.

The RSA boundaries were delineated based on the rationale listed in Table 1.

Table 1 Aquatics Regional Study Area Boundaries

Watershed Name	Boundary		Rational
Christina River	*North:*	Upstream of confluence with Cottonwood Creek	The downstream extent of aquatic resources assessment due to existing, approved and planned development that is expected to have a negligible effect (including any development within the Christina Lake and the Winefred River sub-basin).
	South:	Headwaters of Sunday and Birch Creeks	Most of the proposed development is located at the Christina River headwaters (this boundary lies within the proposed Lease Area).
	East:	Drainage divide of the Christina and Beaver river basins	The full extent of Christina River drainage boundary at the east side.
	West:	Drainage divide of the Christina and Athabasca river basins	The full extent of Christina River drainage boundary at the west side.
Lac la Biche	*North:*	Wiau Lake Tributaries, Headwaters of the Clyde and Logan rivers	The proposed Lease Area partly lies within headwaters of Wiau Lake.
	South:	Drainage divide of the Lac la Biche and Beaver river basins	The full extent of Lac la Biche drainage boundary at the south side.
	East:	Headwaters of Piche River	The full extent of Lac la Biche drainage boundary at the east side.
	West:	Mouth of La Biche River and outlet of Lac la Biche	Most downstream boundary of Lac la Biche watershed. Potential cumulative effect of the existing, approved and planned development within the entire Lac la Biche drainage basin can be captured within this boundary.
Sand River	*North:*	Headwaters of Ipiatik River	The proposed Lease Area would not occupy the Sand River watershed, but has been included to monitor potential effects at its headwaters.
	South:	Downstream of the confluence of Punk Creek	Drainage boundary upstream of the Water Survey Canada Station 06AB001 site.
	East:	Headwaters of Wolf River	Full extent of Sand River drainage boundary at the east side.
	West:	Sand River along the drainage divide of Lac la Biche Basin	Drainage boundary with Lac la Biche watershed.



LEGEND
- ROAD
- RAILWAY
- RIVER
- OPEN WATER
- AQUATICS REGIONAL STUDY AREA
- KIRBY EXPANSION PROJECT LEASE AREA*
- DRAINAGE BASIN AREA
- DRAINAGE SUB-BASIN AREA
- EXISTING AND APPROVED DEVELOPMENTS

Note
*Includes Oil Sands Leases fully and partially held by Canadian Natural

REFERENCE
ALBERTA DIGITAL DATA OBTAINED FROM ALTALIS LTD. (SEPTEMBER 2004). USED UNDER LICENSE. DATUM: NAD83 PROJECTION: UTM ZONE 12. ALBERTA NTDB DIGITAL DATA OBTAINED FROM GEOMATICS CANADA, AUGUST 2001.

20 0 20
SCALE 1:800,000 KILOMETRES

PROJECT
Canadian Natural
KIRBY IN SITU OIL SANDS EXPANSION PROJECT

TITLE
AQUATICS REGIONAL STUDY AREA

Golder Associates
Calgary, Alberta

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CHECK	GD	07/12/11	FIGURE: 2
REVIEW	SM	07/12/11	

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1.1.2 Aquatics Local Study Area

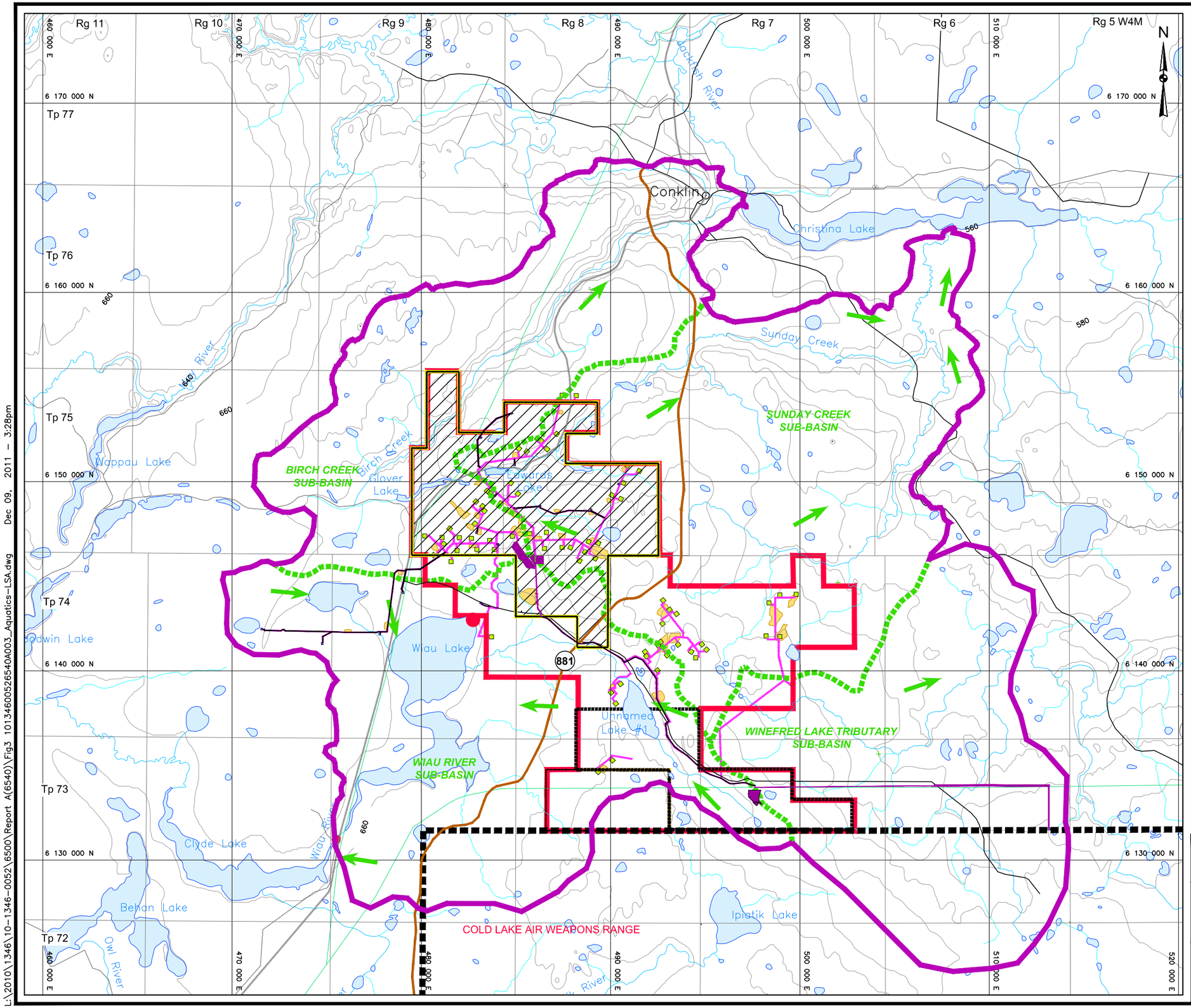
In general, the aquatics LSA was established to follow the boundaries of the natural watercourses (Birch Creek, Sunday Creek, Wiau River, and an unnamed tributary to Winefred Lake) and natural waterbodies (Wiau Lake and Christina Lake), which may have direct or indirect effects due to the Project. The LSA encompasses the areas of Project facility development and the majority of the Lease Area (Figure 1). A small part of the Lease Area in the southern end of the Project is outside the LSA because there is no development planned in this area and it is in a different drainage sub-basin to Ipiatik Lake to the south. The location of the aquatics LSA and the Project footprint are shown in Figure 3.

The LSA boundaries were delineated based on the rationale listed in Table 2. The LSA has a total area of 1,212 km^2 (121,193 ha) and consists of the following four sub-basins as shown in Figure 3:

- Sunday Creek (with the drainage area of 384 km^2: Sunday Creek is one of the major tributaries to the Christina Lake at the south portion of its watershed. Most of the Project Area lies within the headwaters of the Sunday Creek.
- Birch Creek (with the drainage area of 262 km^2 at the WSC Station site): Birch Creek is another major tributary to the Christina Lake at the southwest portion of its watershed.
- Wiau River (with the drainage area of 317 km^2 at the Clyde Lake inlet): Wiau River connects the Wiau Lake to the Clyde Lake that flows into the Clyde River, and eventually drains into the Owl River. The latter contributes flow to the larger Lac la Biche drainage basin.
- Winefred Lake Tributary (with a drainage area of 250 km^2 at the inlet of the unnamed lake) drains into Winefred Lake. The Winefred River drains from Winefred Lake and drains into the larger Christina River.

Sunday Creek, Birch Creek and Winefred Lake tributary sub-basins are located within the Christina River watershed while Wiau River sub-basin is located within the Lac la Biche watershed.

The LSA is characterized by fairly undulating topographic relief with elevation ranging from approximately 560 to 713 masl. The average ground elevation within the LSA is approximately 660 masl. Several small unnamed lakes and watercourses are also found in the LSA, many of which are characterized by low flows and are impeded by debris or beaver dams.



LEGEND

- CONTOUR (20 m INTERVAL)
- ROAD
- RAILWAY
- RIVER
- OPEN WATER
- DIRECTION OF SURFACE DRAINAGE
- AQUATICS LOCAL STUDY AREA
- APPROVED KIRBY SOUTH 2010 PROJECT AREA
- APPROVED KIRBY NORTH 2010 PROJECT AREA
- KIRBY EXPANSION PROJECT LEASE AREA*
- SUB-BASIN AREA

Note

*Includes Oil Sands Leases fully and partially held by Canadian Natural

REFERENCE

ALBERTA DIGITAL DATA OBTAINED FROM ALTALIS LTD. (SEPTEMBER 2004). USED UNDER LICENSE. DATUM: NAD83 PROJECTION: UTM ZONE 12. ALBERTA NTDB DIGITAL DATA OBTAINED FROM GEOMATICS CANADA, AUGUST 2001.

5 0 5
SCALE 1:200,000 KILOMETRES

PROJECT
Canadian Natural

KIRBY IN SITU OIL SANDS EXPANSION PROJECT

TITLE

AQUATICS LOCAL STUDY AREA

Golder Associates
Calgary, Alberta

PROJECT	10.1346.0052.6500		FILE No.	10134600526540A003	
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CHECK	GD	07/12/11			
REVIEW	SM	07/12/11			

FIGURE: 3

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Table 2 Aquatics Local Study Area Boundaries

Watershed Name	Boundary		Rationale
Christina River	*North:*	Mouths of Sunday and Birch creeks at the Inlet of Christina Lake	The proposed Lease Area mostly located within these 2 sub basins. Most downstream of the local watersheds that could potentially be affected by the Project. Further extent of the potential effect due to the Project development (i.e., the potential effect is expected to be negligible at the downstream of this boundary).
	South:	Headwaters of Sunday and Birch creeks	Most upstream of the watershed (this boundary lies within the proposed Lease Area).
	East:	Winefred Lake Tributary at the inlet of Unnamed Lake	The proposed Lease Area lies within the headwaters of the Winefred Lake Tributary. The estimated extent of potential effect due to Project development (i.e., the potential effect is expected to be negligible at the downstream of this boundary)
	West:	Headwaters of Birch Creek	The proposed Lease Area is located within the Birch Creek headwaters
Lac la Biche	*North:*	Unnamed Tributary to Wiau Lake	The proposed Lease Area is located within the Unnamed Tributary to Wiau Lake (i.e., part of headwaters of Wiau Lake)
	South:	Mouth of Wiau River at the Inlet of Clyde Lake	The proposed Lease Area is located within the headwaters of Wiau Lake that flows to the Wiau River. The estimated extent of the potential effect due to the Project development at the south side.
	East:	Unnamed Tributary to Wiau Lake	The Proposed Lease Area is located within the Unnamed Tributary to Wiau Lake (i.e., part of headwaters of Wiau Lake).
	West:	Unnamed Lake and local sub-basin to Wiau Lake	The Proposed Project Lease Area is not located within this sub-basin; it is included for completion of the sub-basin of the Wiau Lake headwaters.

1.2 STUDY OBJECTIVES

The objective of the surface water quality baseline study was to describe the baseline water and sediment quality of watercourses and waterbodies near and downstream of the Project. Specific objectives were as follows;

- compile existing information on water quality within the RSA;
- compile existing information on sediment quality within and near the LSA;
- describe and discuss existing water and sediment quality within and near the LSA;
- where possible, discuss seasonal variation in water quality; and
- compare existing water and sediment quality in the RSA and LSA with relevant guidelines for the protection of aquatic life, human health and wildlife health.

2 AVAILABLE DATA

Much of the historical data used to summarize baseline water quality of the waterbodies and watercourses in the RSA were obtained from Alberta Environment and Water (AEW 2011; formerly Alberta Environment [AENV]). Alberta Environment and Water maintains a water quality database referred to as the Water Data System (WDS). While the data set available from the WDS includes several waterbodies and watercourses in the region, the amount of data per waterbody varies greatly. The number of samples per waterbody ranges from a single sample to over 100 (e.g., Lac la Biche), depending on the objectives of the studies for which the data were originally collected.

To produce the summary tables included in this report, available data for the RSA were requested from AEW. Once the data were received, they were sorted by watercourse/waterbody and the waterbodies of interest were identified. Those with a sufficient amount of data, collected over a reasonable period, were selected for the data summaries. The final list of waterbodies considered to have sufficient historical data included Pinehurst, Touchwood, Wolf, Winefred, Lac la Biche and Christina lakes. The final list of watercourses considered to have sufficient historical data included the Christina, Winefred, Wolf and Sand rivers. A downstream reach of the Christina River outside the aquatics RSA was also included in the baseline data summary.

2.1 HISTORICAL DATA

Publicly available, historical water quality data for the RSA were compiled from:

- Region Aquatics Monitoring Program (RAMP) (Golder 2001, 2002, 2003; RAMP 2004, 2005, 2006, 2007, 2008, 2009, 2010, 2011);
- AEW Water Data System (AEW 2011); and
- baseline reports to support previous oil sands project applications within the RSA.

The RAMP is a multi-stakeholder program supported by local communities, various government agencies and industry (RAMP 2011). The program was established in 1997 to monitor the aquatic effects of oil sands development in the Fort McMurray Oil Sands Region (RAMP 2011).

Alberta Environment and Water has been monitoring water quality in the Oil Sands Region since 1974. The data are stored in the WDS (AEW 2011). The

list of conventional parameters and major ions included in WDS is similar to that used by RAMP, although WDS generally includes fewer metals.

Several baseline studies for oil sands projects were previously completed in the vicinity of the Project, including:

- Kirby North 2010 (Kirby Oil Sands Project Phase 1 (Enermark 2008);
- Kirby South 2010 (KS1) (Kirby In Situ Oil Sands Project [Canadian Natural 2007]);
- Cenovus Narrows Lake Project (Cenovus 2010);
- Devon Jackfish Project (Devon 2004);
- Christina Lake Thermal Expansion Project Phase 1E, 1F and 1G (EnCana 2009);
- OPTI/Nexen Long Lake Project (Gartner Lee 2007);
- Environmental Baseline Survey - Wiau Lake (Golder 1998);
- Christina Lake Regional Project – Phases 1, 2 and 2B (MEG 2005); and
- Christina Lake Regional Project – Phase 3 (MEG 2008).

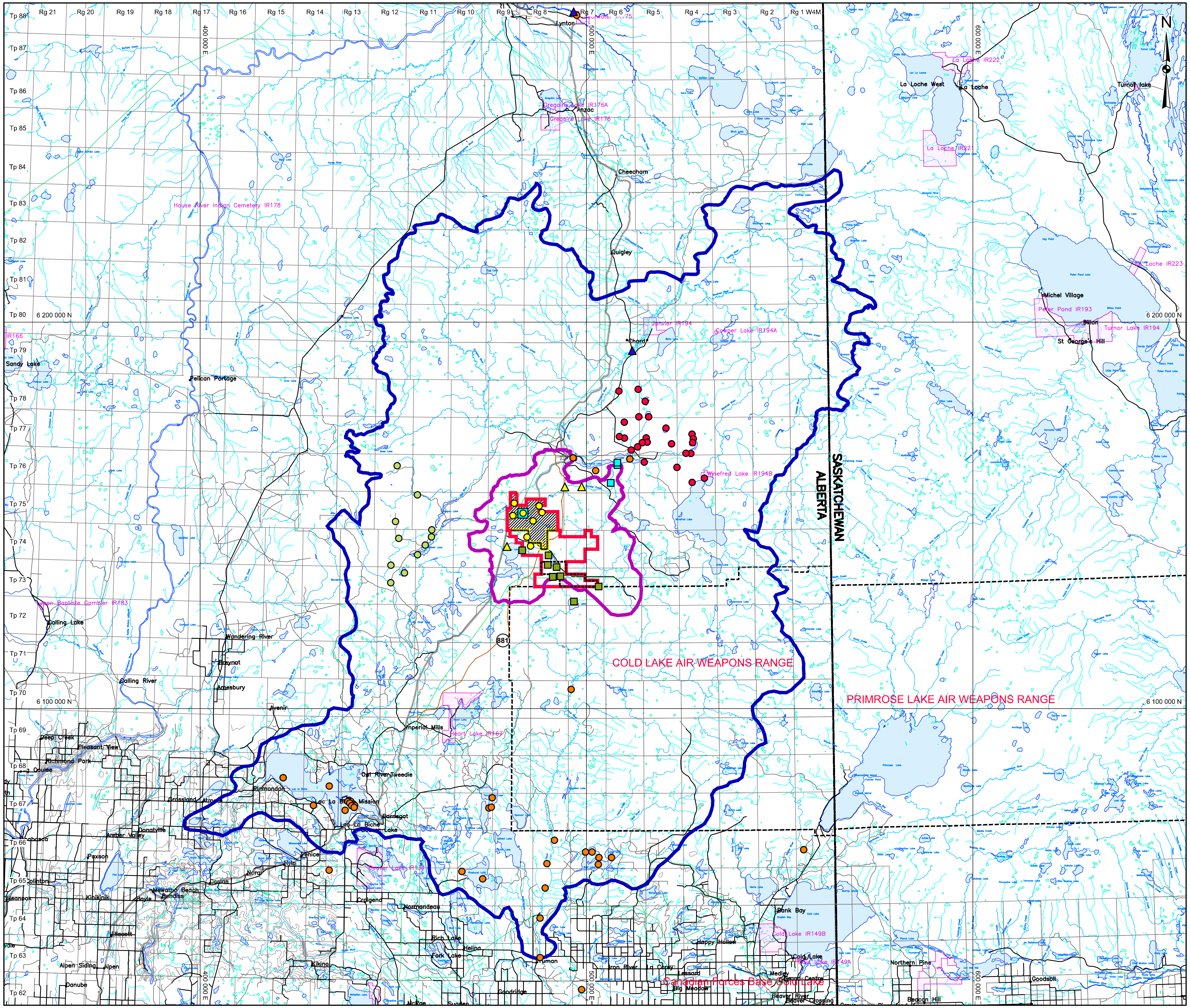
Historical water quality sampling sites are summarized in Table 3 and the sampling locations are provided in Figure 4.

Table 3 Locations of Historical Water Quality Sampling Sites

	Station	Station ID	Source	Station Description
Regional Study Area	Christina Lake	AB07CE0240	AEW 2011	Christina Lake profile at centre
		AB07CE0250	AEW 2011	Christina Lake euphotic composite
		AB07CE0260	AEW2011	Christina Lake profile at centre
		AB07CE0270	AEW 2011	Christina Lake grab sample 200 m from shore
		AB07CE0590	AEW 2011	Christina Lake Section 32, Township 76, Range 7, W4M
		AB07CE0600	AEW 2011	Christina Lake Section 32, Township 76, Range 7, W4M
		CL-1	Cenovus 2009	Centre of Christina Lake
		CL1	MEG 2008	West bay of Christina Lake
		CL-3	Cenovus 2009	West side of Christina Lake
	Lac la Biche	AB07CA0080	AEW 2011	Lac la Biche town bay - east basin profile
		AB07CA0090	AEW2011	Lac la Biche centre of lake profile
		AB07CA0100	AEW 2011	Lac la Biche west basin profile
		AB07CA0110	AEW 2011	Lac la Biche west basin euphotic composite sample
		AB07CA0120	AEW2011	Lac la Biche north of causeway site #1 grab
		AB07CA0130	AEW 2011	Lac la Biche north of causeway site #2 grab
		AB07CA0140	AEW 2011	Lac la Biche north of causeway site #3 grab
		AB07CA0150	AEW 2011	Lac la Biche north of causeway site #4 grab
		AB07CA0160	AEW2011	Lac la Biche south of causeway site #1 grab
		AB07CA0170	AEW 2011	Lac la Biche south of causeway site #2 grab
		AB07CA0180	AEW2011	Lac la Biche south of causeway site #3 grab
		AB07CA0190	AEW2011	Lac la Biche south of causeway site #4 grab
		AB07CA0210	AEW 2011	Lac la Biche euphotic composite sample
		AB07CA0670	AEW 2011	Lac la Biche grab
		AB07CA0200	AEW 2011	Lac la Biche - east basin euphotic composite, provincial parks program
	Pinehurst Lake	AB06AB0260	AEW 2011	Pinehurst Lake main – composite
		AB06AB0270	AEW 2011	Pinehurst Lake discrete
		AB06AB0360	AEW 2011	Pinehurst Lake grab
	Touchwood Lake	AB06AB0150	AEW 2011	Touchwood Lake composite
		AB06AB0160	AEW 2011	Touchwood Lake profile at centre
		AB06AB0420	AEW2011	Touchwood Lake
		AB06AB0430	AEW 2011	Touchwood Lake grab
	Wolf Lake	AB06AB0010	AEW 2011	Wolf Lake outlet stream
		AB06AB0290	AEW 2011	Wolf Lake profile sampling site #1
		AB06AB0300	AEW 2011	Wolf Lake profile sampling site #2
		AB06AB0310	AEW 2011	Wolf Lake profile sampling site #3
		AB06AB0320	AEW 2011	Wolf Lake epilimnetic composite
		AB06AB0390	AEW 2011	Wolf Lake grab
	Christina River	AB07CE0050	AEW 2011	Christina River upstream of confluence with the Clearwater River
		CHR-1	Golder 2001-2003; 2004-2011	Christina River upstream of Fort McMurray
		CHR-2	Golder 2001-2003; RAMP 2004-2011	Christina River upstream of Janvier
		CR-1	Gartner Lee 2007	Downstream of Christina River from the Lease Area
		CR-2	Gartner Lee 2007	Immediately downstream of Christina River from the Lease Area
		CR-3	Gartner Lee 2007	Upstream of Christina River near the Lease Area
	Sand River	AB06AB0040	AEW 2011	Sand River 1.5 km below confluence of Wolf River
		AB06AB0030	AEW 2011	Sand River 1 km downstream of confluence of Wolf River
		AB06AB0060	AEW2011	Sand River 17 km downstream of confluence of Wolf River
		AB06AB0070	AEW2011	Sand River 27 km downstream of confluence of Wolf River
		AB06AB0050	AEW2011	Sand River 8 km downstream of confluence of Wolf River
		AB06AB0100	AEW 2011	Sand River above reservoir
		AB06AB0020	AEW 2011	Sand River at bridge on Highway 55
		AB06AC0010	AEW 2011	Sand River at mouth
		AB06AB0090	AEW2011	Sand River upstream of confluence with the Wolf River
	Wolf River	AB06AB0080	AEW2011	Wolf River upstream of confluence with the Sand River
	Winefred Lake	WB WL	MEG 2008	Winefred Lake
		WB WL	Golder 1998	Winefred Lake
		WC 5-07	MEG 2008	Winefred River above confluence with Winefred lake
		WC 6-07	MEG 2008	Unnamed watercourse 6-07 above confluence with Winefred Lake
	Small Waterbodies in the RSA	Pond WQ1	AEW 2011	Unnamed waterbody
		Pond WQ2	AEW 2011	Unnamed waterbody
		HL1	Devon 2004	Hay Lake
		HL2	Devon 2004	Hay Lake
		CNRL G WB-16	Canadian Natural 2011	Unnamed waterbody
		CNRL G WB-17	Canadian Natural 2011	Unnamed waterbody
		CNRL G WB-8	Canadian Natural 2011	Unnamed waterbody
		GDWN-1	Canadian Natural 2011	Goodwin Lake
		GDWN-2	Canadian Natural 2011	Goodwin Lake
		GDWN-3	Canadian Natural 2011	Goodwin Lake
		IPL	Canadian Natural 2007	Ipiatik Lake
		L2 LAKE	MEG 2005	Unnamed Lake 2
		L5 LAKE	MEG 2005	Unnamed Lake 5
		L6 LAKE	MEG 2005	Unnamed Lake 6
		L7 LAKE	MEG 2005	Unnamed Lake 7
		L8 LAKE	MEG 2005	Unnamed Lake 8
		L9 LAKE	MEG 2005	Unnamed Lake 9
		L11 LAKE	MEG 2005	Unnamed Lake 11
		L12 LAKE	MEG 2005	Unnamed Lake 12
		L13 LAKE	MEG 2005	Unnamed Lake 13
		L15 LAKE	MEG 2005	Unnamed Lake 15
		L16 LAKE	MEG 2005	Unnamed Lake 16
		WB1-07	MEG 2008	Unnamed waterbody 1
		WB-2-07	MEG 2008	Unnamed waterbody 2
		WB-3-07	MEG 2008	Unnamed waterbody 3
		WB-4-07	MEG 2008	Unnamed waterbody 4
		WB-5	MEG 2008	Unnamed waterbody 5
		WB-6-07	MEG 2008	Unnamed waterbody 6
		WB-7	MEG 2008	Unnamed waterbody 7

Table 3 Locations of Historical Water Quality Sampling Sites (continued)

Station		Station ID	Source	Station Description
Regional Study Area	Small Waterbodies in the RSA	WB-8	MEG 2008	Unnamed waterbody 8
		WB-9	MEG 2008	Unnamed waterbody 9
		WB-11	MEG 2008	Unnamed waterbody 11
		WB-12	MEG 2008	Unnamed waterbody 12
		WB-13	MEG 2008	Unnamed waterbody 13
		WB-15	MEG 2008	Unnamed waterbody 15
		WB-16	MEG 2008	Unnamed waterbody 16
	Small Watercourses in the RSA	UC3	Devon 2004	Hay Creek
		UC4	Devon 2004	Hay Creek
		CNRL G WC-18	Canadian Natural 2011	Unnamed watercourse
		CNRL G WC-19	Canadian Natural 2011	Unnamed watercourse
		CNRL G WC-20	Canadian Natural 2011	Unnamed watercourse
		LOGAN-1	Canadian Natural 2011	Logan River
		MANY-1	Canadian Natural 2011	Many Creeks
		MANY-2	Canadian Natural 2011	Many Creeks
		MAY-1	Canadian Natural 2011	May River
		MAY-2	Canadian Natural 2011	May River
		S1	MEG 2005	Unnamed Stream 1
		S10	MEG 2005	Unnamed Stream 10
		S6	MEG 2005	Unnamed Stream 6
		WQ07	Devon 2004	Hay Creek
		WQ04	Devon 2004	Hay Creek
		WC1- 04	MEG 2008	Sawbones Creek
		WC 1-07	MEG 2008	Unnamed watercourse 1-07
		WC 2-07	MEG 2008	Unnamed watercourse 2-07
		WC 3-07	MEG 2008	Unnamed watercourse 3-07
		WC 4-07	MEG 2008	Unnamed watercourse 4-07
		WC 6-04	MEG 2008	Unnamed watercourse 6-04
		WC 10-04	MEG 2008	Unnamed watercourse 10-04
Local Study Area	Wiau Lake	WL-01, WIL	Canadian Natural 2007	Northern basin of Wiau Lake
		site 1	Golder 1998	Wiau Lake Site 1
		site 2	Golder 1998	Wiau Lake Site 2
		site 3	Golder 1998	Wiau Lake Site 3
		site 4	Golder 1998	Wiau Lake Site 4
	Glover Lake	GL-1	Enermark 2008	Glover Lake
	Edwards Lake	EL-1	Enermark 2008	Edwards Lake
	Unnamed Waterbodies	UNL-01	Canadian Natural- 2007	Unnamed Lake 1
		UNL-03	Canadian Natural 2007	Unnamed Lake 3
		UNL-04	Canadian Natural 2007	Unnamed Lake 4
		UNL-05	Canadian Natural 2007	Unnamed Lake 5
		UNL-07	Canadian Natural 2007	Unnamed Lake 7
		UNL-12	Canadian Natural 2007	Unnamed Lake 12
		UNL-13	Canadian Natural 2007	Unnamed Lake 13
		WB-22	Enermark 2008	Unnamed Lake 22
		WB-21	Enermark 2008	Unnamed Lake 21
	Sunday Creek	SC-1 (WC-5)	Cenovus 2009	Sunday Creek above confluence with Christina Lake
		SC-2 (WC-6)	Cenovus 2009	Upstream of Sunday Creek
		WC-12	Enermark 2008	Unnamed watercourse 12
		SU-1	Devon 2004	Sunday Creek
		SU-2	Devon 2004	Sunday Creek
	Birch Creek	BC-1	Enermark 2008	Birch Creek
	Unnamed Tributary 4	TRIB-4	Canadian Natural 2007	Tributary #4
	Unnamed Tributary 5	ST1/REA-01	Canadian Natural 2007	Stream Site 1/Reach 1 of the unnamed tributary to Wiau Lake
		REA-02	Canadian Natural 2007	Reach 2 of the unnamed tributary to Wiau Lake
		ST2/REA-04	Canadian Natural 2007	Stream Site 2/ Reach 4 of the unnamed tributary to Wiau Lake
	Unnamed Watercourses	WC-11	Enermark 2008	Unnamed watercourse 11



LEGEND

- ROAD
- RAILWAY
- RIVER
- OPEN WATER
- AQUATICS LOCAL STUDY AREA
- APPROVED KIRBY SOUTH 2010 PROJECT AREA
- APPROVED KIRBY NORTH 2010 PROJECT AREA
- KIRBY EXPANSION PROJECT LEASE AREA*
- AENV 2011 WQ SITE
- CENOVUS 2009 WQ SITE
- CNRL 2007 WQ SITE
- CNRL 2011 WQ SITE
- DEVON 2004 WQ SITE
- ENERPLUS 2008 WQ SITE
- GOLDER 2001-2003, RAMP 2004-2010 WQ SITE
- MEG 2005/2008 WQ SITE

N

Note

*Includes Oil Sands Leases fully and partially held by Canadian Natural

REFERENCE

ALBERTA DIGITAL DATA OBTAINED FROM ALTALIS LTD. (SEPTEMBER 2004). USED UNDER LICENSE. DATUM: NAD83 PROJECTION: UTM ZONE 12. ALBERTA NTDB DIGITAL DATA OBTAINED FROM GEOMATICS CANADA, AUGUST 2001.

25 0 25

SCALE 1:1,000,000 KILOMETRES

PROJECT

Canadian Natural

KIRBY IN SITU OIL SANDS EXPANSION PROJECT

TITLE

HISTORICAL WATER QUALITY SAMPLING LOCATIONS

Golder Associates
Calgary, Alberta

PROJECT	10.1346.0052.6540		FILE No.	1013460052654OA010
DESIGN	GD	14/10/11	SCALE 1:1,000,000	REV. 0
CADD	TRE	07/12/10		
CHECK	GD	07/12/11	FIGURE: 4	
REVIEW	SM	07/12/11		

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2.2 PROJECT SPECIFIC BASELINE DATA

A baseline sampling program was completed to characterize general water and sediment quality in waterbodies and watercourses that may be directly affected by the Project. Water samples were collected during the winter, summer and fall of 2011. Sediment samples were collected in the fall of 2011. Water sampling was conducted seasonally to represent water quality conditions at important points in the hydrologic cycle. Details of the 2011 field sampling program are provided in Table 4, and field sample locations are shown in Figure 5. Also shown in this figure are water quality sampling locations from the previously approved KS1 and Kirby North 2010 projects.

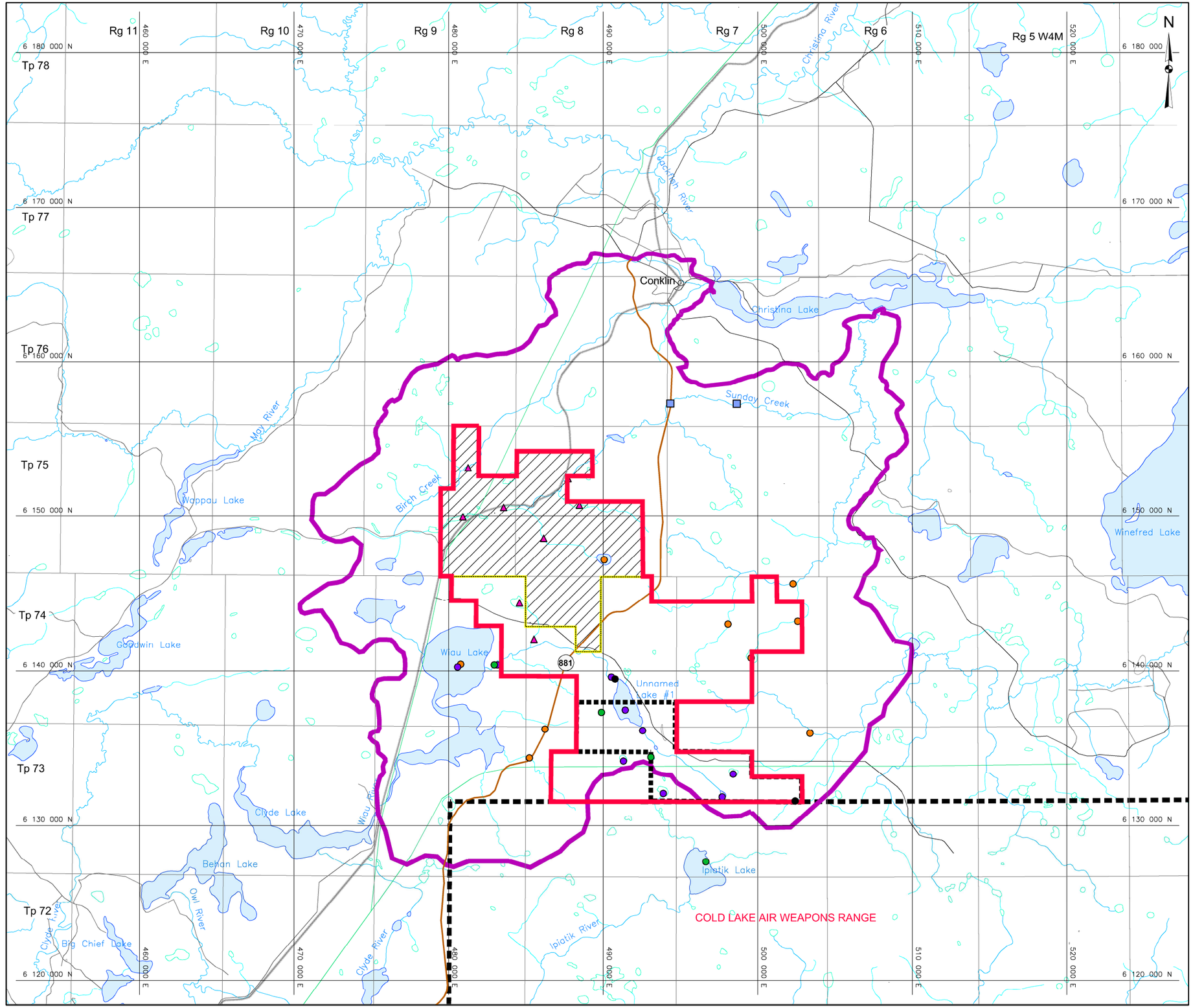
Table 4 Details of the 2011 Surface Water Quality Baseline Field Program

Watercourse or Waterbody Name		Site ID	Location (UTM 12V)		Sampling Season 2011	Samples Collected	
			Northing	Easting		Water	Sediment
Watercourses	Unnamed Tributary	WC-1	6136246	486238	winter	n/a	-
					summer	x	-
					fall	x	x
	Unnamed Tributary	WC-2	6134380	485227	winter	x	-
					summer	x	-
					summer	x	x
	Unnamed Tributary	WC-3	6145631	502287	winter	n/a	-
					summer	x	-
					fall	x	x
	Unnamed Tributary	WC-4	6143214	502591	winter	x	-
					summer	x	-
					fall	x	x
	Unnamed Tributary	WC-5	6143028	498077	winter	x	-
					summer	x	-
					fall	x	x
	Unnamed Tributary	WC-6	6135983	503383	winter	x	-
					summer	x	-
					fall	x	x
Waterbodies	Wiau Lake	WB-1	6140433	480783	winter	x	-
					summer	x	-
					fall	x	x
	Unnamed Waterbody 1	WB-2	6140838	499574	winter	x	-
					summer	x	-
					fall	x	x
	Unnamed Waterbody 2	WB-3	6147196	490066	winter	x	-
					summer	x	-
					fall	x	x

- = No sample collected.

n/a = sample not collected due to watercourses being frozen to the bottom at sampling location.

x = Sample collected.



LEGEND

- ROAD
- RAILWAY
- RIVER
- OPEN WATER
- AQUATICS LOCAL STUDY AREA
- APPROVED KIRBY SOUTH 2010 PROJECT AREA
- APPROVED KIRBY NORTH 2010 PROJECT AREA
- KIRBY EXPANSION PROJECT LEASE AREA*
- KIRBY SOUTH WQ SITE 2001 ONLY
- DEVON CANADA WQ SITE 2004
- KIRBY SOUTH WQ SITE 2006 ONLY
- KIRBY SOUTH WQ SITE 2001, 2006
- KIRBY NORTH WQ SITE 2008
- KIRBY EXPANSION WQ SITE 2011

Note

*Includes Oil Sands Leases fully and partially held by Canadian Natural

REFERENCE

ALBERTA DIGITAL DATA OBTAINED FROM ALTALIS LTD. (SEPTEMBER 2004). USED UNDER LICENSE. DATUM: NAD83 PROJECTION: UTM ZONE 12. ALBERTA NTDB DIGITAL DATA OBTAINED FROM GEOMATICS CANADA, AUGUST 2001.

5 0 5
SCALE KILOMETRES

PROJECT

Canadian Natural

KIRBY IN SITU OIL SANDS EXPANSION PROJECT

TITLE

SURFACE WATER QUALITY SAMPLING LOCATIONS NEAR THE LOCAL STUDY AREA

Golder Associates
Calgary, Alberta

PROJECT 10.1346.0052.6540			FILE No.10134600526540A009	
DESIGN	GD	14/10/11	SCALE 1:250,000	REV. 0
CADD	TRE	05/12/11		
CHECK	GD	05/12/11		
REVIEW	SM	05/12/11		

FIGURE: 5

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2.2.1 Field Sampling Methods and Laboratory Analysis

Water quality samples were collected in the LSA from March to September 2011 from the following waterbodies and watercourses (Figure 5):

- Waterbodies:
  - Wiau Lake;
  - Unnamed Waterbody 2; and
  - Unnamed Waterbody 3.
- Watercourses:
  - Unnamed Tributary 1;
  - Unnamed Tributary 2;
  - Unnamed Tributary 3;
  - Unnamed Tributary 4;
  - Unnamed Tributary 5; and
  - Unnamed Tributary 6.

At each waterbody site, a composite sample was collected with a 1-L bottle, which was used to collect six grab samples from each of three randomly selected locations, resulting in a total volume of 18L. Water collected at a waterbody was decanted into a clean 20L pail and was mixed before filling sample bottles provided by the analytical laboratories.

At watercourse sites, individual grab samples were collected from just below the water surface, at approximately mid-channel.

Field parameters consisting of dissolved oxygen, pH, specific conductivity and water temperature were measured at each water quality sampling site near the water surface. Single measurements were taken at watercourse sites and at three randomly selected sites in each waterbody. Medians were calculated for the three sites at each waterbody. Field measurements were made using a field calibrated multi-meter (YSI 556 or equivalent).

Water samples were collected, preserved, stored and shipped in accordance with established technical procedures for water quality sample collection that are consistent with standard methods (APHA 1992; Environment Canada 1993). Water quality samples collected were split into two parts and shipped to separate laboratories for analysis: one part to the Alberta Innovates – Technology Futures in Vegreville, Alberta, for ultra low detection analysis of methyl mercury; and one

part to the Maxxam Analytics (Maxxam) in Fort McMurray, Alberta, for analysis of all other parameters described below. For dissolved parameter testing, 1-L water samples were collected at each site and sent to Maxxam to be filtered and preserved. For the other parameters that did not require filtration, preservatives were added to sample bottles after collection by the field crew.

The samples were analyzed for a suite of detailed chemical parameters, which provide a broad profile of in-stream water quality and is generally consistent with the parameter list used by the RAMP (2011). Individual water quality sample results from the 2011 program are provided in Attachment A.

The analytical parameters analyzed for water quality included the following:

- Conventional: pH, conductivity, Total Dissolved Solids (TDS), Total Suspended Solids (TSS), hardness, total alkalinity, Dissolved Organic Carbon (DOC), Total Organic Carbon (TOC) and colour.
- Major ions: bicarbonate, calcium, carbonate, chloride, magnesium, potassium, sodium, sulphate and sulphide.
- Nutrients and biological indicators: ammonia, nitrate, nitrite, nitrate plus nitrite, Total Kjeldahl Nitrogen (TKN), total and dissolved phosphorus, Biochemical Oxygen Demand (BOD) and chlorophyll *a*.
- Organics: naphthenic acids, total phenolics and total recoverable hydrocarbons.
- Total and dissolved metals: aluminum, antimony, arsenic, barium, beryllium, boron, cadmium, chromium, cobalt, copper, iron, lead, lithium, manganese, mercury, methyl mercury, molybdenum, nickel, selenium, silver, strontium, thallium, titanium, uranium, vanadium and zinc.

Sediment samples were collected using an Ekman grab. Three grab samples were collected and mixed in a stainless steel pan to prepare a composite sample at each sampling site. Sample jars and bags were filled and submitted to Maxxam Analytics in Fort McMurray, Alberta, for analysis of particle size, carbon and organics content, total metals, Polycyclic Aromatic Hydrocarbons (PAHs) and alkylated PAHs. Individual sediment quality sample results from the 2011 program are provided in Attachment B.

The analytical parameters analyzed for sediment quality include the following:

- Particle size: %sand, % silt, %clay, moisture content.
- Carbon content: total inorganic carbon, total organic carbon, total carbon.

- Organics: total petroleum hydrocarbons, total recoverable hydrocarbons, total volatile hydrocarbons F1 (C_6-C_{10}), total extractable hydrocarbons F2 (C_{10}-C_{16}), F3 (C_{16}-C_{34}), F4 (C_{34}-C_{50}), F4G-SG (CHH-silica), benzene, toluene, ethylbenzene and xylenes.
- Total metals: aluminum, antimony, arsenic, barium, beryllium, boron, cadmium, calcium, chromium, cobalt, copper, iron, lead, lithium, magnesium, manganese, low-level mercury, low-level methyl mercury, molybdenum, nickel, phosphorus, potassium, selenium, silver, sodium, strontium, thallium, titanium, uranium, vanadium and zinc.
- PAHs and alkylated PAHs: acenaphthene, acenaphthylene, anthracene, benzo(a)anthracene, benzo(a)pyrene, benzo(b,j,k)fluoranthene, benzo(g,h,i)perylene, biphenyl, chrysene, dibenzothiophene, fluoranthene, fluorene, indeno(1,2,3-c,d)pyrene, naphthalene, phenanthrene, pyrene, C1-acenaphthenes, C1-benzo(a)anthracenes/ chrysenes, C2-benzo(a)anthracenes/chrysenes, C1-benzofluoranthenes /pyrenes, C2-benzofluoroanthenes/pyrenes, C1-biphenyls, C2-biphenyls, C1-dibenzothiophenes, C2-dibenzothiophenes, C2-dibenzothiophenes, C3-dibenzothiophenes, C4-dibenzothiophenes, C1-fluoranthenes/pyrenes, C2-fluoranthenes/pyrenes, C1-fluorenes, C2-fluorenes, C3-fluorenes, C1-naphthalenes, C2-naphthalenes, C3-naphthalenes, C4-naphthalenes, C1-phenanthrenes/anthracenes, C2-phenanthrenes/anthracenes, C3-phenanthrenes/anthracenes, C4-phenanthrenes/anthracenes, and retene.

Quality control samples were also collected during each sampling period. Blanks were used to assess potential sample contamination during collection, shipping and analysis; duplicate samples were used to check within-site variation and precision of field sampling methods; and split samples were used to test the precision of laboratory analyses. The quality control program and the quality control results are delineated further in Attachment C.

2.3 DATA ANALYSIS

2.3.1 Water Quality

Results of the 2011 water quality sampling program were combined with available historical data, to calculate the seasonal median, minimum and maximum values. Consistent with RAMP (2011), seasons were defined as winter (November through March), spring (April and May), summer (June through August) and fall (September and October). Historical metals data associated with high analytical detection limits relative to recent improvements in the detection limit of low levels (e.g., mercury and silver prior to 2001) were removed from the data

sets before this summary since such results are not representative of baseline conditions and would not add value to the baseline analysis.

2.3.1.1 Water Quality Guidelines

Water quality data were evaluated by comparing concentrations of individual parameters with published water quality guidelines for the protection of freshwater aquatic life, human health and wildlife health (AENV 1999; CCME 1999; Health Canada 2010; U.S. EPA 2002, 2003a, b). In cases where several guidelines were available for a parameter, the most stringent guideline was used, as recommended by AENV (1999), unless otherwise noted. The relevant water quality guidelines are summarized in Table 5.

Water quality guidelines have been developed for many parameters, typically based on measured responses of standard test species (fish and invertebrates) to known concentrations of chemicals. Guidelines for nutrients (e.g., total phosphorus [TP] and total nitrogen [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, usually lethal effects.

Table 5 Surface Water Quality Guidelines

Parameter	Units	Water Quality Guidelines			
		Aquatic Life		Human Health[c]	Wildlife Health[d]
		Acute[a]	Chronic[b]		
Field Measured					
pH	-	6.5 to 8.5	6.5 to 8.5	5 to 9	-
dissolved oxygen	mg/L	5[e]	6.5[f]	-	-
Major Ions					
calcium	mg/L	-	-	-	1,000
chloride	mg/L	860	230	-[g]	-
fluoride	mg/L	-	0.12	1.5	2
sodium	mg/L	-	-	-[g]	-
sulphate	mg/L	-	-	-[g]	1,000
sulphide	mg/L	-	0.014[h]	-[g]	-
total dissolved solids	mg/L	-	-	-	3,000
Nutrients					
ammonia[i]	mg-N/L	5.6	2.43	-	-
nitrate	mg-N/L	-	2.93	10	-
nitrite	mg-N/L	-	0.06	1	10
nitrate and nitrite	mg-N/L	-	-	-	100
total nitrogen	mg-N/L	-	1	-	-
total phosphorus	mg-P/L	-	0.05	-	-
Total Metals					
aluminum	mg/L	0.75	0.1	0.1	5
antimony	mg/L	-	-	0.0055	-
arsenic	mg/L	0.34	0.005	0.01[j]	0.025
barium	mg/L	-	-	1.0	-
beryllium	mg/L	-	-	0.004	0.1
boron	mg/L	29	1.5	5	5
cadmium[k]	mg/L	0.0021[l]	0.00027[l]	0.005	0.08
chromium	mg/L	0.016[m]	0.001[m]	0.05[n]	0.05[n]
cobalt	mg/L	-	-	-	1
copper[o]	mg/L	0.014[l]	0.002[l]	1.3	0.5
iron	mg/L	-	0.3	0.3	-
lead	mg/L	0.082[l]	0.0032[l]	0.01	0.1
manganese	mg/L	-	-	0.05	-
mercury[p]	mg/L	0.000013	0.000005	0.001	0.003
methyl mercury[p]	mg/L	0.000002	0.000001	-	-
molybdenum	mg/L	-	0.073	-	0.5
nickel	mg/L	0.469[l]	0.052[l]	0.34	1
selenium	mg/L	-	0.001	0.01	0.05
silver	mg/L	0.0041[l]	0.0001	-	-
thallium	mg/L	-	0.0008	0.00013	-
uranium	mg/L	0.033	0.015	0.02	0.2
vanadium	mg/L	-	-	-	0.1
zinc	mg/L	0.12[l]	0.03	5.1	50
Organics					
phenolics	mg/L	-	0.004	-	0.002[q]
acenaphthene	µg/L	-	5.8	330	-
anthracene	µg/L	-	0.012	6300	-
benzo(a)anthracene	µg/L	-	0.018	0.0029	-

Table 5 Surface Water Quality Guidelines (continued)

Parameter	Units	Water Quality Guidelines			
		Aquatic Life		Human Health[c]	Wildlife Health[d]
		Acute[a]	Chronic[b]		
benzo(a)pyrene	µg/L	-	0.015	0.0029	-
benzo(b&k)fluoranthenes	µg/L	-	-	0.0029	-
chrysene	µg/L	-	-	0.0029	-
dibenzo(a,h)anthracene	µg/L	-	-	0.0029	-
fluoranthene	µg/L	-	0.04	50	-
fluorene	µg/L	-	3	800	-
indeno(c,d-123)pyrene	µg/L	-	-	0.0029	-
naphthalene	µg/L	-	1.1	-	-
phenanthrene	µg/L	-	0.4	-	-
pyrene	µg/L	-	0.025	5.1	-

[a] Based on the more conservative guideline of: AENV (1999) and U.S. EPA (2002), unless otherwise noted.

[b] Based on the more conservative guideline of: AENV (1999), CCME (1999) and U.S. EPA (2002), unless otherwise noted.

[c] Based on the more conservative guideline for treated drinking water (Health Canada 2010; U.S. EPA 2003a) or human health guidelines for untreated surface waters (U.S. EPA 2002, 2003b using fish consumption rate of 45 g/d [Richardson 1997], unless otherwise noted.

[d] CCME (1999) livestock watering guidelines.

[e] Instantaneous minimum.

[f] 7-day mean.

[g] Health Canada (2010) aesthetic guidelines exist for these parameters, but were not used in this study as they do not relate to toxic thresholds; human health guidelines without this superscript are the maximum acceptable concentrations and interim maximum acceptable concentrations.

[h] Guideline is pH dependent; value shown here corresponds to a pH value of 8; this guideline was altered based on site-specific median conditions using the methods described in U.S. EPA (2002).

[i] Guidelines are pH (acute and chronic) and temperature (chronic) dependent; values shown here correspond to a pH of 8 and a temperature 10°C; these guidelines were calculated based on-site-specific median conditions using the methods described in AENV (1999) and U.S. EPA (2002).

[j] The Health Canada (2010) drinking water guideline for arsenic was used in place of the lower U.S. EPA (2002) human health guideline for surface waters, because the human health guideline is based on the consumption of oysters, a non-resident species in the Oil Sands Region.

[k] The U.S. EPA (2002) chronic cadmium guideline was used in place of the lower CCME (1999) chronic guideline, because, as noted by CCME (1999), most ambient waters contain cadmium levels in excess of the recommended CCME chronic cadmium guideline.

[l] Guidelines are hardness dependent; values shown here are based on a hardness of 100 mg/L; these guidelines were calculated based on-site-specific median hardness levels using the methods described in AENV (1999) and U.S. EPA (2002).

[m] Chromium VI guideline.

[n] Chromium III guideline.

[o] U.S. EPA (2002) acute and CCME (1999) chronic guidelines are shown, because Alberta copper guidelines apply to acid extractable values (as opposed to total values).

[p] Alberta draft guidelines for mercury and methyl mercury are shown.

[q] Guideline for phenols.

- = Not applicable or no guideline.

Concentrations of parameters measured to evaluate baseline water quality may be affected by several 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 many other factors can influence baseline water quality. For example, many elements can be tightly bound to suspended sediments during spring runoff, resulting in elevated concentrations of metals (e.g., aluminum, iron and manganese) and nutrients (e.g., TP) in surface water. Consequently, it is common to measure some water quality parameters above regulatory guidelines in remote areas that are not directly affected by human activities (RAMP 2011). However, these parameters associated higher suspended sediment loads are generally not bioavailable to aquatic organisms.

Concentrations of water quality parameter that are slightly higher than water quality guidelines under natural baseline conditions are generally not considered to be of concern to aquatic life. Guidelines based on laboratory toxicity testing frequently incorporate a safety factor and tend to be conservative. Moreover, aquatic species are adapted to the natural levels of chemicals present in the waters they inhabit. Therefore, concentrations above guidelines do not necessarily indicate that water quality has been compromised by human activities or natural factors.

Similarly, water quality parameters above human health guidelines (e.g., certain metals) do not necessarily indicate a danger to human health. Iron and manganese are commonly measured above guideline levels; however, these guidelines are intended to indicate the suitability of water for industrial or domestic uses (e.g., laundry use) rather than to identify health concerns. For this reason, iron and manganese levels are compared to guidelines, but are not discussed in this report.

A spatial trend analysis was completed for TDS, TSS, TN and TP in the watercourses and waterbodies in the LSA comparing the seasonal summary statistics observed. The seasonal summary statistics (i.e., median, minimum, maximum, 25^{th} percentile and 75^{th} percentile) are presented as box-and-whisker plots to allow visual evaluation of trends. Non-detectable concentrations were set to one-half of the detection limits for these plots.

2.3.1.2 Water Quality Parameters

The following sections describe the major constituents considered when evaluating baseline water quality. These sections also discuss how these parameters are indicative of specific aspects of water quality.

pH

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. Because it is expressed as the -log, the greater the hydrogen ion activity in water, the lower the pH value and the more acidic it is. Solutions with low hydrogen ion activity are alkaline (i.e., basic) and have a high pH. Neutral waters have a pH of 7. Most aquatic organisms can tolerate waters with a pH between 6.5 and 8.5, 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 Ions

Major ion concentrations in surface waters can be measured by hardness, Total Dissolved Solids (TDS) and 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 6. The toxicity of many metals decreases as hardness increases.

Table 6 Qualitative Scale of Water Hardness Based on Concentration of Calcium Carbonate

Hardness Scale	Calcium Carbonate [mg/L]
very soft	0 to 30
soft	31 to 60
moderately soft	61 to 120
hard	121 to 180
very hard	>180

Source: McNeely et al. (1979).

The concentration of TDS is another measure of ion concentration. This concentration is calculated based on 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 7; Mitchell and Prepas 1990).

Table 7 Qualitative Scale of Salinity Based on Concentration of Total Dissolved Solids

Salinity Scale	Total Dissolved Solids [mg/L]
Freshwater	<500
slightly saline	500 to 1,000
moderately saline	1,000 to 5,000
saline	>5,000

Source: Mitchell and Prepas (1990).

Conductivity is a measure of the water's ability to conduct electricity. This ability varies based on the concentration of charged particles in the water. Thus, the concentration of TDS and conductivity of the water are strongly related. Descriptive scales for conductivity and TDS are provided in Table 8.

Table 8 Qualitative Scale of Total Dissolved Solids and Electrical Conductivity

Description	Total Dissolved Solids [mg/L]	Conductivity [µS/cm]
Low	≤100	≤149
moderate	100 to 500	149 to 714
High	>500	>714

- = Not applicable.

Source: The categories in this table were operationally defined to facilitate description of water quality in this document in a standardized format.

Colour

Colour, which often 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 and cobalt compounds to determine the degree of colour (1 mg/L platinum is equal to 1 TCU). A scale of true colour is presented in Table 9. 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). Colour often displays seasonal variation related to the hydrologic regime (e.g., elevated values during spring melt and summer) and local rainstorm events.

Table 9 Colour Scale of Surface Waters

Colour Scale	True Colour Units [as mg/L platinum]
very clear	<4
Coloured	4 to 55
highly coloured	>55

Source: Mitchell and Prepas (1990).

Alkalinity

The capacity of a water sample to neutralize acids is termed alkalinity. This measurement provides an indication of a waterbody's sensitivity to acid deposition or it's Acid Neutralizing Capacity (ANC). Saffran and Trew (1996) presented a scale of surface water sensitivity to acidification based on alkalinity and ANC (Table 10).

Table 10 Scale of Acid Sensitivity Based on Alkalinity in Waterbodies

Acid Sensitivity	Alkalinity [mg/L as $CaCO_3$]	Acid Neutralizing Capacity [µeq/L]
high	0 to 10	0 to 200
moderate	>10 to 20	>200 to 400
low	>20 to 40	>400 to 800
least	>40	>800

Source: Saffran and Trew (1996).

Generally accepted categories of acid sensitivity for watercourses based on alkalinity and ANC are provided in Table 11.

Table 11 Scale of Acid Sensitivity Based on Alkalinity in Watercourses

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

Source: Boward et al. (1999).

Total Suspended Solids

The concentration of all solid particles in the water column is referred to as Total Suspended Solids (TSS). High TSS values can cause stress to aquatic life

depending on both the TSS concentration and the duration of exposure (Newcombe and Jensen 1996). Concentrations of TSS below 25 mg/L are generally not considered harmful to aquatic life (DFO and DOE 1983; EIFAC 1965; U.S. EPA 1973). 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.

Organic Carbon

Total Organic Carbon (TOC) comprises particulate and dissolved organic carbon. 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. Most 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.

Nutrients

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 an indicator of biologically available nitrogen. The TKN concentrations in watercourses 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.

Three qualitative scales were used to categorize the trophic status of watercourses and waterbodies in the results section of the report. A total phosphorus scale developed by Vollenweider and Kerekes (2002) was used to categorize the trophic status of waterbodies (Table 12). This scale also defines Canadian Council of Ministers of the Environment (CCME [CCME 2004]) trigger ranges for management of freshwater systems. A total phosphorus scale developed by Dodds et al. (1998) was used to categorize the trophic status of watercourses. Finally a chlorophyll *a* scale developed by Mitchell and Prepas (1990) was used to also categorize the trophic status of waterbodies (Table 13).

Table 12 Trophic Status Categories Based on Total Phosphorus Concentration

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

[a] Vollenweider and Kerekes (2002).
[b] Dodds et al. (1998).
n/a = not applicable.
Source: CCME (2004).

Table 13 Trophic Status Categories Based on Chlorophyll *a* Concentration

Trophic Status	Maximum Chlorophyll *a* [µg/L]
Oligotrophic	<8
Oligo-mesotrophic	occasionally >8
Mesotrophic	8 to 25
Eutrophic	26 to 75
Hypereutrophic	>75

Source: Mitchell and Prepas (1990).

Metals

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. The toxicity of some metals is also dependent on the hardness of the water, with the toxicity decreasing as the hardness increases. 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.

Organic Compounds

Organic compounds (organics) include chemicals consisting of chains or rings of carbon atoms, such as hydrocarbons, phenols, PAHs and naphthenic acids. These compounds may originate from natural sources (e.g., runoff following forest fires) or may be released from industrial sources (e.g., internal combustion engines, wastewater discharges). Elevated levels of organic compounds may be harmful to aquatic organisms; however, toxicity varies widely by chemical. Recoverable hydrocarbons (or mineral oil and grease) provide an estimate of naturally occurring hydrocarbons.

2.3.2 Sediment Quality

Sediment quality data were evaluated through comparisons of individual parameter concentrations to the CCME guidelines shown in Table 14. These guidelines comprise the *Interim Sediment Quality Guidelines* (ISQG) and Probable Effects Levels (PEL) (CCME 1999). CCME sediment quality guidelines are based on concurrent measurements of bulk sediment chemistry and biological effects of sediment-associated chemicals at a large number of sites. These guidelines are correlation-based rather than cause-effect based (Borgmann 2003) and provides no information regarding bioaccumulation or biomagnification potential. The ISQG can be used to categorize sediments into those that may be toxic and those that are likely non-toxic, but cannot be used to infer potential for toxicity. Toxicity testing of sediments spiked by single substances has shown that ISQGs tend to be highly conservative, which partly reflects the use of sediment data from sites with mixtures of contaminants to develop these guidelines (Borgmann 2003).

Due to the approach used to develop CCME guidelines, they are generic and conservative, and do not take into account site-specific natural background conditions. However, it is known that levels of metals and organic compounds above the ISQG can occur naturally, without adverse effects on resident aquatic organisms (Chapman et al. 2003). Aquatic organisms are adapted to the physical and chemical characteristics of their habitat, which may include elevated levels of certain chemicals as dictated by surficial geology and other factors in the upstream watershed. As a result, concentrations of sediment quality parameters that are higher than sediment quality guidelines under natural baseline conditions are generally not considered to be of concern.

Table 14 Canadian Sediment Quality Guidelines for the Protection of Freshwater Aquatic Life

Parameter	Units [dry wt]	Interim Sediment Quality Guideline[(a)]	Probable Effects Level[(a)]
Total Metals			
arsenic	µg/g	5.9	17
cadmium	µg/g	0.6	3.5
chromium	µg/g	37.3	90
copper	µg/g	35.7	197
lead	µg/g	35	91.3
mercury	µg/g	0.17	0.486
zinc	µg/g	123	315
Polycyclic Aromatic Hydrocarbons			
acenaphthene	µg/g	0.00671	0.0889
acenaphthylene	µg/g	0.00587	0.128
anthracene	µg/g	0.0469	0.245
benzo(a)anthracene	µg/g	0.0317	0.385
benzo(a)pyrene	µg/g	0.0319	0.782
chrysene	µg/g	0.0571	0.862
dibenzo(a,h)anthracene	µg/g	0.00622	0.135
fluoranthene	µg/g	0.111	2.355
fluorene	µg/g	0.0212	0.144
2-methylnaphthalene	µg/g	0.0202	0.201
naphthalene	µg/g	0.0346	0.391
phenanthrene	µg/g	0.0419	0.515
pyrene	µg/g	0.053	0.875

[(a)] Guidelines from CCME (1999).

3 RESULTS AND DISCUSSION

3.1 WATER QUALITY IN THE LOCAL STUDY AREA

Baseline water quality of waterbodies and watercourses within the aquatics LSA is described in the following sections. Results for individual water samples collected during the 2011 sampling programs are summarized in Attachment A. Water quality data for waterbodies and watercourses within the LSA are summarized in Attachment D. These data provide a historical overview, which is used for comparison with data collected during this study. Bolded concentrations in the attachment tables indicate that a value (i.e., concentration) is higher than relevant water quality guideline.

3.1.1 Waterbodies in the Local Study Area

Wiau Lake is the largest lake in the LSA. Other waterbodies in the LSA include Glover and Edwards lakes and a number of other unnamed waterbodies. Water quality guideline exceedances in these waterbodies are summarized in Table 15 and available water quality data are summarized in Attachment D.

Based on field and lab-measured pH values, water in LSA waterbodies was typically neutral to slightly alkaline. Occasional minimum and maximum pH values were outside the acute and chronic aquatic life guideline range during the summer. Dissolved Oxygen (DO) levels were observed below the acute and chronic guidelines for the protection of aquatic life during the winter and spring, suggesting oxygen depletion under ice before spring break-up; and in summer and fall, which may indicate oxygen depletion due to stratification in late summer.

The TSS concentrations were low in the fall (i.e., less than 10 mg/L) and ranged from low to moderate during the other seasons in LSA waterbodies. Major ion concentrations were generally low to moderate as indicated by conductivity values and TDS concentrations. Waters in the LSA were soft to moderately soft during the fall and moderately soft to hard during other seasons. Major ion concentrations and hardness increased in the winter due to “freeze out” of dissolved matter resulting from ice-formation. The TOC concentrations ranged from moderate to high, with the higher values observed during winter. Colour varied from coloured to highly coloured, indicating high dissolved humic matter content. Alkalinity values suggested that these waterbodies are not sensitive to acid deposition.

Table 15 Summary of Water Quality Guideline Exceedances in Waterbodies in the Local Study Area

Parameter	Median	Minimum	Maximum
Field Measured			
pH	-	-	summer [A,C,H]
dissolved oxygen	-	spring, winter [A,C], summer, fall [C]	-
Conventional Parameters			
pH (lab)	-	summer [A,C]	-
Major Ions			
Sulphide	winter [C]	-	winter [C]
Nutrients and Biological Indicators			
nitrogen - total	-	-	winter, spring, summer, fall [C]
phosphorus - total	-	-	spring [C]
General Organics			
total phenolics	winter, spring, summer, fall [W]	spring [W]	winter, spring, summer, fall [C,W]
Metals (Total)			
cadmium	-	-	summer [C]
chromium	-	-	winter, summer, fall [C]
copper	-	-	summer [C]
iron	-	-	winter, spring, summer [C,H]
lead	-	-	summer [C]
manganese	winter [H]	-	winter, spring, fall [H]
mercury	-	-	winter [C]
selenium	-	-	fall [C]

[A] = 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.

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

[W] = concentration higher than the relevant wildlife health guideline.

- = no data or not applicable.

Source: Devon Canada Corporation (2004); Canadian Natural (2007); Golder (1998); Enermark (2008); analytical results for samples collected in 2011. A summary of available water quality data is provided in Attachment D, Table D-1.

Based on the median concentrations of TP, LSA waterbodies are considered mesotrophic to meso-eutrophic. Based on the observed maximum concentration of chlorophyll *a* during summer, the waterbodies are considered oligotrophic. Total nitrogen concentrations were above the chronic aquatic life guideline in all the seasons. The maximum TP concentration was above the chronic aquatic life guideline during the spring, potentially resulting from elevated suspended sediment concentrations resulting from spring runoff. The TKN values ranged from moderate to high.

Naphthenic acids concentrations were usually below the detection limits and total recoverable hydrocarbons typically at or below detection limits. Median and maximum total phenolics concentrations were above the chronic aquatic life and wildlife health guidelines in all the seasons. Maximum concentrations of total

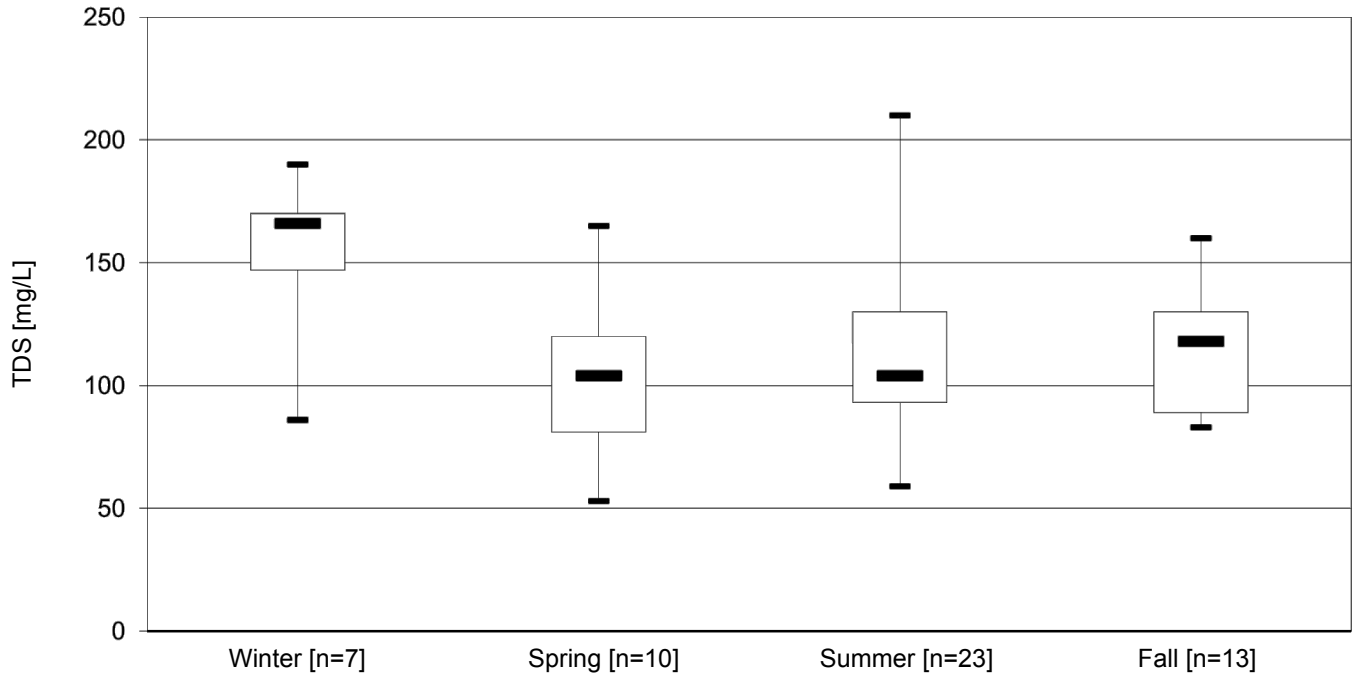
cadmium, total chromium, total copper, total iron, total lead, total mercury and total selenium were above the chronic aquatic life guidelines in one or more seasons.

3.1.1.1 Seasonal Trends

Data from all four seasons were available for most of the parameters measured in LSA waterbodies. Temperature in the waterbodies in the LSA followed a seasonal pattern (decreasing from fall to the winter, and increasing in the spring and summer). Dissolved oxygen is temperature dependent, decreasing with temperature in winter.

In a typical year, winter water quality reflects the input of groundwater and tends to be characterized by elevated dissolved salt levels, low TSS and total metal levels, and low DO concentration. Parameters associated with ionic concentrations (conductivity, hardness, alkalinity) peak in the winter probably associated with exclusion of dissolved matter during ice formation. Spring water quality is usually dominated by the influence of elevated TSS and associated parameters (total metals and nutrients), which decline by the summer. Summer water quality often reflects high flows and associated elevated TSS concentrations, while fall water quality is typically stable, reflecting declining or low flows, except during storm events, and may reflect biological activity (e.g., depletion of nutrients and daily fluctuation of pH and DO).

Consistent with the above annual pattern, the medians of several variables followed a seasonal pattern. A positive seasonal pattern (concentrations increasing from summer through winter and decreasing in the spring) was seen in conductivity, hardness, total alkalinity, TDS (Figure 6), TOC and some total metals. Total metal concentrations including cadmium, chromium, copper, iron, lead, mercury and selenium were observed above one or more water quality guidelines in at least one season. Maximum total iron concentrations were above the chronic aquatic life guideline every season except during the fall.



NOTES

LOWER DASH (OR WHISKER) = MINIMUM
BOTTOM OF BOX = 25TH PERCENTILE
LARGE DASH = MEDIAN
TOP OF BOX = 75TH PERCENTILE
UPPER DASH (OR WHISKER) = MAXIMUM
NON-DETECTABLE RESULTS WERE REPLACED WITH 0.5 THE MDL

PROJECT

Canadian Natural

KIRBY IN SITU OIL SANDS EXPANSION PROJECT

TITLE

SEASONAL VARIATION OF TOTAL DISSOLVED SOLIDS IN LOCAL STUDY AREA WATERBODIES

Golder Associates
Calgary, Alberta

PROJECT 10.1346.0052.6540			FILE No. 10134600526540A001	
DESIGN	EM	14/10/11	SCALE AS SHOWN	REV. 0
CADD	IPG	17/11/11		
CHECK	GD	05/12/11		
REVIEW	SM	05/12/11		

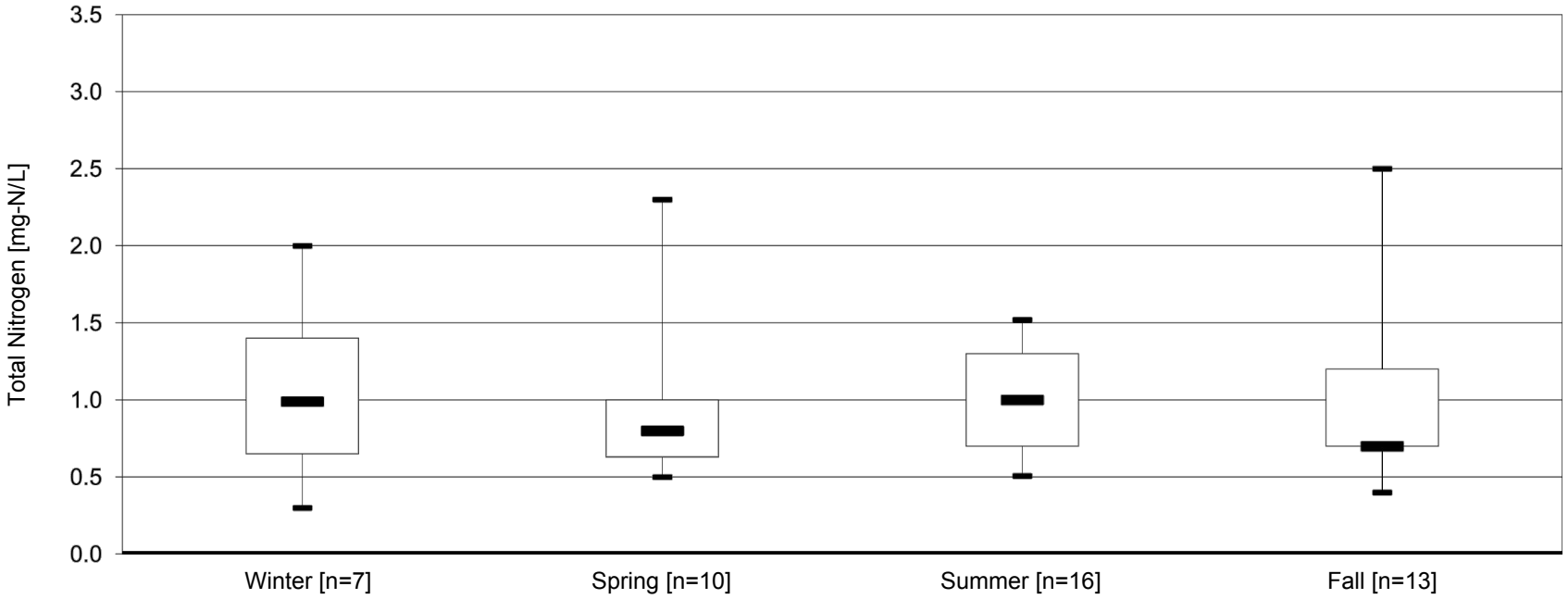
FIGURE: 6

Median total nitrogen concentrations were similar throughout the year, but the maximum values were observed in the fall (Figure 7).

The parameters associated with ionic concentrations (conductivity, hardness, alkalinity) peaked in the winter, probably associated with exclusion of dissolved matter during ice formation and the resulting increases in dissolved solids concentrations.

The median of TSS was higher in summer and winter (Figure 8). However the highest maximum TSS value was observed during the spring reflecting suspended sediment input during the spring freshet. The medians of TP concentrations were higher in the spring and summer and decreased over the winter as temperature decreased. The highest maximum value was observed during the spring (Figure 9).

Total phenolics concentrations did not show evidence of a seasonal trend and the values were consistently above guidelines throughout the year. Total recoverable hydrocarbons were higher during the spring and summer than during other seasons.



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PROJECT

Canadian Natural

KIRBY IN SITU OIL SANDS EXPANSION PROJECT

TITLE

SEASONAL VARIATION OF TOTAL NITROGEN IN LOCAL STUDY AREA WATERBODIES

Golder Associates
Calgary, Alberta

PROJECT 10.1346.0052.6540			FILE No.10134600526540A002	
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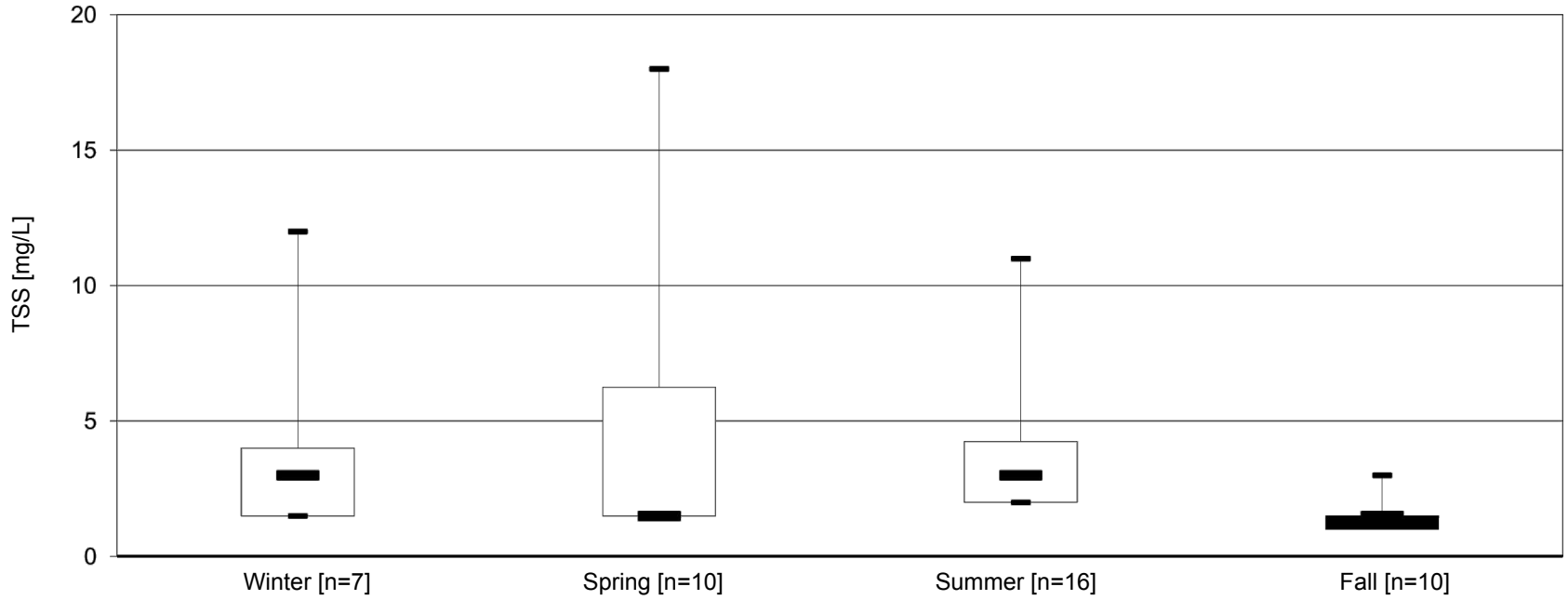
FIGURE: 7



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NON-DETECTABLE RESULTS WERE REPLACED WITH 0.5 THE MDL

PROJECT

Canadian Natural

KIRBY IN SITU OIL SANDS EXPANSION PROJECT

TITLE

SEASONAL VARIATION OF TOTAL SUSPENDED SOLIDS IN LOCAL STUDY AREA WATERBODIES

Golder Associates
Calgary, Alberta

PROJECT 10.1346.0052.6540			FILE No.10134600526540A003	
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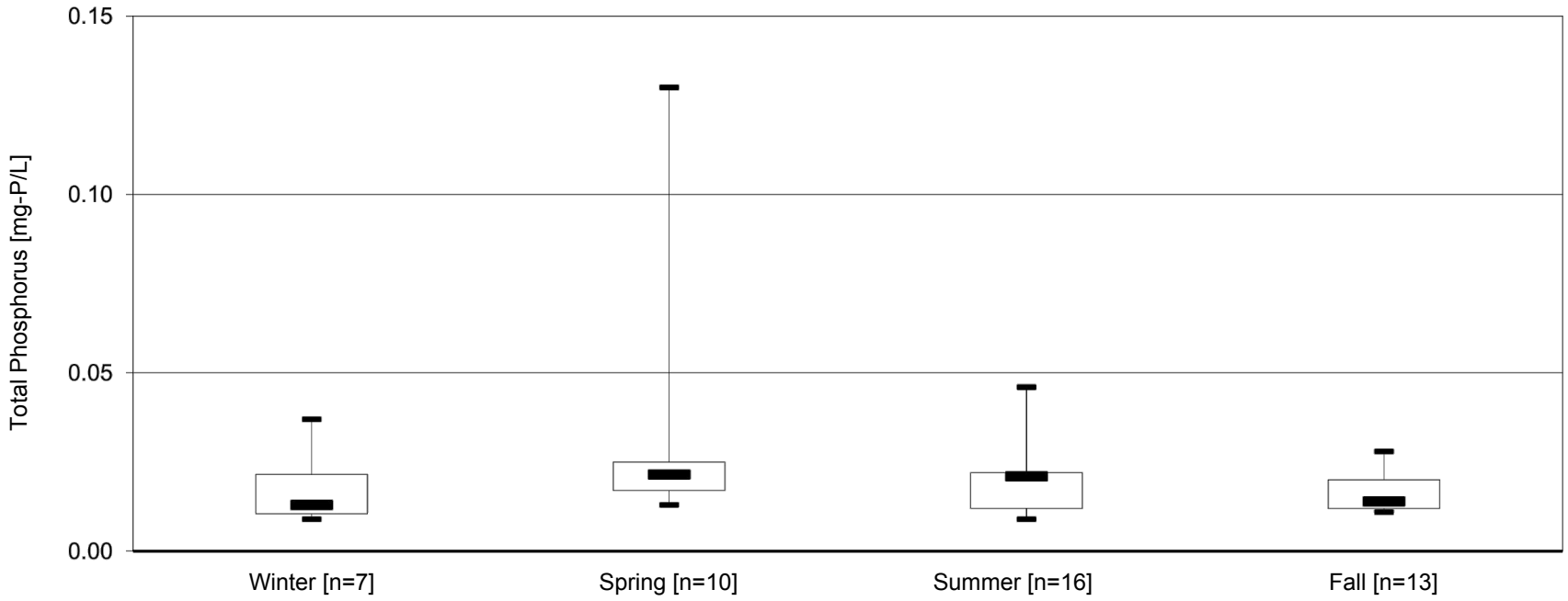
CHECK	GD	05/12/11		
REVIEW	SM	05/12/11		

FIGURE: 8



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PROJECT

Canadian Natural

KIRBY IN SITU OIL SANDS EXPANSION PROJECT

TITLE

SEASONAL VARIATION OF TOTAL PHOSPHORUS IN LOCAL STUDY AREA WATERBODIES

Golder Associates
Calgary, Alberta

PROJECT 10.1346.0052.6540			FILE No.10134600526540A004	
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CADD	IPG	17/11/11		
CHECK	GD	05/12/11		
REVIEW	SM	05/12/11		

FIGURE: 9

3.1.2 Watercourses in the Local Study Area

The main watercourses located in the LSA include Sunday Creek, Birch Creek, and other unnamed watercourses. Water quality guideline exceedances in these watercourses are summarized in Table 16 and available water quality data are summarized in Attachment D.

Based on field and lab-measured pH values, water in LSA watercourses was typically neutral to slightly alkaline. Occasional minimum and maximum pH values were outside the acute and chronic aquatic life guideline range in the summer. Dissolved oxygen levels were outside the acute and chronic guideline range for the protection of aquatic life in winter and outside the chronic guideline range during summer and fall.

The TSS concentrations were low in the fall (i.e., less than 10 mg/L) and ranged from low to high during the rest of the seasons in the LSA watercourses. Major ion concentrations were generally low to moderate as indicated by conductivity values and TDS concentrations. Stream water in the LSA ranged from moderately soft to very hard in the winter, soft to moderately soft in the spring and soft and very hard in summer and fall. Major ion concentrations and hardness increased in the winter due to “freeze out” of dissolved matter during ice formation. The TOC concentrations ranged from moderate to high. Colour varied from coloured to highly coloured indicating high dissolved organic matter content. Median alkalinity values suggested that these watercourses are not sensitive to acid deposition.

Based on the median TP concentrations, the watercourses are considered mesotrophic to eutrophic. Chlorophyll *a* data are limited for the LSA watercourses, and generally indicated a low level of production. Maximum concentrations of TP were above the chronic aquatic life guideline in all the seasons and maximum TN concentrations were above the guideline during the winter and spring. The TKN concentrations ranged from moderate to high, and the highest values were observed in winter.

Naphthenic acids concentrations were below detection limits in all seasons. Maximum total recoverable hydrocarbons were higher during the spring than in other seasons. Maximum total phenolics concentrations were above the chronic aquatic life and wildlife health guidelines in all the seasons.

Maximum concentrations of total aluminum, total arsenic, total chromium, total copper, total iron, total selenium, total silver and total thallium were above the chronic aquatic life guidelines in one or more seasons. The concentration of total aluminum in spring was above the acute aquatic life guideline and maximum

concentrations of total aluminum and total thallium concentrations were above the human health guidelines. Occasional guideline exceedances by seasonal minimum and median metal concentrations were also observed.

Table 16 Summary of Water Quality Guideline Exceedances in Watercourses in the Local Study Area

Parameter	Median	Minimum	Maximum
Field Measured			
pH	-	summer (A,C)	-
dissolved oxygen	winter (A,C)	winter (A,C); summer, fall (C)	-
Major Ions			
sulphide	-	-	winter, summer (C)
Nutrients and Biological Indicators			
nitrogen - total	-	-	winter, spring, summer, fall (C)
phosphorus - total	winter (C)	-	winter, spring, summer, fall (C)
General Organics			
total phenolics	winter (C,W), summer, fall (W)	summer (W)	winter, spring, summer, fall (C,W)
Metals (Total)			
aluminum	spring (C,H)	-	winter, spring (A,C,H); summer, fall (C,H)
arsenic	-	-	winter (C)
chromium	spring (C)	-	winter, spring, summer, fall (C)
copper	-	-	winter, fall (C)
iron	winter, spring, summer, fall (C,H)	winter (C,H)	winter, spring, summer, fall (C,H)
manganese	winter, spring, summer, fall (H)	winter (H)	winter, spring, summer, fall (H)
selenium	-	-	fall (C)
silver	-	-	winter, spring (C)
thallium	-	-	winter, spring (C,H)

(A) = 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.

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

(W) = concentration higher than the relevant wildlife health guideline.

- = no data or not applicable.

Source: Devon (2004); Enermark (2008); Canadian Natural (2007; analytical results for samples collected in 2011. A summary of available water quality data is provided in Attachment D, Table D-2.

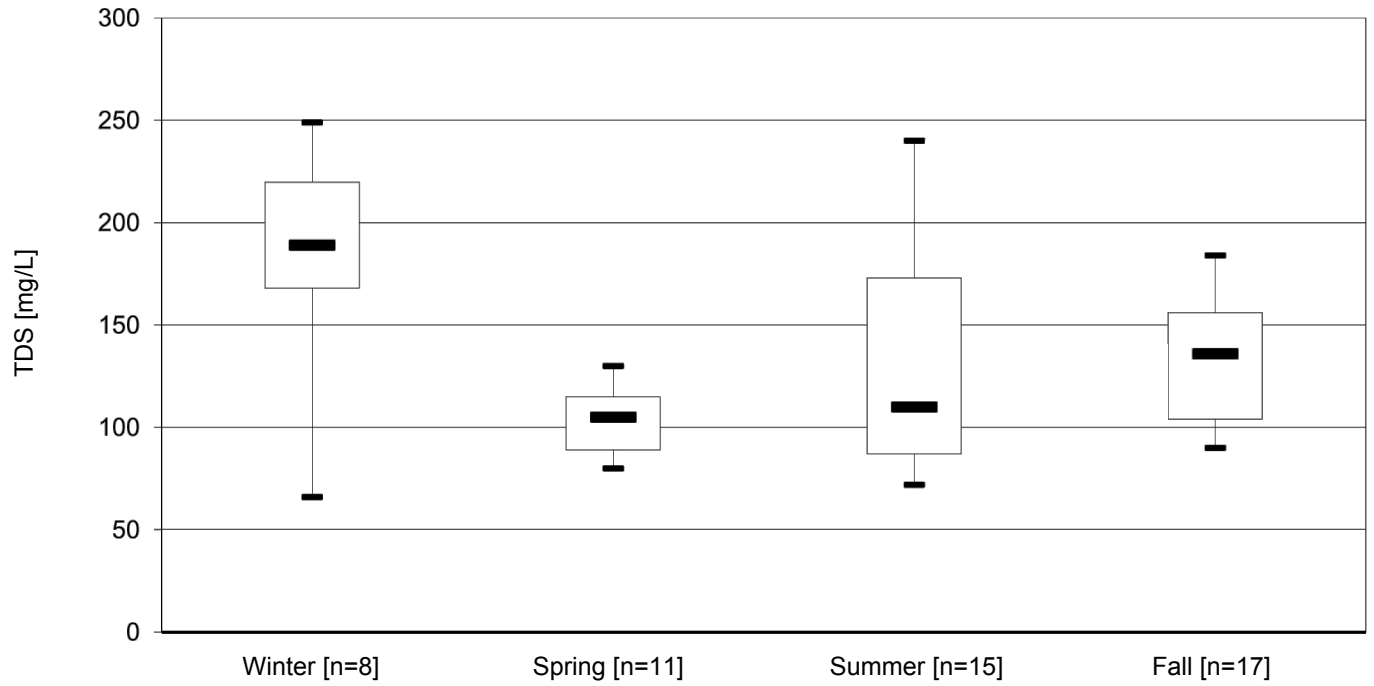
3.1.2.1 Seasonal Tends

The medians of several variables followed a seasonal pattern. Temperature and DO values followed a negative seasonal pattern (decreasing from fall to the winter, and increasing in the spring and summer). A positive seasonal pattern (concentrations increasing from summer through winter and decreasing in the spring) was seen in hardness, total alkalinity, total dissolved solids (Figure 10), TSS (Figure 11), TN (Figure 12) and TP (Figure 13). Parameters associated with

ionic concentrations (conductivity, hardness, alkalinity) peaked in the winter probably associated with exclusion of dissolved matter during ice formation.

Total metal concentrations including aluminum, arsenic chromium, copper, iron, selenium, silver and thallium were observed above one or more water quality guidelines in at least one season. Parameters exceeding guidelines generally appeared to be more frequent in spring than in the other seasons, likely reflecting suspended sediment input during spring freshet. Maximum total iron concentrations were above the chronic aquatic life and human health guidelines every season.

Naphthenic acids concentrations were below detection limits in all seasons. Maximum total recoverable hydrocarbons were higher during the spring. Total phenolics concentrations did not show evidence of a seasonal trend.



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PROJECT

Canadian Natural

KIRBY IN SITU OIL SANDS EXPANSION PROJECT

TITLE

SEASONAL VARIATION OF TOTAL DISSOLVED SOLIDS IN LOCAL STUDY AREA WATERCOURSES

Golder Associates
Calgary, Alberta

PROJECT 10.1346.0052.6540			FILE No.10134600526540A005	
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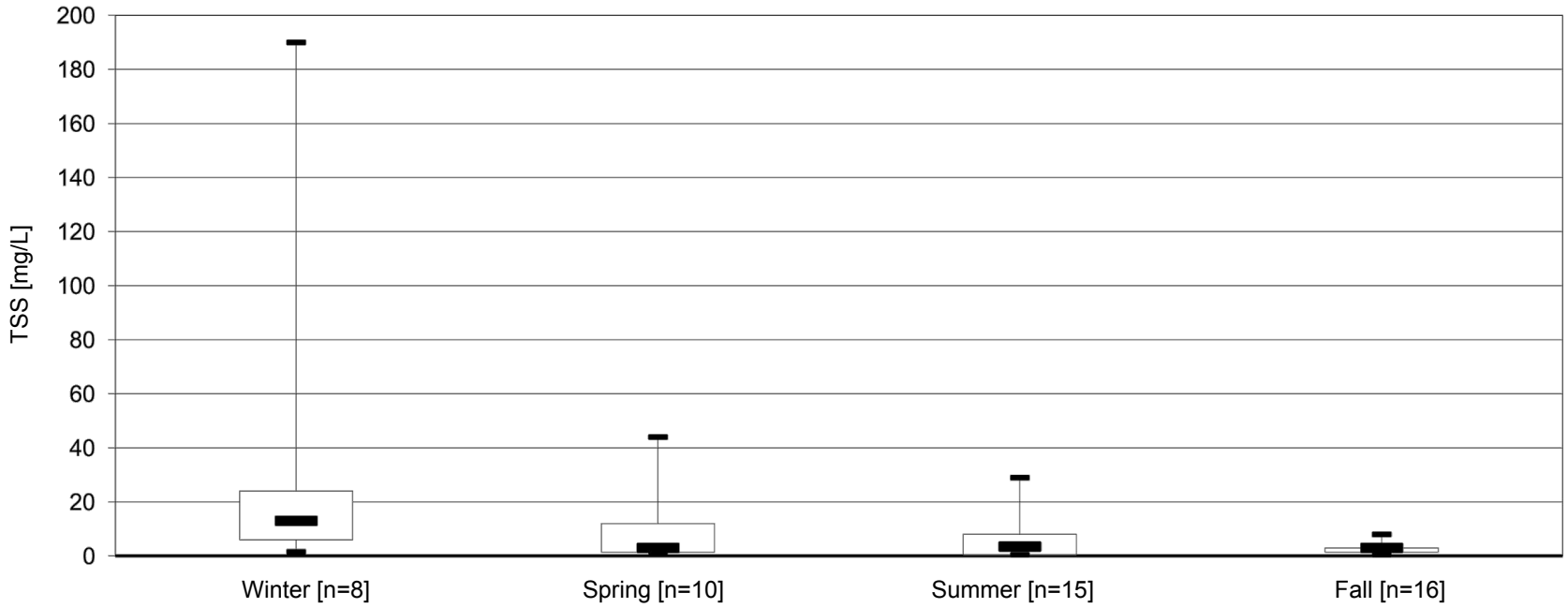
FIGURE: 10



NOTES

LOWER DASH (OR WHISKER) = MINIMUM
BOTTOM OF BOX = 25TH PERCENTILE
LARGE DASH = MEDIAN
TOP OF BOX = 75TH PERCENTILE
UPPER DASH (OR WHISKER) = MAXIMUM
NON-DETECTABLE RESULTS WERE REPLACED WITH 0.5 THE MDL

PROJECT

Canadian Natural

KIRBY IN SITU OIL SANDS EXPANSION PROJECT

TITLE

SEASONAL VARIATION OF TOTAL SUSPENDED SOLIDS IN LOCAL STUDY AREA WATERCOURSES

Golder Associates
Calgary, Alberta

PROJECT 10.1346.0052.6540			FILE No.10134600526540A006	
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REVIEW	SM	05/12/11		

FIGURE: 11

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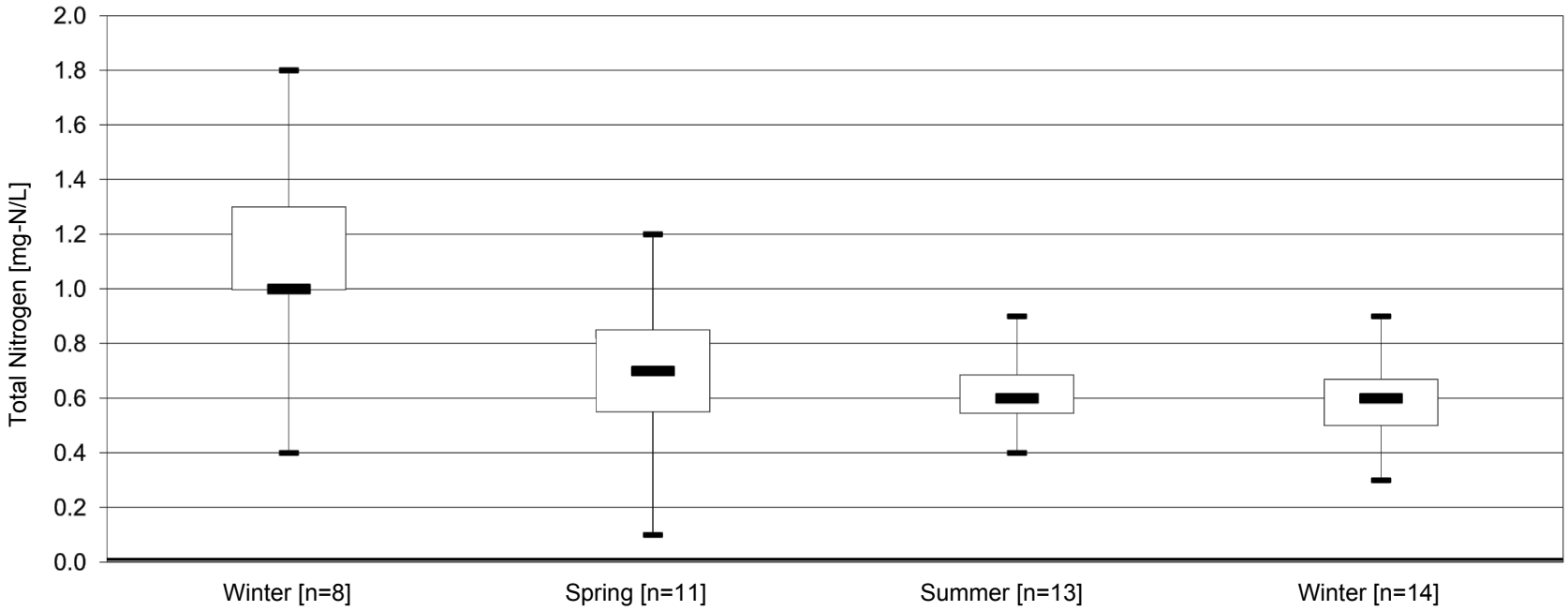

NOTES

LOWER DASH (OR WHISKER) = MINIMUM
BOTTOM OF BOX = 25TH PERCENTILE
LARGE DASH = MEDIAN
TOP OF BOX = 75TH PERCENTILE
UPPER DASH (OR WHISKER) = MAXIMUM
NON-DETECTABLE RESULTS WERE REPLACED WITH 0.5 THE MDL

PROJECT

Canadian Natural

KIRBY IN SITU OIL SANDS EXPANSION PROJECT

TITLE

SEASONAL VARIATION OF TOTAL NITROGEN IN LOCAL STUDY AREA WATERCOURSES

Golder Associates
Calgary, Alberta

PROJECT 10.1346.0052.6540			FILE No.10134600526540A007	
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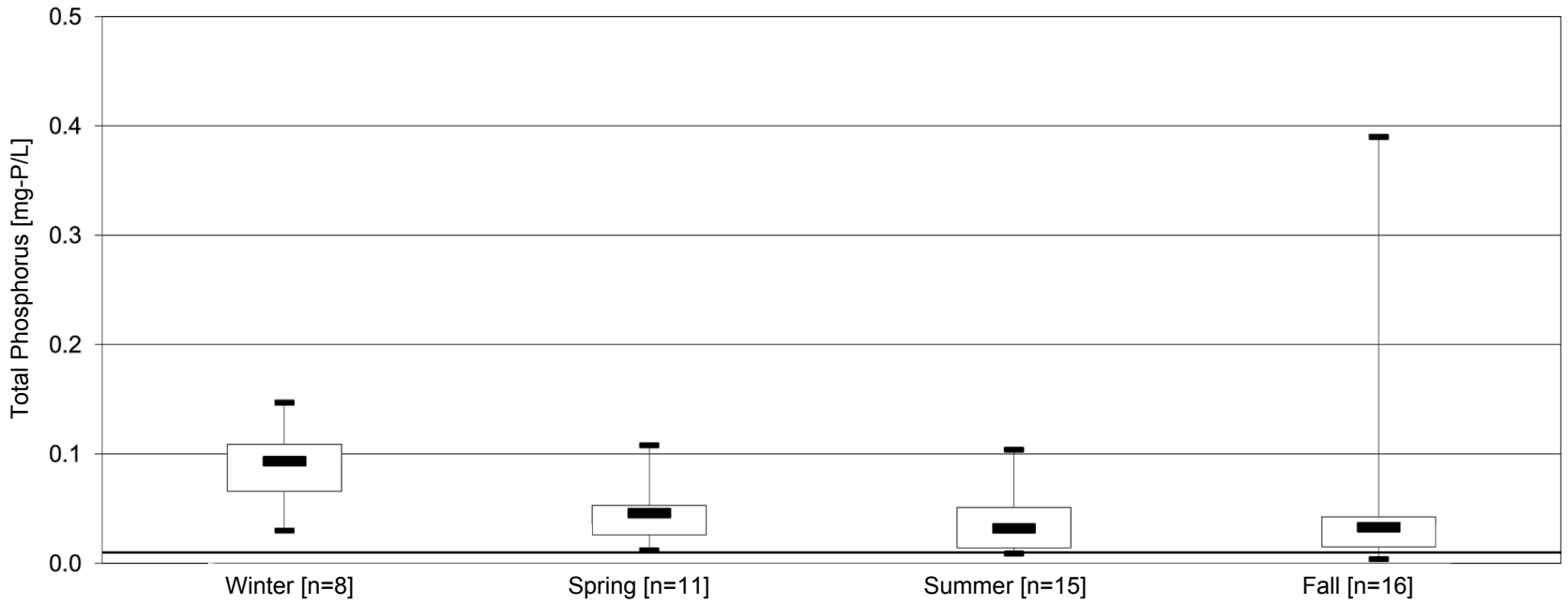
CADD	IPG	17/11/11		
CHECK	GD	05/12/11		
REVIEW	SM	05/12/11		

FIGURE: 12



NOTES

LOWER DASH (OR WHISKER) = MINIMUM
BOTTOM OF BOX = 25TH PERCENTILE
LARGE DASH = MEDIAN
TOP OF BOX = 75TH PERCENTILE
UPPER DASH (OR WHISKER) = MAXIMUM
NON-DETECTABLE RESULTS WERE REPLACED WITH 0.5 THE MDL

PROJECT

Canadian Natural

KIRBY IN SITU OIL SANDS EXPANSION PROJECT

TITLE

SEASONAL VARIATION OF TOTAL PHOSPHORUS IN LOCAL STUDY AREA WATERCOURSES

Golder Associates
Calgary, Alberta

PROJECT 10.1346.0052.6540			FILE No.10134600526540A008	
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CADD	IPG	17/11/11		
CHECK	GD	05/12/11		
REVIEW	SM	05/12/11		

FIGURE: 13

3.2 WATER QUALITY IN THE REGIONAL STUDY AREA

Baseline water quality of waterbodies and watercourses within the aquatics RSA is described in the following sections. Water quality data are summarized in Attachment E. These data provide a historical overview that is used for comparison with data collected specific to this study. Bolded concentrations in the attachment tables indicate that a value is higher than the relevant water quality guideline.

3.2.1 Waterbodies in the Regional Study Area

The main waterbodies in the aquatics RSA include Christina Lake (surface area of 21.3 km^2) and Winefred Lake (surface area of 150 km^2). Other waterbodies of regional significance within the aquatics RSA include Lac la Biche, Touchwood, Wolf and Pinehurst lakes. A summary of water quality guideline exceedances in Christina and Winefred lakes is included in Tables 17 and 18. Table 19 to 23 include the summary for Pinehurst Touchwood, Wolf, Lac la Biche lakes and other small waterbodies in the RSA.

Historical field pH values for Christina Lake indicate that the lake is slightly alkaline and values were generally within guideline levels; however, the minimum winter value was outside of the acute and chronic aquatic life guidelines. The DO levels in Christina Lake were within guidelines for the protection of aquatic life. Field-measured parameters in Winefred Lake show that the lake water was slightly alkaline and well oxygenated. Lac la Biche, Pinehurst, Touchwood, Wolf lakes and other small waterbodies within the RSA all had neutral to alkaline waters with pH levels outside water quality guideline ranges in various occasions. Dissolved oxygen levels were variable and each lake experienced periods of anoxia in two or more seasons.

The TSS concentrations in Christina Lake ranged from low to moderate and the higher concentration was observed during the summer. The TSS concentrations in Winefred, Pinehurst, Pinehurst, Touchwood and Wolf lakes were low in all the seasons. The TSS concentrations in Lac la Biche Lake ranged from low to high during the summer. Other small waterbodies in the RSA had high TSS concentrations in fall and winter, whole TSS ranged from low to moderate in the other seasons.

Major ion concentrations in Christina and Winefred lakes ranged from low to moderate, as reflected by TDS concentrations and conductivity levels (Attachment E, Tables E-1 and E-2). Dissolved solids levels in Lac la Biche, Pinehurst, Touchwood and Wolf lakes were moderate and generally higher in fall

and winter, suggesting higher proportions of groundwater inputs (Attachment E, Tables E-3 to E-6). Lake water in the RSA ranged from soft to hard and hardness values were generally higher in the winter compared to the other seasons. For the waterbodies with available data, water colour can be classified as coloured indicating, high dissolved organic matter content.

Alkalinity values in Christina, Winefred, Lac la Biche, Pinehurst, Touchwood, Wolf lakes and other small waterbodies within the RSA suggested that these waterbodies are not sensitive to acid deposition.

Concentrations of TOC in Christina and Winefred lakes, and other small waterbodies within the RSA were in the moderate range while TKN concentrations were in the high range.

Based on the median TP concentrations, the trophic level of Christina Lake and other small waterbodies varies between mesotrophic and meso-eutrophic. However, the summer maximum levels of chlorophyll *a* were characteristic of an oligotrophic to mesotrophic waterbody. Both TP and chlorophyll *a* concentrations indicate that the Winefred Lake was mesotrophic. Based on the summer maximum levels of chlorophyll *a*, Lac la Biche was hypereutrophic, Pinehurst was mesotrophic and, Touchwood and Wolf lakes were oligotrophic. Nutrient concentrations in the waterbodies were occasionally above the chronic aquatic life guidelines.

Table 17 Summary of Water Quality Guideline Exceedances in Christina Lake (1980 to 2008)

Parameter	Units	Median	Minimum	Maximum
Field Measured				
pH	-	-	winter [A,C]	-
General Organics				
total phenolics	mg/L	winter [C,W]; summer [W]	spring, summer, fall [W]	spring, summer, fall [C,W]
Metals (Total)				
aluminum	mg/L	-		summer [C,H]
chromium	mg/L	-	-	spring, summer [C]
iron	mg/L	-	-	summer [C,H]
manganese	mg/L	-	-	summer [H]

[A] = 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.

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

[W] = concentration higher than the relevant wildlife health guideline.

- = no data or not applicable.

Source: WDS (AEW 2011); MEG (2008); EnCana (2009); Cenovus (2010). A summary of available water quality data is provided in Attachment E, Table E-1.

Table 18 Summary of Water Quality Guideline Exceedances in Winefred Lake and its Tributaries (1998 and 2007)

Parameter	Units	Winefred Lake (WB-WL)	Winefred River (WC5-07)	Unnamed Watercourse 6-07
Major Ions				
sulphide	mg/L	-	-	spring, summer[C]
Nutrients and Biological Indicators				
phosphorus - total	mg-P/L	-	-	spring[C]
General Organics				
total phenolics	mg/L	summer, fall [C,W]	summer, fall [C,W]	summer [C,W]; fall [W]
Total Metals				
aluminum	mg/L	-	-	spring[A,C,H]
chromium	mg/L	-	spring[C]	spring [C]
copper	mg/L	-	spring[C]	-
iron	mg/L	-	-	spring, summer [C,H]
manganese	mg/L	summer [H]	summer [H]	spring, summer [H]
zinc	mg/L	-	-	spring [C]

[A] = 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.

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

[W] = concentration higher than the relevant wildlife health guideline.

- = no data.

Source: MEG (2008). A summary of available water quality data is provided in Attachment E, Table E-2.

Table 19 Summary of Water Quality Guideline Exceedances in Pinehurst Lake (1978 to 1987)

Parameter	Units	Median	Minimum	Maximum
Field Measured				
pH	-	-	winter [A,C]	summer [A,C]; winter [A,C,H]
dissolved oxygen	mg/L	summer [C]	summer, fall, winter [A,C]	-
Conventional Parameters				
pH (lab)	-	summer [A,C]	-	summer, winter [A,C]
Nutrients and Biological Indicators				
nitrogen - ammonia	mg-N/L	-	-	winter [C]
nitrogen - total	mg-N/L	spring, summer, fall, winter [C]	-	summer, fall, winter [C]
phosphorus - total	mg-P/L	-	-	summer, winter [C]
Metals (Total)				
chromium	mg/L	summer[C]	-	-
copper	mg/L	summer[C]	-	-

[A] = 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.

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

[W] = concentration higher than the relevant wildlife health guideline.

- = no data or not applicable.

Source: AEW (2011). A summary of available water quality data is provided in Attachment D Attachment E, Table E-3.

Table 20 Summary of Water Quality Guideline Exceedances in Touchwood Lake (1986 to 2004)

Parameter	Units	Minimum	Maximum
Field Measured			
pH	-	winter [A,C]	summer, fall [A,C]
dissolved oxygen	mg/L	summer, winter [A,C]	-
Conventional Parameters			
pH (lab)	-	-	summer, fall [A,C]
Nutrients and Biological Indicators			
nitrogen - total	mg-N/L	-	winter, fall [C]
phosphorus - total	mg-P/L	-	winter [C]

[A] = 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.

- = no data or not applicable.

Source: AEW (2011). A summary of available water quality data is provided in Attachment E, Table E-4.

Table 21 Summary of Water Quality Guideline Exceedances in Wolf Lake (1975 to 1993)

Parameter	Units	Median	Minimum	Maximum
Field Measured				
pH	-	winter [A,C]	winter [A,C]	summer [A,C]
dissolved oxygen	mg/L	summer, winter [A,C]	winter, spring, summer, fall [A,C]	-
Conventional Parameters				
pH (lab)	-	-	-	summer [A,C]
Nutrients and Biological Indicators				
nitrogen - ammonia	mg-N/L	-	-	summer [A,C]
nitrogen - total	mg-N/L	spring, fall, winter [C]	-	spring, summer, fall, winter [C]
phosphorus - total	mg-P/L	-	-	summer, winter [C]

[A] = 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.

- = no data or not applicable.

Source: AEW (2011). A summary of available water quality data is provided in Attachment E, Table E-5.

Table 22 Summary of Water Quality Guideline Exceedances in Lac la Biche (1977 to 1997)

Parameter	Units	Median	Minimum	Maximum
Field Measured				
pH	-	fall [A,C]	-	winter, fall [A,C]; summer [A,C,H]
dissolved oxygen	mg/L	-	winter, summer, fall [A, C]; spring [C]	-
Conventional Parameters				
pH (lab)	-	-	-	summer, fall [A,C]
Nutrients and Biological Indicators				
nitrogen - total	mg-N/L	fall [C]	-	spring, summer, fall, winter [C]
phosphorus - total	mg-P/L	spring, summer, fall [C]	-	spring, summer, fall, winter [C]
Metals (Total)				
manganese	mg/L	summer [H]	-	summer [H]

[A] = 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.

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

- = no data or not applicable.

Source: AEW (2011). A summary of available water quality data is provided in Attachment E, Table E-6.

Table 23 Summary of Water Quality Guideline Exceedances in Small Waterbodies in the Regional Study Area (2001, 2004, 2007)

Parameter	Units	Median	Minimum	Maximum
Field Measured				
pH	-	-	spring [A,C,H], summer [A,C]	summer [A,C]; fall [A,C,H]
dissolved oxygen	mg/L	-	winter, spring, summer [A,C]	
Conventional Parameters				
pH (lab)	-	-	winter, spring, fall [A,C]	summer [A,C]; fall [A,C,H]
Major Ions				
sulphide	mg/L	spring [C]	winter [C]	winter [C]
Nutrients and Biological Indicators				
nitrogen - ammonia	mg-N/L	-	-	fall [A,C]
nitrogen - total	mg-N/L	winter, summer, fall[C]	-	winter, spring, summer, fall[C]
phosphorus - total	mg-P/L	-	-	winter, summer, fall [C]
General Organics				
total phenolics	mg/L	winter [W], summer, fall [C,W]	winter, summer, fall [W]	winter, summer, fall [C,W], spring [W]
Metals (Total)				
aluminum	mg/L	-	-	fall [C,H]
chromium	mg/L	-	-	spring, fall [C]
copper	mg/L	-	-	winter, fall [C]
iron	mg/L	-	-	winter, spring, summer, fall [C,H]
manganese	mg/L	-	-	winter, spring, summer, fall [H]
silver	mg/L	winter [C]	winter [C]	winter [C], spring [A,C]
thallium	mg/L	-	-	winter, spring [C,H]
zinc	mg/L	-	-	summer [A,C]

[A] = 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.

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

[W] = concentration higher than the relevant wildlife health guideline.

- = no data or not applicable.

Sources: MEG (2005, 2008); Canadian Natural (2007); Canadian Natural-Grouse (2011). A summary of available water quality data is provided in Attachment E, Table E-7.

Maximum concentrations of total aluminum, total chromium, total copper, total iron, total silver, total thallium and total zinc were above the chronic aquatic life guidelines in one or more seasons. Maximum concentrations of total aluminum, and total thallium were above the human health guidelines. Total aluminum and total silver were also above the acute aquatic life guidelines. Occasional guideline exceedances by seasonal minimum and median metal concentrations were also observed.

Concentrations of naphthenic acids and total recoverable hydrocarbons in Christina and Winefred lakes, and other small waterbodies were below detection

limits in all seasons (Attachment E, Tables E-1, E-2 and E-7). Maximum total phenolics concentrations were above the chronic aquatic life and the wildlife health guidelines in Christina Lake and other small waterbodies in most of the seasons (Table 17 and 23). Summer and fall total phenolics concentrations in Winefred Lake exceeded the chronic aquatic life and wildlife health guidelines (Table 18).

3.2.2 Watercourses in the Regional Study Area

The main watercourses in the aquatics RSA include Christina River and Winefred River. Other watercourses of regional significance within the aquatics RSA include Sand River and Wolf River.

Historical field pH values in Christina River were alkaline and were generally within guideline levels; however, in the upstream reach the maximum and minimum field-measured pH levels were occasionally outside of the guideline range for the protection of aquatic life, while in the downstream reach the median spring measurement and the fall maximum were outside the guideline range (Tables 24 and 25). Field-measured parameters show that water in Winefred River and unnamed tributary to Winefred Lake (watercourse 6-07) was slightly alkaline and well oxygenated. All of the field-measured parameters were within regulatory guidelines in these waters (Attachment E, Table E-2). In the Wolf and Sand rivers, the pH was neutral to slightly alkaline in both watercourses, and within water quality guideline ranges (Attachment E, Tables E-10 and E-11). Median field-measured pH values in other small watercourses in the RSA were in the alkaline range. The pH values during the winter, spring and summer were outside the guideline levels (Table 28).

Table 24 Summary of Water Quality Guidelines Exceedances in the Christina River – Upstream

Parameter	Units	Median	Minimum	Maximum
Field Measured				
pH	-	-	winter [A,C]	spring, summer [A,C,H]
dissolved oxygen	mg/L	winter [C]	winter [A,C]	
Major Ions				
sulphide	mg/L	winter, summer [C]	-	winter, fall [C]
Nutrients and Biological Indicators				
nitrogen - total	mg-N/L	winter [C]	-	winter, summer, fall [C]
phosphorus - total	mg-P/L	spring, summer, fall [C]	summer [C]	winter, spring, summer, fall [C]
General Organics				
total phenolics	mg/L	fall [C,W]	-	winter, summer, fall [C,W]
Metals (Total)				
aluminum	mg/L	spring, summer, fall [C,H]	-	winter, summer, fall [C,H]; spring [C,H,A]
chromium	mg/L	-	-	spring, summer [C]
copper	mg/L	-	-	summer, fall [C]
iron	mg/L	winter, spring, summer, fall [C,H]	winter, summer, fall [C,H]	winter, spring, summer, fall [C,H]
nickel	mg/L	-	-	summer [C]
manganese	mg/L	winter, spring, summer, fall [H]	-	winter, spring, summer, fall [H]

[A] = 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.

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

[W] = concentration higher than the relevant wildlife health guideline.

- = no data or not applicable.

Source: WDS (AEW 2011); Golder 2001-2003; RAMP (2004-2011); Gartner Lee (2007). A summary of available water quality data is provided in Attachment E, Table E-8.

Table 25 Summary of Water Quality Guideline Exceedances in the Christina River – Downstream

Parameter	Units	Median	Minimum	Maximum
Field Measured				
pH	-	spring [A,C]	-	fall [A,C]
dissolved oxygen	mg/L	winter [C]	winter [A,C]	-
Major Ions				
chloride	mg/L	-	-	winter [C]
Nutrients and Biological Indicators				
nitrogen – total	mg-N/L	winter, fall [C]	-	winter, spring, summer, fall [C]
phosphorus – total	mg-P/L	winter, spring, summer, fall [C]	winter [C]	winter, spring, summer, fall [C]
General Organics				
total phenolics	mg/L	-	-	winter, spring, summer, fall [C,W]
Metals (Total)				
aluminum	mg/L	winter, summer, fall [C,H]; spring [A,C,H]	spring, summer, fall [C,H]	winter, summer, fall [A,C,H]; spring [A,C,H,W]
cadmium	mg/L	-	-	winter [C]
chromium	mg/L	spring, summer, fall [C]	-	winter, spring, summer, fall [C]
copper	mg/L	-	-	winter, spring, summer [C]
Iron	mg/L	winter, spring, summer, fall [C,H]	winter, spring, summer, fall [C,H]	winter, spring, summer, fall [C,H]
manganese	mg/L	spring, summer, fall [H]	spring, summer [H]	winter, spring, summer, fall [H]
mercury	mg/L	spring [A,C]	-	winter, spring, fall [A,C]; summer [C]
selenium	mg/L	-	-	winter, spring [C]

[A] = 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.

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

[W] = concentration higher than the relevant wildlife health guideline.

- = no data or not applicable.

Source: WDS (AEW 2011); Golder 2001-2003; RAMP (2004-2011); Gartner Lee (2007). A summary of available water quality data is provided in Attachment E, Table E-9.

Table 26 Summary of Water Quality Guideline Exceedances in the Wolf River (1984 to 1985)

Parameter	Units	Winter	
		Median (Min)	Maximum
Nutrients and Biological Indicators			
nitrogen - total	mg-N/L	-	winter[C]
General Organics			
total phenols	mg/L	winter[C,W]	winter[C,W]
Metals (Total)			
chromium	mg/L	-	winter[C]
copper	mg/L	winter[C]	winter[C]
manganese	mg/L	winter [H]	winter [H]

[A] = 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.

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

[W] = concentration higher than the relevant wildlife health guideline.

- = no data or not applicable.

Source: AEW (2011). A summary of available water quality data is provided in Attachment E Table E-10.

Table 27 Summary of Water Quality Exceedances in the Sand River (1983 to 1984)

Parameter	Units	Median	Min	Maximum
Field Measured				
dissolved oxygen	mg/L	winter [A,C]; summer [C]	winter [A,C], summer [C]	-
Nutrients and Biological Indicators				
nitrogen - total	mg-N/L	-	-	winter[C]
phosphorus - total	mg-P/L	-	-	winter, summer [C]
General Organics				
total phenols	mg/L	winter [C,W]; spring, fall [W]	-	winter, summer, fall [C,W]; spring [W]
Metals (Total)				
aluminum	mg/L	-	-	winter, summer, fall [C,H]
cadmium	mg/L	-	-	winter, spring, summer, fall [C]
chromium	mg/L	winter, spring, fall[C]	-	winter, spring, summer, fall [C]
copper	mg/L	-	-	winter[C]
lead	mg/L	-	-	winter [H]; summer [C,H]; fall [C]
manganese	mg/L	winter [H]	-	winter, summer [H]
zinc	mg/L	-	-	winter, summer [A,C]

[A] = 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.

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

[W] = concentration higher than the relevant wildlife health guideline.

- = no data or not applicable.

Source: AEW (2011). A summary of available water quality data is provided in Attachment E, Table E-11.

The Wolf River was well oxygenated when sampled in winter (Attachment E, Table E-10). The Sand River experienced periods of anoxia in winter and DO levels were occasionally below the chronic aquatic life guideline in summer (Table 27). Small watercourses in the RSA experienced periods of anoxia in winter and summer. DO levels were below the chronic and acute aquatic life guidelines in both winter and summer, and were also below the chronic aquatic life guidelines during fall (Table 28).

Concentrations of TSS in the Christina River were variable, ranging from low to high (Attachment E, Table E-8 and E-9). Although the highest concentration was observed in the upstream reach of the Christina River, the concentrations of TSS in the downstream reach of the Christina River were generally higher than those observed in the upstream reach in the spring and fall based on the median TSS concentration. The TSS concentrations were generally low in the Wolf and Sand rivers, although the TSS values were high in the Sand River during summer, which may be a result of increased flows due to storm runoff. The concentrations of TSS in other watercourses were low and the TSS maximum value during the spring was high, likely related to inputs of suspended sediments during spring freshet.

Historical TDS concentrations in the Christina River ranged from low to high. The TDS and conductivity levels in Winefred River were low and dominated by bicarbonate. The TDS and conductivity levels in the unnamed tributary to Winefred Lake ranged from low to moderate. The TDS concentrations in the Wolf and Sand rivers were moderate and were higher in the winter in the Sand River, likely resulting from an increased proportion of groundwater contributions to surface flow. The TDS concentrations in other watercourses in the RSA ranged from low to moderate and were higher in the winter than in other seasons (Attachment E, Table E-12).

Hardness values were indicative of moderately soft water to very hard water in the Christina River. Hardness values ranged from soft to moderately soft and alkalinity values were high in the unnamed tributary to Winefred Lake, and indicated soft water in the Winefred River. Hardness levels concentrations in the Wolf and Sand rivers were moderate and ranged from very soft to very hard in other small watercourses. Hardness values were generally higher in the watercourses in the RSA during the winter compared to other seasons.

Alkalinity values in the Christina, Winefred, Wolf and Sand rivers, unnamed tributary to Winefred Lake, and other small watercourses in the RSA suggest that these watercourses are not sensitive to acid deposition.

Table 28 Summary of Water Quality Guideline Exceedances in Small Watercourses in the Regional Study Area

Parameter	Units	Median	Minimum	Maximum
Field Measured				
pH	-	spring [A,C]	winter, spring, summer [A,C]	-
dissolved oxygen	mg/L	winter [C]	winter, summer [A,C]; fall [C]	-
Conventional Parameters				
pH (lab)	-	-	spring [A,C]	-
Major Ions				
sulphide	mg/L	winter, spring [C]	-	winter, spring, summer, fall [C]
Nutrients and Biological Indicators				
nitrogen - total	mg-N/L	winter [C]	-	winter, summer [C]
phosphorus - total	mg-P/L	winter, summer [C]	-	winter, spring, summer, fall [C]
General Organics				
total phenolics	mg/L	winter, summer, fall [C,W]	-	winter, spring, summer, fall [C,W]
Metals (Total)				
aluminum	mg/L	spring [C]	spring [C]	winter, summer, fall [C,H]; spring [A,C,H]
arsenic	mg/L	-	-	winter [C,H]
chromium	mg/L	-	-	spring, summer [C]
copper	mg/L	-	-	spring [C]
iron	mg/L	winter, spring, summer, fall [C,H]	-	winter, spring, summer, fall [C,H]
manganese	mg/L	winter, summer, fall [H]	winter [H]	winter, spring, summer, fall [H]
mercury	mg/L	fall [A,C]	-	fall [A,C]
selenium	mg/L	-	-	summer [C]
silver	mg/L	-	-	spring [C]
zinc	mg/L	-	-	winter, spring [C]; summer [A,C]
Volatile Organics				
ethylbenzene	µg/L	summer [W]	summer [W]	summer [W]

[A] = 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.

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

[W] = concentration higher than the relevant wildlife health guideline.

- = no data or not applicable.

Sources: MEG (2005, 2008); Canadian Natural (2007); Canadian Natural (2011). A summary of available water quality data is provided in Attachment E, Table E-12.

Concentrations of TKN and TOC in the Christina River ranged from moderate to high (Attachment E, Table E-8 and E-9). The TKN concentrations were high in Winefred Lake and the unnamed tributary to Winefred Lake. The TOC concentrations were moderate in Winefred, Wolf and Sand rivers; in contrast the TOC concentrations were high in the unnamed tributary to Winefred Lake. The TOC concentrations in other small watercourses in the RSA ranged from moderate to high and TKN concentrations ranged from low to high. For the

watercourse with available data, colour can be classified as highly coloured indicating high dissolved organic matter content.

Based on the median TP concentrations, the trophic status of the Christina River varies between mesotrophic and eutrophic. The TP concentrations in the Winefred River indicate that the lake was mesotrophic. The TP concentrations in the unnamed tributary to Winefred Lake (watercourse 6-07) ranged from mesotrophic in the spring to oligotrophic in the fall. The TP and TN concentrations in the watercourses in the RSA were occasionally above guideline for the protection of aquatic life.

Maximum concentrations of total aluminum, total arsenic, total cadmium, total chromium, total copper, total iron, total lead, total mercury, total nickel, total selenium, total silver and total zinc were above the chronic aquatic life guidelines in one or more seasons. Maximum concentrations of total aluminum, total arsenic and total lead were above the human health guidelines. Maximum concentrations of total aluminum, total zinc and total mercury were also above the acute aquatic life guidelines. Occasional guideline exceedances by seasonal minimum and median metal concentrations were also observed.

The maximum naphthenic acids concentrations were slightly above the detection limits in the Christina River and small watercourses in the RSA. The total recoverable hydrocarbons were frequently below detection limits, with the exception of the downstream reach of Christina River were the values were slightly above the detection limit in three out of the four seasons. The maximum concentrations of total phenolics were above the chronic for the protection of aquatic life and wildlife health guidelines in one or more seasons.

3.2.3 Seasonal Trends in the Regional Study Area

Two types of seasonal patterns were apparent in the data available for the RSA, including: (1) negative seasonal pattern (concentrations decreasing from summer to winter); and (2) positive seasonal pattern (concentrations increasing from summer to winter). The first pattern was represented by a decrease in median temperature and TSS. The second trend was found in increasing median hardness, TDS and alkalinity. Total metal concentrations exceeding guidelines generally appeared to be more frequent in spring than in other seasons, likely reflecting suspended sediment input during spring freshet. Total phenolics concentrations did not show a seasonal pattern.

3.3 SEDIMENT QUALITY

Available sediment quality data for selected parameters in waterbodies and watercourses within the LSA are summarized in Tables 29 and 30. Individual sediment sample test results for the 2011 sampling program are provided in Attachment B. A summary of all available sediment quality parameters is provided in Attachment F. Analytical results were compared to the CCME ISQG and PEL. The PAHs and alkylated PAHs results are not included in this report. However they will be submitted later on once received.

The inorganic fraction of the bottom sediments in most waterbodies sampled within and near the LSA consisted primarily of sand, with lesser amounts of silt and clay (Table 29). The TOC content ranged from low to high. Maximum concentrations of total arsenic, total cadmium and total mercury were above the ISQG, while concentrations of other metals, when detectable, were below the ISQG.

The inorganic fraction of the bottom sediments in most watercourses sampled within and near the LSA contained higher proportions of sand than silt and clay (Table 30). The TOC content ranged from low to high. Maximum total arsenic, total cadmium and total zinc concentrations were above the ISQG, while concentrations of other metals, when detectable, were below the ISQG.

Table 29 Summary of Sediment Quality Data for Waterbodies Within the Local Study Area

Parameter	Units (dry wt.)	Fall (2006, 2011)			
		Median	Minimum	Maximum	n
Particle Size					
sand	%	85	72	95	8
silt	%	12	1	27	8
clay	%	4	<1	8	8
moisture content	%	94	27	97	8
Carbon Content					
total inorganic carbon	%	0.2	<0.1	4.2	8
total organic carbon	%	28	0.5	43	8
total carbon	%	29	0.5	45	8
Metals (Total)					
aluminum	µg/g	4,830	290	6,100	8
antimony	µg/g	<1	<1	<2	3
arsenic	µg/g	3.9	0.2	**7.2** [(I)]	8
barium	µg/g	116	10	207	8
beryllium	µg/g	<0.3	<0.2	0.3	8
boron	µg/g	12	<2	15	8
cadmium	µg/g	0.5	<0.1	**0.7** [(I)]	8
calcium	µg/g	10,000	300	17,800	8
chromium	µg/g	11	0.3	16	8
cobalt	µg/g	3.9	0.1	5.0	8
copper	µg/g	9.2	<0.5	24	8
iron	µg/g	9,650	600	12,100	8
lead	µg/g	4.5	<0.5	9.0	8
magnesium	µg/g	2,300	100	2,900	8
manganese	µg/g	237	19	480	8
mercury	µg/g	<0.1	<0.1	**0.2** [(I)]	8
molybdenum	µg/g	0.9	<0.1	1.6	8
nickel	µg/g	11	<0.5	17	8
potassium	µg/g	655	<100	1,200	8
selenium	µg/g	1.0	<0.2	2.0	8
silver	µg/g	<0.2	<0.2	<2	8
sodium	µg/g	115	<100	200	8
strontium	µg/g	25	5	60	8
thallium	µg/g	<0.1	<0.1	0.1	8
titanium	µg/g	53	8	120	8
uranium	µg/g	0.8	<0.1	0.8	8
vanadium	µg/g	15	0.7	24	8
zinc	µg/g	75	<5	115	8

[(I)] = concentration higher than the interim sediment quality guideline (CCME 1999).

Note: **Bolded** concentrations are higher than the relevant sediment quality guideline.

Source: Canadian Natural (2007) analytical results for samples collected in 2011.

Table 30 Summary of Sediment Quality Data for Watercourses Within the Local Study Area

Parameter	Units (dry wt.)	Fall (2006, 2007, 2011)			
		Median	Minimum	Maximum	n
Particle Size					
sand	%	65	7	95	16
silt	%	22	2	50	16
clay	%	10	2	43	16
moisture content	%	67	20	96	16
Carbon Content					
total inorganic carbon	%	0.1	<0.02	4.4	16
total organic carbon	%	5.4	0.2	43	16
total carbon	%	5.4	0.2	43	16
Metals (Total)					
aluminum	µg/g	3,915	940	8,100	16
antimony	µg/g	<1	<1	<2	5
arsenic	µg/g	3.0	0.9	**17** [(I)]	16
barium	µg/g	83	16	205	16
beryllium	µg/g	<0.25	<0.2	0.5	16
boron	µg/g	5	<2	28	16
cadmium	µg/g	0.2	<0.1	**0.7** [(I)]	16
calcium	µg/g	5,400	1,100	30,200	16
chromium	µg/g	7.5	1.9	26	16
cobalt	µg/g	2.7	0.8	7	16
copper	µg/g	5.9	0.7	14	16
iron	µg/g	8,900	2,800	67,700	16
lead	µg/g	4	<1	14	16
magnesium	µg/g	1,710	480	4,520	16
manganese	µg/g	338	83	947	16
mercury	µg/g	<0.1	<0.1	0.1	16
molybdenum	µg/g	0.4	<0.1	2.4	16
nickel	µg/g	6.2	1.5	19	16
potassium	µg/g	550	79	1,200	16
selenium	µg/g	0.5	<0.2	1.2	16
silver	µg/g	<0.2	<0.2	<2	16
sodium	µg/g	100	<50	600	16
strontium	µg/g	16	7	54	16
thallium	µg/g	<0.11	<0.05	0.16	16
titanium	µg/g	65	34	185	16
uranium	µg/g	0.8	0.2	1.2	16
vanadium	µg/g	11	3	28	16
zinc	µg/g	30	8	**159** [(I)]	16

[(I)] = concentration higher than the interim sediment quality guideline (CCME 1999).

Note: **Bolded** concentrations are higher than the relevant sediment quality guideline.

Source: Enermark (2008); Canadian Natural (2007); analytical results for samples collected in 2011.

4 SUMMARY

Water and sediment quality samples were collected within and near the LSA in winter, summer and fall 2011. Water and sediment quality data were compiled, summarized and compared with historical and recent data from the LSA and the RSA. Water quality samples were analyzed for detailed water chemistry, including conventional parameters, ions, nutrients, total and dissolved metals, and selected organics. Sediment samples were analyzed for carbon content, particle size distribution, moisture content, metals and selected organics.

With few exceptions, DO and pH values were within water quality guideline ranges in waterbodies and watercourses in the RSA and LSA. Exceptions tended to occur in the winter when gas exchange is limited by ice formation.

Parameters associated with ionic concentrations (conductivity, hardness, alkalinity) peaked in the winter, probably associated with exclusion of dissolved matter during ice formation. The TSS concentrations were generally higher during the spring as a result of suspended sediment inputs during the spring freshet.

Nutrient concentrations were generally higher in spring and summer and decreased over the winter in waterbodies. Based on TP concentrations, trophic status of waterbodies and watercourses in the RSA and LSA displayed a wide range, from oligo-mesotrophic to eutrophic. Based on the chlorophyll *a* levels, trophic status ranged from oligotrophic to mesotrophic in most of the waterbodies and watercourses, with the exception of Lac la Biche where the trophic status was categorized as hypereutrophic.

Total metal concentrations were generally below water quality guidelines with exception of aluminum, arsenic, cadmium, chromium, copper, iron, lead, mercury, nickel, selenium, silver thallium and zinc. Concentrations in individual samples were observed above one or more water quality guidelines in at least one season. Parameters exceeding guidelines generally appeared to be more frequent in spring than in other seasons, likely reflecting suspended sediment input during spring freshet.

Organic compounds, such as naphthenic acids and recoverable hydrocarbons were generally below detection limits, with some exceptions. Total phenolics concentrations did not show evidence of a seasonal trend and the values were consistently above guidelines throughout the year. These elevated concentrations can be attributed to natural factors and do not indicate that water quality has been compromised.

The sand fraction dominated the inorganic fraction of the bottom sediments in most watercourses and waterbodies. The TOC content ranged from low to high

With few exceptions, metal concentrations in sediments were below guidelines. Total arsenic, total cadmium, total mercury and total zinc concentrations were above the ISQG in some samples, while concentrations of other metals, when detectable, were below the ISQG.

5 CLOSURE

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

GOLDER ASSOCIATES LTD.

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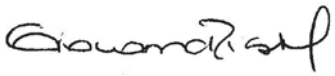

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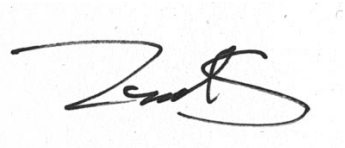

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7 ABBREVIATIONS

%	Percent
<	Less than
>	More than
≤	Less than or equal to
°C	Degree Celsius
-log	Negative logarithm
AENV	Alberta Environment
AEW	Alberta Environment and Water
ANC	Acid neutralizing capacity
BOD	Biochemical oxygen demand
$CaCO_3$	Calcium carbonate
Canadian Natural	Canadian Natural Resources Limited
CCME	Canadian Council of Ministers of the Environment
DO	Dissolved oxygen
DOC	Dissolved organic carbon
e.g.	For example
ERCB	Energy Resources Conservation Board
et al.	And others
g/d	Grams per day
ID	Identification
i.e.	That is
IR	Indian Reserve
ISQG	Interim Sediment Quality Guideline
km	Kilometre
km^2	Square kilometre
L or l	Litre
LSA	Local Study Area
m	metre
m^2	Square metre
masl	Metres above sea level
mg/L	Milligrams per litre
mg-N/L	Milligrams of nitrogen per litre
mg-P/L	Milligrams of phosphorus per litre
NAD	North American Datum
PAH	Polycyclic aromatic hydrocarbons
PEL	Probable effects level
pH	Potential of Hydrogen
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
US EPA	United States Environmental Protection Agency
UTM	Universal Transverse Mercator
W4M	West of the Fourth Meridian
WDS	Water Data System
WQ	Water Quality
WSC	Water Survey of Canada
wt	weight
µeq/L	Microequivalent per litre
µg/g	Micrograms per gram
µg/L	Micrograms per litre
µS/cm	MicroSiemens per centimetre

8 GLOSSARY

Acute	Acute refers to a stimulus severe enough to rapidly induce an effect; 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, 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.
Anoxia	Little to no dissolved oxygen in the water sample. Waters with less than 2 mg/L of dissolved oxygen experience anoxia.
Baseline	A surveyed or predicted condition that serves as a reference point on which later surveys are coordinated or correlated.
Baseline Case	The EIA assessment case that includes existing environmental conditions as well as existing and approved projects or activities.
Basin	A geographic area drained by a single major stream; consists of a drainage system comprised of streams and often natural or artificial (constructed) lakes.
Bioavailable	The amount of chemical that enters the general circulation of the body following administration or exposure.
Biochemical Oxygen Demand	An empirical test in which standardized laboratory procedures are used to determine the relative oxygen requirements of wastewaters, effluents and polluted waters.
Bitumen	A highly viscous, tarry, black hydrocarbon material having an API gravity of about 9 (specific gravity about 1.0). It is a complex mixture of organic compounds. Carbon accounts for 80 to 85% of the elemental composition of bitumen, hydrogen 10%, sulphur 5%, and nitrogen, oxygen and trace elements form the remainder.

Bog	Sphagnum or forest peat materials formed in an ombrotrophic environment due to the slightly elevated nature of the bog, which tends to disassociate it from the nutrient-rich groundwater or surrounding mineral soils. Characterized by a level, raised or sloping peat surface with hollows and hummocks.
Boreal Forest	The northern hemisphere, circumpolar, tundra forest type consisting primarily of black spruce and white spruce with balsam fir, birch and aspen.
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 chemical in environmental media.
Conductivity	A measure of the capacity of water to conduct an electrical current. It is the reciprocal of resistance. This measurement provides an estimate of the total concentration of dissolved ions in the water (specific conductance is normalized to 25°C).
Dissolved Organic Carbon (DOC)	The dissolved portion of organic carbon water; made up of humic substances and partly degraded plant and animal materials.
Dissolved Oxygen (DO)	Measurement of the concentration of dissolved (gaseous) oxygen in the water, usually expressed in milligrams per litre (mg/L).
Drainage Basin	A region of land that eventually contributes water to a river or lake.
Ekman Grab	Cube-shaped mechanical device with a spring-loaded opening that is lowered to the bottom of a waterbody and triggered to close as to collect a sample of bottom sediments.
Electrical Conductivity	The capability of a solution to transmit an electrical current. A capability closely related to the concentration of salts in soils.
Environmental Impact Assessment	A review of the effects that a proposed development will have on the local and regional environment.

Epilimnetic	Localized in the surface layer of a waterbody.
Euphotic	The upper surface layer of a waterbody where sufficient light penetrates to allow photosynthesis to occur.
Eutrophic	The nutrient-rich status (amount of nitrogen, phosphorus and potassium) of an ecosystem.
Fish	Fish as defined in the *Fisheries Act*, includes parts of fish, shellfish, crustaceans, marine animals and any parts of shellfish, crustaceans or marine animals and the eggs, sperm, spawn, larvae, spat and juvenile stages of fish, shellfish, crustaceans and marine animals.
Fresh Water	Water with total dissolved solids concentration below 1,000 mg/L.
Grab Sample	A single sample collected at a particular time and place that represents the composition of the water only at that time and place.
Groundwater	That part of the subsurface water that occurs beneath the water table, in soils and geologic formations that are fully saturated.
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).
Headwater(s)	The source and upper reaches of a stream; also the upper reaches of a reservoir. The water upstream from a structure or point on a stream. The small streams that come together to form a river. Also may be thought of as any and all parts of a river basin except the mainstem river and main tributaries.
Humic Material	Material from the humus portion of the soil, which is the dark, relatively stable organic part, which is so well decomposed that the original sources cannot be identified.
Hydrology	The science of waters of the earth, their occurrence, distribution, and circulation; their physical and chemical properties; and their reaction with the environment, including living beings.
Invertebrates	Any animal lacking a backbone, including all species not classified as vertebrates.
ISQG (Interim Sediment Quality Guideline)	Recommended maximum concentration of a chemical in sediment, intended to be protective of aquatic organisms.

In Situ	Also known as “in place”. Refers to methods of extracting deep deposits of oil sands without removing the groundcover. The in situ technology in oil sands uses underground wells to recover the resources with less impact to the land, air and water than for oil sands mining.
Local Study Area	Defines the spatial extent directly or indirectly affected by the project.
Mesotrophic	Trophic state classification for lakes characterized by moderate productivity and nutrient inputs (particularly total phosphorus).
Muskeg	A soil type comprised primarily of organic matter. Also known as bog peat.
Naphthenic Acid	Generic name used for all the organic acids present in crude oils.
Nutrients	Environmental substances (elements or compounds) such as nitrogen or phosphorus, which 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).
Peat	A material composed almost entirely of organic matter from the partial decomposition of plants growing in wet conditions.
pH	The degree of acidity (or alkalinity) of soil or solution. The pH scale is generally presented from 1 (most acidic) to 14 (most alkaline). A difference of one pH unit represents a ten-fold change in hydrogen ion concentration.
Planned Development Case	The Planned Development Case includes the Application Case components and planned developments that have been publicly disclosed at least six months prior to submission of the Environmental Impact Assessment.

Polycyclic Aromatic Hydrocarbons	Polycyclic aromatic hydrocarbons are a large group of organic compounds comprised of two or more aromatic rings and by-products of combustion. They are found in crude oil and a variety of products such as bitumen, asphalt, coal tar pitch volatiles, and unrefined or mildly refined mineral oils. Polycyclic aromatic hydrocarbons (PAHs) are emitted into the Canadian environment from both natural and anthropogenic sources. Forest fires, which release approximately 2000 tonnes of PAHs per year, are the single most important natural source of PAHs in Canada. However, since releases from that source are generally widely separated in time and space across the country, they do not result in continuous exposure in any specific area. Anthropogenic sources are numerous and result in emissions of PAHs into all environmental compartments
Probable Effects Level (PEL)	Concentration of a chemical in sediment above which adverse effects on an aquatic organism are likely.
Regional Aquatics Monitoring Program (RAMP)	RAMP was established to determine, evaluate and communicate the state of the aquatic environment in the Athabasca Oil Sands Region.
Regional Study Area (RSA)	Defines the spatial extent related to the cumulative effects resulting from the project and other regional developments.
Runoff	The portion of water from rain and snow that flows over land to streams, ponds or other surface waterbodies. It is the portion of water from precipitation that does not infiltrate into the ground, or evaporate.
Sediments	Solid material that is transported by, suspended in, or deposited from water. It originates mostly from disintegrated rocks; it also includes chemical and biochemical precipitates and decomposed organic material, such as humus. The quantity, characteristics and cause of the occurrence of sediment in streams are influenced by environmental factors. Some major factors are degree of slope, length of slope soil characteristics, land usage and quantity and intensity of precipitation.
Specific Conductivity	A measure of the capacity of water to conduct an electrical current. It is the reciprocal of resistance. This measurement provides an estimate of the total concentration of dissolved ions in the water (specific conductance is normalized to 25°C).
Spring Freshet	A spring thaw event resulting from snow and ice melt in rivers.

Steam Assisted Gravity Drainage	An in situ oil sands recovery technique that involves the use of two horizontal wells, one to inject steam and a second to produce the bitumen.
Stratification	Separated into layers. In stratified lakes, there may be mixing within a layer but little mixing occurs between layers. Layers have different densities which may he determined either by temperature and/or salinity.
Suspended Sediments	Particles of matter suspended in the water. Measured as the oven dry weight of the solids, in mg/L, after filtration through a standard filter paper. Less than 25 mg/L would be considered clean water, while an extremely muddy river might have 200 mg/L of suspended sediments.
Total Dissolved Solids (TDS)	The total concentration of all dissolved compounds solids found in a water sample.
Total Kjeldahl Nitrogen (TKN)	The sum of organic nitrogen; ammonia, NH_3 and ammonium, NH_4^+
Total Metals	Metallic elements which have been digested in strong acid before analysis. Includes suspended, dissolved and colloidal forms.
Total Organic Carbon (TOC)	Total organic carbon is composed of both dissolved and particulate forms. Total organic carbon is often calculated as the difference between Total Carbon (TC) and Total Inorganic Carbon (TIC). 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 Petroleum Hydrocarbons	Groups of hydrocarbon chemicals derived from a petroleum source.
Total Recoverable Hydrocarbons	A term that refers to groups of petroleum hydrocarbons recovered using a solvent-specific extraction procedure. Hydrocarbons may include a wide range of fuels, oils and greases.
Total Suspended Solids (TSS)	A measure of the total concentrations of suspended solids in water.
Toxic	A substance, dose or concentration that is harmful to a living organism.

Trophic	Pertaining to part of a food chain, for example, the primary producers are a trophic level just as tertiary consumers are another trophic level.
Trophic Status	Eutrophication is the process by which lakes are enriched with nutrients, increasing the production of rooted aquatic plants and algae. The extent to which this process has occurred is reflected in a lake's trophic classification or status: oligotrophic (nutrient poor), mesotrophic (moderately productive) and eutrophic (very productive).
Waterbody	A general term that refers to ponds, bays, lakes, estuaries and marine areas.
Watercourse	A general term that refers to riverine systems such as creeks, brooks, streams and rivers.
Watershed	The entire surface drainage area that contributes water to a lake or river.

ATTACHMENT A

INDIVIDUAL WATER QUALITY SAMPLE TEST RESULTS FOR PROJECT-SPECIFIC SAMPLING

Table A-1 Water Quality Results for Samples Collected from Waterbodies During the 2011 Field Program

Parameter	Units	WB-1			WB-2			WB-3		
		9-Mar-11	1-Jun-11	7-Sep-11	9-Mar-11	1-Jun-11	8-Sep-11	9-Mar-11	1-Jun-11	7-Sep-11
Field Measured										
pH	-	7.1	**8.9**[A,C]	7.6	7.3	7.3	8.0	6.9	8.2	8.0
conductivity	µS/cm	241	151	162	127	113	122	275	154	153
temperature	°C	1.1	18	17	1.7	17	19	0.6	17	9.3
dissolved oxygen	mg/L	**2.8**[A,C]	10	**6.4**[C]	**2.7**[A,C]	9.9	9.0	**1**[A,C]	9.0	18
Conventional Parameters										
colour	TCU	38	13	15	39	23	21	64	26	27
conductivity	µS/cm	280	150	160	150	110	110	300	150	160
dissolved organic carbon	mg/L	18	13	15	19	14	16	33	20	21
hardness	mg/L	140	81	80	81	61	65	160	81	81
pH (lab)	-	8.0	8.3	8.1	7.9	8.0	7.9	7.9	8.0	8.0
total alkalinity	mg/L	140	82	83	80	60	60	160	84	82
total dissolved solids	mg/L	140	82	80	80	60	62	160	83	79
total organic carbon	mg/L	20	13	16	20	15	16	32	20	21
total suspended solids	mg/L	3	3	2	5	4	3	12	2	1
Major Ions										
bicarbonate	mg/L	180	100	100	98	73	74	190	100	100
calcium	mg/L	37	21	21	21	15	17	40	19	19
carbonate	mg/L	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
chloride	mg/L	1	1	<1	1	2	1	2	2	<1
magnesium	mg/L	11	7	6	7.0	6	6	14	8	8
potassium	mg/L	1	0.9	0.5	0.4	0.4	<0.3	3	2	0.9
sodium	mg/L	4	2	2.0	2	1	1	3	2	1
sulphate	mg/L	<1	<1	<1	<1	<1	<1	<1	<1	<1
sulphide	mg/L	**0.005**[C]	<0.002	<0.002	**0.006**[C]	<0.002	<0.002	**0.048**[C]	<0.002	<0.002
Nutrients and Biological Indicators										
nitrate	mg-N/L	0.010	0.007	<0.003	0.005	0.015	<0.003	0.020	0.013	<0.003
nitrite	mg-N/L	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	0.003	<0.003

Table A-1 Water Quality Results for Samples Collected from Waterbodies During the 2011 Field Program (continued)

Parameter	Units	WB-1			WB-2			WB-3		
		9-Mar-11	1-Jun-11	7-Sep-11	9-Mar-11	1-Jun-11	8-Sep-11	9-Mar-11	1-Jun-11	7-Sep-11
nitrate + nitrite	mg-N/L	0.010	0.007	<0.003	0.005	0.02	<0.003	0.020	0.02	<0.003
nitrogen - ammonia	mg-N/L	0.37	<0.05	0.18	0.17	<0.05	<0.05	0.14	<0.05	0.14
nitrogen - Kjeldahl	mg-N/L	1.40	1.00	1.70	0.90	0.80	0.70	1.80	1.30	1.20
nitrogen - total	mg-N/L	**1.41**[C]	**1.01**[C]	**1.7**[C]	0.91	0.82	0.70	**1.82**[C]	**1.32**[C]	**1.2**[C]
phosphorus - total	mg-P/L	0.011	0.019	0.028	0.010	0.012	0.012	0.037	0.023	0.016
phosphorus - dissolved	mg-P/L	0.002	0.004	0.010	<0.001	0.003	0.007	0.003	0.007	0.008
biochemical oxygen demand	mg/L	<2	<2	<2	<2	<2	<2	5	<2	<2
chlorophyll *a*	µg/L	1.1	2.1	8.9	2.1	1.9	4.4	23	3.6	2.7
General Organics										
naphthenic acids	mg/L	<1	<1	<1	<1	<1	<1	<1	<1	<1
total phenolics	mg/L	**0.004**[W]	**0.003**[W]	**0.004**[W]	**0.005**[C,W]	0.002	**0.004**[W]	**0.01**[C,W]	**0.003**[W]	**0.005**[C,W]
total recoverable hydrocarbons	mg/L	<2	<2	<2	<2	<2	<2	<2	<2	<2
Metals (Total)										
aluminum	mg/L	0.0030	0.0045	0.0040	0.0025	0.0050	0.0041	0.0102	0.0051	0.0068
antimony	mg/L	0.00002	<0.00002	<0.00002	<0.00002	<0.00002	<0.00002	0.00002	<0.00002	0.00003
arsenic	mg/L	0.0007	0.0003	0.0004	0.0003	0.0003	0.0002	0.0009	0.0005	0.0005
barium	mg/L	0.048	0.018	0.030	0.022	0.005	0.011	0.049	0.017	0.021
beryllium	mg/L	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001
bismuth	mg/L	<0.000005	<0.000005	<0.000005	0.000005	<0.000005	<0.000005	0.000005	<0.000005	<0.000005
boron	mg/L	<0.05	<0.05	<0.02	<0.05	<0.05	<0.02	<0.05	<0.05	<0.02
cadmium	mg/L	0.000007	<0.000005	<0.000005	0.000006	<0.000005	<0.000005	0.00001	<0.000005	0.000007
chromium	mg/L	0.0003	0.0002	<0.0001	0.0001	0.0002	<0.0001	0.0001	0.0002	0.0003
cobalt	mg/L	0.00005	0.00003	0.00004	0.00003	0.00002	0.00002	0.00007	0.00002	0.00003
copper	mg/L	0.0004	0.0002	0.0004	0.0003	0.0002	0.0002	0.0011	0.0001	0.0004
iron	mg/L	**1.43**[C,H]	0.09	0.13	**0.99**[C,H]	0.25	0.20	**2.27**[C,H]	0.05	0.05

Table A-1 Water Quality Results for Samples Collected from Waterbodies During the 2011 Field Program (continued)

Parameter	Units	WB-1			WB-2			WB-3		
		9-Mar-11	1-Jun-11	7-Sep-11	9-Mar-11	1-Jun-11	8-Sep-11	9-Mar-11	1-Jun-11	7-Sep-11
lead	mg/L	0.00010	0.00003	0.00020	0.00020	0.00002	0.00004	0.00060	0.00002	0.00007
lithium	mg/L	0.006	0.003	0.004	0.002	0.002	0.002	0.005	0.003	0.003
manganese	mg/L	**0.246**[(H)]	0.021	0.035	**0.181**[(H)]	0.049	**0.075**[(H)]	**0.928**[(H)]	0.041	0.032
mercury	µg/L	<0.002	<0.002	0.002	<0.002	<0.002	0.002	**0.008**[(C)]	<0.002	0.002
methyl mercury	µg/L	<0.00003	-	<0.00004	<0.00003	-	0.00021	<0.00003	-	0.00057
molybdenum	mg/L	0.0001	0.0004	0.0003	<0.00005	0.0001	<0.00005	0.0001	0.0001	0.0002
nickel	mg/L	0.0004	0.00008	0.0001	0.0001	0.00010	0.0002	0.0002	0.0001	0.0001
selenium	mg/L	<0.00004	<0.00004	<0.00004	<0.00004	<0.00004	<0.00004	0.00004	0.00005	<0.00004
silver	mg/L	<0.000005	<0.000005	<0.000005	<0.000005	<0.000005	<0.000005	<0.000005	<0.000005	<0.000005
strontium	mg/L	0.09	0.05	0.05	0.04	0.02	0.03	0.09	0.05	0.05
thallium	mg/L	<0.000002	0.000002	<0.000002	<0.000002	<0.000002	<0.000002	0.000002	0.000002	<0.000002
tin	mg/L	0.00006	<0.00001	0.00001	0.00003	<0.00001	<0.00001	0.00002	<0.00001	<0.00001
titanium	mg/L	0.0008	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	0.0010	<0.0005	<0.0005
uranium	mg/L	0.000008	0.000008	0.000006	0.000003	0.000003	0.000003	0.000010	0.000010	0.000004
vanadium	mg/L	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002
zinc	mg/L	0.004	0.001	0.002[(a)]	0.004	0.001	0.002[(a)]	0.005	0.001	0.004[(a)]
Metals (Dissolved)										
aluminum	mg/L	0.0019	0.0028	0.0023	0.0017	0.0038	0.0020	0.0034	0.0049	0.0041
antimony	mg/L	<0.00002	<0.00002	<0.00002	<0.00002	<0.00002	<0.00002	<0.00002	<0.00002	<0.00002
arsenic	mg/L	0.0006	0.0003	0.0004	0.0003	0.0002	0.0002	0.0009	0.0004	0.0005
barium	mg/L	0.045[(a)]	0.018	0.028	0.02[(a)]	0.004	0.009	0.045[(a)]	0.016	0.02
beryllium	mg/L	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001
bismuth	mg/L	<0.000005	<0.000005	<0.000005	<0.000005	<0.000005	<0.000005	<0.000005	<0.000005	<0.000005
boron	mg/L	<0.05	<0.05	<0.02	<0.05	<0.05	<0.02	<0.05	<0.05	<0.02
cadmium	mg/L	0.000009	<0.000005	0.000006	<0.000005	0.00001	<0.000005	<0.000005	0.000006	<0.000005
chromium	mg/L	0.0002	<0.0001	<0.0001	0.0002	<0.0001	0.0001	0.0002	<0.0001	<0.0001
cobalt	mg/L	0.00005	0.00003	0.00008	0.00004	0.00001	0.00005	0.00007	0.00001	0.00005

Table A-1 Water Quality Results for Samples Collected from Waterbodies During the 2011 Field Program (continued)

Parameter	Units	WB-1			WB-2			WB-3		
		9-Mar-11	1-Jun-11	7-Sep-11	9-Mar-11	1-Jun-11	8-Sep-11	9-Mar-11	1-Jun-11	7-Sep-11
copper	mg/L	0.0019[(a)]	0.0002	0.0007[(a)]	0.0031[(a)]	0.0001	0.0006[(a)]	0.0034[(a)]	0.00010	0.0005[(a)]
iron	mg/L	0.56	0.01	0.04	0.52	0.06	0.01	1.660	0.008	0.02
lead	mg/L	0.0001[(a)]	0.000007	0.00005[(a)]	0.0001[(a)]	0.00001	0.00005[(a)]	0.0003[(a)]	<0.000005	0.00004[(a)]
lithium	mg/L	0.005	0.003	0.004	0.002	0.002	0.002	0.005	0.003	0.003
manganese	mg/L	0.154[(a)]	0.0005	0.0007	0.037[(a)]	0.0003	0.0002	0.89[(a)]	0.0003	0.0006
mercury	µg/L	<0.002	<0.002	0.002	<0.002	<0.002	<0.002	<0.002	<0.002	0.003
molybdenum	mg/L	0.0001	0.00008	0.00008	<0.00005	<0.00005	<0.00005	0.0001	0.00010	0.00007
nickel	mg/L	0.0005	0.0002	0.0001	0.0002	0.0002	0.00007	0.0002	0.00010	0.0001
selenium	mg/L	0.00007	<0.00004	<0.00004	0.00005	<0.00004	<0.00004	<0.00004	<0.00004	<0.00004
silver	mg/L	<0.000005	<0.000005	0.000006	<0.000005	<0.000005	<0.000005	<0.000005	<0.000005	<0.000005
strontium	mg/L	0.09[(a)]	0.05	0.05	0.04[(a)]	0.02	0.03	0.09[(a)]	0.05	0.05
thallium	mg/L	<0.000002	<0.000002	0.000002	<0.000002	<0.000002	<0.000002	<0.000002	<0.000002	<0.000002
tin	mg/L	<0.00001	<0.00001	<0.00001	0.00001	<0.00001	0.00002	<0.00001	<0.00001	<0.00001
titanium	mg/L	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	0.0009	<0.0005	<0.0005
uranium	mg/L	0.00001	0.00001	0.000005	0.000006	0.000004	<0.000002	0.00001	0.00001	0.000005
vanadium	mg/L	<0.0002	<0.0002	0.0004	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002
zinc	mg/L	0.005[(a)]	0.0008	0.002[(a)]	0.006[(a)]	0.001	0.002[(a)]	0.007[(a)]	0.002	0.004[(a)]

[(a)] Results are suspect due to irregularities found in QC samples. Refer to Attachment C for additional information.

- = No data or not applicable.

Notes: **Bolded** concentrations are higher than relevant water quality guidelines.
[(A)] 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.
[(H)] Concentration higher than the relevant human health guideline or beyond the recommended pH range.
[(W)] Concentration higher than the relevant wildlife health guideline.
[(D>)] Analytical detection limit was higher than the relevant water quality guideline(s).

Table A-2 Water Quality Results for Samples Collected from Watercourses During the 2011 Field Program

Parameter	Units	WC-1		WC-2			WC-3		WC-4			WC-5			WC-6		
		2-Jun-11	6-Sep-11	7-Mar-11	2-Jun-11	6-Sep-11	2-Jun-11	11-Sep-11	8-Mar-11	2-Jun-11	11-Sep-11	8-Mar-11	2-Jun-11	8-Sep-11	8-Mar-11	2-Jun-11	6-Sep-11
Field Measured																	
pH	-	**5.8**[A,C]	6.9	6.9	**5.9**[A,C]	7.0	6.9	7.8	7.1	6.8	7.1	7.4	6.6	7.5	7.1	6.7	7.8
conductivity	µS/cm	81	102	446	76	118	139	226	302	174	215	160	95	155	280	103	142
temperature	°C	12	15	1.7	9.7	12	13	13	0.1	13	10	0.1	13	19	0.6	16	16
dissolved oxygen	mg/L	7.6	8.7	**1.3**[A,C]	**6.2**[C]	**6.3**[C]	10	9.0	**3.4**[A,C]	**6.1**[C]	**5.9**[C]	**3.4**[A,C]	8.7	6.7	7.2	8.6	8.5
Conventional Parameters																	
colour	TCU	48	58	570	42	52	37	41	58	36	59	66	38	41	71	35	46
conductivity	µS/cm	78	100	390	74	120	140	230	350	160	210	180	93	130	320	100	140
dissolved organic carbon	mg/L	15	24	23	14	22	11	17	18	12	21	19	12	17	13	12	20
hardness	mg/L	39	57	180	39	67	66	122	180	81	120	92	48	80	150	51	79
pH (lab)	-	7.3	7.8	7.6	7.3	7.8	7.9	8.1	7.9	7.7	7.7	7.7	7.6	7.9	8.0	7.7	8.0
total alkalinity	mg/L	35	51	200	36	61	70	120	190	85	110	93	46	76	170	52	74
total dissolved solids	mg/L	38	100	210	37	110	69	140	180	83	150	94	47	110	160	50	120
total organic carbon	mg/L	16	24	46	13	22	11	16	19	13	21	20	13	17	19	13	20
total suspended solids	mg/L	4	<1	190	<1	10	<1	3	13	1	6	6	<1	2	16	1	<1
Major Ions																	
bicarbonate	mg/L	43	62	250	44	75	86	140	230	100	130	110	57	93	200	64	91
calcium	mg/L	9	13	42	9	14	17	30	45	21	30	23	11	19	40	13	18
carbonate	mg/L	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
chloride	mg/L	3	1	5	1	<1	2	1	2	1	1	2	1	<1	2	<1	<1
magnesium	mg/L	4.0	5.0	19	4.0	6.0	6.0	10.0	15	7.0	9.0	9.0	5.0	6.0	13	5.0	6
potassium	mg/L	<0.3	<0.3	2	<0.3	<0.3	<0.3	0.4	0.6	<0.3	0.3	0.7	<0.3	<0.3	0.5	<0.3	0.3
sodium	mg/L	2	1.0	4.0	1.0	1.0	3	4.0	4	3	3.0	2	1	1.0	4	1	1.0
sulphate	mg/L	<1	<1	<20	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
sulphide	mg/L	<0.002	<0.002	**0.052**[C]	<0.002	<0.002	<0.002	0.005	**0.008**[C]	<0.002	**0.006**[C]	0.005	<0.002	**0.008**[C]	**0.005**[C]	<0.002	<0.002
Nutrients and Biological Indicators																	
nitrate	mg-N/L	<0.02	<0.003	<0.02	<0.003	<0.003	<0.003	<0.003	<0.003	0.018	<0.003	0.045	<0.003	<0.003	0.009	0.013	<0.003
nitrite	mg-N/L	<0.02	<0.003	<0.02	<0.003	<0.003	<0.003	<0.003	<0.003	0.004	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003
nitrate + nitrite	mg-N/L	<0.02	<0.003	<0.02	<0.003	<0.003	<0.003	<0.003	<0.003	0.02	<0.003	0.05	<0.003	<0.003	0.009	0.01	<0.003
nitrogen - ammonia	mg-N/L	<0.05	0.06	0.46	<0.05	<0.05	<0.05	<0.05	0.49	<0.05	<0.05	0.26	<0.05	<0.05	0.89	<0.05	0.06
nitrogen - Kjeldahl	mg-N/L	0.6	0.7	1.6	0.6	0.7	0.6	0.5	1.3	0.6	0.6	1.1	0.6	0.7	1.5	0.7	0.7
nitrogen - total	mg-N/L	0.6	0.7	**1.6**[C]	0.6	0.7	0.6	0.5	**1.3**[C]	0.62	0.6	**1.15**[C]	0.6	0.7	**1.51**[C]	0.71	0.7
phosphorus - total	mg-P/L	0.009	0.010	**0.63**[C]	0.008	0.021	0.015	0.032	**0.087**[C]	0.016	**0.095**[C]	**0.067**[C]	0.012	0.017	**0.1**[C]	0.013	0.009
phosphorus - dissolved	mg-P/L	0.005	0.011	0.082	0.005	0.010	0.009	0.019	0.013	0.007	0.026	0.037	0.007	0.016	0.022	0.006	0.008
biochemical oxygen demand	mg/L	-	<2	<10	-	<2	-	<2	<2	-	<2	<2	-	<2	<2	-	<2
General Organics																	
naphthenic acids	mg/L	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
total phenolics	mg/L	**0.003**[W]	**0.005**[C,W]	**0.015**[C,W]	**0.003**[W]	**0.004**[W]	**0.003**[W]	**0.004**[W]	**0.005**[C,W]	**0.003**[W]	**0.004**[W]	**0.006**[C,W]	**0.003**[W]	0.002	**0.004**[W]	**0.003**[W]	**0.004**[W]
total recoverable hydrocarbons	mg/L	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2

Table A-2 Water Quality Results for Samples Collected from Watercourses During the 2011 Field Program (continued)

Parameter	Units	WC-1		WC-2			WC-3		WC-4			WC-5			WC-6		
		2-Jun-11	6-Sep-11	7-Mar-11	2-Jun-11	6-Sep-11	2-Jun-11	11-Sep-11	8-Mar-11	2-Jun-11	11-Sep-11	8-Mar-11	2-Jun-11	8-Sep-11	8-Mar-11	2-Jun-11	6-Sep-11
Metals (Total)																	
aluminum	mg/L	**0.0155**[C]	0.010	0.058	**0.0099**[C]	**0.106**[C,H]	0.014	0.022	0.011	0.005	0.010	0.026	0.018	0.010	0.027	0.008	0.005
antimony	mg/L	<0.00002	0.00002	<0.0001	<0.00002	<0.00002	<0.00002	<0.00002	<0.00002	<0.00002	<0.00002	<0.00002	<0.00002	<0.00002	0.00005	<0.00002	<0.00002
arsenic	mg/L	0.0004	0.0007	**0.007**[C]	0.0003	0.0007	0.0004	0.0007	0.0006	0.0003	0.0008	0.0008	0.0005	0.0007	0.0014	0.0004	0.0005
barium	mg/L	0.011	0.016	0.105	0.008	0.015	0.015	0.025	0.042	0.018	0.029	0.017	0.010	0.014	0.033	0.010	0.015
beryllium	mg/L	<0.00001	0.00003	<0.00005	<0.00001	0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001
bismuth	mg/L	<0.000005	<0.000005	<0.00003	<0.000005	<0.000005	<0.000005	<0.000005	<0.000005	<0.000005	<0.000005	<0.000005	<0.000005	<0.000005	0.000019	<0.000005	<0.000005
boron	mg/L	<0.02	<0.05	<0.02	<0.02	<0.05	<0.02	<0.02	<0.05	<0.02	<0.02	<0.05	<0.02	<0.02	<0.05	<0.02	<0.05
cadmium	mg/L	0.00001	0.00004	0.00006	0.00001	0.00001	0.00001	0.000007	0.000009	0.00001	<0.000005	0.000009	<0.000005	0.000006	0.00004	<0.000005	<0.000005
chromium	mg/L	0.0001	0.0001	<0.0005	0.0002	0.0002	0.0002	0.0002	0.0002	0.0003	0.0001	0.0002	0.0003	<0.0001	0.0003	0.0003	<0.0001
cobalt	mg/L	0.00009	0.00020	0.0123	0.00007	0.00030	0.00005	0.00010	0.00140	0.00008	0.00010	0.00030	0.00006	0.00007	0.00190	0.00008	0.00007
copper	mg/L	0.0001	0.0002	0.0005	0.0002	0.0003	0.0002	0.0003	0.0003	0.0001	0.0001	0.0004	0.0002	0.0002	0.0008	0.0002	0.0002
iron	mg/L	0.250	**0.48**[C,H]	**37.1**[C,H]	0.16	**0.66**[C,H]	**0.37**[C,H]	**0.75**[C,H]	**5.67**[C,H]	**0.6**[C,H]	**3.18**[C,H]	**2.39**[C,H]	**0.31**[C,H]	**0.41**[C,H]	**6.19**[C,H]	**0.31**[C,H]	0.3
lead	mg/L	0.00002	0.00010	0.00009	0.00002	0.00020	0.00003	0.00006	0.00005	0.00002	0.00003	0.00010	0.00003	0.00002	0.00020	0.00002	0.00003
lithium	mg/L	0.002	0.002	0.006	0.002	0.003	0.003	0.004	0.004	0.003	0.004	0.003	0.002	0.003	0.004	0.002	0.003
manganese	mg/L	0.048	**0.101**[H]	**8.93**[H]	0.025	**0.131**[H]	0.026	**0.099**[H]	**2**[H]	**0.067**[H]	**0.305**[H]	**0.307**[H]	**0.051**[H]	**0.059**[H]	**2.07**[H]	0.033	0.022
mercury	µg/L	0.005	0.004	0.004	0.003	<0.002	0.002	<0.002	<0.002	0.004	<0.002	<0.002	0.002	<0.002	<0.002	0.003	0.004
methyl mercury	µg/L	-	<0.00003	<0.00003	-	<0.00003	-	<0.00003	<0.00003	-	<0.00003	<0.00003	-	0.00007	<0.00003	-	0.00016
molybdenum	mg/L	0.00009	0.00009	0.00080	0.00008	0.00008	0.00010	0.00020	0.00009	0.00007	<0.00005	<0.00005	0.00008	0.00008	0.00009	0.00006	<0.00005
nickel	mg/L	0.0004	0.0005	0.0021	0.0004	0.0007	0.0003	0.0004	0.0004	0.0002	0.0002	0.0003	0.0003	0.0002	0.0010	0.0002	0.0003
selenium	mg/L	<0.00004	<0.00004	0.0007	<0.00004	0.00004	<0.00004	<0.00004	0.00004	<0.00004	<0.00004	<0.00004	<0.00004	<0.00004	0.00004	<0.00004	<0.00004
silver	mg/L	<0.000005	<0.000005	<0.00003	<0.000005	<0.000005	<0.000005	<0.000005	<0.000005	<0.000005	<0.000005	<0.000005	<0.000005	<0.000005	0.000008	<0.000005	<0.000005
strontium	mg/L	0.02	0.03	0.1000	0.02	0.04	0.04	0.07	0.08	0.04	0.06	0.04	0.02	0.04	0.07	0.02	0.04
thallium	mg/L	<0.000002	0.000004	<0.00001	<0.000002	0.000003	<0.000002	<0.000002	<0.000002	<0.000002	<0.000002	<0.000002	<0.000002	<0.000002	<0.000002	<0.000002	<0.000002
tin	mg/L	0.00001	0.297	<0.00005	<0.00001	0.200	<0.00001	<0.00001	0.00001	<0.00001	<0.00001	<0.00001	0.00001	0.00002	0.00004	<0.00001	0.185
titanium	mg/L	<0.0005	<0.0005	<0.003	<0.0005	0.0024	0.0007	0.0012	<0.0005	<0.0005	<0.0005	0.0007	0.0009	<0.0005	0.0007	<0.0005	<0.0005
uranium	mg/L	0.00001	0.00003	0.00040	0.000004	0.00004	0.00003	0.00007	0.00007	0.00001	0.00002	0.00002	0.000007	0.00001	0.00006	0.00001	0.00001
vanadium	mg/L	<0.0002	<0.0002	0.0010	<0.0002	0.0003	<0.0002	0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002
zinc	mg/L	0.002	0.003[a]	0.011	0.001	0.003[a]	0.0008	0.002[a]	0.002	0.0009	0.003[a]	0.003	0.002	0.001[a]	0.0160	0.001	0.002[a]
Metals (Dissolved)																	
aluminum	mg/L	0.0091	0.0082	0.0249	0.0097	0.0071	0.0064	0.005	0.0107	0.0047	0.0049	0.0097	0.0079	0.0046	0.0057	0.0055	0.0029
antimony	mg/L	<0.00002	<0.00002	0.00005	<0.00002	<0.00002	<0.00002	<0.00002	0.00003	<0.00002	<0.00002	0.00002	<0.00002	<0.00002	0.00003	0.00003	<0.00002
arsenic	mg/L	0.0004	0.0006	0.0049	0.0004	0.0005	0.0004	0.0006	0.0003	0.0003	0.0005	0.0006	0.0005	0.0007	0.0007	0.0004	0.0005
barium	mg/L	0.010	0.015	0.070[a]	0.008	0.012	0.015	0.022[a]	0.038[a]	0.017	0.024	0.016[a]	0.009	0.014	0.023[a]	0.010	0.014
beryllium	mg/L	<0.00001	<0.00001	0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001
bismuth	mg/L	<0.000005	<0.000005	<0.000005	<0.000005	<0.000005	<0.000005	<0.000005	<0.000005	<0.000005	<0.000005	<0.000005	<0.000005	<0.000005	<0.000005	0.00001	<0.000005
boron	mg/L	<0.02	<0.05	<0.1	<0.02	<0.05	<0.02	<0.02	<0.05	<0.05	<0.02	<0.05	<0.05	<0.02	<0.05	<0.02	<0.05
cadmium	mg/L	<0.000005	<0.000005	0.00002	<0.000005	0.000005	<0.000005	<0.000005	<0.000005	<0.000005	<0.000005	<0.000005	<0.000005	0.000006	<0.000005	0.00001	<0.000005
chromium	mg/L	0.0002	0.0002	0.0002	<0.0001	0.0001	0.0001	0.0001	<0.0001	<0.0001	<0.0001	<0.0001	0.0003	0.0001	<0.0001	0.0002	0.0001
cobalt	mg/L	0.00003	0.00010	0.01070	0.00005	0.00010	0.00005	0.00006	0.00080	0.00004	0.00010	0.00009	0.00003	0.00006	0.00120	0.00003	0.00005
copper	mg/L	0.0002	0.0006[a]	0.0002[a]	0.0001	0.0004[a]	0.0002	0.0002[a]	0.0001[a]	0.0002	0.0001[a]	0.0001[a]	0.0003	0.0006[a]	0.0001[a]	0.0002	0.0005[a]

Table A-2 Water Quality Results for Samples Collected from Watercourses During the 2011 Field Program (continued)

Parameter	Units	WC-1		WC-2			WC-3		WC-4			WC-5			WC-6		
		2-Jun-11	6-Sep-11	7-Mar-11	2-Jun-11	6-Sep-11	2-Jun-11	11-Sep-11	8-Mar-11	2-Jun-11	11-Sep-11	8-Mar-11	2-Jun-11	8-Sep-11	8-Mar-11	2-Jun-11	6-Sep-11
iron	mg/L	0.12	0.30	25	0.12	0.20	0.25	0.29	1.28	0.33	0.78	1.53	0.20	0.28	1.73	0.15	0.19
lead	mg/L	0.000006	0.00005[(a)]	0.00002[(a)]	0.000300	0.00004[(a)]	0.000008	0.00001[(a)]	0.000008[(a)]	0.000050	0.00001[(a)]	0.00005[(a)]	0.000010	0.00008[(a)]	0.00002[(a)]	0.000030	0.00004[(a)]
lithium	mg/L	0.0018	0.0022	0.0055	0.0021	0.0029	0.0025	0.004	0.0046	0.0031	0.0039	0.0034	0.0018	0.0025	0.0045	0.0022	0.0027
manganese	mg/L	0.004	0.083	8.48[(a)]	0.014	0.069	0.015	0.041	1.53[(a)]	0.013	0.201	0.12[(a)]	0.019	0.041	1.69[(a)]	0.002	0.013
mercury	µg/L	0.004	0.003	<0.006	0.002	0.004	0.002	<0.002	0.002	0.003	<0.002	<0.002	0.003	<0.002	0.005	0.003	0.003
molybdenum	mg/L	0.00020	0.00012	0.00086	0.00008	0.00012	0.00015	0.00021	0.00011	0.00010	<0.00005	0.00006	0.00006	0.00007	0.00017	0.00009	<0.00005
nickel	mg/L	0.0007	0.0004	0.00180	0.0004	0.0004	0.0003	0.0004	0.0004	0.0002	0.0002	0.0003	0.0003	0.0003	0.0004	0.0003	0.0002
selenium	mg/L	0.00004	<0.00004	0.0001	0.00004	<0.00004	<0.00004	<0.00004	0.00004	<0.00004	<0.00004	<0.00004	<0.00004	<0.00004	<0.00004	0.0002	<0.00004
silver	mg/L	<0.000005	<0.000005	<0.000005	<0.000005	<0.000005	<0.000005	<0.000005	<0.000005	<0.000005	<0.000005	<0.000005	<0.000005	<0.000005	<0.000005	0.00001	<0.000005
strontium	mg/L	0.0165	0.0274	0.0915[(a)]	0.0192	0.0367	0.0355	0.0643	0.0802[(a)]	0.0403	0.0582	0.0392[(a)]	0.0211	0.0364	0.0704[(a)]	0.0233	0.0394
thallium	mg/L	<0.000002	<0.000002	<0.000002	<0.000002	<0.000002	<0.000002	<0.000002	<0.000002	<0.000002	<0.000002	<0.000002	<0.000002	<0.000002	<0.000002	<0.000002	<0.000002
tin	mg/L	<0.00001	0.00001	<0.00001	<0.00001	0.00001	<0.00001	<0.00001	0.00001	0.00004	<0.00001	<0.00001	<0.00001	0.00002	<0.00001	0.00001	0.00001
titanium	mg/L	<0.0005	<0.0005	0.0009	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005
uranium	mg/L	0.000003	0.000007	0.0003	0.000004	0.00001	0.00003	0.00007	0.00007	0.000007	0.00002	0.00002	0.000004	0.00001	0.00007	0.00001	0.000006
vanadium	mg/L	<0.0002	<0.0002	0.0007	<0.0002	<0.0002	<0.0002	0.0002	<0.0002	<0.0002	<0.0002	0.0002	<0.0002	<0.0002	<0.0002	0.0003	<0.0002
zinc	mg/L	0.006	0.002[(a)]	0.007[(a)]	0.007	0.002[(a)]	0.0050	0.001[(a)]	0.001[(a)]	0.0070	0.002[(a)]	0.001[(a)]	0.0190	0.005[(a)]	0.001[(a)]	0.012	0.002[(a)]

[(a)] Results are suspect due to irregularities found in QC samples. Refer to Attachment C for additional information.

- = No data or not applicable.

Notes: **Bolded** concentrations are higher than relevant water quality guidelines.

[(A)] 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.

[(H)] Concentration higher than the relevant human health guideline or beyond the recommended pH range.

[(W)] Concentration higher than the relevant wildlife health guideline.

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

ATTACHMENT B

INDIVIDUAL SEDIMENT SAMPLE TEST RESULTS FOR PROJECT-SPECIFIC SAMPLING

Table B-1 Sediment Quality Results for Samples Collected from Watercourses During the 2011 Field Program

Parameter	Units [dry wt.]	Unnamed Watercourse				
		WC-1	WC-2	WC-3	WC-4	WC-5
		6-Sep-11	6-Sep-11	9-Sep-11	9-Sep-11	8-Sep-11
Particle Size						
sand	%	48	70	95	83	58
silt	%	31	15	3	13	25
clay	%	21	15	3	4	17
moisture content	%	68	23	20	70	40
Carbon Content						
total inorganic carbon	%	4.0	0.07	0.08	4.4	<0.02
total organic carbon	%	11	1.4	0.4	8.8	2.9
total carbon	%	15	1.4	0.5	13	2.5
Metals (Total)						
aluminum	µg/g	8,100	4,300	1,300	1,200	6,500
antimony	µg/g	<1	<1	<1	<2	<1
arsenic	µg/g	5	2	<1	3	3
barium	µg/g	130	53	16	70	75
beryllium	µg/g	0.4	<0.4	<0.4	<0.8	<0.4
boron	µg/g	7	<2	<2	3	4
cadmium	µg/g	0.4	0.2	<0.1	<0.2	<0.1
calcium	µg/g	7,500	1,800	1,100	5,200	3,800
chromium	µg/g	17	9	3	3	13
cobalt	µg/g	7	2	<1	<2	5
copper	µg/g	13	<5	<5	<10	7
iron	µg/g	19,000	7,000	2,800	13,000	13,000
lead	µg/g	7	4	<1	<2	4
magnesium	µg/g	3,400	1,100	520	610	2,300
manganese	µg/g	450	83	120	240	730
mercury	µg/g	<0.05	<0.05	<0.05	<0.1	<0.05
molybdenum	µg/g	0.5	<0.4	<0.4	<0.8	<0.4
nickel	µg/g	14	6	2	<2	9
potassium	µg/g	1,000	320	87	79	730
selenium	µg/g	0.7	0.8	<0.5	<1	<0.5
silver	µg/g	<1	<1	<1	<2	<1
sodium	µg/g	74	<50	<50	<50	63
strontium	µg/g	21	<10	<10	14	12
thallium	µg/g	<0.3	<0.3	<0.3	<0.6	<0.3
titanium	µg/g	150	63	34	41	140
uranium	µg/g	<1	1	<1	<2	<1
vanadium	µg/g	28	12	3	5	18
zinc	µg/g	88	21	<10	<20	31
Organics						
F1 (C_6-C_{10})	µg/g	<38	<12	<12	<40	<12
F2 (C_{10}-C_{16})	µg/g	<30	<10	<10	<30	<10
F3 (C_{16}-C_{34})	µg/g	220	14	<10	160	<10
F4 (C_{34}-C_{50})	µg/g	<30	<10	<10	<30	<10
benzene	µg/g	<0.016	<0.005	<0.005	0.048	<0.005
toluene	µg/g	<0.063	<0.02	<0.02	0.53	<0.02
ethylbenzene	µg/g	<0.032	<0.01	<0.01	0.12	<0.01
xylenes (m+o+p)	µg/g	<0.13	<0.04	<0.04	0.58	<0.04

Table B-2 Sediment Quality Results for Samples Collected from Waterbodies During the 2011 Field Program

Parameter	Units [dry wt.]	Wiau Lake	Unnamed Waterbody	
		WB-1	WB-2	WB-3
		7-Sep-11	8-Sep-11	7-Sep-11
Particle Size				
sand	%	89	92	81
silt	%	9	5	15
clay	%	3	3	4
moisture content	%	93	96	94
Carbon Content				
total inorganic carbon	%	4.2	0.24	2.8
total organic carbon	%	22	32	42
total carbon	%	26	32	45
Metals (Total)				
aluminum	µg/g	4,700	6,100	2,700
antimony	µg/g	<1	<1	<2
arsenic	µg/g	4	3	3
barium	µg/g	74	140	100
beryllium	µg/g	<0.4	<0.4	<0.8
boron	µg/g	13	10	15
cadmium	µg/g	**0.7** [(I)]	0.5	0.4
calcium	µg/g	8,600	11,000	16,000
chromium	µg/g	11	15	8
cobalt	µg/g	4	5	2
copper	µg/g	10	17	24
iron	µg/g	10,000	11,000	5,500
lead	µg/g	4	9	6
magnesium	µg/g	2,500	2,500	2,000
manganese	µg/g	220	190	440
mercury	µg/g	**0.16** [(I)]	<0.05	**0.20** [(I)]
molybdenum	µg/g	0.9	1.3	1.2
nickel	µg/g	11	17	9
potassium	µg/g	620	690	300
selenium	µg/g	1.2	1.0	2.0
silver	µg/g	<1	<1	<2
sodium	µg/g	130	100	140
strontium	µg/g	23	25	40
thallium	µg/g	<0.3	<0.3	<0.6
titanium	µg/g	100	120	57
uranium	µg/g	<1	<1	<2
vanadium	µg/g	14	24	8
zinc	µg/g	86	78	50
Organics				
F1 (C_6-C_{10})	µg/g	<170	<320	<200
F2 (C_{10}-C_{16})	µg/g	<100	<300	<200
F3 (C_{16}-C_{34})	µg/g	<100	<300	<200
F4 (C_{34}-C_{50})	µg/g	<100	<300	<200
benzene	µg/g	<0.071	<0.14	<0.084
toluene	µg/g	<0.28	<0.54	<0.33
ethylbenzene	µg/g	<0.14	<0.27	<0.17
xylenes (m+o+p)	µg/g	<0.56	<1.1	<0.67

Notes: **Bolded** concentrations are higher than the relevant sediment quality guideline.
[(I)] Concentration higher than the interim sediment quality guideline (CCME 1999).

ATTACHMENT C

QUALITY ASSURANCE/QUALITY CONTROL RESULTS

1 QUALITY ASSURANCE/QUALITY CONTROL

1.1 INTRODUCTION

Quality Assurance and Quality Control (QA/QC) practices determine data integrity and are relevant to all aspects of a study, from sample collection to data analysis and reporting. Quality Assurance encompasses management and technical practices designed to ensure that the data generated are of consistent high quality. Quality Control is an aspect of QA and includes the procedures used to measure and evaluate data quality, and the corrective actions to be taken when data quality objectives are not met. This appendix describes QA/QC practices applied during this study, evaluates QC data, and describes the implications of QC results to the interpretation of study results.

1.2 QUALITY CONTROL/QUALITY ASSURANCE PRACTICES

1.2.1 Quality Assurance

Quality Assurance applicable to this study covers three areas of internal and external management, as described below.

1.2.1.1 Field Staff Guidance

Field work was completed according to approved specific work instructions (SWIs) and established technical procedures (TPs). SWIs are standardized forms that describe exact sampling locations and provide specific sampling instructions, equipment needs and calibration requirements, required technical procedures, sample labelling and shipping protocols and laboratory contacts. They also provide specific guidelines for field record keeping and sample tracking. TPs are consistent with standard field methods described in the relevant scientific literature (e.g., Environment Canada 1993; American Public Health Association [APHA] 1992), and outline sample collection, preservation, handling, storage and shipping protocols.

During field work, field data were recorded on standardized field data sheets or in a bound field book, according to established field record-keeping procedures. Samples were documented and tracked using chain-of-custody forms and receipt of samples by the analytical laboratory was confirmed.

One field crew member was responsible for managing the sample shipping process to ensure that:

- all required samples were collected;
- chain-of-custody and analytical request forms were completed and correct;
- proper labelling and documentation procedures were followed; and
- samples were delivered to the appropriate locations in a timely manner.

1.2.1.2 Laboratory

One member of the project team was designated as the lab liaison. To ensure that high quality data were generated, laboratories used for the sample analysis are accredited by the Canadian Association for Laboratory Accreditation Inc. (CALA). Under CALA's accreditation program, performance evaluation assessments are conducted annually for laboratory procedures, methods and internal quality control.

1.2.1.3 Office Operations

Office-related QA included use of appropriately trained personnel for each task and senior review of work products at appropriate milestones, use of standardized data manipulation/summary tools, filing of data and project information according to standardized protocols and establishment of a data management system to ensure an organized consistent system of data storage, QC and retrieval.

1.2.2 Quality Control

1.2.2.1 Field Quality Control Procedures

The water quality field QC program consisted of the collection and analysis of field blanks, and duplicate and split samples. Each QC sample type is described below:

- Field blanks consist of de-ionized water provided by the analytical laboratory, which is exposed to the sampling environment at the sample site and handled in the same manner as the surface water samples collected during the field program (e.g., preserved, filtered). Field blanks are used to detect potential sample contamination during sample collection, handling, shipping and analysis.

- Duplicate samples are additional samples collected at the same time and location as surface water samples collected during a field program, using the same sampling methods. They are used to check within-site variation and also precision of the entire program.
- Split Sample are collected from one location and split into two sets of sample containers. They are labelled, preserved individually and submitted separately to the analytical laboratories for identical analyses. Split samples are used to check precision of field and laboratory analyses.

Quality Control samples collected during the field program accounted for approximately 10% of the total number of samples submitted for analysis. These samples were handled, stored and shipped along with field-collected surface water samples, and were submitted "blind" to the analytical laboratories. Quality Control samples were analyzed for the same set of parameters as the samples collected from surface waters.

1.2.2.2 Office Quality Control Procedures

Key elements of office QC procedures included the following:

- comparing sample data entered into the project database and data in report tables against final laboratory reports;
- creating backup files before each major operation as data were being manipulated; and
- verifying the accuracy of calculations performed to generate summary statistics.

Initial Data Screening

Upon receipt of water quality data from the analytical laboratory, a series of standard checks were performed to screen for potential data quality issues. These allowed potential re-analysis of samples to verify questionable data, or generate data for missing parameters. The following data checks were performed:

- verification that all required parameters and samples were analyzed;
- verification that data are reported using the appropriate units;
- logic checks: presence of zero values, comparisons of TDS and conductivity, hardness and alkalinity, total and dissolved phosphorus, total and dissolved metals, measured and calculated TDS;

- checking blanks for evidence of contamination (see next section);
- checking duplicate samples for evidence of unacceptable variation (see next section); and
- checking field-collected data for completeness, and unexpected values and trends.

If results of initial data screening indicated that there were deficiencies or potential data quality issues, the analytical laboratory was contacted and re-analysis of the parameters in question in the affected samples was requested. If data were verified by the analytical laboratory, but remained questionable based on the above evaluation, qualifiers were added to affected concentrations in the project data set and they were excluded for consideration during data summary and analysis.

Similarly, historic data were assessed to identify data points that were associated with high analytical detection limits relative to recent detectable results. These data were flagged and removed from the data summary reports produced for the baseline report. Laboratories were not contacted regarding historical data as laboratory hold times for reanalysis would be exceeded.

Quality Control Data Evaluation

Field Blanks

Concentrations in field blanks were considered notable if they were greater than or equal to five times the corresponding Method Detection Limit (MDL). This threshold is based on the Practical Quantitation Limit defined by the United States Environmental Protection Agency (U.S. EPA 1985), and takes into account the potential for reduced accuracy when concentrations approach or are below MDLs. This criterion was not applied to pH and conductance, which is expected to be above the laboratory-reported MDL in the deionized water used to prepare blanks.

The implications of notable results in blanks to data quality were evaluated relative to concentrations observed in surface waters sampled during the field program. The aim of this evaluation was to determine whether contamination was limited to a blank or was apparent in the corresponding water samples as well and whether it was severe enough to warrant qualifying the affected data. To address these questions, notable concentrations in blanks were interpreted as follows:

- If the blank had a detectable concentration of a parameter that was higher than those in the corresponding surface water samples, it was

assumed that the concentration in the blank was the result of an isolated field or lab error. In this case, the corresponding water samples were considered uncontaminated.

- If the detectable concentration in the blank was less than or equal to 20% of the typical surface water concentration (i.e., surface water concentrations were greater than or equal to five times the blank concentration), the data for the corresponding water samples were considered acceptable for the parameter in question.
- If the detectable concentration in a single blank was greater than 20% of the typical surface water concentration, i.e., surface water concentrations were less than five times the blank concentration), but below those in the corresponding water samples, the water samples were considered potentially contaminated and the constituent results in question were compared to other available data to determine the significance of the potential contamination.

Duplicate Samples

Differences between concentrations measured in duplicate water samples were calculated as the relative percent difference (RPD) for each parameter. Before calculating the RPD, concentrations below the MDL were replaced with the MDL value in cases when only one of the concentrations for a given parameter was detectable. The RPD was calculated using the following formula:

RPD = (difference in concentration between duplicate samples/mean concentration) x 100

The RPD value for a given parameter was considered notable if:

- it was greater than 20%; and
- concentrations in one or both samples were greater than or equal to five times the MDL.

These criteria are consistent with those used by analytical laboratories for their internal QC procedures and take into account the potential for data accuracy error as parameter concentrations approach MDLs. The number of parameters with exceedances of the assessment criteria was compared with the total number of parameters analyzed to evaluate and rate within-site variation as follows:

- low, if less than 10% of the total number of parameters were notably different from one another;

- moderate, if 10 to 30% of the total number of parameters were notably different from one another; or
- high, if more than 30% of the total number of parameters were notably different from one another.

Split Samples

Differences between concentrations measured in split sediment samples were considered notable if:

- they were greater than 30% for polycyclic aromatic hydrocarbons (PAH) and alkylated PAH;
- they were greater than 20% for all other analyses; and
- concentrations were greater than five times the relevant reported MDL.

These criteria are consistent with those used by the respective analytical laboratories as part of internal QC procedures and take into account the potential for data accuracy error as concentrations approach MDLs. Analytical precision was rated as:

- high if less than 10% of the parameters included in the split sample analysis were notably different from one another;
- moderate if 10% to 30% of the parameters included in the split sample analysis were notably different from one another; or
- low if more than 30% of the parameters included in the split sample analysis were notably different from one another.

1.3 QUALITY CONTROL RESULTS

1.3.1 Field Blanks

Concentrations of dissolved sulphide, barium, copper, lead, manganese, strontium and zinc were greater than five times the MDL in the field blank prepared on March 9, 2011 (Table C-1). The observed sulphide concentration in the field blank was greater than the one observed in the corresponding surface water sample. The surface water sample collected for this constituent is considered to be isolated to the blank and free of contamination.

Table C-1 Results for Travel Blank Samples

Parameter	Units	Method Detection Limit	Field Blanks		
			09-Mar-11	02-Jun-11	06-Sep-11
Conventional Parameters					
colour	TCU	2	<2	<2	<2
conductivity [(a)]	µS/cm	1	1	<1	1
dissolved Organic Carbon	mg/L	0.5	0.5	<0.5	<0.5
hardness	mg/L	0.5	<0.5	<0.5	<0.5
pH [(a)]	-	-	6.1	5.4	5.9
total alkalinity	mg/L	0.5	0.6	<0.5	<0.5
total dissolved solids	mg/L	10	<10	<10	<10
total organic carbon	mg/L	0.5	<0.5	<0.5	<0.5
total suspended solids	mg/L	1	1	<1	<1
Major Ions					
bicarbonate	mg/L	0.5	0.7	<0.5	<0.5
calcium	mg/L	0.3	<0.3	<0.3	<0.3
carbonate	mg/L	0.5	<0.5	<0.5	<0.5
chloride	mg/L	1	<1	<1	<1
magnesium	mg/L	0.2	<0.2	<0.2	<0.2
potassium	mg/L	0.3	<0.3	<0.3	<0.3
sodium	mg/L	0.5	<0.5	<0.5	<0.5
sulphate	mg/L	1	<1	<1	<1
sulphide	mg/L	0.002	**0.012**	<0.002	<0.002
Nutrients and Biological Indicators					
nitrate	mg-N/L	0.003	<0.003	0.007	<0.003
nitrite	mg-N/L	0.003	<0.003	<0.003	<0.003
nitrate + nitrite	mg-N/L	0.003	<0.003	0.007	<0.003
ammonia	mg-N/L	0.05	<0.05	<0.05	<0.05
total nitrogen - Kjeldahl	mg-N/L	0.05	<0.05	<0.05	<0.05
total phosphorus	mg-P/L	0.001	<0.001	0.002	0.001
dissolved phosphorus	mg-P/L	0.001	<0.001	0.003	0.003
biochemical oxygen demand	mg/L	2	<2	<2	<2
General Organics					
napthenic acids	mg/L	1	<1	1.2	<1
total phenolics	mg/L	0.002	<0.002	<0.002	0.003
total recoverable hydrocarbons	mg/L	2	<2	<2	<2

Table C-1 Results for Travel and Field Blank Samples (continued)

Parameter	Units	Method Detection Limit	Field Blanks		
			09-Mar-11	02-Jun-11	06-Sep-11
Metals (Total)					
aluminum	mg/L	0.0002	0.0004	0.0006	0.0007
antimony	mg/L	0.00002	<0.00002	<0.00002	<0.00002
arsenic	mg/L	0.00002	<0.00002	<0.00002	<0.00002
barium	mg/L	0.00002	<0.00002	0.00003	0.00005
beryllium	mg/L	0.00001	<0.00001	<0.00001	<0.00001
bismuth	mg/L	0.000005	<0.000005	<0.000005	<0.000005
boron	mg/L	0.05	<0.05	<0.05	<0.02
cadmium	mg/L	0.000005	<0.000005	<0.000005	<0.000005
chromium	mg/L	0.0001	<0.0001	0.0002	<0.0001
cobalt	mg/L	0.000005	<0.000005	<0.000005	<0.000005
copper	mg/L	0.00005	0.00011	0.00009	0.00008
iron	mg/L	0.001	0.001	<0.001	0.002
lead	mg/L	0.000005	0.000015	0.000011	0.000018
lithium	mg/L	0.0005	<0.0005	<0.0005	<0.0005
manganese	mg/L	0.00005	0.00015	<0.00005	<0.00005
mercury	µg/L	0.002	0.003	0.002	<0.002
methyl mercury	µg/L	0.00003	<0.00003	-	**0.00024**
molybdenum	mg/L	0.00005	<0.00005	<0.00005	0.00006
nickel	mg/L	0.00002	<0.00002	0.00004	<0.00002
selenium	mg/L	0.00004	<0.00004	<0.00004	<0.00004
silver	mg/L	0.000005	<0.000005	<0.000005	<0.000005
strontium	mg/L	0.00005	<0.00005	<0.00005	<0.00005
thallium	mg/L	0.000002	<0.000002	<0.000002	<0.000002
titanium	mg/L	0.0005	0.0006	<0.0005	<0.0005
uranium	mg/L	0.000002	<0.000002	<0.000002	<0.000002
vanadium	mg/L	0.0002	<0.0002	<0.0002	<0.0002
zinc	mg/L	0.0001	0.0002	0.0005	**0.0008**
Metals (Dissolved)					
aluminum	mg/L	0.0002	0.0006	0.0008	0.0005
antimony	mg/L	0.00002	<0.00002	<0.00002	0.00003
arsenic	mg/L	0.00002	<0.00002	<0.00002	<0.00002
barium	mg/L	0.00002	**0.00016**	0.00006	<0.00002

Table C-1 Results for Travel and Field Blank Samples (continued)

Parameter	Units	Method Detection Limit	Field Blanks		
			09-Mar-11	02-Jun-11	06-Sep-11
beryllium	mg/L	0.00001	<0.00001	<0.00001	<0.00001
bismuth	mg/L	0.000005	<0.000005	<0.000005	<0.000005
boron	mg/L	0.05	<0.05	<0.05	<0.02
cadmium	mg/L	0.000005	<0.000005	<0.000005	<0.000005
chromium	mg/L	0.0001	0.0001	<0.0001	<0.0001
cobalt	mg/L	0.000005	<0.000005	<0.000005	<0.000005
copper	mg/L	0.00005	**0.00083**	<0.00005	**0.00033**
iron	mg/L	0.001	0.004	<0.001	0.001
lead	mg/L	0.000005	**0.000071**	<0.000005	**0.000037**
lithium	mg/L	0.0005	<0.0005	<0.0005	<0.0005
manganese	mg/L	0.00005	**0.00054**	0.00021	0.00022
mercury	µg/L	0.002	<0.002	<0.002	<0.002
molybdenum	mg/L	0.00005	<0.00005	<0.00005	0.00014
nickel	mg/L	0.00002	0.00007	0.00003	0.00003
selenium	mg/L	0.00004	<0.00004	<0.00004	<0.00004
silver	mg/L	0.000005	<0.000005	<0.000005	<0.000005
strontium	mg/L	0.00005	**0.00026**	0.00009	0.00008
thallium	mg/L	0.000002	<0.000002	<0.000002	<0.000002
titanium	mg/L	0.0005	<0.0005	<0.0005	<0.0005
uranium	mg/L	0.000002	<0.000002	<0.000002	<0.000002
vanadium	mg/L	0.0002	<0.0002	<0.0002	<0.0002
zinc	mg/L	0.0001	**0.0029**	0.0004	**0.0013**

(a) pH and conductivity were excluded from the QC assessment.

-= No data or not applicable.

Note: Values in **bold** were more than five times the method detection limit.

However the dissolved barium, copper, lead, manganese, strontium and zinc concentrations observed in the field water samples were greater than those measured in the field blank. This result suggests that a contamination of samples analyzed for these parameters may have occurred during sampling, sample handling or possibly during analysis. Alternatively, deionized water provided by the analytical laboratory may have been contaminated. Results from these parameters potentially affected by this contamination i.e., field sample concentrations that were less than five times the blank concentration) were flagged and interpreted with this limitation in mind.

In the field blank sample prepared in the spring (June 2, 2011) all the parameters analyzed were less than five times the MDLs (Table C-1), indicating that the corresponding field samples were free of contamination.

Total and dissolved zinc, dissolved copper, dissolved lead and methyl mercury concentrations were greater than five times the MDL in the field blank prepared during the fall 2011 (September 2, 2011) field sampling program (Table C-1). The observed methyl mercury concentration in the field blank was greater than the one observed in the corresponding surface water sample. The surface water sample collected for this constituent is considered to be isolated to the blank and free of contamination. However, the concentrations of total and dissolved zinc, dissolved copper and dissolved lead observed in the field water samples were higher greater than those measured in the field blank. This result suggests that a contamination of samples by zinc, copper and lead may have occurred during sampling, sample handling or possibly during analysis. Alternatively, deionized water provided by the analytical laboratory may have been contaminated. Results from these constituents potentially affected by this contamination (i.e., field sample concentrations that were less than five times the blank concentration) were flagged and interpreted with this limitation in mind.

1.3.2 Duplicate Water Samples

Within-site variability and sample precision were assessed based on the results of duplicate samples collected in each season during the 2011 field sampling program. Duplicate samples were collected at site WC-6 in winter, summer and fall.

Table C-2 Duplicate Water Sample Results

Parameter	Units	Method Detection Limit	WC-6 Duplicate 9-Mar-11		Relative Percent Difference	Method Detection Limit	WC-6 Duplicate 2-Jun-11		Relative Percent Difference	Method Detection Limit	WC-6 Duplicate 6-Sep-11		Relative Percent Difference
			Sample 1	Sample 2			Sample 1	Sample 2			Sample 1	Sample 2	
Conventional													
colour	TCU	2	71	71	0%	2	35	35	0%	2	46	45	2%
conductivity	µS/cm	1	320	320	0%	1	100	100	0%	1	140	140	0%
dissolved organic carbon	mg/L	1	13	13	0%	0.5	12	12	0%	0.5	20	22	10%
hardness	mg/L	0.5	150	150	0%	0.5	51	51	0%	0.5	79	79	0%
pH	-	-	8.0	8.0	-	-	7.7	7.7	-	-	8.0	8.0	-
total alkalinity	mg/L	0.5	170	170	0%	0.5	52	51	2%	0.5	74	75	1%
total dissolved solids	mg/L	10	160	160	0%	10	50	49	-	10	74	74	0%
total organic carbon	mg/L	1	19	18	5%	0.5	13	13	0%	0.5	20	20	0%
total suspended solids	mg/L	1	16	13	**21%**	1	1	<1	-	1	<1	<1	-
Major Ions													
bicarbonate	mg/L	0.5	200	200	0%	0.5	64	62	3%	0.5	91	91	0%
calcium	mg/L	0.3	40	40	0%	0.3	13	13	0%	0.3	20	20	0%
carbonate	mg/L	0.5	<0.5	<0.5	-	0.5	<0.5	<0.5	-	0.5	<0.5	<0.5	-
chloride	mg/L	1	2	2	-	1	<1	<1	-	1	<1	<1	-
magnesium	mg/L	0.2	13	13	0%	0.2	4.8	4.8	0%	0.2	6.8	6.9	1%
potassium	mg/L	0.3	0.5	0.6	-	0.3	<0.3	<0.3	-	0.3	0.3	0.3	-
sodium	mg/L	0.5	3.7	3.2	14%	0.5	1.3	1.2	-	0.5	1.5	1.5	-
sulphate	mg/L	1	<1	<1	-	1	<1	<1	-	1	<1	<1	-
sulphide	mg/L	0.002	0.005	0.004	-	0.002	<0.002	<0.002	-	0.002	<0.002	<0.002	-
Nutrients and Biological Indicators													
nitrate	mg-N/L	0.003	0.009	0.018	**67%**	0.003	0.013	0.011	-	0.003	<0.003	<0.003	-
nitrite	mg-N/L	0.003	<0.003	<0.003	-	0.003	<0.003	<0.003	-	0.003	<0.003	<0.003	-
nitrate + nitrite	mg-N/L	0.003	0.009	0.018	**67%**	0.003	0.013	0.011	-	0.003	<0.003	<0.003	-
ammonia	mg-N/L	0.05	0.89	0.86	3%	0.05	<0.05	<0.05	-	0.05	0.06	<0.05	-
total nitrogen - Kjeldahl	mg-N/L	0.05	1.50	1.40	7%	0.05	0.65	0.61	6%	0.05	0.72	0.67	7%
total phosphorus	mg-P/L	0.001	0.100	0.091	9%	0.001	0.013	0.011	17%	0.001	0.009	0.013	**36%**
dissolved phosphorus	mg-P/L	0.001	0.022	0.014	**44%**	0.001	0.006	0.005	18%	0.001	0.008	0.012	**40%**
biochemical oxygen demand	mg/L	2	<2	<2	-	2	-	-	-	2	<2	<2	-
General Organics													
napthenic acids	mg/L	1	<1	<1	-	1	<1	<1	-	1	<1	<1	-
total phenolics	mg/L	0.002	0.004	0.004	-	0.002	0.003	0.003	-	0.002	0.004	0.003	-
total recoverable hydrocarbons	mg/L	2	<2	<2	-	2	<2	<2	-	2	<2	<2	-
Metals (Total)													
aluminum	mg/L	0.0002	0.0269	0.0247	9%	0.0002	0.0078	0.0134	**53%**	0.0002	0.0049	0.0081	**49%**
antimony	mg/L	0.00002	0.00005	0.00004	-	0.00002	<0.00002	<0.00002	-	0.00002	<0.00002	<0.00002	-
arsenic	mg/L	0.00002	0.00137	0.00133	3%	0.00002	0.00041	0.00040	2%	0.00002	0.00051	0.00056	9%
barium	mg/L	0.00002	0.0325	0.0319	2%	0.00002	0.00992	0.01030	4%	0.00002	0.01450	0.01460	1%
beryllium	mg/L	0.00001	<0.00001	<0.00001	-	0.00001	<0.00001	<0.00001	-	0.00001	<0.00001	<0.00001	-
bismuth	mg/L	0.000005	0.000019	0.00005	**90%**	0.000005	<0.000005	<0.000005	-	0.000005	<0.000005	<0.000005	-
boron	mg/L	0.05	<0.05	<0.05	-	0.02	<0.02	<0.02	-	0.02	<0.05	<0.05	-
cadmium	mg/L	0.000005	0.000038	0.000017	76%	0.000005	<0.000005	<0.000005	-	0.000005	<0.000005	<0.000005	-
chromium	mg/L	0.0001	0.0003	0.0002	-	0.0001	0.0003	0.0004	-	0.0001	<0.0001	0.0002	-
cobalt	mg/L	0.000005	0.001930	0.001900	2%	0.000005	0.000080	0.000072	11%	0.000005	0.000071	0.000071	0%
copper	mg/L	0.00005	0.00083	0.00067	**21%**	0.00005	0.00015	0.00017	-	0.00005	0.00015	0.00018	-
iron	mg/L	0.001	6.190	6.290	2%	0.001	0.308	0.305	1%	0.001	0.298	0.306	3%
lead	mg/L	0.000005	0.000195	0.000174	11%	0.000005	0.000022	0.000029	**27%**	0.000005	0.000031	0.000047	**41%**
lithium	mg/L	0.0005	0.0044	0.0043	2%	0.0005	0.0021	0.0021	-	0.0005	0.0027	0.0027	0%
manganese	mg/L	0.00005	2.07000	2.01000	3%	0.00005	0.03330	0.03340	0%	0.00005	0.02220	0.02330	5%
mercury	mg/L	0.002	<0.002	<0.002	-	0.002	0.003	0.003	-	0.002	0.004	<0.002	-
methyl mercury	ng/L	0.03	<0.03	<0.03	-	-	-	-	-	0.03	0.16	<0.03	**137%**
molybdenum	mg/L	0.00005	0.00009	0.00008	-	0.00005	0.00006	0.00006	-	0.00005	<0.00005	<0.00005	-
nickel	mg/L	0.00002	0.00095	0.00068	**33%**	0.00002	0.00022	0.00028	**24%**	0.00002	0.00028	0.00027	4%

Table C-2 Duplicate Water Sample Results (continued)

Parameter	Units	Method Detection Limit	WC-6 Duplicate 9-Mar-11		Relative Percent Difference	Method Detection Limit	WC-6 Duplicate 2-Jun-11		Relative Percent Difference	Method Detection Limit	WC-6 Duplicate 6-Sep-11		Relative Percent Difference
			Sample 1	Sample 2			Sample 1	Sample 2			Sample 1	Sample 2	
selenium	mg/L	0.00004	0.00004	<0.00004	-	0.00004	<0.00004	<0.00004	-	0.00004	<0.00004	<0.00004	-
silver	mg/L	0.000005	0.000008	<0.000005	-	0.000005	<0.000005	<0.000005	-	0.000005	<0.000005	<0.000005	-
strontium	mg/L	0.00005	0.06940	0.06890	1%	0.00005	0.02450	0.02490	2%	0.00005	0.03940	0.03940	0%
thallium	mg/L	0.000002	<0.000002	<0.000002	-	0.000002	<0.000002	<0.000002	-	0.000002	<0.000002	<0.000002	-
titanium	mg/L	0.0005	0.0007	0.0009	-	0.0005	<0.0005	<0.0005	-	0.0005	<0.0005	<0.0005	-
uranium	mg/L	0.000002	0.000055	0.000061	10%	0.000002	0.000007	0.000007	-	0.000002	0.000009	0.000011	20%
vanadium	mg/L	0.0002	<0.0002	<0.0002	-	0.0002	<0.0002	<0.0002	-	0.0002	<0.0002	<0.0002	-
zinc	mg/L	0.0001	0.0162	0.0099	**48%**	0.0001	0.001	0.0022	**75%**	0.0001	0.0017	0.0018	6%
Metals (Dissolved)													
aluminum	mg/L	0.0002	0.0057	0.0047	19%	0.0002	0.0055	0.004	**32%**	0.0002	0.0029	0.0034	16%
antimony	mg/L	0.00002	0.00003	0.00002	-	0.00002	0.00003	<0.00002	-	0.00002	<0.00002	<0.00002	-
arsenic	mg/L	0.00002	0.00068	0.00067	1%	0.00002	0.00036	0.00039	8%	0.00002	0.00048	0.00048	0%
barium	mg/L	0.00002	0.02330	0.02420	4%	0.00002	0.00952	0.00929	2%	0.00002	0.01370	0.01470	7%
beryllium	mg/L	0.00001	<0.00001	<0.00001	-	0.00001	<0.00001	<0.00001	-	0.00001	<0.00001	<0.00001	-
bismuth	mg/L	0.000005	<0.000005	<0.000005	-	0.000005	0.00001	<0.000005	-	0.000005	<0.000005	<0.000005	-
boron	mg/L	0.05	<0.05	<0.05	-	0.02	<0.02	<0.02	-	0.02	<0.05	<0.05	-
cadmium	mg/L	0.000005	<0.000005	<0.000005	-	0.000005	0.00001	<0.000005	-	0.000005	<0.000005	0.000008	-
chromium	mg/L	0.0001	<0.0001	<0.0001	-	0.0001	0.0002	0.0001	-	0.0001	0.0001	0.0002	-
cobalt	mg/L	0.000005	0.001150	0.001130	2%	0.000005	0.000030	0.000031	3%	0.000005	0.000054	0.000066	20%
copper	mg/L	0.00005	0.00013	0.00026	**67%**	0.00005	0.00022	0.00008	-	0.00005	0.00046	0.00051	10%
iron	mg/L	0.001	1.730	1.620	7%	0.001	0.152	0.151	1%	0.001	0.185	0.228	21%
lead	mg/L	0.000005	0.000021	0.000024	-	0.000005	0.000029	0.000007	**122%**	0.000005	0.000043	0.000055	**24%**
lithium	mg/L	0.0005	0.0045	0.0045	0%	0.0005	0.0022	0.002	-	0.0005	0.0027	0.0029	7%
manganese	mg/L	0.00005	1.69	1.53	10%	0.00005	0.00198	0.00165	18%	0.00005	0.0129	0.0188	**37%**
mercury	mg/L	0.002	0.005	0.005	-	0.002	0.003	0.003	-	0.002	0.003	0.004	-
molybdenum	mg/L	0.00005	0.00017	0.00012	-	0.00005	0.00009	0.00006	-	0.00005	<0.00005	<0.00005	-
nickel	mg/L	0.00002	0.00037	0.00038	3%	0.00002	0.00028	0.00021	**29%**	0.00002	0.00021	0.00026	**21%**
selenium	mg/L	0.00004	<0.00004	<0.00004	-	0.00004	0.0002	<0.00004	-	0.00004	<0.00004	<0.00004	-
silver	mg/L	0.000005	<0.000005	<0.000005	-	0.000005	0.000014	<0.000005	-	0.000005	<0.000005	<0.000005	-
strontium	mg/L	0.00005	0.07040	0.06660	6%	0.00005	0.02330	0.02360	1%	0.00005	0.03940	0.03930	0%
thallium	mg/L	0.000002	<0.000002	<0.000002	-	0.000002	<0.000002	<0.000002	-	0.000002	<0.000002	<0.000002	-
titanium	mg/L	0.0005	<0.0005	<0.0005	-	0.0005	<0.0005	<0.0005	-	0.0005	<0.0005	<0.0005	-
uranium	mg/L	0.000002	0.000071	0.00006	17%	0.000002	0.000012	0.000006	**67%**	0.000002	0.000006	0.000009	-
vanadium	mg/L	0.0002	<0.0002	<0.0002	-	0.0002	0.0003	<0.0002	-	0.0002	<0.0002	<0.0002	-
zinc	mg/L	0.0001	0.0010	0.0014	**33%**	0.0001	0.0121	0.0136	12%	0.0001	0.0021	0.0018	15%

- = No data or not applicable.

Note: Values in **bold** had relative percent difference greater than 20%.

Based on the RPDs, notable (i.e., greater than 20% relative difference) variations observed between concentrations in duplicate samples were as follows (Table C-2):

- March 9, 2011: nitrite, nitrite plus nitrate, dissolved phosphorus, total bismuth, total and dissolved copper, total nickel, total and dissolved zinc.
- June 2, 2011: total and dissolved aluminum, total and dissolved lead, dissolved nickel, dissolved uranium and total zinc.
- September 6, 2011: total and dissolved phosphorus, total aluminum, dissolved lead, dissolved manganese, dissolved nickel and methyl mercury.

The parameters with notable differences account for about 10% of the total number of parameters analyzed. Based on these results, within-site variability was rated moderate for the 2011 water quality baseline monitoring program.

1.3.3 Split Sediment Samples

Split sediment samples were collected during the fall 2011 season at site WC-2. The relative percent differences between concentrations of individual parameters were generally below the QC criterion (Table C-3). Analytical precision was rated as high for the 2011 fall sampling program, as the one sediment parameter with results above the QC criterion represents 3% of the total number of parameters analyzed in the split sample. This difference between the split portions of the sediment samples may have resulted from heterogeneous sample composition, which is common for sediment samples, rather than low analytical precision.

Table C-3 Split Sediment Sample Results

Parameter	Units [dry wt.]	Method Detection Limit (MDL)	Split Samples Collected at WC-2		Relative Percent Difference
			Sample 1	Sample 2	
Particle Size					
sand	%	2	70	74	6%
silt	%	2	15	12	**22%**[(a)]
clay	%	2	15	14	7%
moisture content	%	0.3	23	26	12%
Carbon Content					
total inorganic carbon	%	0.02	0.07	<0.02	-
total organic carbon	%	0.02	1.4	1.7	19%
total carbon	%	0.02	1.4	1.4	0%

Table C-3 Split Sediment Sample Results (continued)

Parameter	Units [dry wt.]	Method Detection Limit (MDL)	Split Samples Collected at WC-2		Relative Percent Difference
			Sample 1	Sample 2	
Metals (Total)					
aluminum	µg/g	10	4,300	4,700	9%
antimony	µg/g	1	<1	<1	-
arsenic	µg/g	1	2	2	-
barium	µg/g	10	53	53	0%
beryllium	µg/g	0.4	<0.4	<0.4	-
boron	µg/g	2	<2	<2	-
cadmium	µg/g	0.1	0.2	0.2	-
calcium	µg/g	50	1,800	1,900	5%
chromium	µg/g	1	9	10	11%
cobalt	µg/g	1	2	2	-
copper	µg/g	5	<5	12	-
iron	µg/g	10	7,000	7,400	6%
lead	µg/g	1	4	4	-
magnesium	µg/g	20	1,100	1,100	0%
manganese	µg/g	10	83	82	1%
mercury	µg/g	0.05	<0.05	<0.05	-
molybdenum	µg/g	0.4	<0.4	<0.4	-
nickel	µg/g	1	6	7	15%
potassium	µg/g	30	320	370	14%
selenium	µg/g	0.5	0.8	0.7	-
silver	µg/g	1	<1	<1	-
sodium	µg/g	50	<50	<50	-
strontium	µg/g	10	<10	<10	-
thallium	µg/g	0.3	<0.3	<0.3	-
titanium	µg/g	1	63	67	6%
uranium	µg/g	1	1	1	-
vanadium	µg/g	1	12	14	15%
zinc	µg/g	10	21	21	-
Organics					
F1 (C_{6}-$_{10}$)	µg/g	12	<12	<12	-
F2 (C_{10}-C_{16})	µg/g	10	<10	<10	-
F3 (C_{16}-C_{34})	µg/g	10	14	<10	-
F4 (C_{34}-C_{50})	µg/g	10	<10	<10	-
benzene	µg/g	0.005	<0.005	<0.005	-
toluene	µg/g	0.02	<0.02	<0.02	-
ethylbenzene	µg/g	0.01	<0.01	<0.01	-
xylenes (m+o+p)	µg/g	0.04	<0.04	<0.04	-

(a) Absolute differences in particle size and moisture content likely indicate that the split sample portions were slightly heterogeneous rather than a reflection of analytical precision.

- = No data or the percent difference was not calculated, since recorded concentration in one or both of the duplicate sample was less than five times the method detection limit or not applicable.

Notes: Percent difference was calculated using the following formula: [(maximum concentration -minimum concentration)/average concentration] x 100.
Notable sample results are in **bold**.

2 REFERENCES

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ATTACHMENT D

PROJECT-SPECIFIC WATER QUALITY SUMMARY

Table D-1 Water Quality of Waterbodies in the Local Study Area

Parameter	Units	Winter (2008, 2011)				Spring (2001, 2007, 2008)				Summer (1998, 2001, 2007, 2008, 2011)				Fall (2006, 2007, 2011)			
		Median	Minimum	Maximum	n	Median	Minimum	Maximum	n	Median	Minimum	Maximum	n	Median	Minimum	Maximum	n
Field Measured																	
pH	-	7.3	6.9	7.6	6	8	7	8.5	28	7.9	6.7	**9.2**(A,C,H)	34	8	7.2	8.3	48
conductivity	µS/cm	251	127	275	7	65	3	249	28	93	55	231	34	154	83	206	48
temperature	°C	1.1	0.6	4	7	13	5.3	14	28	19	9	23	34	17	1.4	19	48
dissolved oxygen	mg/L	2.8	**1**(A,C)	11	7	9.5	**1.6**(A,C)	12	28	10	**5.7**(C)	12	34	8.8	**6.4**(C)	15	48
Conventional Parameters																	
colour	TCU	39	26	64	7	29	15	56	10	32	13	80	16	26	13	58	13
conductivity	µS/cm	233	150	300	7	110	34	269	17	150	87	241	16	160	75	235	13
dissolved organic carbon	mg/L	18	11	33	7	16	11	22	17	19	12	41	23	17	12	28	13
hardness	mg/L	120	81	160	7	53	17	146	17	72	41	132	16	80	41	120	13
pH (lab)	-	8.0	7.7	8.1	7	7.8	6.6	8.1	17	7.9	**6.4**(A,C)	8.4	23	7.9	7.2	8.1	13
total alkalinity	mg/L	129	80	160	7	54	13	149	17	79	42	127	16	82	36	124	13
total dissolved solids	mg/L	166	86	190	7	104	53	165	10	104	59	210	23	118	83	160	13
total organic carbon	mg/L	20	12	32	7	15	12	18	6	19	13	26	12	16	13	21	9
total suspended solids	mg/L	3	<3	12	7	<3	<3	18	10	3	2	11	16	<3	<3	3	13
Major Ions																	
bicarbonate	mg/L	158	98	190	7	66	15	182	17	96	52	151	16	100	44	152	13
calcium	mg/L	33	21	40	7	14	4	39	17	17	11	35	16	19	10	32	13
carbonate	mg/L	<5	<0.5	<5	7	<5	<5	<5	17	<5	<0.5	<5	16	<5	<0.5	<5	13
chloride	mg/L	1	1	2	7	<1	<1	2	17	1	<0.5	2	16	1	<1	2	13
magnesium	mg/L	9.5	7	14	7	5	1	12	17	7	3	11	16	7	4	10	13
potassium	mg/L	2	0.5	3	7	0.7	0.5	2	17	0.8	0.2	2	16	0.9	<0.3	1	13
sodium	mg/L	4	2	5	7	2	<1	3	17	2	<1	4	16	2	1	3	13
sulphate	mg/L	1	0.7	1	7	<0.5	<0.5	3	17	1	0.2	3	16	1	<0.5	3	13
sulphide	mg/L	**0.006**(C)	0.003	**0.048**(C)	6	<0.003	<0.002	0.003	6	<0.003	<0.002	0.003	12	<0.002	<0.002	<0.003	9
Nutrients and Biological Indicators																	
nitrate + nitrite	mg/L	0.1	0.005	0.2	7	< 0.1	< 0.1	0.2	17	< 0.1	0.007	0.02	16	< 0.1	< 0.003	0.8	13
nitrogen - ammonia	mg/L	0.14	<0.05	0.47	7	<0.05	<0.05	<0.05	10	<0.05	0.02	0.13	16	<0.05	<0.05	0.18	13
nitrogen - Kjeldahl	mg/L	0.89	0.3	1.8	7	0.8	0.5	2.1	10	1	0.5	1.5	16	0.7	0.4	1.7	13
nitrogen - total	mg/L	0.9	0.3	**2**(C)	7	0.8	0.5	**2.3**(C)	10	1	0.5	**1.52**(C)	16	0.7	0.4	**2.5**(C)	13
phosphorus - total	mg/L	0.013	0.009	0.037	7	0.022	0.013	**0.13**(C)	10	0.021	0.009	0.046	16	0.014	0.011	0.028	13
phosphorus - dissolved	mg/L	0.009	<0.001	0.016	7	0.008	0.005	0.021	10	0.006	0.003	0.01	12	0.006	0.003	0.01	13
biochemical oxygen demand	mg/L	<2	<2	5	7	<2	<2	<2	4	<2	<2	<2	7	<2	<2	3	9
chlorophyll *a*	µg/L	2	<1	23	7	7	2	16	6	3	1	4	8	3	<1	20	9
General Organics																	
naphthenic acids	mg/L	<1	<1	<1	7	<1	<1	<1	4	<1	<1	<1	8	<1	<1	1	9
total phenolics	mg/L	**0.005**(C,W)	0.002	**0.01**(C,W)	7	**0.004**(W)	**0.003**(W)	**0.005**(C,W)	6	**0.003**(W)	<0.001	**0.006**(C,W)	8	**0.004**(W)	<0.001	**0.007**(C,W)	9
total recoverable hydrocarbons	mg/L	<1	<1	<2	7	<1	<1	7	6	<1	0.8	0.8	8	<1	<0.5	<2	9
Metals (Total)																	
aluminum	mg/L	0.02	0.0025	0.03	7	0.045	> 0.02	0.08	6	> 0.01	0.0045	0.05	11	0.02	0.004	0.04	10
antimony	mg/L	<0.0004	<0.00002	0.00002	7	0.0006	<0.0004	0.0006	6	<0.0004	<0.00002	<0.0004	7	<0.0004	<0.00002	0.0017	10
arsenic	mg/L	0.0007	0.0003	0.001	7	<0.0007	<0.0004	0.0009	6	0.0004	0.0003	0.0009	7	0.0004	0.0002	0.0013	10
barium	mg/L	0.0348	0.003	0.057	7	0.02	0.002	0.061	6	0.02	0.001	0.049	11	0.022	0.002	0.057	10
beryllium	mg/L	<0.001	<0.00001	<0.001	7	<0.001	<0.001	<0.001	6	<0.001	<0.00001	<0.001	11	<0.001	<0.00001	<0.001	10
boron	mg/L	<0.02	<0.02	<0.05	7	<0.02	0.008	0.02	6	<0.02	<0.01	0.02	11	<0.02	<0.02	<0.02	10
cadmium	mg/L	0.000007	0.000006	0.00001	3	-	<0.0002(D>C)	<0.0002(D>C)	2	<0.0002	<0.000005	**0.0015**(C)	7	<0.0001	<0.000005	0.000007	6
chromium	mg/L	0.0008	0.0001	**0.005**(C)	7	<0.0008	<0.0008	<0.0008	6	<0.0008	0.0002	**0.009**(C)	11	<0.0008	<0.0001	**0.0033**(C)	10
cobalt	mg/L	<0.0002	0.00003	0.00007	7	<0.0002	<0.0002	<0.0002	6	0.0002	0.00002	0.0016	11	<0.0002	0.00002	0.0002	10
copper	mg/L	<0.001	0.0003	0.0011	7	<0.001	<0.001	<0.001	6	0.001	0.0001	**0.006**(C)	11	<0.001	0.0002	0.0004	10
iron	mg/L	0.178	0.02	**2.27**(C,H)	7	0.14	0.1	**0.47**(C,H)	6	0.09	0.05	**0.53**(C,H)	11	0.1	0.03	0.29	10
lead	mg/L	0.0003	0.0001	0.0006	7	0.0001	<0.0001	0.0003	6	0.0003	0.00002	0.004	11	0.0001	0.00004	0.0002	10
lithium	mg/L	<0.006	0.002	0.006	7	<0.006	<0.006	<0.006	6	0.005	<0.001	0.005	11	<0.006	0.002	0.004	10
manganese	mg/L	**0.102**(H)	0.008	**0.928**(H)	7	0.038	0.012	**0.19**(H)	6	0.035	0.007	0.049	11	0.03	0.013	**0.195**(H)	10
mercury	mg/L	<0.0000013	<0.0000006	**0.000008**(C)	6	0.0000014	<0.0000006	0.0000019	6	0.000002	0.0000007	0.000003	7	<0.0000006	<0.0000006	0.000002	11

Table D-1 Water Quality of Waterbodies in the Local Study Area (continued)

Parameter	Units	Winter (2008, 2011)				Spring (2001, 2007, 2008)				Summer (1998, 2001, 2007, 2008, 2011)				Fall (2006, 2007, 2011)			
		Median	Minimum	Maximum	n	Median	Minimum	Maximum	n	Median	Minimum	Maximum	n	Median	Minimum	Maximum	n
methyl mercury	mg/L	<0.00000003	<0.00000003	0.00000012	6	0.00000005	<0.00000003	0.0000001	4	<0.00000003	<0.00000003	0.00000005	3	<0.00000003	<0.00000003	0.00000011	7
molybdenum	mg/L	0.00011	<0.00005	0.0004	7	0.0002	<0.0001	0.0005	6	0.0004	<0.0001	0.0004	11	0.0001	<0.00005	0.0004	10
nickel	mg/L	0.0006	0.0001	0.0012	7	0.0008	0.0003	0.001	6	0.0005	0.00008	0.0008	11	0.0003	0.0001	0.0009	10
selenium	mg/L	<0.0004	<0.00004	0.0007	7	<0.0005	<0.0004	0.0005	6	<0.0004	<0.00004	0.00005	7	<0.0004	<0.00004	**0.0015**[(C)]	10
silver	mg/L	0.000005	0.000002	0.000039	6	0.000006	0.000003	0.000007	6	<0.000009	0.0000006	0.000009	11	0.000009	0.000002	0.000027	11
strontium	mg/L	0.0759	0.02	0.09	7	0.05	0.01	0.08	6	0.05	0.008	0.07	11	0.05	0.02	0.07	10
thallium	mg/L	<0.0001	<0.000002	0.000002	7	<0.0001	<0.0001	<0.0001	6	<0.0001	<0.000002	0.000002	7	<0.0001	<0.000002	<0.0001	10
titanium	mg/L	<0.005	<0.0005	0.001	7	<0.005	0.0014	0.0017	6	<0.004	<0.0005	0.009	11	<0.005	<0.0005	<0.005	10
uranium	mg/L	<0.0001	0.000003	0.00001	7	<0.0001	<0.0001	<0.0001	6	<0.0001	0.000003	0.00001	11	<0.0001	0.000003	0.000006	10
vanadium	mg/L	<0.0002	<0.0002	0.0016	7	<0.0002	<0.0002	0.0004	6	<0.0002	<0.0002	0.002	11	<0.0002	<0.0002	0.0011	10
zinc	mg/L	0.006	0.004	0.018	7	0.008	0.005	0.011	6	0.006	0.001	0.018	11	<0.004	0.002	0.006	10
Metals (Dissolved)																	
aluminum	mg/L	<0.01	0.0017	0.0034	7	<0.01	<0.01	<0.01	4	<0.01	0.0028	0.0049	7	<0.01	0.002	0.02	10
antimony	mg/L	<0.0004	<0.00002	<0.0004	7	0.0005	<0.0004	0.0007	4	<0.0004	<0.00002	<0.0004	7	<0.0004	<0.00002	0.001	10
arsenic	mg/L	0.00059	0.0003	0.001	7	<0.0004	<0.0004	0.0007	4	0.0004	0.0002	0.001	7	0.0004	0.0002	0.0013	10
barium	mg/L	0.0325	0.003	0.057	7	0.025	0.0008	0.059	4	0.018	0.0006	0.05	7	0.022	0.001	0.048	10
beryllium	mg/L	<0.0005	<0.00001	<0.0005	7	<0.0005	<0.0005	<0.0005	4	<0.0005	<0.00001	<0.0005	7	<0.0005	<0.00001	<0.0005	10
boron	mg/L	0.024	0.01	0.02	7	0.02	0.01	0.02	4	<0.01	<0.002	0.01	7	0.02	0.004	0.02	10
cadmium	mg/L	<0.0001	<0.000005	0.000009	7	<0.0001	<0.0001	<0.0001	4	<0.0001	<0.000005	0.00001	7	<0.0001	<0.000005	0.000006	10
chromium	mg/L	0.0007	0.0002	0.0059	7	<0.0004	<0.0004	<0.0004	4	<0.0004	<0.0001	<0.0004	7	0.0014	<0.0001	0.0014	10
cobalt	mg/L	<0.0001	0.00004	0.00007	7	0.0002	0.0001	0.0002	4	0.0002	0.00001	0.0009	7	<0.0001	0.00005	0.0001	10
copper	mg/L	0.001	<0.0006	0.0034[((a))]	7	<0.0006	<0.0006	0.0009	4	0.0006	0.0001	0.0026	7	<0.0006	0.0005	0.0013	10
iron	mg/L	0.175	0.01	1.66	7	0.06	0.04	0.14	4	0.01	0.005	0.06	7	0.03	0.01	0.13	10
lead	mg/L	0.0002	0.0001	0.0003[((a))]	7	<0.0001	<0.0001	0.0002	4	0.0001	<0.000005	0.0002	7	<0.0001	0.00004	0.0001	10
lithium	mg/L	0.0039	0.002	0.005	7	0.003	0.002	0.005	4	0.003	0.0009	0.004	7	0.002	<0.0001	0.004	10
manganese	mg/L	0.0371	0.002	0.89[((a))]	7	0.064	0.007	0.142	4	0.001	0.0003	0.003	7	0.002	0.0002	0.141	10
mercury	mg/L	<0.0000013	<0.0000006	<0.000002	6	<0.0000006	<0.0000006	0.0000009	4	<0.0000014	<0.0000006	0.0000007	6	<0.0000006	<0.0000006	0.000003	11
molybdenum	mg/L	0.00014	<0.00005	0.0004	7	0.0002	<0.0001	0.0004	4	0.0001	<0.00005	0.0004	7	0.0001	<0.00005	0.0004	10
nickel	mg/L	0.0006	0.0002	0.0012	7	0.0007	0.0003	0.0008	4	0.0003	0.0001	0.0008	7	0.0001	0.00007	0.0019	10
selenium	mg/L	<0.0004	<0.00004	0.00007	7	<0.0004	<0.0004	<0.0004	4	<0.0004	<0.00004	<0.0004	7	<0.0004	<0.00004	0.0007	10
silver	mg/L	<0.000005	<0.0000005	0.000017	6	0.000001	0.0000006	0.000003	4	<0.000005	<0.0000005	0.000006	6	<0.000005	<0.0000005	0.000013	11
strontium	mg/L	0.0744	0.02	0.09[((a))]	7	0.06	0.008	0.08	4	0.05	0.008	0.07	7	0.05	0.02	0.07	10
thallium	mg/L	<0.00005	<0.000002	<0.00005	7	<0.00005	<0.00005	<0.00005	4	<0.00005	<0.000002	<0.00005	7	<0.00005	<0.000002	0.00017	10
titanium	mg/L	0.0005	0.0004	0.0009	7	<0.0003	<0.0003	<0.0003	4	<0.0003	<0.0003	<0.0005	7	<0.0005	<0.0003	0.002	10
uranium	mg/L	<0.0001	0.000006	0.00001	7	<0.0001	<0.0001	<0.0001	4	<0.0001	0.000004	0.00001	7	<0.0001	<0.000002	0.000005	10
vanadium	mg/L	0.0002	<0.0002	0.0018	7	<0.0001	<0.0001	0.0001	4	<0.0002	<0.0001	0.0002	7	0.0004	<0.0002	0.0006	10
zinc	mg/L	0.0059	0.005	0.024	7	0.007	0.005	0.013	4	0.002	0.0008	0.004	7	0.003	0.002	0.004[((a))]	10
Target PAHs and Alkylated PAHs																	
naphthalene	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	0.01	0.07	2
C1 substituted naphthalenes	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	0.01	0.03	2
C2 substituted naphthalenes	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.04	<0.04	2
C3 substituted naphthalenes	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.04	<0.04	2
C4 substituted naphthalenes	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.04	<0.04	2
acenaphthene	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.01	<0.01	2
C1 substituted acenaphthenes	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.04	<0.04	2
acenaphthylene	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.01	<0.01	2
anthracene	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.01	<0.01	2
dibenzo(a,h)anthracene	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.01[(D>H)]	<0.01[(D>H)]	2
benzo(a) anthracene / chrysene	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.01[(D>H)]	<0.01[(D>H)]	2
C1 substituted benzo(a)anthracene / chrysene	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.04	<0.04	2
C2 substituted benzo(a)anthracene / chrysene	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.04	<0.04	2
benzo(a)pyrene	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.01[(D>H)]	<0.01[(D>H)]	2
C1 substituted benzo(b&k)fluoranthene / benzo(a)pyrene	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.04	<0.04	2

Table D-1 Water Quality of Waterbodies in the Local Study Area (continued)

Parameter	Units	Winter (2008, 2011)				Spring (2001, 2007, 2008)				Summer (1998, 2001, 2007, 2008, 2011)				Fall (2006, 2007, 2011)			
		Median	Minimum	Maximum	n	Median	Minimum	Maximum	n	Median	Minimum	Maximum	n	Median	Minimum	Maximum	n
C2 substituted benzo(b&k)fluoranthene / benzo(a)pyrene	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.04	<0.04	2
benzo(b&k)fluoranthene	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.01 (D>H)	<0.01 (D>H)	2
benzo(g,h,i)perylene	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.01	<0.01	2
biphenyl	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.01	<0.01	2
C1 substituted biphenyl	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.04	<0.04	2
C2 substituted biphenyl	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.04	<0.04	2
dibenzothiophene	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.01	<0.01	2
C1 substituted dibenzothiophenes	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.04	<0.04	2
C2 substituted dibenzothiophenes	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.04	<0.04	2
C3 substituted dibenzothiophenes	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.04	<0.04	2
C4 substituted dibenzothiophenes	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.04	<0.04	2
fluoranthene	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.01	<0.01	2
C1 substituted fluoranthene / pyrene	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.04	<0.04	2
fluorene	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.01	<0.01	2
C1 substituted fluorene	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.04	<0.04	2
C2 substituted fluorene	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.04	<0.04	2
indeno(c,d-123)pyrene	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.01 (D>H)	<0.01 (D>H)	2
phenanthrene	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.01	<0.01	2
C1 substituted phenanthrene / anthracene	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.04	<0.04	2
C2 substituted phenanthrene / anthracene	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.04	<0.04	2
C3 substituted phenanthrene / anthracene	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.04	<0.04	2
C4 substituted phenanthrene / anthracene	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.04	<0.04	2
pyrene	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.01	<0.01	2

(a) Noted maximum concentration value is suspect due to irregularities found in QC samples. Refer to Attachment C for additional information.

- = No data or not applicable.

Notes: **Bolded** concentrations are higher than relevant water quality guidelines.
(A) 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.
(H) Concentration higher than the relevant human health guideline or beyond the recommended pH range.
(W) Concentration higher than the relevant wildlife health guideline.
(D>) Analytical detection limit was higher than the relevant water quality guideline(s).

Source: Devon Canada Corporation (2004); Canadian Natural (2007; includes data from 2001 and 2006); Golder (1998); Enermark (2008); analytical results from samples collected in 2011.

Table D-2 Water Quality of Watercourses in the Local Study Area

Parameter	Units	Winter (2002, 2008, 2011)				Spring (2001, 2002, 2006-2008)				Summer (2001, 2002. 2006, 2008, 2011)				Fall (2002, 2006-2007, 2011)			
		Median	Minimum	Maximum	n	Median	Minimum	Maximum	n	Median	Minimum	Maximum	n	Median	Minimum	Maximum	n
Field Measured					n				n				n				n
pH	-	7.5	6.9	8.1	9	7.5	6.9	8.2	13	6.9	**5.8**(A,C)	7.6	13	7.7	7.0	8.0	17
conductivity	µS/cm	304	160	510	9	105	37	168	13	140	76	365	13	162	101	230	17
temperature	°C	0.3	0	1.74	9	9.86	5	16	12	14	9.7	19	13	7	1.3	19	17
dissolved oxygen	mg/L	**4.2**(A,C)	**1.3**(A,C)	13	9	10	6.5	12	13	8.7	**6.1**(C)	14	13	10	**5.9**(C)	14	17
Conventional Parameters																	
colour	TCU	58	26	570	7	46	<2	56	9	40	23	61	14	47	15	59	16
conductivity	µS/cm	314	180	390	7	150	80	179	9	160	78	381	14	151	100	259	16
dissolved organic carbon	mg/L	18	10	23	7	14	11	19	9	15	9	20	14	16	11	24	15
hardness	mg/L	167	92	237	9	73	40	108	11	88	39	204	16	104	57	142	18
pH (lab)	-	7.9	7.7	8.1	7	7.7	7.4	8.2	9	7.8	7.3	8.2	14	7.9	7.3	8.2	16
total alkalinity	mg/L	172	93	246	9	76	39	135	11	87	35	205	16	97	51	162	18
total dissolved solids	mg/L	198	66	249	9	105	80	130	11	108	72	240	16	128	90	184	18
total organic carbon	mg/L	19	10	46	7	14	12	19	9	16	11	1010	14	17	12	24	15
total suspended solids	mg/L	13	<3	190	9	3	<3	44	10	4	<1	29	16	3	<1	8	17
Major Ions																	
bicarbonate	mg/L	210	110	300	9	93	47	165	11	105	43	250	16	116	62	197	18
calcium	mg/L	44	23	61	9	19.8	11	29	11	23	9	53	16	26	13	37	18
carbonate	mg/L	<0.5	<0.5	<5	7	<5	<5	<5	9	<5	<0.5	<5	14	<5	<0.5	<5	16
chloride	mg/L	2	1	5	7	1	0.6	11	11	1	0.6	3	15	1	<1	2	18
magnesium	mg/L	14	9	19	9	6	3	9	11	8	4	18	16	8	5	12	18
potassium	mg/L	2	0.7	2	9	1.2	0.8	2	11	0.4	0.1	1	16	0.7	<0.3	1	18
sodium	mg/L	5	2	17	9	2	2	7	11	3	1	8	16	3	1	8	18
sulphate	mg/L	<2	<0.5	4	9	0.75	<0.5	3	10	1	<0.5	6	16	1	<0.5	4	18
sulphide	mg/L	0.005	<0.002	**0.052**(C)	7	<0.003	<0.002	0.004	9	0.003	<0.002	**0.006**(C)	14	<0.003	<0.002	0.008	15
Nutrients and Biological Indicators																	
nitrate + nitrite	mg/L	0.1	<0.003	0.3	9	<0.1	0.03	0.1	10	<0.1	<0.003	0.02	14	<0.1	<0.003	0.2	17
nitrogen - ammonia	mg/L	0.26	0.1	0.89	9	<0.05	<0.05	0.09	11	<0.05	<0.05	<0.05	14	<0.05	<0.05	0.06	15
nitrogen - Kjeldahl	mg/L	0.9	0.4	1.6	9	0.7	0.1	1.1	11	0.6	0.4	0.9	16	0.6	0.3	0.7	17
nitrogen - total	mg/L	1.0	0.4	**1.6**(C)	9	0.7	0.1	**1.2**(C)	10	0.6	0.4	0.9	14	0.6	0.3	0.7	17
phosphorus - total	mg/L	**0.1**(C)	0.03	**0.63**(C)	9	0.046	0.012	**0.108**(C)	11	0.027	0.008	**0.104**(C)	16	0.032	0.004	**0.39**(C)	17
phosphorus - dissolved	mg/L	0.033	0.013	0.104	9	0.015	0.009	0.026	9	0.014	0.005	0.034	14	0.018	0.004	0.032	17
biochemical oxygen demand	mg/L	<2	<2	<2	7	<2	<2	2	7	<2	<2	<2	7	<2	<2	<2	15
chlorophyll *a*	µg/L	-	-	-	-	4	<1	6	3	3	2	3	4	<1	<1	2	4
General Organics																	
naphthenic acids	mg/L	<1	<1	<1	6	<1	<1	<1	7	<1	<1	<1	14	<1	<1	<1	17
total phenolics	mg/L	**0.005**(C,W)	0.001	**0.015**(C,W)	7	**0.004**(W)	<0.001	**0.006**(C,W)	7	**0.004**(W)	**0.003**(W)	**0.012**(C,W)	14	**0.004**(W)	<0.001	**0.005**(C,W)	13
total recoverable hydrocarbons	mg/L	<2	<1	<2	6	<1	<1	7.2	9	<1	<0.5	<2	14	<1	<0.5	0.6	15
Metals (Total)																	
aluminum	mg/L	0.0269	0.0105	**1.5**(A,C,H)	9	**0.13**(C,H)	0.03	**0.77**(A,C,H)	11	0.035	0.0046	**0.71**(C,H)	15	0312	0.0049	**0.14**(C,H)	18
antimony	mg/L	<0.0001	<0.00002	0.00005	7	0.0006	<0.0004	0.0019	7	<0.0002	<0.00002	0.0007	12	<0.0004	<0.00002	0.0028	16
arsenic	mg/L	0.0009	0.0005	**0.007**(,C)	7	<0.0007	<0.0004	0.0012	9	0.0006	0.0003	0.0009	15	0.0007	<0.0004	0.001	18
barium	mg/L	0.075	0.017	0.832	9	0.0285	0.007	0.051	11	0.024	0.008	0.099	15	0.022	0.006	0.065	18
beryllium	mg/L	<0.0003	<0.00001	0.0006	8	<0.001	<0.001	<0.001	9	<0.001	<0.00001	0.001	13	<0.001	<0.00001	0.00003	16
boron	mg/L	0.05	<0.02	0.05	9	<0.02	0.007	0.03	11	<0.02	0.01	0.04	15	<0.02	0.02	0.03	18
cadmium	mg/L	0.00002	0.000009	0.00006	4	<0.0002	<0.0002(D>C)	<0.0002	3	0.00001	<0.000005	0.0001	10	<0.0001	<0.000005	0.00004	12
chromium	mg/L	0.0005	0.0002	**0.0034**(C)	7	**0.0011**(C)	<0.0008	**0.0027**(C)	9	0.0008	0.0001	**0.0022**(C)	14	<0.0008	<0.0001	**0.0015**(C)	16
cobalt	mg/L	0.0007	<0.0002	0.0123	8	<0.0002	<0.0002	0.0008	10	0.0002	0.00005	0.0011	15	0.0002	0.00007	0.0003	16
copper	mg/L	0.0009	0.0003	**0.008**(C)	7	<0.001	<0.001	0.001	9	0.001	0.0001	0.002	13	<0.001	0.0001	**0.004**(C)	18
iron	mg/L	**2.48**(C,H)	**1**(C,H)	**37.1**(C,H)	8	**0.82**(C,H)	0.03	**2.37**(C,H)	11	**0.74**(C,H)	0.16	**1.72**(C,H)	15	**0.69**(C,H)	0.08	**3.18**(C,H)	18
lead	mg/L	0.0001	0.00005	0.0012	7	0.0002	<0.0001	0.0007	9	0.0001	0.00002	0.0004	15	<0.0001	0.00002	0.0002	16
lithium	mg/L	0.006	0.003	0.019	9	<0.006	<0.006	0.008	11	0.003	0.002	0.011	14	0.006	0.002	0.007	18
manganese	mg/L	**0.39**(H)	**0.097**(H)	**8.93**(H)	9	**0.068**(H)	0.003	**0.143**(H)	11	**0.06**(H)	0.019	**0.239**(H)	15	**0052**(H)	0.013	**0.305**(H)	18

Table D-2 Water Quality of Watercourses in the Local Study Area (continued)

Parameter	Units	Winter (2002, 2008, 2011)				Spring (2001, 2002, 2006-2008)				Summer (2001, 2002. 2006, 2008, 2011)				Fall (2002, 2006-2007, 2011)			
		Median	Minimum	Maximum	n	Median	Minimum	Maximum	n	Median	Minimum	Maximum	n	Median	Minimum	Maximum	n
mercury	mg/L	<0.000002	<0.0000006	<0.000002	7	<0.0000006	<0.0000006	<0.0000006	9	0.0000019	<0.0000006	0.000005	13	<0.0000012	<0.0000006	0.000004	16
methyl mercury	mg/L	<0.00000003	<0.00000003	0.00000022	7	0.00000003	<0.00000003	0.00000006	5	<0.00000003	<0.00000003	0.00000004	6	0.00000003	<0.00000003	0.00000005	8
molybdenum	mg/L	0.0001	<0.00005	0.0009	7	0.0002	0.0001	0.0003	9	0.0001	0.00006	0.0007	13	0.0001	<0.00005	0.0007	16
nickel	mg/L	0.001	0.0003	0.005	8	0.0007	0.0003	0.0128	9	0.0005	0.0002	0.001	14	0.0006	<0.0002	0.0016	16
selenium	mg/L	<0.0004	<0.00004	0.0007	7	<0.0004	0.0003	0.0006	10	<0.0004	<0.00004	0.0008	13	0.0004	<0.00004	**0.0013**[(C)]	16
silver	mg/L	0.00002	<0.000005	**0.001**[(C)]	8	0.0000277	0.000004	**0.002**[(C)]	10	0.000011	<0.000005	0.0001	13	0.000005	0.000003	0.000031	16
strontium	mg/L	0.1	0.04	0.18	9	0.0434	0.02	0.08	11	0.05	0.02	0.13	15	0.06	0.02	0.11	18
thallium	mg/L	<0.00006	<0.000002	**0.009**[(C,H)]	8	<0.0001	<0.0001	**0.007**[(C,H)]	10	<0.0001	<0.000002	<0.0001	13	<0.0001	<0.000002	0.000003	16
titanium	mg/L	<0.005	<0.0005	0.0429	9	0.0055	<0.0001	0.02	10	<0.005	<0.0005	0.025	14	<0.005	<0.0005	0.0024	18
uranium	mg/L	0.0001	0.00002	0.0004	7	<0.0001	<0.0001	0.0001	8	0.0001	0.000004	0.0001	13	<0.0001	0.000009	0.00007	16
vanadium	mg/L	0.0005	<0.0002	0.003	8	0.001	0.0004	0.0048	9	0.0006	<0.0002	0.0026	15	0.0003	<0.0002	0.0006	18
zinc	mg/L	0.005	0.002	0.016	9	0.007	0.003	0.027	11	0.003	0.0008	0.005	14	0.004	0.001	0.01	18
Metals (Dissolved)																	
aluminum	mg/L	0.01	0.0057	0.042	9	0.01	<0.01	0.051	9	0.01	0.0047	0.029	14	<0.01	0.0029	0.01	16
antimony	mg/L	0.00005	0.00002	0.00005	7	0.0008	<0.0004	0.0011	7	<0.0002	<0.00002	0.001	12	<0.0004	<0.00002	0.0012	16
arsenic	mg/L	0.0007	0.0003	0.0049	7	<0.0004	<0.0004	0.0006	7	0.0005	0.0003	0.0011	14	0.0006	<0.0004	0.0009	18
barium	mg/L	0.069	0.016	0.093	9	0.0261	0.006	0.041	9	0.024	0.008	0.097	14	0.018	0.005	0.059	18
beryllium	mg/L	<0.00001	<0.00001	<0.0005	7	<0.0005	<0.0005	<0.0005	7	<0.0003	<0.00001	<0.0005	12	<0.0005	<0.00001	<0.0005	16
boron	mg/L	0.05	0.003	0.05	9	0.013	0.002	0.04	9	<0.02	<0.002	0.03	14	0.02	0.004	0.04	18
cadmium	mg/L	<0.00002	<0.000005	<0.0001	7	<0.0001	<0.0001	<0.0001	7	<0.00006	<0.000005	0.00001	12	<0.0001	<0.000005	0.000006	16
chromium	mg/L	0.0002	<0.0001	0.0044	7	<0.0004	<0.0004	0.0011	7	<0.0004	<0.0001	0.0007	14	0.0004	<0.0002	0.0012	17
cobalt	mg/L	0.0002	0.00009	0.0107	7	0.00065	0.0002	0.005	8	0.0002	0.00003	0.0072	12	0.0001	0.00005	0.0003	16
copper	mg/L	0.0006	0.002	0.015	9	<0.0006	<0.0006	0.012	9	0.0006	0.0002	0.001	13	<0.0006	0.0001	0.0006[(a)]	16
iron	mg/L	1.38	0.08	25.1	9	0.267	0.02	0.73	9	0.2	0.06	0.47	14	0.36	0.05	0.78	17
lead	mg/L	0.00005	0.000008	0.0002	7	<0.0001	<0.0001	0.0001	7	0.0001	0.000006	0.0003	12	<0.0001	0.00001	0.00008[(a)]	16
lithium	mg/L	0.006	0.002	0.015	9	0.0035	0.0007	0.006	9	0.003	0.002	0.009	14	0.002	<0.0001	0.008	18
manganese	mg/L	0.219	0.02	8.48[(a)]	9	0.02	0.001	0.059	9	0.025	0.002	0.136	14	0.041	0.008	0.201	17
mercury	mg/L	<0.000002	<0.0000006	0.000005	7	<0.0000006	<0.0000006	<0.0000006	7	0.0000016	0.0000001	0.000004	12	<0.0000006	<0.0000006	0.000003	16
molybdenum	mg/L	0.0002	0.00006	0.0009	7	0.0002	<0.0001	0.0003	7	0.0002	0.00006	0.0007	12	0.0001	<0.00005	0.0004	16
nickel	mg/L	0.001	0.0003	0.004	9	0.0009	<0.0001	0.002	9	0.0004	0.0002	0.0012	12	0.0006	<0.0001	0.0021	16
selenium	mg/L	<0.0001	<0.00004	<0.00004	7	<0.0004	<0.0004	<0.0004	7	<0.0004	<0.00004	0.0002	12	<0.0004	<0.00004	0.0007	16
silver	mg/L	0.000005	0.000001	0.000007	7	0.0000026	0.0000006	0.000014	7	0.000005	0.0000008	0.000014	13	0.000005	<0.0000005	0.000006	16
strontium	mg/L	0.08	0.02	0.2	9	0.0482	0.02	0.1	9	0.05	0.02	0.13	14	0.05	0.02	0.1	18
thallium	mg/L	<0.00002	<0.000002	<0.00005	7	<0.00005	<0.00005	<0.00005	7	<0.00003	<0.000002	<0.00005	12	<0.00005	<0.000002	0.00007	16
titanium	mg/L	0.0007	<0.0005	0.0025	8	0.0009	<0.0003	0.0031	9	<0.0005	<0.0003	0.0016	14	<0.0005	<0.0003	0.0024	16
uranium	mg/L	0.0001	0.00002	0.0003	7	<0.0001	<0.0001	<0.0001	7	0.00007	0.000003	0.0001	12	<0.0001	0.000006	0.00007	16
vanadium	mg/L	0.0004	<0.0002	0.003	9	0.00025	<0.0001	0.001	8	0.0002	<0.0001	0.0006	14	0.0002	<0.0001	0.0006	16
zinc	mg/L	0.003	0.001	0.007[(a)]	9	0.004	<0.002	0.015	9	0.004	0.001	0.019	14	0.002	0.001	0.005[(a)]	16
Target PAHs and Alkylated PAHs																	
naphthalene	µg/L	-	<0.1	<0.1	2	-	<0.1	<0.1	2	-	<0.1	<0.1	2	<0.02	<0.01	0.02	5
C1 substituted naphthalenes	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	<0.01	<0.01	0.01	3
C2 substituted naphthalenes	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	<0.04	<0.04	<0.04	3
C3 substituted naphthalenes	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	<0.04	<0.04	<0.04	3
C4 substituted naphthalenes	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	<0.04	<0.04	<0.04	3
acenaphthene	µg/L	-	<0.1	<0.1	2	-	<0.1	<0.1	2	-	<0.1	<0.1	2	<0.01	<0.01	<0.01	5
C1 substituted acenaphthenes	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	<0.04	<0.04	<0.04	3
acenaphthylene	µg/L	-	<0.1	<0.1	2	-	<0.1	<0.1	2	-	<0.1	<0.1	2	<0.01	<0.01	<0.1	5
anthracene	µg/L	-	<0.01[(D>C)]	<0.01[(D>C)]	2	-	<0.01[(D>C)]	<0.01[(D>C)]	2	-	<0.01[(D>C)]	<0.01[(D>C)]	2	<0.01	<0.01	<0.1[(D>C)]	5
dibenzo(a,h)anthracene	µg/L	-	<0.01[(D>H)]	<0.01[(D>H)]	2	-	<0.01[(D>H)]	<0.01[(D>H)]	2	-	<0.01[(D>H)]	<0.01[(D>H)]	2	<0.01[(D>H)]	<0.01[(D>H)]	<0.01[(D>H)]	5
benzo(a)anthracene / chrysene	µg/L	-	<0.1[(D>C,H)]	<0.1[(D>C,H)]	2	-	<0.1[(D>C,H)]	<0.1[(D>C,H)]	2	-	<0.1[(D>C,H)]	<0.1[(D>C,H)]	2	<0.01[(D>H)]	<0.01[(D>H)]	<0.1[(D>C,H)]	5
C1 substituted benzo(a)anthracenes / chrysenes	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	<0.04	<0.04	<0.04	3
C2 substituted benzo(a)anthracenes / chrysenes	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	<0.04	<0.04	<0.04	3
benzo(a)pyrene	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	<0.01[(D>H)]	<0.01[(D>H)]	<0.01[(D>H)]	3

Table D-2 Water Quality of Watercourses in the Local Study Area (continued)

Parameter	Units	Winter (2002, 2008, 2011)				Spring (2001, 2002, 2006-2008)				Summer (2001, 2002. 2006, 2008, 2011)				Fall (2002, 2006-2007, 2011)			
		Median	Minimum	Maximum	n	Median	Minimum	Maximum	n	Median	Minimum	Maximum	n	Median	Minimum	Maximum	n
C1 substituted benzo(b&k)fluoranthenes / benzo(a)pyrenes	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	<0.04	<0.04	<0.04	3
C2 substituted benzo(b&k)fluoranthenes / benzo(a)pyrenes	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	<0.04	<0.04	<0.04	3
benzo(b&k)fluoranthenes	µg/L	-	<0.01 (D>H)	<0.01 (D>H)	2	-	<0.01 (D>H)	<0.01 (D>H)	2	-	<0.01 (D>H)	<0.01 (D>H)	2	<0.01 (D>H)	<0.01 (D>H)	<0.01 (D>H)	5
benzo(g,h,i)perylene	µg/L	-	<0.1	<0.1	2	-	<0.1	<0.1	2	-	<0.1	<0.1	2	<0.01	<0.01	<0.1	5
biphenyl	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	<0.01	<0.01	<0.01	3
C1 substituted biphenyls	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	<0.04	<0.04	<0.04	3
C2 substituted biphenyls	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	<0.04	<0.04	<0.04	3
dibenzothiophene	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	<0.01	<0.01	<0.01	3
C1 substituted dibenzothiophenes	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	<0.04	<0.04	<0.04	3
C2 substituted dibenzothiophenes	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	<0.04	<0.04	<0.04	3
C3 substituted dibenzothiophenes	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	<0.04	<0.04	<0.04	3
C4 substituted dibenzothiophenes	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	<0.04	<0.04	<0.04	3
fluoranthene	µg/L	-	<0.1 (D>C)	<0.1 (D>C)	2	-	<0.1 (D>C)	<0.1 (D>C)	2	-	<0.1 (D>C)	<0.1 (D>C)	2	<0.01	<0.01	<0.1 (D>C)	5
C1 substituted fluoranthenes / pyrenes	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	<0.04	<0.04	<0.04	3
fluorene	µg/L	-	<0.1	<0.1	2	-	<0.1	<0.1	2	-	<0.1	<0.1	2	<0.01	<0.01	<0.1	5
C1 substituted fluorenes	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	<0.04	<0.04	<0.04	3
C2 substituted fluorenes	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	<0.04	<0.04	<0.04	3
indeno(c,d-123)pyrene	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	<0.01 (D>H)	<0.01 (D>H)	<0.01 (D>H)	3
phenanthrene	µg/L	-	<0.1	<0.1	2	-	<0.1	<0.1	2	-	<0.1	<0.1	2	<0.01	<0.01	<0.1	5
C1 substituted phenanthrene / anthracene	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	<0.04	<0.04	<0.04	3
C2 substituted phenanthrene / anthracene	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	<0.04	<0.04	<0.04	3
C3 substituted phenanthrene / anthracene	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	<0.04	<0.04	<0.04	3
C4 substituted phenanthrene / anthracene	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	<0.04	<0.04	<0.04	3
pyrene	µg/L	-	<0.02	<0.02	2	-	<0.02	<0.02	2	-	<0.02	<0.02	2	<0.01	<0.01	<0.02	5
Volatile Organics																	
ethylbenzene	µg/L	-	<0.001	<0.001	2	-	<0.001	<0.001	2	-	<0.001	<0.001	2	-	<0.001	<0.001	2
xylenes	µg/L	-	<0.001	<0.001	2	-	<0.001	<0.001	2	-	<0.001	<0.001	2	-	<0.001	<0.001	2

(a) Noted maximum concentration value is suspect due to irregularities found in QC samples. Refer to Attachment C for additional information.

- = No data or not applicable.

Notes: **Bolded** concentrations are higher than relevant water quality guidelines.
(A) 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.
(H) Concentration higher than the relevant human health guideline or beyond the recommended pH range.
(W) Concentration higher than the relevant wildlife health guideline.
(D>) Analytical detection limit was higher than the relevant water quality guideline(s).

Source: Devon Canada Corporation (2004); Canadian Natural (2007; includes data from 2001 and 2006); Golder (1998); Enermark (2008); analytical results from samples collected in 2011.

ATTACHMENT E

REGIONAL STUDY AREA WATER QUALITY SUMMARY TABLES

Table E-1 Water Quality of Christina Lake

Parameter	Units	Winter (1986, 2008)				Spring (1980, 1988, 2006, 2008)				Summer (1983, 2004, 2006, 2008)				Fall (2006-2007)			
		Median	Minimum	Maximum	n	Median	Minimum	Maximum	n	Median	Minimum	Maximum	n	Median	Minimum	Maximum	n
Field Measured																	
pH	-	6.5	**6.0** (A,C)	8.0	33	-	7.4	8.3	2	7.9	7.6	8.1	4	7.8	7.8	7.9	3
conductivity	µS/cm	193	184	237	33	-	160	173	2	-	137	190	2	162	156	169	3
temperature	°C	-	0.5	3.8	2	-	7.7	11.7	2	19	15.3	19.8	3	11.2	8.4	16	3
dissolved oxygen	mg/L	-	9.3	11.6	2	-	11.1	12.5	2	9.6	9.2	13	3	11.9	8.9	12.5	3
Conventional Parameters																	
colour	TCU	32	-	-	1	30	17	34	3	30	30	60	3	33	30	46	3
conductivity	µS/cm	225	217	239	5	170	139	193	4	193	176	220	4	187	135	193	3
dissolved organic carbon	mg/L	16	-	-	1	13	11	17	3	16	15	16	3	17	15	17	3
hardness	mg/L	114	105	117	5	80	62	100	4	97	86	98	4	93	90	96	3
pH (lab)	-	7.8	7.4	8.0	5	7.9	7.6	8.3	4	8.2	8.1	8.4	4	8.1	8.0	8.1	3
total alkalinity	mg/L	116	111	124	5	90	69	103	4	99	92	115	4	99	97	100	3
total dissolved solids	mg/L	130	119	151	5	103	76	134	4	125	117	140	4	130	124	134	3
total organic carbon	mg/L	16	-	-	1	-	13	19	2	16	15	17	3	17	16	19	3
total suspended solids	mg/L	<3	-	-	1	<3	<3	4	3	3	<3	13	3	-	<3	3	2
Major Ions																	
bicarbonate	mg/L	142	135	151	5	109	85	125	4	117	113	140	4	121	118	121	3
calcium	mg/L	31	28	32	5	21	16	26	4	25	23	26	4	25	24	25	3
carbonate	mg/L	<5	-	-	1	-	<5	<5	2	<5	<5	<5	3	<5	<5	<5	3
chloride	mg/L	<1	<1	1.0	5	2	< 1	2	4	2	< 1	2	4	2	1	2	3
magnesium	mg/L	9.0	8.0	9.0	5	7	5	8	4	8	7	8	4	8	7	8	3
potassium	mg/L	1.0	0.9	2.0	5	1	0.8	1	4	0.9	0.7	1	4	1	0.9	2	3
sodium	mg/L	8.0	7.0	8.0	5	6	4	6	4	6	3	7	4	6	6	6	3
sulphate	mg/L	<5	3.0	<5	4	4	2	< 5	4	3	1	< 5	4	2	2	2	3
sulphide	mg/L	0.002	-	-	1	-	<0.002	<0.003	2	0.005	<0.003	0.007	3	<0.003	<0.002	<0.003	3
Nutrients and Biological Indicators																	
nitrate + nitrite	mg-N/L	0.2	0.08	0.5	7	<0.1	0.05	<0.1	3	<0.1	<0.05	<0.1	4	<0.1	<0.1	<0.1	3
nitrogen - ammonia	mg-N/L	<0.05	-	-	1	-	<0.05	<0.05	2	<0.05	<0.05	<0.05	3	<0.05	<0.05	<0.05	3
nitrogen - Kjeldahl	mg-N/L	0.5	0.4	0.5	7	0.7	0.7	1.0	3	0.6	0.5	0.8	4	0.6	0.5	0.6	3
nitrogen - total	mg-N/L	0.6	0.5	1.0	7	0.7	0.7	1.0	3	0.6	0.5	0.8	3	0.6	0.5	0.6	3
phosphorus - total	mg-P/L	0.022	0.016	0.034	5	0.033	0.018	0.039	3	0.017	0.014	0.046	4	0.017	0.012	0.021	3
phosphorus - dissolved	mg-P/L	0.013	-	-	1	0.012	-	-	1	0.006	0.005	0.02	3	0.007	0.005	0.008	3
biochemical oxygen demand	mg/L	<2	-	-	1	<2	-	-	1	<2	-	-	1	-	<2	<2	2
chlorophyll *a*	µg/L	3.0	-	-	1	-	7.0	13	2	-	6.0	6.0	2	11	3.0	13	3
General Organics																	
naphthenic acids	mg/L	<1	-	-	1	-	<1	<1	2	<1	<1	<1	3	<1	<1	1.0	3
total phenolics	mg/L	**0.005** (C,W)	-	-	1	-	**0.003** (W)	**0.009** (C,W)	2	**0.004** (W)	**0.004** (W)	**0.01** (C,W)	3	-	**0.004** (W)	**0.006** (C,W)	2
total recoverable hydrocarbons	mg/L	<0.5	-	-	1	-	<1	<1	2	<1	<0.5	<1	3	<1	<1	<1	3
Metals (Total)																	
aluminum	mg/L	<0.02	-	-	1	-	0.02	0.04	2	<0.02	<0.02	**0.51** (C,H)	3	<0.02	<0.02	<0.02	3
antimony	mg/L	0.0011	-	-	1	-	0.0008	0.0013	2	0.0006	<0.0004	0.0006	3	0.001	<0.0004	0.0039	3
arsenic	mg/L	0.0007	-	-	1	0.0005	0.0005	0.0006	3	0.0006	0.0005	0.0009	3	0.0006	0.0005	0.0006	3
barium	mg/L	0.03	-	-	1	0.026	0.019	0.029	3	0.025	0.021	0.036	3	0.026	0.022	0.028	3
beryllium	mg/L	<0.001	-	-	1	<0.001	<0.001	<0.001	3	<0.001	<0.001	<0.001	3	<0.001	<0.001	<0.001	3
boron	mg/L	0.02	-	-	1	-	<0.02	0.03	2	0.02	<0.02	0.02	3	<0.02	<0.02	0.02	3
cadmium	mg/L	<0.0002	-	-	1	-	< 0.0002 (D>C)	<0.0002	2	<0.0002	<0.0002	<0.0002	3	<0.0002	<0.0002	<0.0002	3
chromium	mg/L	<0.0008	-	-	1	<0.0008	<0.0008	**0.002** (C)	3	0.0008	<0.0008	**0.0014** (C)	3	<0.0008	<0.0008	<0.0008	3
cobalt	mg/L	<0.0002	-	-	1	<0.0002	<0.0002	<0.001	3	<0.0002	<0.0002	0.0002	3	<0.0002	<0.0002	0.0006	3
copper	mg/L	<0.001	-	-	1	0.001	<0.001	0.002	3	<0.001	<0.001	0.002	3	<0.001	<0.001	<0.001	3
iron	mg/L	0.18	-	-	1	-	0.09	0.24	2	0.06	0.04	**0.94** (C,H)	3	0.09	0.05	0.09	3
lead	mg/L	0.0001	-	-	1	-	<0.0001	0.0002	2	0.0003	0.0001	0.0005	3	<0.0001	<0.0001	<0.0001	3
lithium	mg/L	<0.006	-	-	1	-	<0.006	0.006	2	<0.006	<0.006	<0.006	3	<0.006	<0.006	<0.006	3
manganese	mg/L	0.021	-	-	1	0.025	0.01	0.048	3	0.01	0.008	**0.063** (H)	3	0.014	0.014	0.019	3
mercury	mg/L	<0.0000006	-	-	1	-	<0.0000006	<0.0000006	2	0.0000011	<0.0000006	0.0000014	3	-	<0.0000006	0.0000009	2

Table E-1 Water Quality of Christina Lake (continued)

Parameter	Units	Winter (1986, 2008)				Spring (1980, 1988, 2006, 2008)				Summer (1983, 2004, 2006, 2008)				Fall (2006-2007)			
		Median	Minimum	Maximum	n	Median	Minimum	Maximum	n	Median	Minimum	Maximum	n	Median	Minimum	Maximum	n
methyl mercury	mg/L	<0.00000003	-	-	1	0.00000008	-	-	1	<0.00000003	-	-	1	0.00000003	-	-	1
molybdenum	mg/L	0.0003	-	-	1	0.0003	0.0002	<0.001	3	0.0003	0.0002	0.0003	3	0.0003	0.0003	0.0003	3
nickel	mg/L	0.001	-	-	1	0.0008	<0.0002	0.002	3	0.0007	0.0007	0.0007	3	0.0009	0.0008	0.0009	3
selenium	mg/L	<0.0004	-	-	1	<0.0004	<0.0002	<0.0004	3	<0.0004	<0.0004	<0.0004	3	<0.0004	<0.0004	0.0005	3
silver	mg/L	0.00001	-	-	1	-	0.000012	0.000016	2	0.000007	0.000004	0.000008	3	-	0.0000008	0.000002	2
strontium	mg/L	0.08	-	-	1	-	0.07	0.08	2	0.06	0.06	0.07	3	0.07	0.06	0.07	3
thallium	mg/L	<0.0001	-	-	1	-	<0.0001	<0.0001	2	<0.0001	<0.0001	<0.0001	3	<0.0001	<0.0001	<0.0001	3
titanium	mg/L	<0.005	-	-	1	-	<0.005	<0.005	2	<0.005	<0.005	0.016	3	<0.005	<0.005	<0.005	3
uranium	mg/L	<0.0001	-	-	1	-	<0.0001	<0.0001	2	<0.0001	<0.0001	<0.0001	3	<0.0001	<0.0001	<0.0001	3
vanadium	mg/L	0.001	-	-	1	0.0003	0.0002	<0.002	3	0.0003	<0.0002	0.0016	3	<0.0002	<0.0002	0.0002	3
zinc	mg/L	0.016	-	-	1	0.008	<0.004	0.017	3	<0.004	<0.004	0.006	3	<0.004	<0.004	0.006	3
Metals (Dissolved)																	
aluminum	mg/L	<0.01	-	-	1	-	<0.01	<0.01	2	<0.01	<0.01	0.02	3	<0.01	<0.01	<0.01	3
antimony	mg/L	<0.0004	-	-	1	-	0.0008	0.0008	2	0.0006	<0.0004	0.0007	3	<0.0004	<0.0004	0.0007	3
arsenic	mg/L	0.0007	-	-	1	-	0.0005	0.0005	2	0.0005	0.0005	0.0007	3	0.0006	0.0006	0.0012	3
barium	mg/L	0.029	-	-	1	-	0.025	0.027	2	0.024	0.021	0.029	3	0.025	0.022	0.025	3
beryllium	mg/L	<0.0005	-	-	1	-	<0.0005	<0.0005	2	<0.0005	<0.0005	<0.001	3	<0.0005	<0.0005	<0.0005	3
boron	mg/L	0.02	-	-	1	-	0.02	0.02	2	0.02	0.01	0.02	3	0.02	0.02	0.02	3
cadmium	mg/L	<0.0001	-	-	1	-	<0.0001	<0.0001	2	<0.0001	<0.0001	<0.0001	3	<0.0001	<0.0001	<0.0001	3
chromium	mg/L	<0.0004	-	-	1	-	0.0006	0.0011	2	0.0005	0.0004	0.0007	3	0.0006	<0.0004	0.0006	3
cobalt	mg/L	0.0006	-	-	1	-	0.0002	0.0026	2	0.0008	<0.0001	0.001	3	<0.0001	<0.0001	0.0003	3
copper	mg/L	<0.0006	-	-	1	-	<0.0006	0.0012	2	<0.0006	<0.0006	<0.0006	3	<0.0006	<0.0006	<0.0006	3
iron	mg/L	0.11	-	-	1	-	0.04	0.11	2	0.02	0.01	0.2	3	0.03	0.02	0.03	3
lead	mg/L	<0.0001	-	-	1	-	<0.0001	<0.0001	2	<0.0001	<0.0001	0.0004	3	<0.0001	<0.0001	<0.0001	3
lithium	mg/L	0.004	-	-	1	-	0.003	0.006	2	0.005	0.004	0.005	3	0.005	0.004	0.005	3
manganese	mg/L	0.019	-	-	1	-	0.003	0.016	2	0.003	<0.001	0.023	3	<0.001	<0.001	0.001	3
mercury	mg/L	<0.0001	-	-	1	-	<0.00000006	<0.0000006	2	<0.0000006	<0.00000006	<0.0001	3	<0.0001	0.0000006	<0.0001	3
molybdenum	mg/L	0.0002	-	-	1	-	0.0002	0.0003	2	0.0003	0.0002	0.0005	3	0.0002	0.0002	0.0002	3
nickel	mg/L	0.0012	-	-	1	-	<0.0001	0.001	2	0.0009	0.0004	0.0012	3	0.0008	0.0008	0.001	3
selenium	mg/L	<0.0004	-	-	1	-	<0.0004	<0.0004	2	<0.0004	<0.0004	<0.0004	3	<0.0004	<0.0004	<0.0004	3
silver	mg/L	<0.0002	-	-	1	-	0.000001	0.000001	2	<0.0000008	<0.0000005	<0.0002	3	<0.0002	0.0000005	<0.0002	3
strontium	mg/L	0.08	-	-	1	-	0.07	0.07	2	0.06	0.06	0.07	3	0.07	0.06	0.07	3
thallium	mg/L	<0.00005	-	-	1	-	<0.00005	<0.00005	2	<0.00005	<0.00005	0.00005	3	<0.00005	<0.00005	<0.00005	3
titanium	mg/L	<0.0003	-	-	1	-	0.0005	0.0006	2	0.0004	<0.0003	0.001	3	0.0004	<0.0003	0.0006	3
uranium	mg/L	<0.0001	-	-	1	-	<0.0001	<0.0001	2	<0.0001	<0.0001	<0.0001	3	<0.0001	<0.0001	<0.0001	3
vanadium	mg/L	<0.0001	-	-	1	-	0.0001	0.0003	2	0.0005	0.0003	0.0006	3	0.0002	0.0001	0.0037	3
zinc	mg/L	0.012	-	-	1	-	<0.002	0.014	2	<0.002	<0.002	0.003	3	<0.002	<0.002	0.003	3

- = No data or not applicable.

Notes: **Bolded** concentrations are higher than relevant water quality guidelines.
(A) 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.
(H) Concentration higher than the relevant human health guideline or beyond the recommended pH range.
(W) Concentration higher than the relevant wildlife health guideline.
(D>) Analytical detection limit was higher than the relevant water quality guideline(s).

Source: WDS (AEW 2011); MEG (2008); Encana (2009); Cenovus (2010).

Table E-2 Water Quality of Winefred Lake

Parameter	Units	Winefred Lake (WB-WL)				Winefred River (WC5-07)			Unnamed Watercourse 6-07		
		Spring	Summer	Summer	Fall	Spring	Summer	Fall	Spring	Summer	Fall
		2007	1998	2007	2007	2007	2007	2007	2007	2007	2007
Field Measured											
pH	-	8.1	-	-	8.5	8	8.5	8.5	7	7.4	7.6
conductivity	µS/cm	176	-	-	173	177	197	171	77	173	145
temperature	°C	8.5	-	-	8.2	7.9	19.4	8.6	7.8	15	5.2
dissolved oxygen	mg/L	11.2	-	-	13.2	11.1	10.3	13.4	10.1	9.7	12.3
Conventional Parameters											
colour	TCU	8	10	8	18	9	8	10	69	110	43
conductivity	µS/cm	166	195	196	203	165	194	196	78	167	165
dissolved organic carbon	mg/L	8	7	12	11	8	10	16	20	32	21
hardness	mg/L	89	-	93	100	89	98	95	41	91	89
pH (lab)	-	8.3	8.2	8.5	8.4	8.2	8.3	8.3	7.6	8	7.8
total alkalinity	mg/L	96	102	104	112	96	101	104	41	85	88
total dissolved solids	mg/L	120	-	135	119	101	114	132	89	145	136
total organic carbon	mg/L	9	-	10	11	9	10	11	20	31	21
total suspended solids	mg/L	3	-	5	6	9	6	5	51	7	3
Major Ions											
bicarbonate	mg/L	117	124	121	133	118	122	124	50	103	108
calcium	mg/L	25	27	26	28	25	27	26	11	24	22
carbonate	mg/L	<5	-	<5	<5	<5	<5	<5	<5	<5	<5
chloride	mg/L	1	0.3	1	<1	<1	1	<1	2	1	<1
magnesium	mg/L	6	8	7	7	6	8	7	3	7	8
potassium	mg/L	0.9	0.9	0.8	1	1	1	1	0.7	0.8	0.8
sodium	mg/L	3	4	3	4	3	5	3	1	2	1
sulphate	mg/L	1	0.5	2	2	1	1	1	<0.5	0.8	0.7
sulphide	mg/L	<0.003	-	0.004	<0.003	0.004	0.003	<0.003	**0.007**[(C)]	**0.006**[(C)]	<0.003
Nutrients and Biological Indicators											
nitrate + nitrite	mg-N/L	<0.1	0.01	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
nitrogen - ammonia	mg-N/L	<0.05	0.01	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
nitrogen - Kjeldahl	mg-N/L	0.4	-	0.7	0.8	0.5	0.8	0.6	0.7	0.9	0.5
nitrogen - total	mg-N/L	0.4	0.02	0.7	0.8	0.5	0.8	0.6	0.7	0.9	0.5
phosphorus - total	mg-P/L	0.023	0.038	0.041	0.027	0.033	0.029	0.036	**0.062**[(C)]	0.024	0.003
phosphorus - dissolved	mg-P/L	0.005	0.006	0.008	0.007	0.004	0.007	0.01	0.01	0.016	0.003
biological oxygen demand	mg/L	<2	-	<2	<2	<2	<2	2	<2	<2	<2
chlorophyll *a*	µg/L	5	17	10	21	-	-	-	-	-	-
General Organics											
naphthenic acids	mg/L	<1	-	<1	<1	<1	<1	<1	<1	<1	<1
total phenolics	mg/L	<0.001	-	**0.006**[(C,W)]	**0.005**[(C,W)]	<0.001	**0.006**[(C,W)]	**0.006**[(C,W)]	<0.001	**0.012**[(C,W)]	**0.004**[(W)]
total recoverable hydrocarbons	mg/L	<1	-	-	<1	<1	<1	<1	<1	<1	<1
Metals (Total)											
aluminum	mg/L	0.04	-	<0.02	<0.02	0.04	<0.02	<0.02	**0.84**[(A,C,H)]	0.04	<0.02
antimony	mg/L	0.0013	-	<0.0004	0.0014	0.0005	0.0005	<0.0004	0.0007	0.0016	<0.0004
arsenic	mg/L	0.0005	-	0.0008	0.0005	0.0013	0.0006	0.0006	0.0009	0.0009	0.0006
barium	mg/L	0.025	-	0.025	0.028	0.039	0.024	0.025	0.021	0.016	0.007
beryllium	mg/L	<0.001	-	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
boron	mg/L	<0.02	-	<0.02	<0.02	0.03	<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	<0.0002[(D>C)]	<0.0002	<0.0002
chromium	mg/L	0.0009	-	<0.0008	<0.0008	**0.0033**[(C)]	<0.0008	<0.0008	**0.0024**[(C)]	<0.0008	<0.0008
cobalt	mg/L	<0.0002	-	<0.0002	0.0003	0.0008	<0.0002	<0.0002	0.0006	<0.0002	<0.0002
copper	mg/L	<0.001	-	<0.001	<0.001	**0.003**[(C)]	<0.001	<0.001	0.001	<0.001	<0.001
iron	mg/L	0.08	-	0.07	0.05	0.16	0.07	0.06	**1.6**[(C,H)]	**0.68**[(C,H)]	0.11
lead	mg/L	0.0001	-	<0.0001	<0.0001	0.0009	<0.0001	<0.0001	0.0006	0.0001	<0.0001
lithium	mg/L	<0.006	-	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006
manganese	mg/L	0.028	-	**0.051**[(H)]	0.024	0.05	**0.054**[(H)]	0.04	**0.08**[(H)]	**0.062**[(H)]	0.009

Table E-2 Water Quality of Winefred Lake (continued)

Parameter	Units	Winefred Lake (WB-WL)				Winefred River (WC5-07)			Unnamed Watercourse 6-07		
		Spring	Summer	Summer	Fall	Spring	Summer	Fall	Spring	Summer	Fall
		2007	1998	2007	2007	2007	2007	2007	2007	2007	2007
mercury	mg/L	<0.0000006	-	<0.0000006	-	<0.0000006	<0.0000006	-	0.000005	<0.0000006	-
methyl mercury	mg/L	0.00000009	-	<0.00000003	-	0.00000012	<0.00000003	-	0.00000015	<0.00000003	-
molybdenum	mg/L	0.0002	-	0.0002	0.0002	0.0003	0.0002	0.0002	0.0001	0.0001	<0.0001
nickel	mg/L	0.0004	-	0.0006	0.0007	0.0028	0.0006	0.0011	0.0015	0.0008	0.0007
selenium	mg/L	<0.0004	-	<0.0004	<0.0004	0.0008	<0.0004	<0.0004	<0.0004	<0.0004	0.0004
silver	mg/L	0.000002	-	0.000002	-	0.000075	0.00001	-	0.000099	0.000014	-
strontium	mg/L	0.05	-	0.05	0.05	0.06	0.05	0.05	0.02	0.06	0.04
thallium	mg/L	<0.0001	-	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
titanium	mg/L	<0.005	-	<0.005	<0.005	0.011	<0.005	<0.005	0.027	<0.005	<0.005
uranium	mg/L	<0.0001	-	<0.0001	<0.0001	0.0003	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
vanadium	mg/L	0.0003	-	<0.0002	<0.0002	0.0036	<0.0002	<0.0002	0.0029	<0.0002	<0.0002
zinc	mg/L	0.005	-	0.004	0.009	0.017	<0.004	0.008	**0.035**[(C)]	<0.004	0.008
Metals (Dissolved)											
aluminum	mg/L	<0.01	-	<0.01	<0.01	<0.01	<0.01	<0.01	0.01	0.02	<0.01
antimony	mg/L	0.0005	-	<0.0004	0.0006	0.0005	0.0005	0.0006	0.0005	0.0004	0.0006
arsenic	mg/L	<0.0004	-	0.0007	0.0012	<0.0004	0.0007	0.0006	<0.0004	0.001	0.0005
barium	mg/L	0.023	-	0.023	0.027	0.023	0.024	0.025	0.008	0.014	0.007
beryllium	mg/L	<0.0005	-	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005
boron	mg/L	0.01	-	0.03	0.02	0.02	0.02	0.02	0.006	0.01	0.006
cadmium	mg/L	<0.0001	-	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
chromium	mg/L	<0.0004	-	<0.0004	<0.0004	0.0006	<0.0004	<0.0004	0.0005	<0.0004	<0.0004
cobalt	mg/L	0.0004	-	0.0024	<0.0001	0.0004	0.0001	<0.0001	0.0004	0.0003	<0.0001
copper	mg/L	<0.0006	-	<0.0006	0.0016	<0.0006	<0.0006	<0.0006	<0.0006	0.0006	<0.0006
iron	mg/L	0.008	-	0.01	0.01	0.009	0.01	0.01	0.13	0.45	0.05
lead	mg/L	<0.0001	-	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
lithium	mg/L	0.002	-	0.004	0.004	0.002	0.004	0.002	0.002	0.004	0.002
manganese	mg/L	0.003	-	0.011	<0.001	0.004	0.001	<0.001	0.027	0.053	0.006
mercury	mg/L	<0.0000006	-	<0.0000006	-	<0.0000006	<0.0000006	-	<0.0000006	0.0000011	-
molybdenum	mg/L	0.0001	-	0.0002	0.0002	0.0002	0.0002	0.0002	<0.0001	0.0001	<0.0001
nickel	mg/L	0.0005	-	0.001	0.0007	0.0005	0.0005	0.0007	0.0004	0.0007	0.0006
selenium	mg/L	<0.0004	-	<0.0004	<0.0004	0.0006	<0.0004	<0.0004	<0.0004	<0.0004	<0.0004
silver	mg/L	0.0000007	-	<0.0000005	-	0.000013	-	-	0.000005	-	-
strontium	mg/L	0.05	-	0.05	0.06	0.05	0.05	0.06	0.02	0.05	0.05
thallium	mg/L	<0.00005	-	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005
titanium	mg/L	<0.0003	-	<0.0003	<0.0003	<0.0003	<0.0003	0.0004	0.0005	0.0004	0.0006
uranium	mg/L	<0.0001	-	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
vanadium	mg/L	0.0002	-	<0.0001	0.004	0.0002	<0.0001	0.0001	0.0003	<0.0001	<0.0001
zinc	mg/L	0.005	-	<0.002	0.006	0.003	0.47	0.006	0.003	0.87	0.008

- = No data or not applicable.

Notes: **Bolded** concentrations are higher than relevant water quality guidelines.
[(A)] 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.
[(H)] Concentration higher than the relevant human health guideline or beyond the recommended pH range.
[(W)] Concentration higher than the relevant wildlife health guideline.
[(D>)] Analytical detection limit was higher than the relevant water quality guideline(s).

Source: MEG (2008).

Table E-3 Water Quality of Pinehurst Lake (1978-1987)

Parameter	Units	Spring			Summer			Fall			Winter		
		Median (Min)	Maximum	n	Median (Min)	Maximum	n	Median (Min)	Maximum	n	Median (Min)	Maximum	n
Field Measured													
pH	-	7.6 (7.2)[a]	8.3	21	7.7 (6.8)[a]	**8.7**[(A,C)]	87	7.8 (6.5)[a]	8.2	48	7.2 (**6.1**[(A,C)])	**9.1**[(A,C,H)]	51
conductivity	µS/cm	273	274	21	279	291	87	279	283	60	281	297	51
dissolved oxygen	mg/L	9 (6.7)[a]	12.1	21	**6.2**[(C)] (**0.1**[(A,C)])[a]	10.4	80	9.0 (**0.6**[(A,C)])[a]	11.1	52	7.3 (**0.2**[(A,C)])	15.3	39
Conventional Parameters													
conductivity	µS/cm	285	-	1	274	278	5	284	290	3	304	306	6
dissolved organic carbon	mg/L	13	-	1	13	14	4	13	14	3	13	15	8
hardness	mg/L	125	-	1	131	141	5	136	137	3	141	145	6
pH (lab)	-	8.1	-	1	**8.7**[(A,C)] (8.4)[a]	**8.8**[(A,C)]	5	8.4 (8.3)[a]	8.5	3	8.0 (7.7)	**8.6**[(A,C)]	6
total alkalinity	mg/L	150	-	1	147	149	5	149	150	3	158	163	6
total dissolved solids	mg/L	151	-	1	152	154	5	153	154	3	161	164	6
total suspended solids	mg/L	7	-	1	11	11	2	8	9	3	-	-	-
Major Ions													
bicarbonate	mg/L	183	-	1	163	173	5	178	181	3	190	195	6
calcium	mg/L	32	-	1	32	38	5	32	33	3	34	35	6
chloride	mg/L	0.5	-	1	0.5	2	5	0.5	0.5	3	0.5	0.5	6
magnesium	mg/L	11	-	1	13	14	5	13	14	3	14	14	6
potassium	mg/L	4	-	1	4	4	5	4	4	3	4	4	6
sodium	mg/L	8	-	1	8	9	5	8	9	3	8	9	6
sulphate	mg/L	-	-	-	10	-	1	-	-	-	-	-	-
Nutrients and Biological Indicators													
nitrate + nitrite	mg-N/L	0.003	-	1	0.002	<0.05	5	0.003	0.02	3	0.05	0.2	11
nitrogen - ammonia	mg-N/L	0.02	-	1	0.01	0.02	4	0.018	0.022	3	0.24	**0.64**[(C)]	11
nitrogen - Kjeldahl	mg-N/L	1.1	-	1	1.2	1.2	7	1.3	1.3	3	1.1	1.7	11
nitrogen - total	mg-N/L	**1.1**[(C)]	-	1	**1.2**[(C)]	**1.2**[(C)]	7	**1.3**[(C)]	**1.32**[(C)]	3	**1.25**[(C)]	**1.8**[(C)]	11
phosphorus - total	mg-P/L	0.046	-	1	0.034	**0.1**[(C)]	8	0.044	0.05	3	0.037	**0.097**[(C)]	11
phosphorus - dissolved	mg-P/L	0.009	-	1	0.008	0.088	5	0.008	0.011	3	0.021	0.071	8
chlorophyll *a*	µg/L	18.1	-	1	10.9	16.4	3	14.8	16.6	3	0.5	13.9	3
Metals (Total)													
arsenic	mg/L	-	-	-	0.0004	-	1	-	-	-	-	-	-
cadmium	mg/L	-	-	-	<0.0005[(D>C)]	-	1	-	-	-	-	-	-
chromium	mg/L	-	-	-	**0.005**[(C)]	-	1	-	-	-	-	-	-
copper	mg/L	-	-	-	**0.004**[(C)]	-	1	-	-	-	-	-	-
iron	mg/L	-	-	-	0.05	-	1	-	-	-	-	-	-
manganese	mg/L	-	-	-	0.026	-	1	-	-	-	-	-	-
molybdenum	mg/L	-	-	-	0.006	-	1	-	-	-	-	-	-
nickel	mg/L	-	-	-	0.003	-	1	-	-	-	-	-	-
vanadium	mg/L	-	-	-	0.005	-	1	-	-	-	-	-	-

[(a)] Minimum values are in brackets and are only presented for parameters with guidelines that consist of ranges of values.

- = No data or not applicable.

Notes: **Bolded** concentrations are higher than relevant water quality guidelines.
[(A)] 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.
[(H)] Concentration higher than the relevant human health guideline or beyond the recommended pH range.
[(W)] Concentration higher than the relevant wildlife health guideline.
[(D>)] Analytical detection limit was higher than the relevant water quality guideline(s).

Source: AEW (2011).

Table E-4 Water Quality of Touchwood Lake (1986-2004)

Parameter	Units	Winter			Spring			Summer			Fall		
		Median (Min)	Maximum	n	Median (Min)	Maximum	n	Median (Min)	Maximum	n	Median (Min)	Maximum	n
Field Measured													
pH	-	6.9 (**6.3**$^{(A,C)}$) [a]	8.3	42	8.1	-	1	8.5 (6.8) [a]	**8.8**$^{(A,C)}$	10	8.4 (7.9) [a]	**8.7**$^{(A,C)}$	5
conductivity	µS/cm	259	280	42	253	-	1	264	282	10	265	267	5
temperature	°C	2.3	22	42	13	-	1	18.1	20.5	10	12.7	15.4	5
dissolved oxygen	mg/L	8 (**0.08**$^{(A,C)}$) [a]	10.8	42	12	-	1	8.7 (**0.1**$^{(A,C)}$) [a]	10.8	10	9.1 (8.5) [a]	9.4	5
Conventional Parameters													
colour	TCU	-	-	-	10	10	4	8	20	6	8	20	3
conductivity	µS/cm	285	293	13	265	271	5	265	284	10	272	275	6
dissolved organic carbon	mg/L	10	11	27	13	-	1	11	12	4	10	12	4
hardness	mg/L	132	151	13	130	134	5	126	135	10	128	134	7
pH (lab)	-	7.9 (7.4) [a]	8.2	13	8.2 (8.0) [a]	8.4	5	8.5 (8.2) [a]	**8.6**$^{(A,C)}$	10	8.3 (8.1) [a]	**8.8**$^{(A,C)}$	7
total alkalinity	mg/L	148	156.7	13	144	147	4	144	146	10	147	224	7
total dissolved solids	mg/L	151	160	13	144	147	4	144	146	10	147	224	7
total organic carbon	mg/L	0.4	0.6	13	-	-	-	-	-	-	-	-	-
total suspended solids	mg/L	<0.4	4	4	4	-	1	2	3	3	2	3	4
Major Ions													
bicarbonate	mg/L	180	191	13	170	177	5	164	174	10	171	175	7
calcium	mg/L	33	37	13	32	33	5	31	33	9	32	34	5
carbonate	mg/L	<0.5	<0.5	3	1	4	4	<5	6	10	5	6	6
chloride	mg/L	<1	<1	13	<0.5	<1	5	<0.8	<1	10	1	2	7
magnesium	mg/L	12	14	13	13	13	5	12	13	9	13	13	5
potassium	mg/L	3	3	13	3	3	5	3	3	10	3	14	7
sodium	mg/L	7	9	13	8	9	5	8	9	10	8	21	7
sulphate	mg/L	<5	<5	13	2	<5	5	4	<5	10	<5	61	7
Nutrients and Biological Indicators													
nitrate + nitrite	mg-N/L	0.1	0.3	43	-	<0.01	2	<0.005	<0.1	9	0.008	<0.1	6
nitrogen - ammonia	mg-N/L	0.03	0.5	43	<0.002	-	1	0.012	0.034	6	0.014	0.036	5
nitrogen - Kjeldahl	mg-N/L	0.6	1.2	43	0.7	-	1	0.6	0.7	6	0.6	1.4	5
nitrogen - total	mg-N/L	0.73	**1.21**$^{(C)}$	43	-	0.68	2	0.6	0.73	9	0.61	**1.42**$^{(C)}$	5
phosphorus - total	mg-P/L	0.026	**0.104**$^{(C)}$	40	0.022	0.028	5	0.016	0.042	20	0.019	0.026	6
phosphorus - dissolved	mg-P/L	0.023	0.038	25	0.007	-	1	0.006	0.033	7	0.008	0.019	5
chlorophyll *a*	µg/L	0.65	3.7	8	5.4	11.9	5	2.6	4.4	19	3.8	4.5	8
Metals (Total)													
aluminum	mg/L	-	-	-	-	-	-	0.0352	-	1	0.0177	0.0231	2
antimony	mg/L	-	-	-	-	-	-	0.00004	-	1	0.00002	0.00002	2
arsenic	mg/L	-	-	-	-	-	-	0.0006	-	1	0.0006	0.0006	2
barium	mg/L	-	-	-	-	-	-	0.036	-	1	0.034	0.036	2
beryllium	mg/L	-	-	-	-	-	-	<0.000003	-	1	<0.00002	<0.00004	2
boron	mg/L	-	-	-	-	-	-	0.04	-	1	0.03	0.04	2
cadmium	mg/L	-	-	-	-	-	-	0.000005	-	1	<0.00001	<0.00002	2
chromium	mg/L	-	-	-	-	-	-	0.0002	-	1	0.0002	0.0003	2
cobalt	mg/L	-	-	-	-	-	-	0.00001	-	1	0.00002	0.00002	2
copper	mg/L	-	-	-	-	-	-	0.0003	-	1	0.0008	0.0014	2
iron	mg/L	-	-	-	-	-	-	0.03	-	1	0.01	0.02	2
lead	mg/L	-	-	-	-	-	-	0.00006	-	1	0.0003	0.0006	2
lithium	mg/L	-	-	-	-	-	-	0.011	-	1	0.01	0.01	2
manganese	mg/L	-	-	-	-	-	-	0.006	-	1	0.012	0.017	2
mercury	mg/L	<0.0001$^{(D>A,C)}$	<0.0001$^{(D>A,C)}$	3	-	-	-	<0.0001$^{(D>A,C)}$	-	1	-	-	-
molybdenum	mg/L	-	-	-	-	-	-	0.0001	-	1	0.0001	0.0001	2

Table E-4 Water Quality of Touchwood Lake (1986-2004) (continued)

Parameter	Units	Winter			Spring			Summer			Fall		
		Median (Min)	Maximum	n	Median (Min)	Maximum	n	Median (Min)	Maximum	n	Median (Min)	Maximum	n
nickel	mg/L	-	-	-	-	-	-	<0.000005	-	1	<0.00003	<0.00006	2
selenium	mg/L	-	-	-	-	-	-	<0.0001	-	1	0.0003	<0.0005	2
silver	mg/L	-	-	-	-	-	-	<0.0000005	-	1	0.000003	<0.000005	2
strontium	mg/L	-	-	-	-	-	-	0.13	-	1	0.13	0.13	2
thallium	mg/L	-	-	-	-	-	-	0.000002	-	1	0.000003	0.000006	2
titanium	mg/L	-	-	-	-	-	-	0.0008	-	1	0.0005	0.0007	2
uranium	mg/L	-	-	-	-	-	-	0.0001	-	1	0.0001	0.0001	2
vanadium	mg/L	-	-	-	-	-	-	0.0002	-	1	0.0001	0.0002	2
zinc	mg/L	-	-	-	-	-	-	0.003	-	1	0.002	0.004	2
Metals (Dissolved)													
iron	mg/L	-	-	-	-	-	-	<0.06	<0.06	2	<0.06	-	1

(a) Minimum values are in brackets and are only presented for parameters with guidelines that consist of ranges of values.

- = No data or not applicable.

Notes: **Bolded** concentrations are higher than relevant water quality guidelines.
(A) 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.
(H) Concentration higher than the relevant human health guideline or beyond the recommended pH range.
(W) Concentration higher than the relevant wildlife health guideline.
(D>) Analytical detection limit was higher than the relevant water quality guideline(s).

Source: AEW (2011).

Table E-5 Water Quality of Wolf Lake

Parameter	Units	Summer			Fall			Winter			Spring		
		Median (Min)	Maximum	n	Median (Min)	Maximum	n	Median (Min)	Maximum	n	Median (Min)	Maximum	n
Field Measured													
pH	-	8 (7.5) [a]	**9**[(A,C)]	73	-	-	-	**6.3**[(A,C)] (**5.3**[(A,C)]) [a]	6.9	47	-	-	-
conductivity	µS/cm	318	354	311	339	384	122	314	460	79	347	389	61
dissolved oxygen	mg/L	**4.5**[(A,C)] (**0.06**[(A,C)]) [a]	10.9	221	8.3 (**0.2**[(A,C)]) [a]	9.8	74	**8.5** (**1**[(A,C)]) [a]	11.4	103	8 (**0.3**[(A,C)]) [a]	13.8	63
Conventional Parameters													
conductivity	µS/cm	296	311	9	339	339	3	347	374	6	296	-	1
dissolved organic carbon	mg/L	14	15	9	13	15	3	14	15	4	13	13	2
hardness	mg/L	144	152	3	-	-	-	169	176	6	-	-	-
pH (lab)	-	8.3 (7.4) [a]	**8.8**[(A,C)]	9	7.5 (7.5) [a]	8	3	8.0 (7.7) [a]	8.3	6	7.7	-	1
total alkalinity	mg/L	157	171	9	158	158	3	185	195	6	156	-	1
total dissolved solids	mg/L	175	198	8	-	-	-	187	197	7	199	-	1
total organic carbon	mg/L	14	15	7	14	15	2	14	16	7	14	14	2
total suspended solids	mg/L	3	4	3	-	-	-	1	1	2	5	-	1
Major Ions													
bicarbonate	mg/L	190	198	4	-	-	-	226	238	6	-	-	-
calcium	mg/L	28	33	9	36	36	3	35	35	3	30	-	1
carbonate	mg/L	6	11	3	-	-	-	-	-	-	-	-	-
chloride	mg/L	1	2	9	1	1	3	1	2	6	1	-	1
magnesium	mg/L	16	18	9	14	16	3	20	20	6	15	-	1
potassium	mg/L	2	2	9	2	2	3	2	3	6	2	-	1
sodium	mg/L	11	14	9	12	12	3	13	14	6	12	-	1
sulphate	mg/L	3	10	7	2	3	3	9	-	1	3	-	1
sulphide	mg/L	0.004	0.004	2	-	-	-	-	-	-	-	-	-
Nutrients and Biological Indicators													
nitrate + nitrite	mg-N/L	<0.0005	0.06	4	-	-	-	0.1	0.2	10	-	-	-
nitrogen - ammonia	mg-N/L	0.31	**1**[(A,C)]	39	0.64	1.42	20	0.22	1.05	12	0.105	0.28	8
nitrogen - Kjeldahl	mg-N/L	1	3.9	41	1.6	4.5	20	1.2	2.1	18	1.6	2.1	8
nitrogen - total	mg-N/L	1	**3.9**[(C)]	41	**1.6**[(C)]	**4.5**[(C)]	20	**1.3**[(C)]	**2.2**[(C)]	18	**1.6**[(C)]	**2.1**[(C)]	8
phosphorus - total	mg-P/L	0.021	**0.064**[(C)]	10	0.025	0.045	4	0.034	**0.08**[(C)]	5	0.034	0.039	2
phosphorus - dissolved	mg-P/L	0.01	0.018	8	0.007	0.022	4	-	-	-	0.012	0.015	2
chlorophyll *a*	µg/L	6.1	7.6	8	6.7	12.8	4	-	-	-	16.2	20.3	2
Metals (Total)													
iron	mg/L	0.05	-	1	-	-	-	-	-	-	-	-	-
vanadium	mg/L	-	-	-	0.004	-	1	-	-	-	-	-	-

[(a)] Minimum values are in brackets and are only presented for parameters with guidelines that consist of ranges of values.

- = No data or not applicable.

Notes: **Bolded** concentrations are higher than relevant water quality guidelines.
[(A)] 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.
[(H)] Concentration higher than the relevant human health guideline or beyond the recommended pH range.
[(W)] Concentration higher than the relevant wildlife health guideline.
[(D>)] Analytical detection limit was higher than the relevant water quality guideline(s).

Source: AEW (2011).

Table E-6 Water Quality of Lac la Biche (1977-1997)

Parameter	Units	Winter			Spring			Summer			Fall		
		Median (Min)	Maximum	n	Median (Min)	Maximum	n	Median (Min)	Maximum	n	Median (Min)	Maximum	n
Field Measured													
pH	-	7.9 (6.7) [a]	**8.8** [(A,C)]	38	8.1 (7.9) [a]	8.4	16	8.3 (7) [a]	**9.1** [(A,C,H)]	34	**8.7** [(A,C)] (8.0) [a]	**8.8** [(A,C)]	17
conductivity	µS/cm	308	340	45	281	330	20	256	410	69	271	300	42
temperature	°C	1.7	4.5	56	8.5	10.8	20	17.9	22	70	10.4	17.1	48
dissolved oxygen	mg/L	10.6 (**0.04** [(A,C)]) [a]	13.6	54	9.9 (**6.3** [(C)]) [a]	12.2	20	8.7 (**0** [(A,C)]) [a]	13.6	70	9.3 (**0.06** [(A,C)]) [a]	12.7	48
Conventional Parameters													
colour	TCU	-	-	-	14	20	2	20	40	6	9	-	1
conductivity	µS/cm	301	347	40	252	303	20	247	307	65	242	310	43
dissolved organic carbon	mg/L	10	12	12	9	9	4	9	20	36	10	12	29
hardness	mg/L	133	162	40	120	142	20	115	142	65	114	133	43
pH (lab)	-	8.2 (7.6) [a]	8.5	40	8 (7.7) [a]	8.3	20	8.3 (6.7) [a]	**9** [(A,C)]	65	8.4 (7.7) [a]	**8.9** [(A,C)]	43
total alkalinity	mg/L	150	176	40	120	151	20	120	155	65	123	153	43
total dissolved solids	mg/L	163	191	40	136	169	20	134	168	64	136	166	43
total organic carbon	mg/L	9	46	21	10	45	13	14	45	41	16	59	40
total suspended solids	mg/L	<0.4	<3	4	2	3	4	6	37	14	4	8	13
Major Ions													
bicarbonate	mg/L	190	214	24	176	180	7	163	184	24	169	179	14
calcium	mg/L	35	42	24	34	34	7	33	35	22	32	33	10
carbonate	mg/L	<5	<5	10	<0.5	2	3	6	15	19	4	10	10
chloride	mg/L	3	4	40	2	4	20	2	5	65	2	12	43
magnesium	mg/L	11	15	40	11	14	20	10	13	63	10	13	39
potassium	mg/L	2	3	40	2	3	20	2	3	65	2	3	43
sodium	mg/L	12	17	40	9	15	20	9	16	65	9	17	43
sulphate	mg/L	9	32	40	10	11	20	8	13	65	9	18	43
Nutrients and Biological Indicators													
nitrate + nitrite	mg-N/L	0.05	0.4	51	0.006	<0.05	18	<0.05	0.3	64	0.01	0.2	41
nitrogen - ammonia	mg-N/L	0.03	0.4	49	<0.05	0.06	17	0.04	0.19	58	0.05	0.44	40
nitrogen - Kjeldahl	mg-N/L	0.7	1.1	43	0.9	1.1	17	0.9	5.5	59	1	1.8	42
nitrogen - total	mg-N/L	0.82	**1.32** [(C)]	48	0.95	**1.05** [(C)]	18	0.85	**5.48** [(C)]	64	**1.05** [(C)]	**1.84** [(C)]	43
phosphorus - total	mg-P/L	0.05	**0.74** [(C)]	51	**0.063** [(C)]	**0.117** [(C)]	36	**0.074** [(C)]	**0.6** [(C)]	122	**0.14** [(C)]	**0.256** [(C)]	75
phosphorus - dissolved	mg-P/L	0.051	0.16	30	0.03	0.046	25	0.036	0.35	91	0.123	0.193	54
chlorophyll *a*	µg/L	0.6	9.5	36	7.1	16.77	36	16.1	392.8	120	28.8	86.1	77
Metals (Total)													
aluminum	mg/L	-	-	-	-	-	-	0.0149	0.0167	2	0.01	0.0111	2
antimony	mg/L	-	-	-	-	-	-	0.00009	0.0001	2	0.00005	0.00005	2
arsenic	mg/L	-	-	-	-	-	-	0.0016	0.0018	2	0.0012	0.0013	2
barium	mg/L	-	-	-	-	-	-	0.055	0.056	2	0.053	0.053	2
beryllium	mg/L	-	-	-	-	-	-	<0.000003	<0.000003	2	<0.000003	<0.000003	2
boron	mg/L	-	-	-	-	-	-	0.04	0.04	2	0.04	0.04	2
cadmium	mg/L	-	-	-	-	-	-	0.000005	0.000005	2	<0.000002	<0.000002	2
chromium	mg/L	-	-	-	-	-	-	0.0002	0.0003	2	0.0001	0.0001	2

Table E-6 Water Quality of Lac la Biche Lake (1977-1997) (continued)

Parameter	Units	Winter			Spring			Summer			Fall		
		Median (Min)	Maximum	n	Median (Min)	Maximum	n	Median (Min)	Maximum	n	Median (Min)	Maximum	n
cobalt	mg/L	-	-	-	-	-	-	0.00004	0.00006	2	0.00002	0.00002	2
copper	mg/L	-	-	-	-	-	-	0.0005	0.0006	2	0.0008	0.0013	2
iron	mg/L	-	-	-	-	-	-	0.03	0.04	2	0.005	0.007	2
lead	mg/L	-	-	-	-	-	-	0.00005	0.00006	2	0.00003	0.00004	2
lithium	mg/L	-	-	-	-	-	-	0.011	0.011	2	0.011	0.011	2
manganese	mg/L	-	-	-	-	-	-	**0.179**$^{(H)}$	**0.182**$^{(H)}$	2	0.009	0.012	2
molybdenum	mg/L	-	-	-	-	-	-	0.0006	0.0006	2	0.0005	0.0005	2
nickel	mg/L	-	-	-	-	-	-	<0.000005	<0.000005	2	<0.000005	<0.000005	2
selenium	mg/L	-	-	-	-	-	-	0.0001	0.0001	2	0.0001	0.0002	2
silver	mg/L	-	-	-	-	-	-	<0.0000005	<0.0000005	2	0.000001	0.000002	2
strontium	mg/L	-	-	-	-	-	-	0.15	0.15	2	0.15	0.15	2
thallium	mg/L	-	-	-	-	-	-	0.000002	0.000003	2	0.000002	0.000002	2
titanium	mg/L	-	-	-	-	-	-	0.0022	0.0029	2	0.0016	0.0017	2
uranium	mg/L	-	-	-	-	-	-	0.00008	0.00008	2	0.00008	0.00008	2
vanadium	mg/L	-	-	-	-	-	-	0.0002	0.0003	2	0.0003	0.0003	2
zinc	mg/L	-	-	-	-	-	-	0.001	0.002	2	0.002	0.002	2
Metals (Dissolved)													
iron	mg/L	-	-	-	-	-	-	<0.06	-	1	-	-	-
lead	mg/L	<0.033	<0.06	2	-	-	-	-	-	-	-	-	-
mercury	mg/L	0.002	-	1	-	-	-	-	-	-	-	-	-

[a] Minimum values are in brackets and are only presented for parameters with guidelines that consist of ranges of values.

- = No data or not applicable.

Notes: **Bolded** concentrations are higher than relevant water quality guidelines.
[A] 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.
[H] Concentration higher than the relevant human health guideline or beyond the recommended pH range.
[W] Concentration higher than the relevant wildlife health guideline.
[D>] Analytical detection limit was higher than the relevant water quality guideline(s).

Source: AEW (2011).

Table E-7 Water Quality of Small Waterbodies in the Regional Study Area

Parameter	Units	Winter				Spring				Summer				Fall			
		Median	Minimum	Maximum	n	Median	Minimum	Maximum	n	Median	Minimum	Maximum	n	Median	Minimum	Maximum	n
Field Measured																	
pH	-	7.5	6.5	8.1	10	6.5	**4.5**(A,C,H)	8.1	20	7.4	**6.3**(A,C)	**9.0**(A,C)	14	7.7	6.9	**9.6**(A,C,H)	22
conductivity	µS/cm	110	20	460	10	58	11	176	18	84	43	308	12	103	19	220	22
temperature	°C	0.5	0.1	0.7	10	12	8.5	15.3	18	16.7	13.1	18.8	13	8.7	2.2	11.2	22
dissolved oxygen	mg/L	9	**2**(A,C)	13.8	11	9.5	**4.1**(A,C)	11.2	20	8.9	**4.2**(A,C)	12.2	14	12	6.5	18.3	22
Conventional Parameters																	
colour	TCU	-	-	-	-	43	8	70	14	50	8	160	19	45	18	220	17
conductivity	µS/cm	120	27	270	7	88	18	166	26	85	20	196	23	99	20	203	20
dissolved organic carbon	mg/L	15	11	27	6	16	8	27	25	20	10	40	23	23	11	36	20
hardness	mg/L	99	12	264	10	49	7	106	28	44	8	117	25	56	7	109	22
pH (lab)	-	7.8	**6.4**(A,C)	8.0	6	7.9	**6.4**(A,C)	8.3	26	7.9	6.6	**8.7**(A,C)	23	7.8	**5.8**(A,C)	**9.4**(A,C,H)	20
total alkalinity	mg/L	103	6	258	10	47	3	106	28	42	3	116	25	56	2	114	22
total dissolved solids	mg/L	108	11	260	10	70	<10	144	28	80	<10	160	25	112	<10	176	22
total organic carbon	mg/L	-	-	-	-	18	9	27	11	25	10	51	11	20	11	35	9
total suspended solids	mg/L	17	3	59	4	<3	<1	4	13	3	<3	14	13	4	<3	97	19
Major Ions																	
bicarbonate	mg/L	125	7	314	10	57	3	129	28	51	4	141	25	68	3	139	22
calcium	mg/L	27	3	69	10	11	1	28	28	12	2	31	25	15	2	28	22
carbonate	mg/L	<0.5	<0.5	<6	10	<5	<0.5	<6	28	<5	<0.5	6	24	<5	<0.5	30	22
chloride	mg/L	<1	<0.5	<5	10	1	<0.5	<5	29	1	<0.5	2	25	<1	0.7	3	22
magnesium	mg/L	9	1	22	10	4	0.7	9	28	4	0.9	10	25	5	0.8	9	22
potassium	mg/L	1	1	3	10	1	0.4	2	28	0.4	<0.1	2	25	0.8	<0.4	2	22
sodium	mg/L	3	0.7	10	10	2	0.7	4	28	2	<0.5	5	25	2	0.5	6	22
sulphate	mg/L	<1	<1	3	10	1	<0.5	2	29	2	<1	4	25	0.5	0.2	2	22
sulphide	mg/L	0.004	**0.003**(C)	**0.041**(C)	6	**0.003**(C)	<0.002	0.006	20	0.003	<0.002	0.006	14	0.003	<0.002	0.006	12
Nutrients and Biological Indicators																	
nitrate + nitrite	mg-N/L	0.01	<0.003	0.4	10	<0.1	<0.003	0.2	25	<0.1	<0.003	0.1	16	<0.1	<0.003	<0.1	22
nitrogen - ammonia	mg-N/L	<0.05	<0.05	1.8	10	<0.05	<0.05	0.2	22	<0.05	<0.05	0.18	16	0.055	<0.05	**0.51**(A,C)	22
nitrogen - Kjeldahl	mg-N/L	1.4	0.6	3.3	10	0.9	0.4	1.4	22	1.0	0.7	2.2	16	1.1	0.6	2.5	22
nitrogen - total	mg-N/L	**1.5**(C)	0.7	**3.3**(C)	10	1.0	0.4	**1.5**(C)	22	**1.1**(C)	0.7	**2.2**(C)	16	**1.2**(C)	0.6	**2.5**(C)	5
phosphorus - total	mg-P/L	0.048	0.01	**0.1**(C)	10	0.02	0.007	0.041	22	0.028	0.005	**0.123**(C)	16	0.024	0.011	**0.102**(C)	22
phosphorus - dissolved	mg-P/L	<0.1	0.026	<0.1	10	0.012	0.002	<0.1	22	0.011	0.004	0.1	16	0.009	0.003	<0.1	22
biochemical oxygen demand	mg/L	<3	<2	8	10	<2	<2	3	9	<3	<2	5	5	<2	<2	4	11
chlorophyll *a*	µg/L	-	-	-	-	5	2	10	11	2	<1	17	11	<1	<1	21	9
General Organics																	
naphthenic acids	mg/L	<1	<1	<1	6	<1	<1	1	20	<1	<1	2	13	<1	<1	<1	14
total phenolics	mg/L	**0.004**(W)	**0.004**(W)	**0.011**(C,W)	5	<0.001	<0.001	**0.003**(W)	19	**0.014**(C,W)	**0.004**(W)	**0.018**(C,W)	12	**0.007**(C,W)	**0.003**(W)	**0.012**(C,W)	11
total recoverable hydrocarbons	mg/L	-	-	-	-	<0.5	<0.5	<1	11	<0.5	<0.5	<1	10	<1	<1	<1	9
Metals (Total)																	
aluminum	mg/L	0.008	0.002	0.078	10	0.02	0.006	0.08	22	0.02	0.009	0.079	16	0.03	0.013	**0.23**(C,H)	14
antimony	mg/L	<0.0002	<0.0002	<0.006(D>H)	10	0.0009	<0.0002	<0.005	22	0.0007	<0.0002	0.0031	16	0.0009	<0.0002	0.0039	14
arsenic	mg/L	0.0007	0.0006	<0.01(D>C)	10	0.0007	<0.0004	<0.01(D>C)	22	0.0005	0.0003	0.0009	16	0.0005	<0.0004	<0.001	14
barium	mg/L	0.039	0.01	0.06	10	0.01	0.002	0.04	22	0.01	0.004	0.03	16	0.014	0.005	0.03	14
beryllium	mg/L	<0.001	<0.0001	<0.001	10	<0.001	<0.0005	<0.001	22	<0.001	<0.0001	<0.001	16	<0.001	<0.0001	<0.005(D>H)	14
boron	mg/L	0.02	0.02	0.03	10	<0.02	<0.002	<0.05	22	<0.02	<0.002	0.06	16	<0.02	<0.002	<0.02	14
cadmium	mg/L	<0.000005	<0.000005	<0.0006(D>C)	10	<0.0002(D>C)	<0.000005	<0.0005(D>C)	22	<0.0002(D>C)	<0.000005	<0.0002(D>C)	16	<0.0002(D>C)	<0.000005	<0.0002(D>C)	14
chromium	mg/L	<0.001	<0.0005	<0.001	10	<0.001	<0.0008	**0.0034**(C)	22	<0.0008	<0.0005	<0.001	16	<0.0008	<0.0005	<0.005(D>C)	14
cobalt	mg/L	<0.0003	<0.0001	<0.0008	10	<0.0003	<0.0002	<0.0007	22	<0.0002	<0.0001	0.0004	16	<0.0003	<0.0001	<0.002	14
copper	mg/L	0.0004	<0.0002	**0.007**(C)	10	<0.001	<0.0002	0.002	22	<0.001	0.0003	0.002	16	<0.001	0.0006	**0.004**(C)	14
iron	mg/L	<0.09	<0.06	**4.6**(C,H)	10	0.14	0.07	**1.51**(C,H)	22	0.1	0.04	**0.34**(C,H)	16	0.09	0.05	**0.4**(C,H)	14
lead	mg/L	<0.0002	<0.0002	<0.002	10	<0.0002	<0.0001	<0.002(D>C)	22	<0.0002	<0.0001	0.0005	16	<0.0001	<0.0001	<0.001	14
lithium	mg/L	<0.02	0.006	<0.02	10	<0.008	<0.006	<0.02	19	<0.006	0.002	<0.02	16	<0.006	0.004	<0.02	14
manganese	mg/L	0.027	<0.004	**2**(H)	10	0.023	0.006	**0.08**(H)	22	0.036	0.016	**0.054**(H)	16	0.02	0.011	**0.075**(H)	14
mercury	mg/L	<0.0000035	<0.000002	<0.0002(D>A,C)	10	0.0000006	0.0000001	<0.0001(D>A,C)	21	<0.0000006	<0.0000006	<0.0001(D>A,C)	16	0.0000016	<0.0000006	<0.0001(D>A,C)	14

Table E-7 Water Quality of Small Waterbodies in the Regional Study Area (continued)

Parameter	Units	Winter				Spring				Summer				Fall			
		Median	Minimum	Maximum	n	Median	Minimum	Maximum	n	Median	Minimum	Maximum	n	Median	Minimum	Maximum	n
methyl mercury	mg/L	-	-	-	-	<0.00000003	<0.00000003	0.00000009	5	<0.00000003	<0.00000003	0.00000008	5	<0.00000003	<0.00000003	0.00000019	9
molybdenum	mg/L	<0.0003	<0.0002	<0.001	10	<0.0002	<0.0001	<0.001	22	<0.0001	<0.0001	<0.001	16	<0.0002	<0.0001	<0.001	14
nickel	mg/L	<0.0005	<0.0005	0.0047	10	<0.0005	<0.0002	0.0024	22	0.0005	<0.0002	0.0014	16	0.0006	0.0003	<0.003	14
selenium	mg/L	<0.0002	<0.0002	0.0002	10	<0.0003	<0.0002	0.0005	22	<0.0004	<0.0002	<0.0004	16	<0.0004	<0.0002	<0.001	14
silver	mg/L	-	**0.002**[(C)]	**0.003**[(C)]	2	0.000008	0.000002	**0.003**[(A,C)]	10	0.000003	<0.0000005	0.000004	10	0.000015	0.000003	0.000036	9
strontium	mg/L	0.06	<0.02	0.14	10	0.03	0.01	0.06	22	0.03	0.02	0.08	16	0.03	<0.02	0.07	14
thallium	mg/L	<0.0002	<0.00005	**0.009**[(C,H)]	10	<0.0002	<0.0001	**0.009**[(C,H)]	22	<0.0001	<0.00005	<0.0002	16	<0.0001	<0.00005	<0.001[(D>C,H)]	14
titanium	mg/L	<0.001	<0.0005	0.001	10	<0.003	<0.0004	<0.005	22	<0.005	0.0006	<0.005	16	<0.005	<0.0005	<0.005	14
uranium	mg/L	<0.0001	<0.0001	<0.0005	8	<0.0001	<0.0001	<0.0001	20	<0.0001	<0.0001	0.0005	16	<0.0001	<0.0001	0.0013	14
vanadium	mg/L	0.001	<0.0001	<0.01	10	0.001	<0.0002	0.002	22	<0.0002	0.0001	<0.001	16	<0.0002	<0.0001	0.006	14
zinc	mg/L	0.004	<0.003	0.015	10	0.005	<0.003	0.023	22	0.008	0.002	**6.19**[(A,C)]	16	0.007	0.0008	<0.02	14
Metals (Dissolved)																	
aluminum	mg/L	0.004	<0.001	0.11	10	0.01	<0.001	0.06	22	<0.01	0.003	0.069	16	<0.01	0.002	0.13	14
antimony	mg/L	<0.0002	<0.0002	<0.005	10	0.0006	<0.0002	<0.005	22	0.0005	<0.0002	0.0006	16	0.0006	<0.0002	<0.001	14
arsenic	mg/L	0.0007	0.0003	0.01	10	0.0004	<0.0002	<0.01	22	0.0005	0.0002	0.0012	16	0.0006	<0.0004	0.0012	14
barium	mg/L	0.032	0.003	0.05	10	0.01	0.002	0.03	22	0.008	0.002	0.03	16	0.012	0.004	0.03	14
beryllium	mg/L	<0.001	<0.0001	<0.001	10	<0.001	<0.0005	<0.001	22	<0.0005	<0.0001	<0.001	16	<0.0005	<0.0001	<0.005	14
boron	mg/L	0.02	0.02	0.2	10	0.01	0.003	0.02	22	0.01	0.009	0.03	16	0.02	0.008	0.02	14
cadmium	mg/L	<0.00001	<0.000005	<0.0005	10	<0.0001	<0.000005	<0.0005	22	<0.0001	<0.000005	<0.0001	16	<0.0001	<0.000005	<0.0001	14
chromium	mg/L	<0.001	<0.0008	0.001	10	<0.0008	<0.0004	<0.001	22	<0.0005	<0.0004	<0.005	16	<0.0005	<0.0004	<0.005	14
cobalt	mg/L	<0.0003	<0.0001	<0.0007	10	0.0003	0.0001	<0.0007	22	<0.0001	<0.0001	0.0024	16	<0.0001	<0.0001	0.0035	14
copper	mg/L	0.0015	<0.0002	0.014	10	<0.0006	<0.0002	0.011	22	<0.0006	<0.0002	0.006	16	<0.0006	<0.0002	0.0016	14
iron	mg/L	0.06	0.02	3.8	10	0.06	0.008	1.14	22	0.05	0.01	0.22	16	0.03	0.01	0.37	14
lead	mg/L	<0.0002	<0.0001	<0.002	10	<0.0002	<0.0001	<0.002	22	0.0001	<0.0001	0.001	16	<0.0001	<0.0001	<0.001	14
lithium	mg/L	<0.02	0.005	<0.02	10	0.004	0.001	<0.02	22	0.003	0.0006	<0.02	16	0.004	0.0009	<0.02	14
manganese	mg/L	0.007	<0.004	2.1	10	0.004	<0.001	0.039	22	0.008	0.001	0.146	16	0.006	<0.001	0.079	14
mercury	mg/L	<0.000004	<0.000002	<0.0001	10	<0.0001	<0.0000006	<0.0001	13	<0.0001	<0.0000006	<0.0001	11	<0.0000006	<0.0000006	0.000006	12
molybdenum	mg/L	<0.0003	<0.0002	<0.001	10	<0.0002	<0.0001	<0.001	22	<0.0002	<0.0001	<0.001	16	<0.0002	<0.0001	<0.001	14
nickel	mg/L	0.0009	<0.0005	0.005	10	0.0005	<0.0001	0.002	22	0.0005	<0.0001	0.001	16	0.0006	0.0004	<0.003	14
selenium	mg/L	<0.0002	<0.0002	0.0009	8	<0.0003	<0.0002	0.0008	22	<0.0004	<0.0002	<0.0004	16	<0.0004	<0.0002	<0.001	14
silver	mg/L	<0.0001	<0.0001	<0.001	10	0.000003	0.0000007	0.000009	5	<0.00015	<0.0000005	<0.0002	12	0.0000072	0.0000005	0.0000196	7
strontium	mg/L	0.06	<0.02	0.15	10	0.03	0.02	0.06	22	0.02	<0.02	0.07	16	0.03	0.02	0.07	14
thallium	mg/L	<0.0002	<0.00005	<0.004	10	<0.00013	<0.00005	<0.004	22	<0.00005	<0.00005	<0.0002	16	<0.00005	<0.00005	<0.001	14
titanium	mg/L	<0.001	<0.0004	0.0021	10	<0.001	<0.0003	0.0013	22	<0.0003	<0.0003	<0.001	16	<0.0003	<0.0003	<0.005	14
uranium	mg/L	<0.0001	<0.0001	<0.0001	6	<0.0001	<0.0001	<0.0001	20	<0.0001	<0.0001	<0.0001	14	<0.0001	<0.0001	<0.0005	12
vanadium	mg/L	<0.001	<0.0001	0.002	10	<0.0007	<0.0001	0.001	22	<0.0002	<0.0001	<0.001	16	<0.0001	<0.0001	<0.005	14
zinc	mg/L	0.005	<0.001	0.009	10	0.005	<0.0006	0.014	22	0.004	<0.002	0.027	16	0.004	<0.001	<0.02	14
Target PAHs and Alkylated PAHs																	
naphthalene	µg/L	<0.1	<0.1	**2.3**[(C)]	10	<0.1	<0.1	<0.1	11	<0.1	<0.1	<0.1	5	<0.1	<0.1	<0.1	5
acenaphthene	µg/L	<0.1	<0.1	<0.1	10	<0.1	<0.1	<0.1	11	<0.1	<0.1	<0.1	5	<0.1	<0.1	<0.1	5
acenaphthylene	µg/L	<0.1	<0.1	<0.1	10	<0.1	<0.1	<0.1	11	<0.1	<0.1	<0.1	5	<0.1	<0.1	<0.1	5
anthracene	µg/L	<0.01	<0.01	<0.1[(D>C)]	10	<0.01	<0.01	<0.1[(D>C)]	11	<0.01	<0.01	<0.1[(D>C)]	5	<0.01	<0.01	<0.1[(D>C)]	5
dibenzo(a,h)anthracene	µg/L	<0.008[(D>H)]	<0.008[(D>H)]	<0.01[(D>H)]	10	<0.008[(D>H)]	<0.008[(D>H)]	<0.01[(D>H)]	11	<0.008[(D>H)]	<0.008[(D>H)]	<0.01[(D>H)]	5	<0.008[(D>H)]	<0.008[(D>H)]	<0.01[(D>H)]	5
benzo(a)anthracene / chrysene	µg/L	<0.1[(D>C,H)]	<0.1[(D>C,H)]	<0.1[(D>C,H)]	4	-	<0.1[(D>C,H)]	<0.1[(D>C,H)]	2	-	<0.1[(D>C,H)]	<0.1[(D>C,H)]	2	-	<0.1[(D>C,H)]	<0.1[(D>C,H)]	2
C1 substituted benzo(a)anthracenes / chrysenes	µg/L	<0.009	<0.009	<0.009	6	<0.009	<0.009	<0.009	9	<0.009	<0.009	<0.009	3	<0.009	<0.009	<0.009	3
benzo(a)pyrene	µg/L	<0.0075[(D>H)]	<0.0075[(D>H)]	<0.01[(D>H)]	10	<0.0075[(D>H)]	<0.0075[(D>H)]	<0.01[(D>H)]	11	<0.0075[(D>H)]	<0.0075[(D>H)]	<0.01[(D>H)]	5	<0.0075[(D>H)]	<0.0075[(D>H)]	<0.01[(D>H)]	5
benzo(b&k)fluoranthenes	µg/L	<0.009[(D>H)]	<0.009[(D>H)]	<0.01[(D>H)]	10	<0.009[(D>H)]	<0.009[(D>H)]	<0.01[(D>H)]	11	<0.009[(D>H)]	<0.009[(D>H)]	<0.01[(D>H)]	5	<0.009[(D>H)]	<0.009[(D>H)]	<0.01[(D>H)]	5
benzo(g,h,i)perylene	µg/L	<0.04	<0.04	<0.1	10	<0.04	<0.04	<0.1	11	<0.04	<0.04	<0.1	5	<0.04	<0.04	<0.1	5
fluoranthene	µg/L	<0.04	<0.04	<0.1[(D>C)]	10	<0.04	<0.04	<0.1[(D>C)]	11	<0.04	<0.04	<0.1[(D>C)]	5	<0.04	<0.04	<0.1[(D>C)]	5
fluorene	µg/L	<0.05	<0.05	<0.1	10	<0.05	<0.05	<0.1	11	<0.05	<0.05	<0.1	5	<0.05	<0.05	<0.1	5
indeno(c,d-123)pyrene	µg/L	<0.009[(D>H)]	<0.009[(D>H)]	<0.1[(D>H)]	10	<0.009[(D>H)]	<0.009[(D>H)]	<0.1[(D>H)]	11	<0.009[(D>H)]	<0.009[(D>H)]	<0.1[(D>H)]	5	<0.009[(D>H)]	<0.009[(D>H)]	<0.1[(D>H)]	5
phenanthrene	µg/L	<0.05	<0.05	<0.1	10	<0.05	<0.05	<0.1	11	<0.05	<0.05	<0.1	5	<0.05	<0.05	<0.1	5
pyrene	µg/L	<0.02	<0.02	<0.02	10	<0.02	<0.02	<0.02	11	<0.02	<0.02	<0.02	5	<0.02	<0.02	<0.02	5

Table E-7 Water Quality of Small Waterbodies in the Regional Study Area (continued)

Parameter	Units	Winter				Spring				Summer				Fall			
		Median	Minimum	Maximum	n	Median	Minimum	Maximum	n	Median	Minimum	Maximum	n	Median	Minimum	Maximum	n
Volatile Organics																	
benzene	µg/L	<0.001	<0.001	<0.001	4	-	<0.001	<0.001	2	-	<0.001	<0.001	2	-	<0.001	<0.001	2
ethylbenzene	µg/L	<0.001	<0.001	0.001	4	-	<0.001	<0.001	2	-	<0.001	<0.001	2	-	<0.001	<0.001	2
toluene	µg/L	<0.001	<0.001	0.003	4	-	<0.001	<0.001	2	-	<0.001	<0.001	2	-	<0.001	<0.001	2
xylenes	µg/L	<0.001	<0.001	0.01	4	-	<0.001	<0.001	2	-	<0.001	<0.001	2	-	<0.001	<0.001	2

- = No data or not applicable.

Notes: **Bolded** concentrations are higher than relevant water quality guidelines.
(A) 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.
(H) Concentration higher than the relevant human health guideline or beyond the recommended pH range.
(W) Concentration higher than the relevant wildlife health guideline.
(D>) Analytical detection limit was higher than the relevant water quality guideline(s).

Sources: MEG (2005, 2008); Canadian Natural (2007; includes data from 2001 and 2006); Canadian Natural (2011).

Table E-8 Water Quality of the Christina River - Upstream

Parameter	Units	Winter (2002-07)				Spring (2003-06)				Summer (2002-2006)				Fall (2002-2007, 2009)			
		Median	Minimum	Maximum	n	Median	Minimum	Maximum	n	Median	Minimum	Maximum	n	Median	Minimum	Maximum	n
Field Measured																	
pH	-	7.3	**5.7** (A,C)	7.8	5	7.8	6.6	**9.7** (A,C,H)	4	7.7	7.1	**9.1** (A,C,H)	5	8.0	7.6	8.3	4
conductivity	µS/cm	377	190	518	6	134	90	261	6	193	134	246	8	190	156	260	5
temperature	°C	<0.1	<0.03	9.7	7	12.4	9.1	14.8	6	18.3	14	21.6	8	12.3	8	16.7	6
dissolved oxygen	mg/L	**5.7** (C)	**1.4** (A,C)	13	6	10.2	8.5	10.9	6	8.3	7.1	9.1	8	10.1	8.1	10.8	4
Conventional Parameters																	
colour	TCU	50	24	80	8	80	70	125	3	100	50	125	4	89	60	125	8
conductivity	µS/cm	419	358	651	8	117	95	244	6	180	141	299	8	219	187	703	8
dissolved organic carbon	mg/L	14	11	33	8	17	13	22	6	20	13	24	7	17	13	22	8
hardness	mg/L	211	183	327	8	57	46	127	6	92	75	136	8	107	97	263	8
pH (lab)	-	7.9	7.3	8.4	8	7.9	7.8	8.2	6	8	7.9	8.2	8	8.2	8.0	8.3	8
total alkalinity	mg/L	208	172	340	8	54	43	120	6	89	69	139	8	110	92	333	8
total dissolved solids	mg/L	250	200	440	8	140	110	160	3	160	65	200	7	166	130	464	8
total organic carbon	mg/L	14	11	33	8	19	14	23	6	21	15	25	8	18	16	32	8
total suspended solids	mg/L	5	<3	9	8	25	6	121	6	23	16	740	8	7	<3	13	8
Major Ions																	
bicarbonate	mg/L	254	209	402	8	59	43	147	6	108	69	169	8	134	113	407	8
calcium	mg/L	58	51	85	8	16	13	34	7	25	21	37	8	29	26	68	8
carbonate	mg/L	<5	<5	7	8	<5	<5	<5	6	<5	<5	<5	8	<5	<5	<5	8
chloride	mg/L	1	<1	11	8	1	0.3	12	6	1	0.2	2	8	2	<0.5	32	8
magnesium	mg/L	16	14	28	8	5	4	10	6	7	6	11	8	9	8	23	8
potassium	mg/L	3	2	4	8	1	0.8	2	6	0.9	0.7	3	8	1	0.7	2	8
sodium	mg/L	16	13	34	8	4	3	14	6	6	4	11	8	8	6	70	8
sulphate	mg/L	16	12	27	8	4	2	16	6	5	2	13	8	6	3	17	8
sulphide	mg/L	**0.005** (C)	<0.003 (D>C)	**0.031** (C)	8	<0.052 (D>C)	<0.003 (D>C)	<0.1	6	**0.005** (C)	<0.003	0.018	8	0.007	0.002	**0.04** (C)	8
Nutrients and Biological Indicators																	
nitrate + nitrite	mg-N/L	0.6	0.2	1.1	8	<0.06	<0.02	<0.1	6	<0.1	0.08	0.1	8	<0.1	<0.07	<0.1	8
nitrogen - ammonia	mg-N/L	0.065	<0.05	0.55	8	<0.05	<0.05	0.07	6	<0.05	<0.05	<0.05	8	<0.05	<0.05	0.07	8
nitrogen - Kjeldahl	mg-N/L	0.7	0.3	5.4	8	0.6	0.5	1	6	0.9	0.6	1	8	0.8	0.5	1.3	8
nitrogen - total	mg-N/L	**1.2** (C)	0.8	**6.2** (C)	8	0.6	0.5	1.0	6	0.9	0.6	**1.1** (C)	8	0.8	0.5	**1.3** (C)	8
phosphorus - total	mg-P/L	0.043	0.035	**0.14** (C)	8	**0.082** (C)	**0.052** (C)	**0.279** (C)	6	**0.09** (C)	**0.058** (C)	**0.133** (C)	8	**0.064** (C)	0.048	**0.095** (C)	8
phosphorus - dissolved	mg-P/L	0.016	0.011	0.06	8	0.062	0.027	0.13	6	0.051	0.016	<0.08	8	0.033	0.026	0.051	8
chlorophyll *a*	µg/L	<1	<1	2	5	2	<1	3	5	3	2	8	7	2	1	5	3
General Organics																	
napthenic acids	mg/L	<1	<1	1	8	<1	<1	6	6	<1	<1	1	8	<1	0.2	1	8
total phenolics	mg/L	<0.001	<0.001	**0.009** (C,W)	8	<0.002	<0.001	<0.002	6	<0.002	<0.001	**0.01** (C,W)	8	**0.009** (C,W)	<0.001	**0.019** (C,W)	8
total recoverable hydrocarbons	mg/L	<0.8	<0.5	<1	8	<0.4	<0.1	<0.5	6	<0.5	<0.1	<0.5	8	<0.8	<0.5	<1	8
Metals (Total)																	
aluminum	mg/L	0.04	0.02	**0.12** (C,H)	8	**0.11** (C,H)	0.04	**2.31** (A,C,H)	6	**0.20** (C,H)	0.03	**0.45** (C,H)	8	**0.19** (C,H)	0.05	**0.37** (C,H)	7
antimony	mg/L	0.00002	0.00002	0.0013	7	0.00005	0.00002	0.00007	6	0.0001	0.00002	0.0007	7	0.00002	0.00002	0.00003	7
arsenic	mg/L	0.0007	0.0005	<0.001	8	0.0008	0.0007	0.002	6	0.0011	0.0008	0.0014	8	0.0009	0.0007	0.0012	7
barium	mg/L	0.07	0.05	0.089	8	0.035	0.026	0.063	6	0.035	0.027	0.045	8	0.035	0.028	0.037	7
beryllium	mg/L	<0.00003	<0.000003	<0.001	8	0.00004	0.00002	0.0001	6	0.00006	0.00002	<0.001	8	0.00001	0.00001	<0.00004	7
boron	mg/L	0.08	0.06	0.13	8	0.03	0.02	0.05	6	0.03	0.03	0.06	8	0.03	0.03	0.05	7
cadmium	mg/L	<0.00002	<0.000006	<0.0002	7	0.00005	0.00001	0.0001	6	<0.00003	<0.00001	0.0003	7	0.000008	0.000004	<0.00002	7
chromium	mg/L	0.0003	0.0002	<0.005 (D>C)	8	<0.001	<0.0001	**0.0036** (C)	6	0.001	0.0003	**0.0035** (C)	8	0.0004	<0.0001	0.0007	7
cobalt	mg/L	0.0002	0.00008	<0.002	8	0.0002	0.0001	0.0013	6	0.0003	0.00008	0.0006	8	0.0001	0.0001	0.0003	7
copper	mg/L	0.0008	0.0003	0.0018	8	0.0013	0.0004	0.0027	6	0.0009	0.0005	**0.0032** (C)	8	0.0004	0.0001	**0.0043** (C)	7
iron	mg/L	**0.69** (C,H)	**0.4** (C,H)	**1.66** (C,H)	8	**1.37** (C,H)	**0.78** (C,H)	**4.1** (C,H)	6	**1.53** (C,H)	**0.68** (C,H)	**2.08** (C,H)	8	**1.13** (C,H)	**1** (C,H)	**2.62** (C,H)	7
lead	mg/L	0.0001	0.00004	0.0005	8	0.0003	0.0001	0.0023	6	0.0003	0.00007	0.001	8	0.0001	0.00007	0.0003	7
lithium	mg/L	0.02	0.015	0.027	8	0.006	0.004	0.01	6	0.007	0.006	0.012	8	0.007	0.006	0.011	7
manganese	mg/L	**0.105** (H)	0.049	**1.040** (H)	8	**0.061** (H)	0.015	**0.19** (H)	6	**0.087** (H)	0.005	**0.145** (H)	8	**0.057** (H)	0.05	**0.093** (H)	7

Table E-8 Water Quality of the Christina River - Upstream (continued)

Parameter	Units	Winter (2002-07)				Spring (2003-06)				Summer (2002-2006)				Fall (2002-2007, 2009)			
		Median	Minimum	Maximum	n	Median	Minimum	Maximum	n	Median	Minimum	Maximum	n	Median	Minimum	Maximum	n
mercury	mg/L	<0.0000012	<0.0000006	<0.0002 (D>A,C)	8	<0.0000134 (D>A,C)	<0.0000012	<0.000025 (D>A,C)	6	<0.0000025	<0.0000006	**0.000026** (A,C)	8	<0.0000012	<0.0000006	0.0000023	8
molybdenum	mg/L	0.0011	0.0007	<0.005	8	0.0004	0.0003	0.0006	6	0.0005	0.0004	0.001	8	0.0004	0.0003	0.0007	7
nickel	mg/L	0.0003	<0.000005	0.0077	8	0.0014	0.0002	0.0033	6	0.0007	0.0004	**0.079** (C)	8	0.0003	<0.00006	0.0006	7
selenium	mg/L	<0.0004	<0.0001	<0.0008	8	<0.0005	<0.0001	<0.0005	6	<0.0005	<0.0001	<0.0008	8	<0.0003	0.00006	<0.0005	7
silver	mg/L	<0.000011	0.000005	<0.0004 (D>C)	8	0.00002	0.000007	0.00009	6	0.000008	0.000002	0.000021	8	<0.000005	0.000001	0.000007	7
strontium	mg/L	0.27	0.21	0.38	6	0.06	0.05	0.13	6	0.09	0.08	0.17	8	0.1	0.08	0.16	7
thallium	mg/L	0.000006	0.000003	<0.0001	8	0.000005	0.000002	0.00006	6	0.00002	0.000005	<0.0001	8	0.000004	<0.000003	0.000008	7
titanium	mg/L	0.003	0.002	<0.005	8	0.004	0.0021	0.0697	6	0.0055	<0.0002	0.0101	8	0.0042	0.0019	0.0096	7
uranium	mg/L	0.0002	0.0001	0.0003	8	0.00007	0.00004	0.0003	6	0.0001	0.00006	0.0005	8	0.00009	0.00007	0.0001	7
vanadium	mg/L	0.0002	0.0002	<0.001	8	0.0005	0.0002	0.0069	6	0.0008	0.0005	0.0012	8	0.0006	0.0003	0.0013	7
zinc	mg/L	0.005	0.002	0.015	8	0.007	0.003	0.017	6	0.004	0.002	0.022	8	0.002	0.0008	0.005	7
Metals (Dissolved)																	
aluminum	mg/L	0.002	0.001	0.020	8	0.020	0.006	0.054	6	0.013	<0.01	0.030	8	0.008	0.004	0.013	7
antimony	mg/L	0.00003	0.000008	0.0008	8	0.00006	0.00002	0.0002	6	0.00004	0.00002	<0.0008	8	0.00002	0.00002	0.0001	7
arsenic	mg/L	0.0004	0.0004	0.0008	8	0.0007	0.0006	0.0008	6	0.0009	0.0005	0.001	8	0.0007	0.0006	0.0009	7
barium	mg/L	0.064	0.047	0.09	8	0.025	0.022	0.031	6	0.028	0.026	0.035	8	0.027	0.022	0.032	7
beryllium	mg/L	<0.0001	<0.000003	<0.001	8	0.0001	0.000004	0.0002	6	0.00005	0.000004	<0.0005	8	<0.00001	0.000003	<0.00004	7
boron	mg/L	0.07	0.06	0.13	8	0.02	0.02	0.05	6	0.03	0.02	0.06	8	0.03	0.03	0.04	7
cadmium	mg/L	<0.00002	<0.000006	<0.0001	8	0.0002	0.000004	0.0004	6	0.00003	0.000004	<0.0001	8	<0.000006	0.000003	0.00002	7
chromium	mg/L	0.0003	0.0002	<0.005	8	0.0011	<0.0001	0.003	6	<0.0005	0.00003	<0.001	8	<0.0003	<0.0001	<0.0003	7
cobalt	mg/L	0.0002	0.00006	<0.002	8	0.0001	0.00008	0.0002	6	0.0001	0.00008	0.0002	8	0.00007	0.00004	0.0001	7
copper	mg/L	0.0006	0.0003	<0.001	8	0.001	0.0004	0.0011	6	0.0007	0.0004	0.0026	8	0.0003	<0.00008	0.0005	7
iron	mg/L	0.12	0.02	1.28	8	0.89	0.56	1.71	6	0.76	0.12	1.01	8	0.64	0.39	1.41	7
lead	mg/L	0.00007	0.000006	0.0001	8	0.0002	0.00004	0.0003	6	0.0001	0.00005	0.0006	8	0.00002	0.00002	0.00004	7
lithium	mg/L	0.019	0.015	0.026	8	0.005	0.004	0.009	6	0.006	0.006	0.015	8	0.007	0.005	0.012	7
manganese	mg/L	0.111	0.04	1.04	8	0.018	0.002	0.063	6	0.012	0.003	0.042	8	0.015	0.005	0.027	7
mercury	mg/L	<0.00005	<0.00001	<0.0001	7	<0.000025	<0.00001	<0.00004	6	<0.000025	<0.00001	<0.00004	6	<0.00005	<0.00001	<0.00005	7
molybdenum	mg/L	0.001	0.0007	<0.005	8	0.0004	0.0004	0.0007	6	0.0005	0.0004	0.0009	8	0.0004	0.0003	0.0007	7
nickel	mg/L	<0.0002	<0.000005	<0.002	8	0.0011	0.0001	0.0018	6	0.0007	<0.0001	0.0755	8	0.0002	<0.00006	0.0003	7
selenium	mg/L	<0.0004	<0.0001	<0.0005	8	0.0005	<0.0001	0.001	6	<0.0005	<0.0001	0.0005	8	<0.0003	<0.0001	<0.0005	7
silver	mg/L	<0.000005	<0.0000005	<0.0001	7	0.000018	<0.0000005	0.000072	6	0.000009	<0.0000005	0.000042	6	<0.000005	<0.0000005	0.000006	7
strontium	mg/L	0.27	0.21	0.38	6	0.05	0.05	0.13	6	0.09	0.08	0.17	8	0.09	0.08	0.15	7
thallium	mg/L	<0.000005	<0.0000003	<0.0001	8	0.00001	0.000002	0.00002	6	0.00002	0.000003	<0.00005	8	0.000003	0.0000009	<0.000003	7
titanium	mg/L	0.0014	<0.001	0.0029	8	0.0025	0.001	0.0029	6	0.001	0.0005	0.0016	8	0.0011	0.0008	0.0015	7
uranium	mg/L	0.0002	0.0001	0.0003	8	0.00006	0.00004	0.0001	6	0.0001	0.00005	0.0002	8	0.00008	0.00007	0.0001	7
vanadium	mg/L	0.0002	<0.00005	<0.001	8	0.0014	0.0002	0.0028	6	0.0003	<0.0001	0.0006	8	0.0002	0.0001	0.0003	7
zinc	mg/L	0.005	0.002	0.016	8	0.005	0.003	0.009	6	0.003	0.002	0.011	8	0.001	0.0007	0.004	7
Target PAHs and Alkylated PAHs																	
naphthalene	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.02	0.04	2
C1 substituted naphthalenes	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.02	0.03	2
C2 substituted naphthalenes	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.04	0.05	2
C3 substituted naphthalenes	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.04	<0.04	2
C4 substituted naphthalenes	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.04	<0.04	2
acenaphthene	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.02	<0.02	2
C1 substituted acenaphthene	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.04	<0.04	2
acenaphthylene	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.02	<0.02	2
anthracene	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.02 (D>C)	<0.02 (D>C)	2
dibenzo(a,h)anthracene	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.02 (D>C)	<0.02 (D>C)	2
benzo(a) anthracene / chrysene	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	<0.02 (D>C)	-	-	1
C1 substituted benzo(a)anthracene / chrysene	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.04	<0.04	2
C2 substituted benzo(a)anthracene / chrysene	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.04	<0.04	2
benzo(a)pyrene	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.02 (D>C)	<0.02 (D>C)	2

Table E-8 Water Quality of the Christina River - Upstream (continued)

Parameter	Units	Winter (2002-07)				Spring (2003-06)				Summer (2002-2006)				Fall (2002-2007, 2009)			
		Median	Minimum	Maximum	n	Median	Minimum	Maximum	n	Median	Minimum	Maximum	n	Median	Minimum	Maximum	n
C1 substituted benzo(b&k)fluoranthene / benzo(a)pyrene	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.04	<0.04	2
C2 substituted benzo(b&k)fluoranthene / benzo(a)pyrene	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.04	<0.04	2
benzo(b&k)fluoranthene	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	<0.02 (D>C)	-	-	1
benzo(g,h,i)perylene	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.02	<0.02	2
biphenyl	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.04	<0.04	2
C1 substituted biphenyl	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.04	<0.04	2
C2 substituted biphenyl	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.04	<0.04	2
dibenzothiophene	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.02	<0.02	2
C1 substituted dibenzothiophene	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.04	<0.04	2
C3 substituted dibenzothiophene	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.04	<0.04	2
C4 substituted dibenzothiophene	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.04	<0.04	2
fluoranthene	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.02	<0.02	2
C1 substituted fluoranthene / pyrene	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.04	<0.04	2
fluorene	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.02	<0.02	2
C1 substituted fluorene	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.04	<0.04	2
C2 substituted fluorene	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.04	<0.04	2
indeno(c,d-123)pyrene	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.02 (D>C)	<0.02 (D>C)	2
phenanthrene	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.02	0.03	2
C1 substituted phenanthrene / anthracene	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.04	<0.04	2
C2 substituted phenanthrene / anthracene	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.04	<0.04	2
C3 substituted phenanthrene / anthracene	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.04	<0.04	2
C4 substituted phenanthrene / anthracene	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.04	<0.04	2
pyrene	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.02	<0.02	2

- = No data or not applicable.

Notes: **Bolded** concentrations are higher than relevant water quality guidelines.
(A) 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.
(H) Concentration higher than the relevant human health guideline or beyond the recommended pH range.
(W) Concentration higher than the relevant wildlife health guideline.
(D>) Analytical detection limit was higher than the relevant water quality guideline(s).

Source: WDS (AEW 2011), RAMP (2002-2011); Gartner Lee (2007).

Table E-9 Water Quality of the Christina River – Downstream

Parameter	Units	Winter (1978-79, 2002-2005, 2007)				Spring (2002-2005)				Summer (1978, 2002-2005)				Fall (1978, 2002-2009)			
		Median	Minimum	Maximum	n	Median	Minimum	Maximum	n	Median	Minimum	Maximum	n	Median	Minimum	Maximum	n
Field Measured																	
pH	-	-	7.7	8.4	2	**8.9** (A,C)	-	-	1	8.1	7.8	8.5	4	8.3	7.9	**8.7** (A,C)	6
conductivity	µS/cm	587	16	1300	4	292	149	770	4	208	125	395	6	322	63	372	6
temperature	°C	0.1	0	0.4	3	10.7	8.7	15.8	4	17	14.5	20.5	7	12.7	1.2	17.9	8
dissolved oxygen	mg/L	**6.3** (C)	**4** (A,C)	8.8	4	10.5	9.8	11.6	4	8.9	7.6	12.4	6	10.2	8.1	13.3	6
Conventional Parameters																	
colour	TCU	50	34	80	5	85	30	150	4	78	50	100	4	76	60	140	8
conductivity	µS/cm	747	400	1390	10	298	143	751	4	249	190	444	7	288	199	375	10
dissolved organic carbon	mg/L	16	10	21	10	14	12	22	4	20	13	33	7	20	14	25	10
hardness	mg/L	214	185	266	5	86	63	147	4	97	80	116	6	104	96	114	8
pH (lab)	-	7.9	7.5	8.5	10	8.2	8.0	8.2	4	8.2	7.8	8.4	7	8.3	7.5	8.4	10
total alkalinity	mg/L	188	133	259	10	90	58	155	4	105	86	144	7	104	66	120	10
total dissolved solids	mg/L	454	264	790	10	180	140	450	4	210	125	300	7	187	130	250	10
total organic carbon	mg/L	16	11	27	10	16	14	24	4	20	16	34	7	20	14	27	10
total suspended solids	mg/L	5	<3	128	10	38	3	359	4	23	13	63	7	22	<3	144	10
Major Ions																	
bicarbonate	mg/L	263	222	316	5	109	70	189	4	123	105	146	4	130	116	147	8
calcium	mg/L	48	30	71	10	19	17	39	5	27	21	36	7	27	18	32	11
carbonate	mg/L	<5	<5	<5	5	<5	<5	<5	4	<5	<5	<5	4	<5	<5	<5	8
chloride	mg/L	119	56	**279** (C)	10	35	5	131	4	25	14	64	7	23	9	41	10
magnesium	mg/L	15	10	22	10	7	5	12	4	8	7	12	7	8	5	9	10
potassium	mg/L	2	0.9	3	10	2	1	3	4	0.8	0.7	1	7	1	0.5	1	10
sodium	mg/L	90	40	212	10	28	8	100	4	23	15	50	7	25	11	34	10
sulphate	mg/L	21	13	48	10	10	8	27	4	7	4	15	7	7	2	9	10
sulphide	mg/L	0.003	<0.003	0.008	5	0.005	<0.003	0.007	4	0.004	<0.003	0.006	4	0.006	<0.003	0.011	8
Nutrients and Biological Indicators																	
nitrate + nitrite	mg-N/L	0.4	0.1	0.8	10	<0.1	<0.1	<0.1	4	<0.1	<0.003	<0.1	7	<0.1	0.007	<0.1	10
nitrogen - ammonia	mg-N/L	0.12	<0.05	0.32	5	<0.05	<0.05	<0.05	4	<0.05	<0.05	<0.05	4	<0.05	<0.05	<0.05	8
nitrogen - Kjeldahl	mg-N/L	0.9	0.4	2.2	10	0.9	0.5	2	4	0.9	0.7	1.7	7	1	0.5	1.7	10
nitrogen - total	mg-N/L	**1.3** (C)	0.8	**2.3** (C)	10	0.9	0.5	**2.0** (C)	4	0.9	0.7	**1.7** (C)	7	**1.0** (C)	0.5	**1.7** (C)	10
phosphorus - total	mg-P/L	**0.067** (C)	**0.051** (C)	**0.17** (C)	10	**0.069** (C)	0.031	**0.322** (C)	4	**0.074** (C)	0.03	**0.179** (C)	7	**0.063** (C)	0.049	**0.142** (C)	10
phosphorus - dissolved	mg-P/L	0.020	0.017	0.024	5	0.025	0.010	0.045	4	0.036	0.017	0.048	4	0.024	0.018	0.054	8
biochemical oxygen demand	mg/L	<2	<2	<2	5	3	<2	4	4	<2	<2	2	4	<2	<2	5	8
chlorophyll *a*	µg/L	<1	<1	2	3	4	4	5	3	-	3	6	2	9	1	1.5	3
General Organics																	
napthenic acids	mg/L	<1	<1	2	5	<1	<1	<1	4	<1	<1	3	4	<1	0.2	<1	8
total phenolics	mg/L	<0.001	<0.001	**0.005** (C,W)	10	<0.001	<0.001	**0.008** (C,W)	4	<0.001	<0.001	**0.01** (C,W)	7	0.002	<0.001	**0.014** (C,W)	10
total recoverable hydrocarbons	mg/L	0.8	<0.5	1.3	10	<0.5	<0.5	<0.5	4	<0.5	<0.5	1.5	7	<0.5	<0.5	0.9	10
Metals (Total)																	
aluminum	mg/L	**0.13** (C,H)	0.06	**1.38** (A,C,H)	5	**0.85** (A,C,H)	**0.31** (C,H)	**5.45** (A,C,H,W)	4	**0.74** (C,H)	**0.53** (C,H)	**4.86** (A,C,H)	4	**0.60** (C,H)	**0.24** (C,H)	**0.84** (A,C,H)	8
antimony	mg/L	0.00004	0.00002	0.0001	4	0.00004	0.00003	0.00009	3	0.00007	0.00004	0.0006	4	0.00003	0.00002	0.00005	8
arsenic	mg/L	0.0009	0.0008	0.0011	5	0.0011	0.001	0.0024	4	0.0013	0.001	0.0021	4	0.0011	0.0007	0.0017	8
barium	mg/L	0.047	0.043	0.073	5	0.036	0.032	0.096	4	0.037	0.033	0.068	4	0.032	0.02	0.041	8
beryllium	mg/L	<0.00001	0.000007	<0.001	5	0.0002	<0.00004	<0.001	4	0.00004	0.00002	<0.001	4	0.00004	0.00002	0.0001	8
boron	mg/L	0.14	0.11	0.24	5	0.06	0.04	0.13	4	0.05	0.05	0.08	4	0.05	0.03	0.07	8
cadmium	mg/L	0.00002	0.00001	**0.0018** (C)	5	0.00005	0.00002	0.00008	3	0.00002	0.00001	0.00004	3	0.00001	<0.000006	0.00002	8
chromium	mg/L	0.0008	<0.0003	**0.0023** (C)	5	**0.0015** (C)	<0.0008	**0.0076** (C)	4	**0.0011** (C)	0.0007	**0.0058** (C)	4	**0.0011** (C)	0.0007	**0.0017** (C)	8
cobalt	mg/L	0.0002	0.0001	0.0008	5	0.0006	<0.0002	0.0029	4	0.0004	0.0003	0.0018	4	0.0003	0.0002	0.0006	8
copper	mg/L	0.0006	0.0005	**0.0048** (C)	5	0.0016	0.0009	**0.0061** (C)	4	0.001	0.001	**0.0039** (C)	4	0.0009	0.0006	0.0012	8
iron	mg/L	**0.96** (C,H)	**0.74** (C,H)	**1.69** (C,H)	5	**1.81** (C,H)	**0.36** (C,H)	**7.24** (C,H)	4	**1.69** (C,H)	**0.51** (C,H)	**5.81** (C,H)	4	**1.35** (C,H)	**0.78** (C,H)	**2.51** (C,H)	8
lead	mg/L	0.0004	0.00008	0.0013	5	0.0007	0.0003	0.0046	4	0.0006	0.0001	0.0022	4	0.0003	0.0002	0.0005	8
lithium	mg/L	0.022	0.017	0.038	5	0.011	0.008	0.022	4	0.01	0.008	0.012	4	0.009	0.004	0.011	8

Table E-9 Water Quality of the Christina River – Downstream (continued)

Parameter	Units	Winter (1978-79, 2002-2005, 2007)				Spring (2002-2005)				Summer (1978, 2002-2005)				Fall (1978, 2002-2009)			
		Median	Minimum	Maximum	n	Median	Minimum	Maximum	n	Median	Minimum	Maximum	n	Median	Minimum	Maximum	n
manganese	mg/L	0.03	0.027	**1.1** (H)	5	**0.072** (H)	**0.057** (H)	**0.226** (H)	4	**0.115** (H)	**0.091** (H)	**0.167** (H)	4	**0.062** (H)	0.044	**0.112** (H)	8
mercury	mg/L	<0.0000012	0.000001	**0.0001** (A,C)	5	**0.0000148** (A,C)	<0.0000012	**0.0000263** (A,C)	4	0.0000029	<0.0000006	**0.0000105** (C)	4	<0.0000012	<0.0000006	**0.0000158** (A,C)	8
molybdenum	mg/L	0.0005	0.0005	0.001	5	0.0005	0.0002	0.0009	4	0.0004	0.0003	0.0006	4	0.0004	0.0002	0.0004	8
nickel	mg/L	0.0005	0.0003	0.0018	5	0.0014	0.0007	0.0066	4	0.0011	0.0008	0.0041	4	0.0008	0.0004	0.0014	8
selenium	mg/L	0.001	0.0006	**0.0011** (C)	5	0.0004	0.0001	**0.0011** (C)	4	0.0004	0.0003	0.0008	4	0.0003	0.0003	<0.0005	8
silver	mg/L	0.000013	0.000003	0.00004	5	0.000021	0.000011	0.000042	4	0.00001	0.000005	0.00003	4	0.000007	0.000001	0.000017	8
strontium	mg/L	0.38	0.26	0.52	5	0.12	0.07	0.3	4	0.11	0.1	0.18	4	0.13	0.08	0.15	8
thallium	mg/L	0.00002	0.000004	<0.0001	5	0.0001	0.00002	0.00013	4	0.00008	0.00001	0.0002	4	0.00001	0.000007	0.0001	8
titanium	mg/L	0.0046	0.0027	0.0314	5	0.0224	0.008	0.0859	4	0.0188	0.007	0.0819	4	0.0138	0.0058	0.035	8
uranium	mg/L	0.0002	0.0001	0.0005	5	0.0002	0.0001	0.0006	4	0.0002	0.0001	0.0003	4	0.0001	0.00009	0.0002	8
vanadium	mg/L	0.0006	0.0002	0.0027	5	0.0029	0.0014	0.0134	4	0.0024	0.0014	0.0098	4	0.0019	0.0008	0.0022	8
zinc	mg/L	0.006	0.003	0.015	5	0.01	0.005	0.022	4	0.012	<0.004	0.018	4	0.003	0.002	0.009	8
Metals (Dissolved)																	
aluminum	mg/L	0.003	0.001	0.040	5	0.022	0.012	0.066	4	0.012	0.011	0.040	4	0.010	0.007	0.018	8
antimony	mg/L	0.00004	0.00002	<0.0008	5	0.0001	0.00003	<0.0008	4	0.00007	0.00003	<0.0004	4	0.00003	0.00002	0.00004	8
arsenic	mg/L	0.0006	0.0005	0.0014	5	0.0006	0.0004	0.0009	4	0.0009	0.0008	0.001	4	0.0008	0.0005	0.0012	8
barium	mg/L	0.043	0.037	0.065	5	0.024	0.022	0.035	4	0.025	0.024	0.028	4	0.025	0.014	0.027	8
beryllium	mg/L	<0.00001	<0.000003	<0.0005	5	0.00003	0.000006	<0.0005	4	<0.00002	<0.000003	<0.0005	4	0.00001	<0.000003	0.0002	8
boron	mg/L	0.13	0.1	0.24	5	0.05	0.03	0.14	4	0.04	0.04	0.09	4	0.05	0.02	0.07	8
cadmium	mg/L	0.00001	0.000003	0.0002	5	0.00003	0.000004	<0.0001	4	0.000009	0.000005	<0.0001	4	<0.000006	<0.000002	0.00001	8
chromium	mg/L	0.0004	<0.0003	0.002	5	0.0004	0.0003	0.0008	4	0.0004	<0.00003	0.0005	4	0.0004	0.0002	0.0007	8
cobalt	mg/L	0.00009	0.00006	0.0004	5	0.0001	0.0001	0.0002	4	0.00009	0.00007	0.0001	4	0.00009	0.00004	0.0001	8
copper	mg/L	0.0006	0.0004	0.0031	5	0.0012	0.0009	0.0015	4	0.0008	0.0007	0.001	4	0.0005	0.0003	0.0012	8
iron	mg/L	0.04	<0.002	0.33	5	0.41	0.12	0.58	4	0.46	0.12	0.48	4	0.43	0.26	0.96	8
lead	mg/L	0.0001	0.00002	0.0002	5	0.0002	0.00009	0.0002	4	0.0002	0.0001	0.0004	4	0.00005	0.00003	0.0003	8
lithium	mg/L	0.022	0.016	0.037	5	0.008	0.005	0.023	4	0.007	0.006	0.014	4	0.008	0.004	0.011	8
manganese	mg/L	0.016	0.002	0.936	5	0.015	0.003	0.019	4	0.005	0.003	0.055	4	0.004	0.002	0.01	8
mercury	mg/L	<0.000025	<0.00001	<0.00005	4	<0.0000218	<0.00001	<0.00004	3	<0.0000104	<0.00001	<0.00004	3	<0.00004	<0.00001	<0.00005	8
molybdenum	mg/L	0.0005	0.0005	0.0007	5	0.0004	0.0002	0.0009	4	0.0004	0.0003	0.0006	4	0.0004	0.0002	0.0004	8
nickel	mg/L	0.0003	0.00004	0.001	5	0.0005	0.0003	0.0017	4	0.0007	0.0005	0.0017	4	0.0004	0.00009	0.0007	8
selenium	mg/L	0.0004	0.0003	0.0007	5	0.0003	0.0001	0.0006	4	0.0004	0.0003	0.0006	4	0.0003	0.0002	<0.0005	8
silver	mg/L	0.000003	<0.0000005	0.00001	4	0.000008	0.000003	0.00001	3	0.0000008	0.0000007	0.000008	3	<0.000005	<0.0000005	0.000005	8
strontium	mg/L	0.38	0.24	0.51	5	0.12	0.06	0.3	4	0.11	0.09	0.18	4	0.12	0.08	0.15	8
thallium	mg/L	0.00001	0.000004	0.00017	5	0.00004	0.000004	0.0002	4	0.00005	0.000004	0.0002	4	0.000006	0.000001	0.0001	8
titanium	mg/L	0.002	0.0009	0.0041	5	0.0022	0.0018	0.0077	4	0.0018	0.0017	0.0023	4	0.0018	0.0013	0.0025	8
uranium	mg/L	0.0002	0.0001	0.0002	5	0.0001	0.00009	0.0002	4	0.0001	0.0001	0.0001	4	0.0001	0.00006	0.0001	8
vanadium	mg/L	0.0003	<0.00001	0.0023	5	0.0006	0.0003	0.0008	4	0.0004	0.0004	0.0006	4	0.0004	0.0003	0.0005	8
zinc	mg/L	0.004	0.002	0.04	5	0.003	<0.002	0.005	4	0.008	<0.002	0.01	4	0.001	0.0003	0.006	8
Target PAHs and Alkylated PAHs																	
naphthalene	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	<0.02	<0.02	<0.02	3
C1 substituted naphthalenes	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	<0.02	<0.02	<0.02	3
C2 substituted naphthalenes	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.04	<0.04	2
C3 substituted naphthalenes	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.04	<0.04	2
C4 substituted naphthalenes	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.04	<0.04	2
acenaphthene	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	<0.02	<0.02	<0.02	3
C1 substituted acenaphthene	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	<0.04	<0.04	<0.04	3
acenaphthylene	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	<0.02	<0.02	<0.02	3
anthracene	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	<0.02 (D>C)	<0.02 (D>C)	<0.02 (D>C)	3
dibenzo(a,h)anthracene	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	<0.02 (D>H)	<0.02 (D>H)	<0.02 (D>H)	3
benzo(a) anthracene / chrysene	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.02 (D>C,H)	<0.02 (D>C,H)	2
C1 substituted benzo(a)anthracene / chrysene	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	<0.04	<0.04	<0.04	3
C2 substituted benzo(a)anthracene / chrysene	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.04	<0.04	2

Table E-9 Water Quality of the Christina River – Downstream (continued)

Parameter	Units	Winter (1978-79, 2002-2005, 2007)				Spring (2002-2005)				Summer (1978, 2002-2005)				Fall (1978, 2002-2009)			
		Median	Minimum	Maximum	n	Median	Minimum	Maximum	n	Median	Minimum	Maximum	n	Median	Minimum	Maximum	n
benzo(a)pyrene	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	<0.02 (D>C,H)	<0.02 (D>C,H)	<0.02 (D>C,H)	3
C1 substituted benzo(b&k)fluoranthene / benzo(a)pyrene	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	<0.04	<0.04	<0.04	3
C2 substituted benzo(b&k)fluoranthene / benzo(a)pyrene	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.04	<0.04	2
benzo(b&k)fluoranthene	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.02 (D>H)	<0.02 (D>H)	2
benzo(g,h,i)perylene	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	<0.02	<0.02	<0.02	3
biphenyl	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	<0.04	<0.04	<0.04	3
C1 substituted biphenyl	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	<0.04	<0.04	<0.04	3
C2 substituted biphenyl	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.04	<0.04	2
dibenzothiophene	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	<0.02	<0.02	<0.02	3
C1 substituted dibenzothiophene	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	<0.04	<0.04	<0.04	3
C3 substituted dibenzothiophene	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.04	<0.04	2
C4 substituted dibenzothiophene	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.04	<0.04	2
fluoranthene	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	<0.02	<0.02	<0.02	3
C1 substituted fluoranthene / pyrene	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	<0.04	<0.04	<0.04	3
fluorene	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	<0.02	<0.02	<0.02	3
C1 substituted fluorene	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	<0.04	<0.04	<0.04	3
C2 substituted fluorene	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.04	<0.04	2
indeno(c,d-123)pyrene	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	<0.02 (D>H)	<0.02 (D>H)	<0.02 (D>H)	3
phenanthrene	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	<0.02	<0.02	<0.02	3
C1 substituted phenanthrene / anthracene	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	<0.04	<0.04	<0.04	3
C2 substituted phenanthrene / anthracene	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.04	<0.04	2
C3 substituted phenanthrene / anthracene	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.04	<0.04	2
C4 substituted phenanthrene / anthracene	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.04	<0.04	2
pyrene	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	<0.02	<0.02	<0.02	3

- = No data or not applicable.

Notes: **Bolded** concentrations are higher than relevant water quality guidelines.
(A) 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.
(H) Concentration higher than the relevant human health guideline or beyond the recommended pH range.
(W) Concentration higher than the relevant wildlife health guideline.
(D>) Analytical detection limit was higher than the relevant water quality guideline(s).

Source: WDS (AEW 2011), RAMP (2002-2011); Gartner Lee (2007).

Table E-10 Water Quality of the Wolf River

Parameter	Units	Winter (1984-1985)		
		Median (Min)	Maximum	n
Field Measured				
dissolved oxygen	mg/L	10.7 (8.5) [a]	11.2	10
Conventional Parameters				
conductivity	µS/cm	436	538	7
hardness	mg/L	203	268	7
pH (lab)	-	7.8 (7.5) [a]	8.1	7
total alkalinity	mg/L	240	295	7
total dissolved solids	mg/L	235	297	7
total organic carbon	mg/L	15	16	6
total suspended solids	mg/L	5	6	3
Major Ions				
bicarbonate	mg/L	292	360	7
calcium	mg/L	50	71	7
chloride	mg/L	<1	2	7
magnesium	mg/L	19	22	7
potassium	mg/L	2	2	7
sodium	mg/L	14	18	7
sulphate	mg/L	<5	<5	7
Nutrients and Biological Indicators				
nitrate + nitrite	mg-N/L	0.05	0.2	7
nitrogen - Kjeldahl	mg-N/L	0.9	1	7
nitrogen - total	mg-N/L	0.95	**1.1** (C)	7
phosphorus - total	mg-P/L	0.021	0.034	7
phosphorus - dissolved	mg-P/L	0.01	0.012	5
chlorophyll *a*	µg/L	1.2	-	1
General Organics				
total phenols	mg/L	**0.008** (C,W)	**0.009** (C,W)	2
Metals (Total)				
aluminum	mg/L	0.06	0.065	5
arsenic	mg/L	0.0007	0.0009	5
beryllium	mg/L	<0.001	<0.001	3
cadmium	mg/L	<0.001 (D>C)	<0.001 (D>C)	5
chromium	mg/L	<0.001	**0.004** (C)	5
cobalt	mg/L	<0.001	<0.001	5
copper	mg/L	**0.005** (C)	**0.006** (C)	5
lead	mg/L	<0.003	0.007	5
manganese	mg/L	**0.328** (H)	**0.615** (H)	5
molybdenum	mg/L	<0.001	<0.001	5
nickel	mg/L	0.004	0.005	5
zinc	mg/L	0.002	0.017	5
Metals (Dissolved)				
beryllium	mg/L	<0.001	<0.001	2

(a) Minimum values are in brackets and are only presented for parameters with guidelines that consist of ranges of values.

- = No data or not applicable.

Notes: **Bolded** concentrations are higher than relevant water quality guidelines.
(A) 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.
(H) Concentration higher than the relevant human health guideline or beyond the recommended pH range.
(W) Concentration higher than the relevant wildlife health guideline.
(D>) Analytical detection limit was higher than the relevant water quality guideline(s).

Source: AEW (2011).

Table E-11 Water Quality of the Sand River (1983-1984)

Parameter	Units	Winter			Spring			Summer			Fall		
		Median (Min)	Maximum	n	Median (Min)	Maximum	n	Median (Min)	Maximum	n	Median (Min)	Maximum	n
Field Measured													
dissolved oxygen	mg/L	**3.8**$^{(A,C)}$ (**0**$^{(A,C)}$) [a]	11.8	60	10.8 (8.9) [a]	13.4	5	8.4 (**6.4**$^{(C)}$) [a]	11.3	8	11.3 (10.7) [a]	13.5	5
Conventional Parameters													
conductivity	µS/cm	409	538	30	276	315	5	289	322	7	308	320	5
hardness	mg/L	193	377	27	120	135	2	123	156	4	146	155	2
pH (lab)	-	7.6 (7.3) [a]	8.1	29	8.2 (8.0) [a]	8.4	5	8.3 (7.4) [a]	8.5	7	8.3 (8.2) [a]	8.4	5
total alkalinity	mg/L	223	295	29	144	169	5	153	172	7	164	166	5
total dissolved solids	mg/L	222	297	29	148	167	5	154	174	7	167	169	5
total organic carbon	mg/L	14	16	27	9	12	5	14	16	7	13	17	5
total suspended solids	mg/L	8	20	16	7	9	5	12	98	6	7	13	5
Major Ions													
bicarbonate	mg/L	271	360	27	175	198	2	131	187	4	196	203	2
calcium	mg/L	51	71	29	33	36	5	34	41	7	39	39	5
chloride	mg/L	2	2	29	<1	2	5	<1	2	7	<1	2	5
magnesium	mg/L	16	22	28	10	11	5	11	13	7	13	14	5
potassium	mg/L	2	2	29	2	2	5	1	1	7	0.9	1	5
sodium	mg/L	13	18	29	10	10	5	6	12	7	9	11	5
sulphate	mg/L	<5	10	29	<5	<5	5	<5	6	7	<5	<5	5
sulphide	mg/L	<0.02$^{(D>C)}$	<0.02$^{(D>C)}$	7	-	-	-	-	-	-	-	-	-
Nutrients and Biological Indicators													
nitrate + nitrite	mg-N/L	0.1	0.2	29	0.004	0.01	5	0.003	0.02	7	0.005	0.04	5
nitrogen - Kjeldahl	mg-N/L	0.8	1.2	29	0.5	0.5	5	0.6	0.9	7	0.6	0.7	5
nitrogen - total	mg-N/L	0.9	**1.3**$^{(C)}$	29	0.5	0.51	5	0.62	0.91	7	0.63	0.72	5
phosphorus - total	mg-P/L	0.036	**0.138**$^{(C)}$	29	0.036	0.043	5	0.045	**0.168**$^{(C)}$	8	0.032	0.048	5
phosphorus - dissolved	mg-P/L	0.012	0.03	19	0.011	0.016	2	0.015	0.023	4	0.013	-	1
biochemical oxygen demand	mg/L	1	2	6	2	2	3	<1	1	3	<1	1	3
chlorophyll *a*	µg/L	1.2	3.3	7	3.5	3.6	3	4.6	8.6	4	2.5	2.8	3
General Organics													
total phenols	mg/L	**0.006**$^{(C,W)}$	**0.012**$^{(C,W)}$	12	**0.004**$^{(W)}$	**0.005**$^{(W)}$	5	**0.004**$^{(W)}$	**0.009**$^{(C,W)}$	7	**0.005**$^{(W)}$	**0.009**$^{(C,W)}$	5
Metals (Total)													
aluminum	mg/L	0.065	**0.38**$^{(C,H)}$	24	0.03	0.045	5	0.051	**0.352**$^{(C,H)}$	7	0.05	**0.11**$^{(C,H)}$	5
arsenic	mg/L	0.0007	0.0017	24	0.0008	0.0009	5	0.0012	0.002	7	0.0008	0.0011	5
barium	mg/L	0.057	-	1	-	-	-	-	-	-	-	-	-
beryllium	mg/L	<0.001	<0.001	13	<0.001	<0.001	5	<0.001	<0.001	7	<0.001	<0.001	5
cadmium	mg/L	<0.001$^{(D>C)}$	**0.002**$^{(C)}$	24	<0.001$^{(D>C)}$	**0.002**$^{(C)}$	5	<0.001$^{(D>C)}$	**0.002**$^{(C)}$	7	<0.001$^{(D>C)}$	**0.002**$^{(C)}$	5
chromium	mg/L	**0.003**$^{(C)}$	**0.007**$^{(C)}$	24	**0.006**$^{(C)}$	**0.014**$^{(C)}$	5	<0.001	**0.004**$^{(C)}$	7	**0.003**$^{(C)}$	**0.003**$^{(C)}$	5
cobalt	mg/L	<0.001	0.002	24	<0.001	<0.001	5	<0.001	<0.001	7	<0.001	<0.001	5
copper	mg/L	<0.001	**0.011**$^{(C)}$	24	<0.001	0.002	5	0.002	0.002	6	<0.001	0.002	5
lead	mg/L	<0.003	**0.012**$^{(H)}$	24	<0.003	0.004	5	<0.003	**0.016**$^{(C,H)}$	7	<0.003	**0.008**$^{(C)}$	5
manganese	mg/L	**0.407**$^{(H)}$	**3.29**$^{(H)}$	24	0.039	0.044	5	0.047	**0.121**$^{(H)}$	7	0.025	0.039	5
molybdenum	mg/L	<0.001	0.004	24	<0.001	0.007	5	<0.001	<0.001	7	<0.001	<0.001	5
nickel	mg/L	0.004	0.007	24	0.004	0.006	5	0.004	0.008	7	0.004	0.004	5
selenium	mg/L	<0.0002	<0.0002	24	<0.0002	<0.0002	5	<0.0002	<0.0002	6	<0.0002	<0.0002	5
vanadium	mg/L	<0.002	0.005	24	0.003	0.003	5	0.003	0.005	7	<0.002	0.004	5
zinc	mg/L	0.004	**0.8**$^{(A,C)}$	24	0.004	0.007	5	0.007	**0.208**$^{(A,C)}$	7	0.003	0.005	5
Metals (Dissolved)													
beryllium	mg/L	<0.001	<0.001	-	-	-	-	-	-	-	-	-	-

[a] Minimum values are in brackets and are only presented for parameters with guidelines that consist of ranges of values.

- = No data or not applicable.

Notes: **Bolded** concentrations are higher than relevant water quality guidelines.

(A) 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.

(H) Concentration higher than the relevant human health guideline or beyond the recommended pH range.

(W) Concentration higher than the relevant wildlife health guideline.

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

Source: AEW (2011).

Table E-12 Water Quality of Small Watercourses in the Regional Study Area (1998, 2003, 2004, 2007, 2010, 2011)

Parameter	Units	Winter				Spring				Summer				Fall			
		Median	Minimum	Maximum	n	Median	Minimum	Maximum	n	Median	Minimum	Maximum	n	Median	Minimum	Maximum	n
Field Measured																	
pH	-	7.3	**5.4**[A,C]	8.1	7	**6.3**[A,C]	**5**[A,C]	8.0	15	7.6	**5.5**[A,C]	8.5	15	7.6	6.9	8.5	14
conductivity	µS/cm	35	30	158	7	117	34	184	15	197	89	646	15	155	62	328	14
temperature	°C	0.2	0.1	0.7	7	8.2	4.6	11.2	15	15.7	12.9	23.3	14	6.3	4.8	9.4	14
dissolved oxygen	mg/L	**5**[C]	**2.9**[A,C]	10.2	7	9.6	7.4	11.5	15	7.9	**2.1**[A,C]	11.5	13	9.1	**6**[C]	13.4	14
Conventional Parameters																	
colour	TCU	-	-	-	-	60	9	100	11	60	8	110	7	59	10	72	9
conductivity	µS/cm	420	210	470	5	98	31	220	19	189	71	340	15	177	62	320	14
dissolved organic carbon	mg/L	8	6	30	5	18	8	31	19	26	10	36	15	23	8	28	14
hardness	mg/L	190	100	230	7	45	13	110	19	123	36	181	15	91	32	157	14
pH (lab)	-	8.0	7.5	8.2	5	7.6	**6.2**[A,C]	8.2	19	7.9	6.5	8.3	15	7.9	7.2	8.3	14
total alkalinity	mg/L	220	110	260	7	47	5	110	19	102	26	180	17	93	27	160	14
total dissolved solids	mg/L	220	110	250	7	89	13	140	19	145	39	226	15	136	32	164	14
total organic carbon	mg/L	-	-	-	-	18	9	23	11	27	10	32	9	23	11	25	9
total suspended solids	mg/L	-	2	2	2	4	<3	54	11	6	3	12	9	<3	<3	10	9
Major Ions																	
bicarbonate	mg/L	260	130	310	7	57	6	130	19	124	32	220	17	113	33	190	14
calcium	mg/L	51	26	61	7	12	4	28	19	27	9	49	17	23	8	42	14
carbonate	mg/L	<0.5	<0.5	<6	7	<5	<0.5	<5	19	<5	<0.5	<5	17	<5	<0.5	<5	14
chloride	mg/L	1	<0.5	4	7	1	<1	5	19	1	0.9	8	17	1	<1	3	14
magnesium	mg/L	16	9	18	7	4	1	9	19	8	3	14	17	7	3	13	14
potassium	mg/L	1	0.7	3	7	1	0.7	2	19	0.7	0.1	2	17	0.9	0.3	1	14
sodium	mg/L	10	4	11	7	3	1	10	19	6	1	17	17	3	<1	8	14
sulphate	mg/L	2	<1	4	7	1	<0.5	<10	19	1	<0.5	<10	17	1	<0.5	1	14
sulphide	mg/L	**0.023**[C]	<0.002	**0.045**[C]	5	**0.005**[C]	<0.002	**0.025**[C]	19	0.007	0.003	**0.02**[C]	15	0.005	<0.003	**0.016**[C]	14
Nutrients and Biological Indicators																	
nitrate + nitrite	mg-N/L	<0.006	<0.003	0.1	7	<0.1	<0.003	<0.1	19	<0.1	<0.003	<0.1	17	<0.1	0.005	<0.1	14
nitrogen - ammonia	mg-N/L	0.44	0.08	1.2	7	<0.05	<0.05	0.33	19	<0.05	<0.05	0.07	17	<0.05	<0.05	0.12	14
nitrogen - Kjeldahl	mg-N/L	1	0.8	2.4	7	0.7	<0.2	0.9	19	0.7	0.6	2.1	17	0.7	0.4	0.9	14
nitrogen - total	mg-N/L	**1.0**[C]	0.9	**2.4**[C]	7	0.7	<0.2	0.9	19	0.7	0.6	**2.1**[C]	17	0.7	0.4	0.9	14
phosphorus - total	mg-P/L	**0.086**[C]	0.008	**0.81**[C]	7	0.035	0.012	**0.21**[C]	19	**0.059**[C]	0.017	**0.38**[C]	17	0.024	0.003	**0.15**[C]	14
phosphorus - dissolved	mg-P/L	<0.1	0.008	<0.1	7	0.032	0.004	0.1	19	0.032	0.007	0.2	17	0.016	0.003	<0.1	14
biochemical oxygen demand	mg/L	-	<4	<4	2	<2	<2	3	14	<2	<2	<3	12	<2	<2	2	11
chlorophyll *a*	µg/L	-	-	-	-	3	2	4	5	-	<1	5	2	-	-	-	-
General Organics																	
napthenic acids	mg/L	<1	<1	<1	5	<1	<1	1.7	19	<1	<1	4	14	<1	<1	<1	14
total phenolics	mg/L	**0.009**[C,W]	<0.002	**0.07**[C,W]	5	<0.001	<0.001	**0.012**[C,W]	19	**0.007**[C,W]	<0.002	**0.012**[C,W]	15	**0.007**[C,W]	<0.002	**0.07**[C,W]	14
total recoverable hydrocarbons	mg/L	-	-	-	-	<1	<0.5	<1	11	<1	<0.5	<1	9	<1	<1	<1	9
Metals (Total)																	
aluminum	mg/L	0.062	0.005	**0.139**[C,H]	7	**0.09**[C]	**0.008**[C]	**0.84**[A,C,H]	19	0.04	0.02	**0.27**[C,H]	17	0.02	0.013	**0.6**[C,H]	14
antimony	mg/L	0.0002	<0.0002	0.0008	7	0.0007	<0.0002	0.0018	19	0.0006	<0.0002	0.0016	17	<0.0004	<0.0002	0.0014	14
arsenic	mg/L	0.0015	0.0007	**0.012**[C,H]	7	0.0008	<0.0004	0.0026	19	0.0009	<0.0004	0.002	17	0.0006	<0.0004	0.0015	14
barium	mg/L	0.08	0.04	0.11	7	0.013	0.007	0.07	19	0.024	0.011	0.11	17	0.013	0.006	0.08	14
beryllium	mg/L	<0.001	<0.0001	<0.001	7	<0.001	<0.001	<0.001	19	<0.001	<0.001	<0.001	17	<0.001	<0.001	<0.005[D>H]	14
boron	mg/L	0.03	<0.02	0.06	7	<0.02	<0.02	0.04	19	0.03	<0.002	0.06	17	<0.02	<0.002	<0.02	14
cadmium	mg/L	<0.000006	<0.000005	0.00001	7	<0.0002[D>C]	<0.000005	<0.0002[D>C]	19	<0.0002	<0.000005	<0.0002	17	<0.0002	<0.000005	<0.0002	14
calcium	mg/L	-	-	-	-	13	7	24	9	24	13	35	8	22	12	27	9
chromium	mg/L	<0.001	<0.0005	<0.001	7	<0.001	<0.0008	**0.0033**[C]	19	<0.0008	<0.0008	**0.009**[C]	17	<0.0008	<0.0008	<0.005[D>C]	14
cobalt	mg/L	0.0003	0.0001	0.013	7	<0.0003	<0.0002	0.0008	19	<0.0003	<0.0002	0.011	17	<0.0003	<0.0002	<0.002	14
copper	mg/L	0.0003	0.0001	0.0006	7	0.0001	<0.0002	**0.003**[C]	19	0.001	0.0003	0.001	17	<0.001	0.0004	0.001	14
iron	mg/L	**2.4**[C,H]	0.3	**41**[C,H]	7	**0.46**[C,H]	0.12	**3.4**[C,H]	19	**0.87**[C,H]	0.07	**7.5**[C,H]	17	**0.4**[C,H]	0.06	**3**[C,H]	14
lead	mg/L	<0.0002	<0.0002	0.0002	7	<0.0002	<0.0001	0.0009	19	<0.0002	<0.0001	0.0004	17	<0.0001	<0.0001	<0.001	14
lithium	mg/L	<0.02	<0.02	0.02	7	<0.006	<0.0001	<0.02	19	<0.006	<0.006	<0.02	17	<0.006	<0.006	<0.02	14

Table E-12 Water Quality of Small Watercourses in the Regional Study Area (continued)

Parameter	Units	Winter				Spring				Summer				Fall			
		Median	Minimum	Maximum	n	Median	Minimum	Maximum	n	Median	Minimum	Maximum	n	Median	Minimum	Maximum	n
magnesium	mg/L	14	14	14	2	5	2	7	9	5	3	11	10	7	4	9	9
manganese	mg/L	**0.7**[H]	**0.05**[H]	**5.4**[H]	7	0.03	0.005	**0.13**[H]	19	**0.098**[H]	0.024	**0.78**[H]	17	**0.06**[H]	0.005	**0.3**[H]	14
mercury	mg/L	0.000002	<0.000002	0.000004	7	0.0000015	0.0000004	0.000005	19	0.000002	<0.0000006	0.000026	17	**0.000102**[A,C]	<0.0000006	**0.0003**[A,C]	14
methyl mercury	mg/L	-	-	-	-	0.00000003	<0.00000003	0.00000015	6	<0.00000003	<0.00000003	0.00000018	6	-	<0.00000003	0.00000004	2
molybdenum	mg/L	0.001	<0.0002	0.0014	7	0.0002	<0.0001	0.0009	19	0.0003	<0.0001	0.001	17	0.0002	<0.0001	0.001	14
nickel	mg/L	<0.0005	<0.0005	0.0029	7	0.0007	0.0004	0.0028	19	0.0008	0.0003	0.021	17	0.0009	0.0004	<0.003	14
potassium	mg/L	-	-	-	-	0.8	0.3	2	9	0.3	<0.1	0.8	8	0.3	<0.1	0.8	9
selenium	mg/L	<0.0002	<0.0002	<0.0002	7	<0.0004	<0.0002	0.0008	19	<0.0004	<0.0002	**0.0011**[C]	17	<0.0004	<0.0002	<0.001	14
silicon	mg/L	-	7.1	7.2	2	-	-	-	-	-	-	-	-	-	-	-	-
silver	mg/L	<0.0001	<0.0001	<0.0001	7	0.0000468	0.0000052	**0.000117**[C]	7	0.00001645	0.0000013	0.0000542	8	-	0.0000005	0.0000005	2
sodium	mg/L	-	-	-	-	2	1	9	9	4	1	17	8	4	1	7	9
strontium	mg/L	0.24	0.1	0.3	7	0.05	0.02	0.15	19	0.09	0.04	0.24	17	0.06	0.03	0.19	14
sulphur	mg/L	0.5	0.3	1.5	7	0.8	0.3	2	8	0.4	<0.2	0.6	6	0.4	0.3	0.9	5
thallium	mg/L	<0.0002	<0.00005	<0.0002	7	<0.0001	<0.0001	<0.0002	19	<0.0001	<0.0001	<0.0002	15	<0.0001	<0.0001	<0.001[D>C;H]	14
titanium	mg/L	0.0027	<0.001	0.0041	7	<0.005	<0.001	0.027	19	<0.005	0.0007	<0.005	17	<0.005	<0.001	0.021	14
uranium	mg/L	<0.0001	<0.0001	<0.0005	7	<0.0001	<0.0001	0.0003	19	<0.0001	<0.0001	0.0003	17	<0.0001	<0.0001	<0.0005	14
vanadium	mg/L	0.001	0.0004	<0.01	7	0.001	<0.0002	0.004	19	<0.0003	<0.0002	<0.001	17	<0.0002	<0.0002	<0.005	14
zinc	mg/L	0.003	<0.003	**0.042**[C]	7	0.008	<0.003	**0.035**[C]	19	0.007	<0.004	**0.515**[A,C]	17	0.008	<0.003	<0.02	14
Metals (Dissolved)																	
aluminum	mg/L	<0.005	<0.001	0.049	7	0.01	0.004	0.37	19	<0.01	<0.001	0.19	15	0.01	0.003	0.13	14
antimony	mg/L	<0.0002	<0.0002	<0.0002	7	0.0005	<0.0002	0.0011	19	0.0005	<0.0002	0.0007	15	0.0006	<0.0002	<0.001	14
arsenic	mg/L	0.0008	0.0006	0.0081	7	0.0004	0.0003	0.0011	19	0.0007	<0.0002	0.0011	15	0.0006	<0.0004	<0.001	14
barium	mg/L	0.04	0.03	0.1	7	0.01	0.004	0.06	19	0.024	0.009	0.1	15	0.014	0.006	0.08	14
beryllium	mg/L	<0.001	<0.0001	<0.001	7	<0.001	<0.0005	<0.001	19	<0.0005	<0.0005	<0.001	15	<0.0005	<0.0005	<0.005	14
boron	mg/L	0.02	<0.02	0.05	7	0.02	0.006	0.04	19	0.03	0.01	0.09	15	0.02	0.006	0.02	14
cadmium	mg/L	<0.000005	<0.000005	0.00001	7	<0.0001	<0.000005	<0.0001	19	<0.0001	<0.000005	<0.0001	15	<0.0001	<0.000005	<0.0001	14
chromium	mg/L	<0.001	<0.001	0.001	7	<0.0005	<0.0004	<0.001	19	<0.001	<0.0004	0.0015	15	<0.0004	<0.0004	<0.005	14
cobalt	mg/L	<0.0003	<0.0001	0.013	7	0.0003	0.0002	0.0035	19	0.0003	<0.0001	0.0071	15	<0.0001	<0.0001	<0.002	14
copper	mg/L	0.0005	<0.0002	0.003	7	0.0006	<0.0002	0.0013	19	<0.0006	<0.0002	0.0006	15	<0.0006	<0.0006	0.0047	14
iron	mg/L	0.16	0.07	2.2	7	0.28	0.009	1.1	19	0.45	0.01	4	15	0.24	0.01	3	14
lead	mg/L	<0.0002	<0.0002	<0.001	7	<0.0001	<0.0001	0.0002	19	<0.0002	<0.0001	0.0004	15	<0.0001	<0.0001	<0.001	14
lithium	mg/L	<0.02	0.006	0.02	7	0.006	0.001	<0.02	19	0.007	0.002	<0.02	15	0.004	0.001	<0.02	14
manganese	mg/L	0.68	0.038	4.4	7	0.015	0.003	0.11	19	0.053	0.001	0.66	15	0.03	<0.001	0.3	14
mercury	mg/L	<0.000002	<0.000002	<0.0001	7	<0.0000006	<0.0000006	<0.0001	11	<0.0000006	<0.0000006	<0.0001	9	<0.000051	<0.0000006	0.0001	14
molybdenum	mg/L	0.001	0.0007	0.0013	7	0.0002	<0.0001	0.0007	19	0.0002	<0.0001	0.0007	15	0.0002	<0.0001	<0.001	14
nickel	mg/L	<0.0005	<0.0005	0.0035	7	0.0005	0.0003	0.002	19	0.0008	<0.0005	0.003	15	0.0008	0.0004	<0.003	14
selenium	mg/L	<0.0002	<0.0002	0.0002	5	<0.0004	<0.0002	0.0007	19	<0.0004	<0.0002	0.0005	15	<0.0004	<0.0002	<0.001	14
silver	mg/L	<0.0001	<0.0001	0.0001	7	0.00000875	0.0000018	0.0000135	6	0.00000555	0.0000023	0.0000115	4	-	0.0000005	0.0000005	2
strontium	mg/L	0.24	0.08	0.3	7	0.05	0.02	0.14	19	0.07	0.03	0.25	15	0.06	0.03	0.19	14
thallium	mg/L	<0.0002	<0.00005	<0.0002	7	<0.00005	<0.00005	<0.0002	19	<0.00012	<0.00005	0.00024	15	<0.00005	<0.00005	<0.001	14
titanium	mg/L	<0.001	<0.0005	0.001	7	<0.0006	<0.0003	0.001	19	0.001	<0.0003	0.002	15	0.0007	<0.0003	<0.005	14
uranium	mg/L	0.0001	<0.0001	0.0002	5	<0.0001	<0.0001	<0.0001	19	<0.0001	<0.0001	0.0001	15	<0.0001	<0.0001	<0.0005	14
vanadium	mg/L	<0.001	0.0001	<0.001	7	<0.0004	<0.0001	<0.001	19	<0.0003	<0.0001	<0.001	15	<0.0001	<0.0001	<0.005	14
zinc	mg/L	0.003	0.001	0.036	7	0.003	0.002	0.013	19	0.004	<0.003	0.869	15	0.01	<0.002	4.13	14
Target PAHs and Alkylated PAHs																	
naphthalene	µg/L	<0.1	<0.1	<0.1	7	<0.1	<0.1	<0.1	8	<0.1	<0.1	<0.1	6	<0.1	<0.1	<0.1	5
acenaphthene	µg/L	<0.1	<0.1	<0.1	7	<0.1	<0.1	<0.1	8	<0.1	<0.1	<0.1	6	<0.1	<0.1	<0.1	5
acenaphthylene	µg/L	<0.1	<0.1	<0.1	7	<0.1	<0.1	<0.1	8	<0.1	<0.1	<0.1	6	<0.1	<0.1	<0.1	5
anthracene	µg/L	<0.01	<0.01	<0.1[D>C]	7	<0.01	<0.01	<0.01	8	<0.01	<0.01	<0.01	6	<0.01	<0.01	<0.01	5
dibenzo(a,h)anthracene	µg/L	<0.008[D>H]	<0.008[D>H]	<0.01[D>H]	7	<0.008[D>H]	<0.008[D>H]	<0.008[D>H]	8	<0.008[D>H]	<0.008[D>H]	<0.008[D>H]	6	<0.008[D>H]	<0.008[D>H]	<0.008[D>H]	5
benzo(a)anthracene / chrysene	µg/L	<0.0085[D>H]	<0.0085[D>H]	<0.1[D>C,H]	7	<0.0085[D>H]	<0.0085[D>H]	<0.0085[D>H]	8	<0.0085[D>H]	<0.0085[D>H]	<0.0085[D>H]	6	<0.0085[D>H]	<0.0085[D>H]	<0.0085[D>H]	5
benzo(a)pyrene	µg/L	<0.0075[D>H]	<0.0075[D>H]	<0.01[D>H]	7	<0.0075[D>H]	<0.0075[D>H]	<0.0075[D>H]	8	<0.0075[D>H]	<0.0075[D>H]	<0.0075[D>H]	6	<0.0075[D>H]	<0.0075[D>H]	<0.0075[D>H]	5
benzo(b&k)fluoranthenes	µg/L	<0.009[D>H]	<0.009[D>H]	<0.01[D>H]	7	<0.009[D>H]	<0.009[D>H]	<0.009[D>H]	8	<0.009[D>H]	<0.009[D>H]	<0.009[D>H]	6	<0.009[D>H]	<0.009[D>H]	<0.009[D>H]	5

Table E-12 Water Quality of Small Watercourses in the Regional Study Area (continued)

Parameter	Units	Winter				Spring				Summer				Fall			
		Median	Minimum	Maximum	n	Median	Minimum	Maximum	n	Median	Minimum	Maximum	n	Median	Minimum	Maximum	n
benzo(g,h,i)perylene	µg/L	<0.009	<0.009	<0.1	7	<0.009	<0.009	<0.009	8	<0.009	<0.009	<0.009	6	<0.009	<0.009	<0.009	5
fluoranthene	µg/L	<0.04	<0.04	<0.1 (D>C)	7	<0.04	<0.04	<0.04	8	<0.04	<0.04	<0.04	6	<0.04	<0.04	<0.04	5
fluorene	µg/L	-	<0.1	<0.1	2	-	-	-	-	-	-	-	-	-	-	-	-
indeno(c,d-123)pyrene	µg/L	<0.009 (D>H)	<0.009 (D>H)	<0.1 (D>H)	7	<0.009 (D>H)	<0.009 (D>H)	<0.009 (D>H)	8	<0.009 (D>H)	<0.009 (D>H)	<0.009 (D>H)	6	<0.009 (D>H)	<0.009 (D>H)	<0.009 (D>H)	5
phenanthrene	µg/L	<0.05	<0.05	<0.1	7	<0.05	<0.05	<0.05	8	<0.05	<0.05	<0.05	6	<0.05	<0.05	<0.05	5
pyrene	µg/L	<0.02	<0.02	<0.02	7	<0.02	<0.02	<0.02	8	<0.02	<0.02	<0.02	6	<0.02	<0.02	**0.04 (C)**	5
Volatile Organics																	
ethylbenzene	µg/L	-	<0.001	<0.001	2	-	-	-	-	**-**	**3 (W)**	**4 (W)**	2	-	-	-	-

- = No data or not applicable.

Notes: **Bolded** concentrations are higher than relevant water quality guidelines.

(A) 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.
(H) Concentration higher than the relevant human health guideline or beyond the recommended pH range.
(W) Concentration higher than the relevant wildlife health guideline.
(D>) Analytical detection limit was higher than the relevant water quality guideline(s).

Sources: MEG (2005, 2008); Canadian Natural (2007; includes data from 2001 and 2006); Canadian Natural (2011).

ATTACHMENT F

PROJECT-SPECIFIC SEDIMENT QUALITY SUMMARY

Table F-1 Waterbodies Sediment Quality in the Local Study Area

Parameter	Units [dry wt.]	Fall (2006-2011)			
		Median	Minimum	Maximum	n
Particle Size					
sand	%	85	72	95	8
silt	%	12	1	27	8
clay	%	3.5	<1	8	8
moisture content	%	94	27	97	8
Carbon Content					
total inorganic carbon	%	0.2	<0.1	4.2	8
total organic carbon	%	28	0.5	43	8
total carbon	%	29	0.5	45	8
Metals (Total)					
aluminum	µg/g	4,830	290	6,100	8
antimony	µg/g	<1	<1	<2	3
arsenic	µg/g	3.9	0.2	**7.2** [(l)]	8
barium	µg/g	116	10	207	8
beryllium	µg/g	<0.3	<0.2	0.3	8
boron	µg/g	12	<2	15	8
cadmium	µg/g	0.5	<0.1	**0.7** [(l)]	8
calcium	µg/g	10,000	300	17,800	8
chromium	µg/g	11	0.3	16	8
cobalt	µg/g	3.9	0.1	5	8
copper	µg/g	9.2	<0.5	24	8
iron	µg/g	9,650	600	12,100	8
lead	µg/g	4.5	<0.5	9	8
magnesium	µg/g	2,300	100	2,900	8
manganese	µg/g	237	19	480	8
mercury	µg/g	<0.1	<0.1	**0.2** [(l)]	8
molybdenum	µg/g	0.9	<0.1	1.6	8
nickel	µg/g	11	<0.5	17	8
potassium	µg/g	655	<100	1,200	8
selenium	µg/g	1	<0.2	2	8
silver	µg/g	<0.2	<0.2	<2	8
sodium	µg/g	115	<100	200	8
strontium	µg/g	25	5	60	8
thallium	µg/g	<0.1	<0.1	0.1	8
titanium	µg/g	53	8	120	8
uranium	µg/g	0.75	<0.1	0.8	8
vanadium	µg/g	15	0.7	24	8
zinc	µg/g	75	<5	115	8
Organics					
total recoverable hydrocarbons	µg/g	1,100	100	2,500	5
F1 (C_6-C_{10})	µg/g	<200	<170	<320	3
F2 (C_{10}-C_{16})	µg/g	<200	<100	<300	3
F3 (C_{16}-C_{34})	µg/g	<200	<100	<300	3
F4 (C_{34}-C_{50})	µg/g	<200	<100	<300	3
total volatile hydrocarbons (C_5-C_{10})	µg/g	<0.5	<0.5	<50	5
total extractable hydrocarbons (C_{11}-C_{30})	µg/g	<10	<5	<10	5
benzene	µg/g	<0.084	<0.071	<0.14	3
toluene	µg/g	<0.33	<0.28	<0.54	3
ethylbenzene	µg/g	<0.17	<0.14	<0.27	3
xylenes (m+o+p)	µg/g	<0.67	<0.56	<1.1	3

Notes: **Bolded** concentrations are higher than the relevant sediment quality guideline.
[(l)] Concentration higher than the interim sediment quality guideline (CCME 1999).

Source: Canadian Natural (2007; includes data from 2001 and 2006); analytical results from samples collected in 2011.

Table F-2 Watercourses Sediment Quality in the Local Study Area

Parameter	Units [dry wt.]	Fall (2006-2011)			
		Median	Minimum	Maximum	n
Particle Size					
sand	%	65	7	95	16
silt	%	22	2	50	16
clay	%	9.5	2	43	16
moisture content	%	67	20	96	16
Carbon Content					
total inorganic carbon	%	0.1	<0.02	4.4	16
total organic carbon	%	5.4	0.2	43	16
total carbon	%	5.4	0.2	43	16
Metals (Total)					
aluminum	µg/g	3,915	940	8,100	16
antimony	µg/g	<1	<1	<2	5
arsenic	µg/g	3	0.9	**17** [(I)]	16
barium	µg/g	83	16	205	16
beryllium	µg/g	<0.25	<0.2	0.5	16
boron	µg/g	4.5	<2	28	16
cadmium	µg/g	0.2	<0.1	**0.7** [(I)]	16
calcium	µg/g	5,400	1,100	30,200	16
chromium	µg/g	7.45	1.9	26	16
cobalt	µg/g	2.7	0.8	7	16
copper	µg/g	5.9	0.7	14	16
iron	µg/g	8,900	2,800	67,700	16
lead	µg/g	3.8	<1	14	16
magnesium	µg/g	1,710	480	4,520	16
manganese	µg/g	338	83	947	16
mercury	µg/g	<0.1	<0.1	0.1	16
molybdenum	µg/g	0.4	<0.1	2.4	16
nickel	µg/g	6.15	1.5	19	16
potassium	µg/g	550	79	1,200	16
selenium	µg/g	0.45	<0.2	1.2	16
silver	µg/g	<0.2	<0.2	<2	16
sodium	µg/g	100	<50	600	16
strontium	µg/g	16	7	54	16
thallium	µg/g	<0.11	<0.05	0.16	16
titanium	µg/g	65	34	185	16
uranium	µg/g	0.77	0.2	1.15	16
vanadium	µg/g	11	3	28	16
zinc	µg/g	30	8	**159** [(I)]	16
Organics					
total recoverable hydrocarbons	µg/g	600	<100	8,400	11
F1 (C_6-C_{10})	µg/g	<12	<12	<40	5
F2 (C_{10}-C_{16})	µg/g	<10	<10	<30	5
F3 (C_{16}-C_{34})	µg/g	14	<10	220	5
F4 (C_{34}-C_{50})	µg/g	<10	<10	<30	5
total volatile hydrocarbons (C_5-C_{10})	µg/g	<2	<0.5	<17.5	11
total extractable hydrocarbons (C_{11}-C_{30})	µg/g	150	<10	850	11
benzene	µg/g	<0.005	<0.005	0.048	5
toluene	µg/g	<0.02	<0.02	0.53	5
ethylbenzene	µg/g	<0.01	<0.01	0.12	5
xylenes (m+o+p)	µg/g	<0.04	<0.04	0.58	5

Notes: **Bolded** concentrations are higher than the relevant sediment quality guideline.
(I) Concentration higher than the interim sediment quality guideline (CCME 1999).

Source: Enermark (2008); Canadian Natural (2007; includes data from 2001 and 2006); analytical results from sample collected in 2011.