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STP MCKAY
THERMAL PROJECT – PHASE 2:
SURFACE AQUATIC RESOURCES REPORT

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LIST OF ACRONYMS

AENV	Alberta Environment
AEPEA	Alberta Environment Protection and Enhancement Act
AQRSA	air quality regional study area
ASRD	Alberta Sustainable Resource Development
BC MOE	British Columbia Ministry of Environment
CCME	Canadian Council of Ministers of the Environment
CEMA	Cumulative Environmental Management Association
CL	critical load
COSEWIC	Committee on the Status of Endangered Wildlife
CPF	central processing facility
CWQG	Canadian Water Quality Guidelines
DOC	dissolved organic carbon
EIA	environmental impact assessment
EPEA	Environmental Protection and Enhancement Act
EUB	Energy Utilities Board
% EPT	percentage *Ephemeroptera*, *Trichoptera* and *Plecoptera*
FWMIS	Fish and Wildlife Management Information System
HSI	habitat suitability index
ISQG	interim sediment quality guideline
LSA	local study area
MEMS	Millennium EMS Solutions Limited
PAI	potential acid input
PDC	planned development case
PDD	public disclosure statement
QA/QC	quality assurance/quality control
RAMP	Regional Aquatics Monitoring Program
RSA	regional study area
SAGD	steam-assisted gravity drainage
TCUs	total colour units
TDS	total dissolved solids
TEK	traditional ecological knowledge
ToR	terms of reference
TSS	total suspended solids
US EPA	US Environmental Protection Agency
VECs	valued environmental components

1.0 INTRODUCTION

1.1 OVERVIEW

This report is an Environmental Impact Assessment (EIA) for aquatic resources (surface water quality, fish resources, and aquatic habitat) for the proposed Southern Pacific Resource Corp. (STP) McKay Steam-Assisted Gravity Drainage (SAGD) Thermal Project - Phase 2 (the Phase 2 Project) northwest of Fort McMurray, Alberta in the Athabasca oil sands region. This report was prepared by Hatfield Consultants Partnership (Hatfield) for STP and was prepared as a component of an integrated formal application by STP for the Phase 2 Project.

1.2 TERMS OF REFERENCE

The format and contents of this report are guided by the Final Terms of Reference (ToR) for the Environmental Impact Assessment Report for the Phase 2 Project issued in July 2011 (Alberta Environment [AENV] 2011). The final ToR was developed following release of the Project Public Disclosure Document (PDD) in April 2011 (STP 2011); the ToR outlines the format and contents for the entire regulatory application and EIA (i.e., all environmental disciplines). This report addresses the components of the ToR relevant to aquatic resources.

Table 1 Terms of Reference sections applicable to this assessment.

Final ToR for Project (from AENV 2011)		Report Section
3.4	**Surface Water Quality**	**Section 3**
3.4.1	**Baseline Information**	
	[A] Describe the baseline water quality of watercourses and waterbodies.	3.1.1, 3.2.1
3.4.2	**Impact Assessment**	
	[A] Describe the potential impacts of the Project on surface water quality and proposed mitigation measures to maintain surface water quality at all stages of the Project.	**Section 4** 4.1, 4.3
3.5	**Aquatic Ecology**	
3.5.1	**Baseline Information**	**Section 2 and 3**
	[A] Describe and map the fish, fish habitat and aquatic resources (e.g., aquatic and benthic invertebrates) of the lakes, rivers, ephemeral water bodies and other waters. Describe the species composition, distribution, relative abundance, movements and general life history parameters of fish resources. Also identify any species that are:	2,1,1, 2.1.2, 3.1.2, 3.1.3, 3.1.4, 3.2.2, 3.2.3, 3.2.4
	a) listed as “at Risk, May be at Risk and Sensitive” in the Status of Alberta Species (Alberta Sustainable Resource Development);	Table 4
	b) listed in Schedule 1 of the federal *Species at Risk Act*;	Table 4
	c) listed as “at risk” by COSEWIC; and	Table 4
	d) traditionally used species.	Table 4
	[B] Identify any barriers to fish passage.	None required
	[C] Describe and map existing critical or sensitive areas such as spawning, rearing, and overwintering habitat, seasonal habitat use including migration and spawning routes.	3.2.4
	[D] Describe the current and potential use of the fish resources by aboriginal, sport or commercial fisheries.	2.3.1

Table 1 (Cont'd.)

Final ToR for Project (from AENV 2011)		Report Section
	[E] Identify the key aquatic indicators that the Proponent used to assess project impacts. Discuss the rationale for their selection.	3.2.4
3.5.2	**Impact Assessment**	**Section 4**
	[A] Describe and assess the potential impacts of the Project to fish, fish habitat, and other aquatic resources, considering:	
	a) potential habitat loss and alteration;	4.5
	b) potential creation of barriers to fish passage;	4.5
	c) potential impacts on riparian areas that could affect aquatic biological resources and productivity;	4.1, 4.2
	d) potential increased fishing pressures in the region that could arise from the increased workforce and improved access from the Project;	4.1.8
	e) changes to benthic invertebrate communities that might affect food quality and availability for fish;	4.1, 4.2, 4.3, 4.4, 4.5, 4.6, 4.7
	f) potential increased habitat fragmentation;	4.7
	g) potential acidification; and	4.3
	h) potential groundwater surface water interactions.	
	[B] Discuss mitigation measures to avoid or minimize potential impacts of the Project on fish, fish habitat and other aquatic resources. Clearly identify those mitigation measures that will be implemented and provide the rationale for their selection.	4.1, 4.2, 4.3, 4.4, 4.5, 4.6, 4.7
	[C] Identify plans proposed to offset any loss in the productivity of fish habitat. Indicate how environmental protection plans address applicable provincial and federal policies on fish habitat including the development of a "No Net Loss" fish habitat objective.	None required

1.3 PROJECT LOCATION AND SCOPE

The Phase 2 Project will be located approximately 40 km northwest of Fort McMurray, Alberta. The Phase 2 Project will be located to the west of Highway No. 63, and within Township 91, Range 14, W4M (Figure 1). The Project is located in the MacKay River watershed and lies within the Wabasca Lowland Ecoregion, which is part of the Boreal Plains Ecozone.

The Phase 2 Project consists of an expansion of Southern Pacific's 12,000 bpd STP-McKay Thermal Project – Phase 1 (Phase 1 Project), currently under construction following approval in October and November 2010 (AENV 2011). The Phase 2 Project will consist of SAGD well pairs, pipelines, a central processing facility and access roads designed to produce an additional 24,000 bpd of bitumen for a planned total of 36,000 bpd of bitumen production from the STP McKay leases.

1.4 SUMMARY PROJECT DESCRIPTION

The Phase 2 Project will be developed in two stages (A and B), each increasing production by 12,000 bpd. Phase 2 will require an additional thirty-two well pads (Figure 2). The total disturbance area for the Phase 2 Project will be approximately 502 ha, located entirely in the MacKay River watershed.

Key components of the Phase 2 Project include:

- construction, operation and decommissioning of well pads, horizontal well pairs and associated infrastructure (e.g., access roads, electrical supply, fuel gas supply, pipelines, borrow pits and remote sumps) so that the bitumen can be extracted from the oil sands reservoir and transferred to one of two central processing facilities (CPFs);
- operation and decommissioning of the CPFs, including bitumen processing facilities, steam generation facilities and process water treatment;
- construction, operation and decommissioning of water management facilities including settling ponds, diversion ditches, sanitary and potable water supply and wastewater disposal; and
- operation and decommissioning of temporary and permanent camps, established to house the Project's workforce.

1.5 GOVERNMENT REGULATION AND POLICY

This report has been prepared in consideration of the following government laws, regulations, and standards:

- *Alberta Environmental Protection and Enhancement Act* (EPEA 2000), with associated regulations and amendments in force;
- *Alberta Water Act* (2000), with associated regulations and amendments in force, particularly the *Alberta Code of Practice for Watercourse Crossings* and the *Code of Practice for Pipelines and Telecommunication Lines Crossing A Water Body*;
- The *Canada Fisheries Act (*Minister of Justice 2010), with associated regulations and amendments in force;
- Surface Water Quality Guidelines for Use in Alberta (AENV 1999);
- Canadian Council of Ministers of the Environment (CCME) Canadian Water Quality Guidelines (CWQG) (CCME 2007) and CCME Freshwater Sediment Quality Guidelines (CCME 2002); and
- Additional water quality guidelines as required, including guidelines from the US Environmental Protection Agency (US EPA 1999), Canada Health and the British Columbia Ministry of Environment (BC MOE 2003, 2006).

1.6 DATA SOURCES

Data sources used in the preparation of this report include:

- a previous EA report completed for the Phase 1 Project (STP 2009);
- aquatic environment assessment reports prepared for two proposed stream crossings for an access road to support oil sands development activities on the STP leases (Hatfield 2008, Hatfield 2009);

- baseline surface water hydrology conditions and impact assessments as described in the Surface Water Hydrology Report of the Phase 2 Project (nhc 2011);
- baseline groundwater conditions and impact assessments as described in the Hydrogeology Report of the Phase 2 Project (MEMS 2011a);
- baseline air quality conditions and impact assessments as described in the Air Quality Report of the Phase 2 Project (MEMS 2011b); and
- results of monitoring and research programs specifically focused on the Athabasca oil sands region of northeastern Alberta, in particular the Regional Aquatics Monitoring Program (RAMP 2004, 2005, 2006, 2007, 2008, 2009, 2010, and 2011) and outputs of a number of working groups of the Cumulative Environmental Management Association (CEMA).

2.0 SCOPE OF ENVIRONMENTAL ASSESSMENT

2.1 STUDY AREAS

2.1.1 Local Study Area

The Local Study Area (LSA) for the Phase 2 Project was selected based on the Phase 2 Project footprint and the local drainage patterns of rivers, ephemeral and other waterbodies within the spatial extent of potential direct Project effects (Figure 3). The LSA encompasses a portion of the upper MacKay River watershed. The MacKay River watershed within the LSA contains the MacKay River (sixth-order stream), one fourth-order stream, and a series of third- and lower-order streams and small beaver ponds.

2.1.2 Regional Study Area

The Regional Study Area (RSA) was selected to examine the potential of the Phase 2 Project to contribute to cumulative impacts on aquatic resources of the larger landscape within which the Phase 2 Project is situated. Criteria used for the selection of the RSA were:

- drainage patterns in the MacKay River watershed;
- spatial extent of potential impacts from the Phase 2 Project and all other development projects in the MacKay River watershed; and
- a review of existing information regarding fish species composition, distribution, relative abundance, and migrations in the region.

Based on these criteria, the proposed RSA (Figure 3) for surface aquatic resources includes the watercourses of the LSA plus the mainstem of the MacKay River downstream to its confluence the Athabasca River. Within the RSA, the MacKay River is a sixth-order watercourse.

2.1.3 Study Area for the Effects of Acidifying Emissions

Potential effects of acidifying emissions on aquatic resources were assessed over the entire Air Quality Regional Study Area (AQRSA) (Figure 4).

2.2 AQUATIC RESOURCES ISSUES CONSIDERED

The surface aquatic resources issues considered in this assessment were developed from a review of:

- issues identified from a review of the Phase 2 Project description and existing information from the Phase 1 Project (STP 2009);
- the scope and findings of environmental assessments and studies conducted for the Phase 1 Project (STP 2009) and elsewhere in the MacKay River watershed; and
- findings of primary field data collection during aquatic resource baseline studies for the Project (Section 3.0 of this report).

The final list of issues considered in this report is summarized in Table 2. Direct effects potentially caused by the Phase 2 Project are considered, as well as all possible indirect effects.

Table 2 Aquatic resource issues considered in this report.

Issue/Description of Potential Effect	Phase 2 Project Activities
Changes in surface water quality Changes in fish health and fish tissue, including fish tainting	Construction, operation, reclamation and decommissioning Project activities giving rise to: ▪ Surface disturbances and increased sediment loading; ▪ Accidental release or seepage of Project affected water; ▪ Accidental spills of chemicals and waste products; ▪ Acidifying emissions from Project facilities and equipment; ▪ Potential contamination of groundwater; and ▪ Potential interactions between groundwater and surface water.
Alteration of fish resources and aquatic habitat	Construction, operation, reclamation and decommissioning Project activities giving rise to: ▪ Changes in surface water quality; ▪ Physical changes in stream channel morphology; ▪ Changes in surface water flow rates; and ▪ Modified access to and increased fishing pressures in fish-bearing watercourses and waterbodies.

2.3 VALUED ENVIRONMENTAL COMPONENTS

For this Project, Valued Environmental Components (VECs) are defined as:

> *"those environmental attributes associated with the proposed project development, which have been identified to be of concern either by directly-affected stakeholders, government or the professional community".*

The identification of key issues relevant to aquatic resources confirmed that surface water quality and fish resources are the VECs to be considered in this assessment.

2.3.1 Variables Used to Characterize VECs

2.3.1.1 Surface Water Quality

The selection of variables used to characterize surface water quality for the Phase 2 Project (Table 3) was guided by a review of:

- requirements of the ToR for this EIA (AENV 2011);
- water quality variables that have regulatory concern in the form of guidelines;
- water quality variables identified by CEMA as being variables of concern with respect to development in the Athabasca oil sands region (CEMA 2004); and
- various water quality variables required for interpretation of effects on other aquatic components, particularly fish populations and human health.

Table 3 Variables used to characterize surface water quality.

Group	Water Quality Variables
Conventional variables	Colour; total organic carbon; dissolved organic carbon; total dissolved solids; total suspended solids; pH; conductivity; total alkalinity; total hardness; dissolved oxygen; turbidity.
Major ions	Bicarbonate; calcium; chloride; magnesium; potassium; sodium; sulphate; sulphide.
Nutrients	Ammonia nitrogen; Nitrate+Nitrite; total Kjeldahl nitrogen; total phosphorus; chlorophyll *a*.
Organics and Hydrocarbons	Phenols; hydrocarbons (recoverable); naphthenic acids.
Total and dissolved metals	Aluminum; antimony; arsenic; barium; beryllium; boron; cadmium; chromium; cobalt; copper; iron; lead; lithium; manganese; ultra-trace mercury; molybdenum; nickel; selenium; silver; strontium; thallium; titanium; uranium; zinc.

2.3.1.2 Fish Resources

A set of key indicator species was developed to describe fish resources in the LSA and the RSA (Table 4). These key indicator species were selected with a review of:

- fish species presence and abundance including the suitability of respective habitats as determined during the 2008 to 2010 field programs for the baseline studies and stream crossing assessments (Hatfield 2008, 2009);
- the fish species reasonably expected to be present in the types of stream orders within the LSA and RSA, as documented in the Fish and Wildlife Management Information System (FWMIS) database (ASRD 2011);

- key indicator species or guild status as defined by other approved oil sands projects, research studies and monitoring programs in the region such as RAMP (2009);
- importance of particular species as a traditional resource; and
- species designated as having a status of special concern (ASRD 2005) or a status of candidate wildlife species by a federal agency (COSEWIC 2010).

Table 4 Summary of key indicator fish species.

Fish Species	Scientific Name	Species Code	Recovered in FWMIS Database[1]	Review of Historical Fish Studies[2]	Captured in Baseline Field Studies[3]	Status of Special Concern[4]
Large-Bodied Species						
Arctic grayling	*Thymallus arcticus*	ARGR	√	√		√
Burbot	*Lota lota*	BURB		√		
Flathead chub	*Platygobio gracilis*	FLCH	√	√		
Goldeye	*Hiodon alosoides*	GOLD		√		
Lake whitefish	*Coregonus clupeaformis*	LKWH		√		
Longnose sucker	*Catostomus catostomus*	LNSC	√	√	√	
Mountain whitefish	*Prosopium williamsoni*	MNWH		√		
Northern pike	*Esox lucius*	NRPK	√	√		
Walleye	*Sander vitreus*	WALL	√	√		
White sucker	*Catostomus commersoni*	WHSC	√	√	√	
Yellow perch	*Perca flavescens*	YLPR		√		
Small-Bodied Species						
Brook stickleback	*Culaea inconstans*	BRST	√	√	√	
Emerald shiner	*Notropis atherinoides*	EMSH		√	√	
Fathead minnow	*Pimphales promelas*	FTMN	√	√		
Finescale dace	*Phoxinus neogaeus*	FNDC	√	√		
Lake chub	*Couesius plumbeus*	LKCH	√	√	√	
Longnose dace	*Rhinichthys cataractae*	LNDC	√	√	√	
Northern redbelly dace	*Phoxinus eos*	NRDC	√	√		
Pearl dace	*Semotilus margarita*	PRDC	√	√		
Slimy sculpin	*Cottus cognatus*	SLSC	√	√		√
Spoonhead sculpin	*Cottus ricei*	SPSC	√	√	√	
Trout-perch	*Percopsis omiscomaycus*	TRPR	√	√		

[1] from ASRD (2011).

[2] from Golder (2003).

[3] from Hatfield (2009).

[4] from http://www.cosewic.gc.ca/eng/sct3/index_e.cfm assessment cases.

2.3.2 Baseline Case

The Baseline Case consists of the existing and approved developments described in STP (2011) which may be influencing aquatic resources in the vicinity of the Phase 2 Project. The Baseline Case, described in Section 3.0 of this report, assumes that: (i) any effects of existing projects on aquatic resources are already reflected in the data gathered to establish the baseline conditions; and (ii) existing projects will not cause any different effects on aquatic resources in the future.

2.3.3 Application Case

The Application Case is an assessment of the incremental environmental effects of the Phase 2 Project to existing conditions as defined by the Baseline Case. Essentially, the Application Case is a cumulative effects assessment whereby the environmental effects of the Phase 2 Project are added to existing environmental conditions.

2.3.4 Planned Development Case

The Planned Development Case is an assessment of the incremental environmental effects of the Phase 2 Project relative to the existing conditions described in the Baseline Case, plus planned developments that have been publicly disclosed at least six months prior to submission of this report.

There are no planned developments upstream of the Phase 2 Project that would potentially affect water quality, fish, and aquatic habitat within the LSA and RSA. Therefore, the Planned Development Case is only assessed for possible effects on aquatic resources via changes in acidifying emissions within the Air Quality Local and Regional Study Areas (Figure 4).

3.0 AQUATIC RESOURCES BASELINE CASE

The aquatic resources Baseline Case consists of a description of surface water quality, fish resources, aquatic habitat, (physical conditions, sediment quality, and benthic invertebrate communities), first for the watercourses within the LSA, followed by the watercourses that comprise the RSA.

3.1 BASELINE CASE FOR LOCAL STUDY AREA

Table 5 and Figure 5 contain a summary of the baseline aquatic resources field program conducted in support of this EIA. Additional existing information for the LSA includes results from the baseline assessment for the Phase 1 Project, completed in July 2008 (STP 2009) and three stream crossing assessments completed for the Phase 1 Project (Hatfield 2008, 2009).

3.1.1 Water Quality

The Baseline Case for surface water quality is based on surface water quality field studies undertaken in the LSA on watercourses upstream and downstream of the Phase 2 Project footprint (Table 5). For the baseline assessment for the Phase 1 Project, all sampling was conducted during the summer season. Therefore, given the tributaries in the Phase 1 Project area of the MacKay River watershed are similar in habitat and size, the assessment for the Phase 2 Project focused on obtaining and analyzing water quality for the other seasons (i.e., spring, fall, and winter). During the winter season, there were a few watercourses that were not frozen to depth; therefore, samples could only be collected at a subset of watercourses in the LSA.

Table 5 Summary of sampling conducted in the LSA for the aquatic resources Baseline Case.

Site Code	Location	UTM (Zone 12 NAD 83)		Season			
		Easting	Northing	Spring 2010	Summer 2010	Fall 2010	Winter 2011[1]
SPE1	Tributary to MacKay River	428904	6309428	afhi	ih^	afhi	h^
SPE2	Tributary to MacKay River	430154	6309751	ih^	ih^	ih^	h^
SPE3	Tributary to MacKay River	431609	6309454	afhi	ih^	afhi	h^
SPE4	Tributary to MacKay River	432880	6310534	ih^	ih^	ih^	h^
SPE5	MacKay River downstream of Phase 2 Project Area	435434	6310089	afhi	fh^	afhi	h^
SPE6	Tributary to MacKay River	435744	6306915	afhi	ih^	afhi	aih^
SPE7	Tributary to MacKay River	436592	6308547	afhi	fh^	afhi	aih^
SP1	MacKay River upstream of Phase 1 Project Area	423988	6302952	-	-	afhi	-
SP3	Tributary to MacKay River	425039	6304162	-	-	afhi	-
SP8	Tributary to MacKay River	426751	6306101	-	-	afhi	-
SP11	Tributary to MacKay River	426111	6306753	-	-	afhi	-
SP17	Birchwood Creek	428824	6306355	-	-	afhi	aih^
SP20	Tributary to MacKay River	428472	6308613	-	-	afhi	-

[1] Analytical water quality was collected only in watercourses that were not frozen to depth.
a analytical water quality; sampling methodology is described in Appendix A1.
f fish inventory; inventory methods are described in Appendix A3.
h detailed physical habitat survey; survey methods are described in Appendix A5.
i *in situ* water quality.
^ simple physical habitat survey; survey methods are described in Appendix A5.

Appendix A1 contains a description of the methods used for the surface water field sampling program, as well as a quality assurance/quality control (QA/QC) analysis of surface water quality data obtained.

Detailed water quality information for watercourses is provided in Appendix A2. Table 7 provides a summary of seasonal and annual median, minimum and maximum concentrations for surface water quality variables measured in watercourses within the LSA with supporting water quality guidelines provided in Table 6. Table 8 provides the seasonal and annual frequency of guideline exceedances for each season.

The water quality of watercourses in the LSA is generally characteristic of coloured brown-water systems with a median true color level ranging from 172 total colour units (TCU) (fall) to 282 (winter) TCU and median concentrations of dissolved organic carbon (DOC) ranging from 36.2 mg/L (spring) to 54.2 mg/L (winter) across all watercourses. Surface water in the LSA is hard, with median concentrations ranging from 62.2 mg/L (spring) to 153 mg/L (winter). Watercourses in the LSA generally have circumneutral pH and pH is generally consistent across seasons.

Surface water in the LSA has high concentrations of total dissolved solids (TDS) (median values ranging from 158 mg/L [fall] to 306 mg/L [winter]) and conductivity (median value ranging from 127 µS/cm [spring] to 306 µs/cm [winter]) consistent with concentrations and levels in regional baseline watercourses in the Athabasca oil sands region (RAMP 2011).

Median concentrations of total suspended solids (TSS) in watercourses in the LSA ranged from 4 mg/L (fall) to 8 mg/L (winter) and were fairly consistent across watercourses with the exception of site SPE7 that had a TSS concentration of 98 mg/L in fall 2010. The increase observed at site SPE7, primarily beaver pond habitat could be due to rainfall, or a disturbance event (e.g., wildlife) in the beaver pond prior to sampling.

Watercourses in the LSA are classified as mesotrophic to eutrophic based on spring total phosphorus and total nitrogen concentrations (Dodds *et al*. 1998).

The ionic composition of the watercourses in the LSA is dominated by calcium and bicarbonate (Figure 6).

Most of the cases in which concentrations of water quality variables exceed their guidelines in the watercourses of the LSA are attributable to total and dissolved iron, total phosphorus, total Kjeldahl nitrogen, and total nitrogen (Table 7, Table 8). Concentrations of total iron, total phosphorus, and total nitrogen (derived from total Kjeldahl nitrogen) are generally above their water quality guidelines throughout the Athabasca oil sands region and are positively correlated with concentrations of TSS (Golder 2003, RAMP 2011). The rest of the water quality guideline exceedances in the watercourses of the LSA were occasional exceedances in concentrations of dissolved oxygen, total aluminum, total cadmium, total chromium, total manganese, and total selenium.

Concentrations of a number of water quality variables, including mercury (ultra-trace), total arsenic, almost all dissolved metals and phenols never exceeded their water quality guidelines in the watercourses of the LSA. Concentrations of naphthenic acids across watercourses were consistent with historical concentrations measured in the MacKay River watershed (RAMP 2010) and total recoverable hydrocarbons were below detection limits across all seasons in all watercourses.

Table 6 Sources of water quality guidelines used in this report.

Notation in Water Quality Tables	Description/Explanation
a	at pH ≥ 6.5; Hardness ≥ 4mg/L; [DOC] ≥ 2 mg/L (CCME 2007).
b	at pH 8.0, 10°C (CCME 2007).
c	CCME (2007). AENV (1999) guideline: "To be in the range of 6.5 to 8.5 but not altered by more than 0.5 pH units from background values."
d	BC ambient water quality guideline for boron (BC MOE 2003).
e	Is equal to $10^{(0.86*\log_e[Hardness]-3.2)}$ (CCME 2007).
f	Set to US Environmental Protection Agency continuous and maximum concentration guideline (USEPA 1999).
g	Guideline for chromium III is 0.0089 mg/L; guideline for chromium VI is 0.0010 mg/L (CCME 2007). More stringent guideline (0.001 mg/L) is used.
h	BC working water quality guidelines (BCMOE 2006).
i	Guideline is hardness-dependent: 0.002 mg/L at hardness = 0 to 120 mg/L; 0.003 mg/L at hardness = 120 to 180 mg/L; 0.004 mg/L at hardness > 180 mg/L (CCME 2007).
j	Alberta acute and chronic guideline for dissolved oxygen (AENV 1999); guideline is a minimum value.
k	Guideline is hardness-dependent: 0.001 mg/L at hardness = 0 to 60 mg/L; 0.002 mg/L at hardness = 60 - 120 mg/L; 0.004 mg/L at hardness > 120 mg/L (CCME 2007).
l	For chronic and acute concentrations (AENV 1999).
m	Guideline is hardness-dependent: 0.025 mg/L at hardness = 0 to 60 mg/L; 0.065 mg/L at hardness = 60 to 120 mg/L; 0.11 mg/L at hardness = 120 to 180 mg/L; 0.15 mg/L at hardness > 180 mg/L (CCME 2007).
n	CCME guideline for nitrate is 13 mg/L; CCME guideline for nitrite is 0.06 mg/L (CCME 2007)
o	BC approved water quality guideline (BC MOE 2006).
p	BC Acute guideline is hardness-dependent: 0.8mg/L at hardness= 0 to 25 mg/L; 1.1 mg/L at hardness= 25 to 50 mg/L;1.6mg/L at hardness= 50 to 100 mg/L; 2.2 mg/L at hardness= 100 to 150 mg/L;3.8 mg/L at hardness= 150 to 300 mg/L (BCMOE 2006).
q	Guideline is for chronic total (organic and inorganic) phosphorus (AENV 1999).
r	US Environmental Protection Agency continuous and maximum concentration guideline (as H_2S). (US EPA 1999).

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Table 7 Surface water quality by season for watercourses in the LSA.

Water Quality Category	Water Quality Variable	Units	Guideline[1]	Detection Limit	Spring				Fall				Winter			
					n	Minimum	Median	Maximum	n	Minimum	Median	Maximum	n[5]	Minimum	Median	Maximum
Field Measurements	Dissolved Oxygen	mg/L	5, 6.5[j]	-[3]	7	**3.9**	6.4	10.7	12	**3.4**	**7.6**	10.1	3	**2.2**	5.8	11.2
	Conductivity	µS/cm	-	-[3]	7	72	115	229	12	75	106	233	3	**2.2**	5.8	11.2
	pH	pH	6.5 - 9.0[c]	-[3]	7	**5.93**	6.96	7.25	12	**5.80**	7.01	7.65	3	**2.2**	5.8	11.2
	Temperature	deg. Celsius	-	-[3]	7	9.3	15.1	17.1	12	4.7	7.3	10.1	3	**2.2**	5.8	11.2
Conventional Variables	Conductivity (EC)	µS/cm	-	0.2	7	105	127	180	11	98.4	139	337	3	271	308	389
	Dissolved Organic Carbon	mg/L	-	1	5	27.9	36.2	41.4	11	32.3	36	48	3	36	53.4	54.8
	Hardness (as $CaCO_3$)	mg/L	-	-	5	53.3	62.2	88	11	56.7	64	162	3	145	153	187
	pH	pH	6.5 - 9.0[c]	0.1	5	7.65	7.87	8.05	11	7.44	7.76	8.04	3	7.35	7.43	7.9
	Alkalinity, Total (as $CaCO_3$)	mg/L	-	5	5	49.2	50.8	83.2	11	45.7	61.9	174	3	143	163	220
	Total Dissolved Solids	mg/L	-	10	5	120	164	191	11	128	158	282	3	239	306	358
	Total Suspended Solids	mg/L	-	3	5	<5	8	12	11	<3	4	98	3	<4	11	13
	Total Organic Carbon	mg/L	-	1	5	29.7	37.2	45.1	11	32.1	36.9	53.9	3	35.3	55.5	57.4
	Color, True	T.C.U.	-	2	5	131	187	280	11	118	172	292	3	178	282	468
General Organics	Naphthenic Acids	mg/L	-	0.02	5	0.47	0.9	1.32	11	0.77	1.28	1.77	3	1.3	1.56	1.6
	Phenols	mg/L	4	0.001	5	0.0061	0.008	0.0121	11	0.0059	0.0089	0.0158	3	0.0086	0.0137	0.0172
	Hydrocarbons, Recoverable (I.R.)	mg/L	-	1	-	-	-	-	11	<1	<1	<1	3	<1	<1	<1
	Oil & Grease	mg/L	-	1	5	<1	<1	<1	-	-	-	-	-	-	-	-
Major Ions	Bicarbonate (HCO_3)	mg/L	-	5	5	60	62	102	11	55.7	75.6	213	3	174	199	269
	Calcium (Ca) Dissolved	mg/L	-	0.5	5	12.8	15.1	22.2	11	13.7	16	40	3	36.2	36.8	44.9
	Carbonate (CO_3)	mg/L	-	5	5	<5	<5	<5	11	<5	<5	<5	3	<5	<5	<5
	Chloride (Cl)	mg/L	230, 860[f]	0.5	5	<0.5	<0.5	7.09	11	<0.5	<0.5	0.9	3	<0.5	<0.5	0.63
	Hydroxide (OH)	mg/L	-	5	5	<5	<5	<5	11	<5	<5	<5	3	<5	<5	<5
	Magnesium (Mg) Dissolved	mg/L	-	0.1	5	5.18	5.37	7.9	11	5.23	5.9	15	3	12.9	15.1	18.3
	Potassium (K) Dissolved	mg/L	-	0.5	5	<0.5	0.78	3.13	11	<0.5	0.64	1.97	3	<0.9	1.02	3.62
	Sodium (Na) Dissolved	mg/L	-	1	5	5.7	8.7	10.1	11	3	8.7	14.5	3	6.6	10.9	20
	Sulfate (SO_4)	mg/L	100[o]	0.5	5	1.09	6.1	10.9	11	<0.5	2.39	6.98	3	<0.5	0.94	3.99
	Sulphide	mg/L	2[r]	0.002	5	0.0029	0.0189	0.0237	11	0.0034	0.0135	0.0942	3	0.0111	0.0478	0.0755
Nutrients	Ammonia (N)	mg/L	1.37[b]	0.05	5	<0.05	<0.05	0.053	11	<0.05	<0.05	<0.05	3	0.327	0.579	0.826
	Biochemical Oxygen Demand	mg/L	-	2	5	2.2	3.3	6.7	11	<2	<2	7.3	3	<2	<7	12.5
	Nitrate (as N)	mg/L	13	0.05	5	<0.05	<0.05	<0.05	11	<0.05	<0.05	<0.05	3	<0.05	<0.05	0.065
	Nitrate and Nitrite as N	mg/L	1.3	0.071	5	<0.071	<0.071	<0.071	11	<0.071	<0.071	<0.071	3	<0.071	<0.071	<0.071
	Nitrite (as N)	mg/L	0.06	0.05	5	<0.05	<0.05	<0.05	11	<0.05	<0.05	<0.05	3	<0.05	<0.05	<0.05
	Phosphorus, Total	mg/L	0.05[q]	0.001	5	0.0084	0.0355	**0.0987**	11	0.0062	0.0284	**0.366**	3	**0.133**	**0.217**	**0.347**
	Phosphorus, Total Dissolved	mg/L	0.05	0.001	5	0.0056	0.0251	**0.0502**	11	0.0024	0.0198	0.0478	3	**0.0983**	**0.186**	**0.238**
	Total Kjeldahl Nitrogen	mg/L	1[2]	0.2	5	**1.13**	**1.85**	**2.28**	11	0.9	**1.12**	**4.92**	3	**1.27**	**2.14**	**2.59**
	Total Nitrogen*	mg/L	1	-	5	**1.20**	**1.92**	**2.35**	11	0.97	**1.19**	**4.99**	3	**1.34**	**2.21**	**2.66**
Metals - Dissolved	Aluminum	mg/L	-[a]	0.0002	5	0.013	0.025	0.0552	11	0.00639	0.0213	0.0419	3	0.023	0.0241	0.0451
	Antimony	mg/L	0.02	0.0000005	5	0.0000205	0.0000317	0.0000402	11	0.0000113	0.0000275	0.0000544	3	0.0000228	0.0000361	0.0000408
	Arsenic	mg/L	0.005	0.00002	5	0.000299	0.000491	0.000849	11	0.00037	0.000511	0.000677	3	0.000518	0.00107	0.00185
	Barium	mg/L	5[h]	0.000004	5	0.00625	0.0132	0.0177	11	0.0066	0.00981	0.0386	3	0.0318	0.0356	0.0358
	Beryllium	mg/L	-	0.000003	5	<0.000003	0.0000098	0.0000301	11	<0.000003	0.0000067	0.0000128	3	<0.000003	0.0000107	0.0000109
	Bismuth	mg/L	-	0.000001	5	<0.000001	0.0000015	0.0000024	11	<0.000001	<0.000001	0.0000023	3	<0.000002	0.0000018	0.0000033
	Boron	mg/L	1.2[d]	0.00003	5	0.0251	0.0408	0.0756	11	0.0133	0.0315	0.067	3	0.0191	0.0276	0.0412
	Cadmium	mg/L	[e]	0.000002	5	<0.000002	<0.000003	0.0000058	11	<0.000002	<0.000002	0.000004	3	<0.000002	0.0000025	0.0000026
	Calcium	mg/L	-	0.004	5	9.35	11	16.6	11	9.76	12.6	34.7	3	31.8	33	38.3
	Chlorine	mg/L	-	0.1	5	<0.1	<0.1	0.149	11	<0.1	0.277	0.483	3	<0.3	0.379	0.99
	Chromium	mg/L	0.001[g]	0.00004	5	<0.00014	0.000219	0.000283	11	0.0000765	0.000131	0.000446	3	0.000349	0.000594	0.000724
	Cobalt	mg/L	0.11	0.000001	5	0.000046	0.0000834	0.000141	11	0.0000339	0.0000582	0.000113	3	0.000452	0.00098	0.00387
	Copper	mg/L	[i]	0.00005	5	0.00031	0.000421	0.000652	11	0.000148	0.000314	0.00065	3	0.000263	0.000293	0.000312

Values in bold indicate concentrations exceeding guidelines for the protection of aquatic life.

* Total nitrogen = Nitrate + nitrite plus total Kjeldahl nitrogen (TKN); Non-detectable results were assumed to be equal to the detection limit for calculating total nitrogen.

1 Alberta Environment Guidelines for the Protection of Freshwater Aquatic Life (AENV 1999), unless otherwise specified.

2 Guideline is for total nitrogen.

3 Field measurements were taken *in situ* and therefore there is no detection limit.

4 The detection limit for selenium changed from 0.00004 in spring 2010 to 0.001 in fall 2010.

5 The sample size for winter 2011 was low given most watercourses were frozen to depth.

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Table 7 (Cont'd.)

	Water Quality Variable	Units	Guideline[1]	Detection Limit	Spring				Fall				Winter			
					n	Minimum	Median	Maximum	n	Minimum	Median	Maximum	n	Minimum	Median	Maximum
Metal - Dissolved (Cont'd.)	Iron	mg/L	0.3	0.002	5	0.0626	0.445	**0.697**	11	0.0938	0.262	**1**	3	**2.33**	**3.96**	**6.46**
	Lead	mg/L	-	0.000001	5	0.0000027	0.000015	0.0000496	11	0.0000038	0.0000109	0.0000387	3	0.0000256	0.0000451	0.0000464
	Lithium	mg/L	2.5	0.00002	5	0.00589	0.00979	0.0107	11	0.00476	0.00865	0.0185	3	0.00635	0.00968	0.015
	Manganese	mg/L	[p]	0.000003	5	0.00188	0.00819	0.0117	11	0.000806	0.00285	0.0148	3	0.224	0.252	2.13
	Molybdenum	mg/L	0.073	0.000001	5	0.0000302	0.0000839	0.000299	11	0.000024	0.0000396	0.000158	3	0.0000297	0.0000419	0.0000663
	Nickel	mg/L	[m]	0.000005	5	0.000341	0.000858	0.00161	11	0.000215	0.000487	0.00108	3	0.000296	0.000933	0.0016
	Selenium	mg/L	0.001	0.00004, 0.0001[4]	5	<0.00004	<0.00004	0.000085	11	<0.0001	<0.0001	0.000203	3	<0.0001	<0.0001	0.00019
	Silver	mg/L	0.0001	0.0000005	5	0.00000052	0.0000013	0.000003	11	<0.0000005	<0.0000005	0.0000005	3	<0.0000005	0.0000043	0.0000107
	Strontium	mg/L	-	0.000004	5	0.0442	0.0525	0.114	11	0.0506	0.0615	0.215	3	0.162	0.165	0.256
	Sulphur	mg/L	-	0.2	5	0.647	2.91	4.43	11	0.475	2.22	25.4	3	0.663	1.13	1.83
	Thallium	mg/L	0.0008[c]	0.0000003	5	0.0000009	0.0000017	0.000002	11	0.0000006	0.0000018	0.0000064	3	0.0000006	0.0000006	0.0000014
	Thorium	mg/L	-	0.0000003	5	0.0000117	0.0000246	0.0000565	11	<0.0000023	0.0000109	0.0000591	3	0.0000189	0.0000407	0.0000666
	Tin	mg/L	-	0.00003	5	<0.00003	<0.00003	<0.00003	11	<0.00003	<0.00003	0.00003	3	<0.00003	<0.00003	<0.00003
	Titanium	mg/L	0.1	0.00004	5	0.000707	0.000891	0.00171	11	0.000733	0.00105	0.00173	3	0.00209	0.00211	0.00241
	Uranium	mg/L	0.03[h]	0.0000001	5	0.0000135	0.0000559	0.0000863	11	0.0000055	0.000031	0.0000656	3	0.0000843	0.0000996	0.000194
	Vanadium	mg/L	-	0.000005	5	0.000167	0.000255	0.000564	11	0.000127	0.000169	0.000361	3	0.000341	0.000875	0.000877
	Zinc	mg/L	-	0.00005	5	0.000811	0.00086	0.00252	11	0.000544	0.00104	0.00725	3	0.00106	0.00118	0.00219
Metal - Total	Aluminum	mg/L	0.1[a]	0.0005	5	0.0299	0.107	0.441	11	0.0282	**0.114**	**1.09**	3	0.0546	0.0704	**0.073**
	Antimony	mg/L	0.02	0.0000005	5	0.0000207	0.000032	0.0000406	11	0.0000114	0.0000278	0.000055	3	0.000023	0.0000365	0.0000412
	Arsenic	mg/L	0.005	0.00002	5	0.000392	0.000575	0.000925	11	0.000396	0.000629	0.00235	3	0.000606	0.00135	0.00321
	Barium	mg/L	5[h]	0.000004	5	0.00772	0.0148	0.0194	11	0.00718	0.012	0.0631	3	0.0351	0.0438	0.0556
	Beryllium	mg/L	-	0.000003	5	0.0000057	0.0000163	0.0000352	11	<0.000003	0.0000105	0.0000371	3	<0.000010	0.000011	0.0000183
	Bismuth	mg/L	-	0.000001	5	0.000001	0.0000024	0.0000049	11	<0.000001	<0.000001	0.0000097	3	<0.000002	0.0000022	0.0000048
	Boron	mg/L	1.2[d]	0.00005	5	0.0281	0.0421	0.0769	11	0.0146	0.0326	0.088	3	0.022	0.0306	0.0428
	Cadmium	mg/L	[e]	0.000002	5	<0.000002	0.0000037	0.000008	11	<0.000002	0.0000032	**0.0000303**	3	<0.000004	0.0000039	0.0000118
	Calcium	mg/L	-	0.004	5	10	11.3	17.1	11	10.5	13.7	35.1	3	33.4	33.7	41.2
	Chlorine	mg/L	-	0.1	5	<0.1	0.153	0.177	11	<0.1	0.297	1.09	3	<0.3	0.405	1
	Chromium	mg/L	0.001[g]	0.00004	5	0.000215	0.000308	0.000496	11	0.000116	0.000233	**0.00138**	3	0.000353	0.0006	0.000731
	Cobalt	mg/L	0.11	0.000001	5	0.0000774	0.00024	0.000308	11	0.0000597	0.000109	0.00598	3	0.00052	0.00418	0.00539
	Copper	mg/L	[i]	0.00005	5	0.000313	0.000425	0.000719	11	0.000149	0.000361	0.00103	3	0.000315	0.00052	**0.000969**
	Iron	mg/L	0.3	0.002	5	0.13	**0.79**	**0.967**	11	0.124	**0.474**	**5.63**	3	**3.07**	**7.61**	**16.2**
	Lead	mg/L	-	0.000001	5	0.0000681	0.000102	0.000184	11	0.0000095	0.000101	0.000644	3	0.0000778	8.39E-05	0.000238
	Lithium	mg/L	-	0.00002	5	0.00626	0.00993	0.0111	11	0.00524	0.00956	0.0193	3	0.00705	0.012	0.015
	Manganese	mg/L	[p]	0.000003	5	0.0041	0.0335	0.0947	11	0.00481	0.0342	**2.55**	3	0.257	2.28	**2.49**
	Mercury (ultra-trace)	ng/L	5, 13[l]	0.6	5	1.5	2.3	2.8	11	<0.6	<0.6	1	3	<0.6	<0.6	<0.6
	Molybdenum	mg/L	0.073	0.000001	5	0.0000329	0.0000852	0.000314	11	0.0000274	0.0000674	0.000209	3	0.000042	0.00006	0.0000716
	Nickel	mg/L	[m]	0.000005	5	0.000446	0.000945	0.00173	11	0.000229	0.000614	0.00213	3	0.000474	0.00112	0.00163
	Selenium	mg/L	0.001	0.00004, 0.0001[4]	5	<0.00004	0.000076	0.000086	11	<0.0001	0.000139	**0.00351**		<0.0001	<0.00018	0.000232
	Silver	mg/L	0.0001	0.0000005	5	0.0000019	0.000003	0.0000076	11	<0.0000005	<0.0000005	0.0000121	3	<0.0000036	7.7E-06	0.0000141
	Strontium	mg/L	-	0.000004	5	0.0493	0.0525	0.12	11	0.0538	0.0791	0.224	3	0.168	0.175	0.282
	Sulphur	mg/L	-	0.2	5	0.647	2.91	4.43	11	0.475	2.22	25.4	3	0.663	1.13	1.83
	Thallium	mg/L	0.0008[c]	0.0000003	5	0.0000014	0.000002	0.0000055	11	0.0000006	0.0000027	0.0000142	3	0.0000007	0.0000015	0.0000021
	Thorium	mg/L	-	0.0000003	5	0.0000222	0.0000292	0.0000732	11	<0.0000023	0.000011	0.000195	3	0.0000229	0.0000661	0.0000694
	Tin	mg/L	-	0.00003	5	<0.00003	<0.00003	<0.00003	11	<0.00003	<0.00003	<0.00003	3	<0.00003	<0.00003	<0.00003
	Titanium	mg/L	0.1	0.00004	5	0.000986	0.00202	0.00867	11	0.00106	0.0034	0.0208	3	0.00282	0.0032	0.00339
	Uranium	mg/L	0.033, 0.015	0.0000001	5	0.0000184	0.0000615	0.000102	11	0.0000074	0.0000334	0.0000953	3	0.000091	0.000114	0.000238
	Vanadium	mg/L	-	0.000005	5	0.000185	0.000435	0.00106	11	0.000177	0.000347	0.00362	3	0.000416	0.00121	0.00171
	Zinc	mg/L	0.03	0.0001	5	0.000918	0.00169	0.00328	11	0.00055	0.0021	0.0281	3	0.00107	0.00119	0.00654

Values in bold indicate concentrations exceeding guidelines for the protection of aquatic life.

* Total nitrogen = Nitrate + nitrite plus total Kjeldahl nitrogen (TKN); Non-detectable results were assumed to be equal to the detection limit for calculating total nitrogen.

[1] Alberta Environment Guidelines for the Protection of Freshwater Aquatic Life (AENV 1999), unless otherwise specified.

[2] Guideline is for total nitrogen.

[3] Dissolved oxygen measurements were taken *in situ* and therefore there is no detection limit.

[4] The detection limit for selenium changed from 0.00004 in spring 2010 to 0.001 in fall 2010.

[5] The sample size for winter 2011 was low given most watercourses were frozen to depth.

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Table 8 Frequency of exceedance of water quality guidelines.

	Water Quality Variable	Units	Guideline[1]	All Seasons		Seasons Where Frequencies Were Observed
				n	Frequency	
Conventional Variables, Major Ions, and Nutrients	Ammonia-N	mg/L	1.37	19	0%	-
	Chloride (Cl)	mg/L	230, 860[f]	19	0%	-
	Nitrate (as N)	mg/L	2.9	19	0%	-
	Nitrate and Nitrite	mg/L	1.3	19	0%	-
	Nitrite (as N)	mg/L	0.06	19	0%	-
	pH	pH	6.5 - 9.0[c]	19	0%	-
	Phenols	mg/L	4	19	0%	-
	Phosphorus, Total	mg/L	0.05	19	52%	Spring, Fall, Winter
	Phosphorus, Total Dissolved	mg/L	0.05	19	40%	Spring, Winter
	Sulfate (SO_4)	mg/L	100[o]	19	0%	-
	Sulphide	mg/L	2[r]	19	0%	-
	Total Kjeldahl Nitrogen	mg/L	1[2]	19	91%	Spring, Fall, Winter
Metal - Dissolved	Aluminum	mg/L	0.0002	19	0%	-
	Antimony	mg/L	0.0000005	19	0%	-
	Arsenic	mg/L	0.00002	19	0%	-
	Barium	mg/L	0.000004	19	0%	-
	Beryllium	mg/L	0.000003	19	0%	-
	Bismuth	mg/L	0.000001	19	0%	-
	Boron	mg/L	0.00003	19	0%	-
	Cadmium	mg/L	0.000002	19	0%	-
	Calcium	mg/L	0.004	19	0%	-
	Chlorine	mg/L	0.1	19	0%	-
	Chromium	mg/L	0.00004	19	0%	-
	Cobalt	mg/L	0.000001	19	0%	-
	Copper	mg/L	0.00005	19	0%	-
	Iron	mg/L	0.002	19	53%	Spring, Fall, Winter
	Lead	mg/L	0.000001	19	0%	-
	Lithium	mg/L	0.00002	19	0%	-
	Manganese	mg/L	0.000003	19	0%	-
	Molybdenum	mg/L	0.000001	19	0%	-
	Nickel	mg/L	0.000005	19	0%	-
	Selenium	mg/L	0.00004,	19	0%	-
	Silver	mg/L	0.0000005	19	0%	-
	Strontium	mg/L	0.000004	19	0%	-
	Sulphur	mg/L	0.2	19	0%	-
	Thallium	mg/L	0.0000003	19	0%	-
	Thorium	mg/L	0.0000003	19	0%	-
	Tin	mg/L	0.00003	19	0%	-
	Titanium	mg/L	0.00004	19	0%	-
	Uranium	mg/L	0.0000001	19	0%	-
	Vanadium	mg/L	0.000005	19	0%	-
	Zinc	mg/L	0.00005	19	0%	-
Metals - Total	Aluminum	mg/L	0.1	19	21%	Fall
	Antimony	mg/L	0.02	19	0%	-
	Arsenic	mg/L	0.005	19	0%	-
	Barium	mg/L	5[h]	19	0%	-
	Boron	mg/L	1.2[d]	19	0%	-
	Cadmium	mg/L	[e]	19	3%	Fall
	Chromium	mg/L	0.001[g]	19	0%	-
	Cobalt	mg/L	0.11	19	0%	-
	Copper	mg/L	[i]	19	0%	-
	Iron	mg/L	0.3	19	81%	Spring, Fall, Winter
	Manganese	mg/L	[p]	19	14%	Fall, Winter
	Mercury (ultra-trace)	ng/L	5, 13[l]	19	0%	-
	Molybdenum	mg/L	0.073	19	0%	-
	Nickel	mg/L	[m]	19	0%	-
	Selenium	mg/L	0.001	19	3%	Fall
	Silver	mg/L	0.0001	19	0%	-
	Thallium	mg/L	0.0008[c]	19	0%	-
	Titanium	mg/L	0.1	19	0%	-
	Uranium	mg/L	0.033, 0.015	19	0%	-
	Zinc	mg/L	0.03	19	0%	-

[1] Guideline is for total nitrogen.

3.1.2 Fish Resources

The Baseline Case for fish resources in the LSA was developed from a review of fish resources in the MacKay River watershed in stream orders similar to those found in the LSA, contained in the Fisheries and Wildlife Management Information System (FWMIS) database (ASRD 2011) and fish inventory surveys conducted in support of the Phase 1 Project, stream crossing assessment conducted in support of the construction of the access road into the STP leases, and fish inventories conducted in support of the Phase 2 Project (Table 5).

The watercourses in the LSA consist of first to third, and sixth order streams. Table 9 lists the fish species found in the FWMIS database within watercourses, by stream order, in the MacKay River watershed. Given the MacKay River is a sixth order stream within the LSA, most fish species present in the watershed can be present in the LSA. Table 10 indicates the probability of capturing small-bodied, large-bodied, or sportfish species by stream order (a description of the methods by which data from the FWMIS database were analyzed is provided in Appendix A3).

The analysis of FWMIS data indicates a high probability of first to sixth order streams containing small-bodied fish in the LSA. In addition, there is a moderate probability of large-bodied fish present in fifth and sixth order streams. These fish species are primarily white and longnose sucker. Sportfish, primarily walleye and northern pike, have a low probability of capture in most streams with the exception of the MacKay River, which is the only sixth order stream in the LSA. The MacKay River can be expected to have a much higher probability of all types of fish and much more diverse species assemblage than the lower order streams that flow into this river.

Table 9 Documented fish presence in the MacKay River watershed.

Species	Stream Order					
	1	2	3	4	5	6
Arctic grayling						√
Brassy minnow				√		
Brook stickleback	√	√	√	√	√	√
Emerald shiner						√
Flathead chub						√
Finescale dace	√	√	√	√		√
Fathead minnow	√	√	√	√		
Lake chub	√	√	√	√	√	√
Lake trout	√					
Longnose dace				√		√
Longnose sucker	√	√	√	√	√	√
Northern redbelly dace			√			
Northern pike		√		√		√
Pearl dace	√	√	√	√	√	√
Slimy sculpin	√		√	√		√
Spoonhead sculpin						√
Trout-perch					√	√
Walleye						√
White sucker	√	√	√	√	√	√
Total Number of Fish Species Present	**9**	**8**	**9**	**11**	**6**	**15**

Note: Species in bold are sportfish. Information extracted from FWMIS database (ASRD 2011).

Note: Shaded columns denote stream orders found within the LSA.

Table 10 Probability of capturing small-bodied, large-bodied, or sportfish by stream order for the MacKay River watershed.

Stream Order	Number of FWMIS Data Records	# of Times Present			Probability of Capture[1]		
		Small-Bodied Fish	Large-Bodied Fish	Sportfish	Small-Bodied Fish	Large-Bodied Fish	Sportfish
1	31	31	3	1	100	10	3
2	23	23	4	1	100	17	4
3	43	43	12	0	100	28	0
4	13	12	4	1	92	31	8
5	5	4	3	0	80	60	0
6	33	33	23	15	100	70	45

Note: Shaded columns denote stream orders found within the LSA.

[1] Low Probability: <50%; Moderate Probability: 50% to 75%; and High Probability: >75%.

Results of Baseline Fish Inventories

Baseline fish inventories were conducted at ten watercourses in the LSA (Table 5). A total of 854 fish, comprising 11 species, were captured in watercourses in the LSA (Table 11). The majority of fish captured were northern redbelly dace (30%), finescale dace (13%), slimy sculpin (13%), brook stickleback (11%) with fewer white sucker, lake chub, pearl dace, longnose dace, trout-perch, northern pike, and longnose sucker captured. Most of the fish were captured at site SPE7, a tributary to MacKay River in spring and fall (45%) while the majority of fish captured in summer were from site SPE5 (35%).

Large-bodied species captured during the study included longnose sucker, northern pike, and white sucker. White sucker were prevalent in a number of watercourses whereas longnose sucker were only captured at site SPE5, a tributary to the Mackay River. A single northern pike was captured at site SP1 in fall, in the MacKay River, upstream of the Phase 2 Project Area.

3.1.3 Physical Aquatic Habitat

Detailed physical aquatic habitat surveys were conducted in seven watercourses for the Project, as well as eight watercourses for the existing Phase 1 project. Detailed results of these surveys are provided in Appendix A3.

The watercourses in the LSA have mostly a run morphology (Table 12). A number of tributaries had evidence of either past or current beaver activity. Vegetation bordering the sampled watercourses comprises grasses and shrubs with some muskeg and immature to established deciduous or mixed forest. Where beaver ponds are present large areas of vegetation have been flooded. Instream vegetation is minimal in larger watercourses, but smaller tributaries and dammed pools have high amounts of instream vegetation.

Table 11 Summary of fish captured in watercourses in the LSA, 2010.

Season	Site	BRST	FNDC	LKCH	LNDC	LNSC	NRDC	NRPK	PRDC	SLSC	TRPR	WHSC	Total
Spring													
	SPE1	-	1	-	-	-	1	-	-	-	-	-	**2**
	SPE3	-	37	-	-	-	-	-	-	-	-	-	**37**
	SPE5	-	-	-	-	2	-	-	6	4	-	18	**30**
	SPE6	-	-	-	-	-	-	-	-	-	-	-	**0**
	SPE7	14	69	-	-	-	-	-	-	-	-	-	**83**
Summer													
	SPE5	-	-	38	30	-	-	-	-	55	3	9	**135**
	SPE7	10	-	-	-	-	-	-	-	-	-	-	**10**
Fall													
	SP3	12	-	26	-	-	-	-	22	-	-	6	**66**
	SP8	-	-	-	-	-	-	-	-	-	-	-	**0**
	SP11	-	-	-	-	-	-	-	-	-	-	-	**0**
	SP20	-	-	20	-	-	1	-	1	-	-	1	**23**
	SP1	-	-	-	2	-	-	1	9	1	2	4	**19**
	SPE3	-	-	-	-	-	9	-	-	-	-	-	**9**
	SPE5	-	-	-	9	-	-	-	45	50	13	16	**133**
	SPE6	10	-	-	-	-	2	-	-	-	-	-	**12**
	SPE7	50	-	-	-	-	245	-	-	-	-	-	**295**

Species codes:

BRST-brook stickleback; FNDC-finescale dace; LKCH-lake chub; LNDC-longnose dace; LNSC-longnose sucker; NRDC-northern redbelly dace; NRPK-northern pike; PRDC-pearl dace; SLSC-slimy sculpin; TRPR-trout-perch; WHSC-white sucker.

Instream cover in these watercourses is dominated by instream vegetation, substrate and large woody debris with approximately equal amounts of each and lesser amounts of small woody debris and detritus. Stream substrates are dominated by fines and organic material with lesser amounts of gravels, cobbles, and boulders. On average, left and right bank slopes were about 50 degrees in slope with about 8% of the sampled length being unstable.

Visual aerial observations of watercourses in the LSA made during the baseline field studies suggest that most of the watercourses have similar characteristics as those described above and presented in detail in Table 12 and Appendix A5. In particular, beaver dams, often well-established, are frequent in the watercourses of the LSA, creating pool habitats in the upper portion of several watercourses and more defined channels in the lower portions where watercourses flow into the MacKay River.

Table 12 Physical aquatic habitat summary for watercourses in the LSA.

Streambed Material (% Streambed Area)		**Crown Closure and Instream Cover**	
		%Total Instream Cover as:	
Organic	32	Small woody debris	14
Fines	43	Large woody debris	22
Gravels	10	Detritus	9
Cobbles	10	Instream vegetation	35
Boulders	5	Substrate	20
Rock	0	% Total Instream Vegetation as:	
Anthropogenic Materials	-	Rooted vegetation	73
Bank Morphology (Average)		Free-floating vegetation and algae	7
Unstable Bank (%)	5	Flooded terrestrial and mosses	20
Left Bank Slope (deg)	42	**Overhead Cover (%)**	
Right Bank Slope (deg)	44	Litter <150 mm	5
Undercut (%)	1	Undercut banks	2
Channel Morphology (% Stream Area)		Grasses	34
Run	59	Litter >150 mm	13
Pool	27	Trees	19
Riffle	14	Shrubs	27
Other	-	**Channel Width (Average m)**	18

Given the limited amount of water available under ice for sites SPE1 through SPE5 (0 to 8 cm, Table 13), water quality samples were not collected at these sites in winter 2011. Winter habitat quality with respect to fish overwintering was variable. Both sites SPE6 and SPE7 are beaver pond habitat and appear to have water depth and dissolved oxygen concentrations suitable for overwintering of small-bodied fish species. Large-bodied fish species have not been documented in this type of habitat in any field studies. Site SP17 is located in Birchwood Creek, where large-bodied fish species have been documented (STP 2009).

Concentrations of dissolved oxygen (11.2 mg/L) in Birchwood Creek in winter 2011 are well above any concentrations where chronic or acute effects would be observed in large-bodied fish species (AEP 1997) (i.e., 2.4 mg/L of dissolved oxygen produces a chronic effect in white sucker, which have been captured in Birchwood Creek).

Table 13 Winter 2011 ice conditions in the LSA.

Site	Total Depth (cm)	Ice Thickness (cm)	Water Depth Under Ice (cm)
SPE1	35	35	0
SPE2	35	35	0
SPE3	38	30	8
SPE4	30	30	0
SPE5	50	45	5
SPE6	95	40	45
SPE7	75	40	35
SP17	95	30	65

3.1.4 Fish Habitat Suitability Assessment for Local Study Area

A number of habitat suitability index (HSI) models (Golder 2005) were applied to the LSA to assess overall habitat suitability for fish populations in the LSA. HSI models were applied to all species captured during baseline studies. Table 14 summarizes the results of the habitat suitability index models for the dominant species captured, while details of the application of the habitat suitability index models are provided in Appendix A5.

Based on data available, the habitat suitability models suggest that the MacKay River watershed is suitable for all life stages of fish species captured and expected, particularly brook stickleback, white sucker, finescale dace, and northern redbelly dace. Most sites show average suitability for all species assessed with the following exceptions:

- The MacKay River watershed was found to have no suitable habitat for longnose dace, despite this species being captured in the baseline field studies in 2010 in the MacKay River. Given the MacKay is only one river of many that were assessed; the weighted suitability is expected to be low.

- The MacKay River watershed, in the LSA, was found to have below average suitable habitat for slimy sculpin and pearl dace given the lower amount of fast flowing riffle habitat and hard substrate that these species require. However, the MacKay River further downstream exhibits more erosional habitat suitable to these species.

Table 14 Summary of HSI values for dominant species captured or expected to be present in the MacKay River watershed.

Species	Habitat Suitability	
	Suitability Index	Suitability Index Rating
Brook stickleback	0.63	Average
Lake chub	0.50	Average
White sucker	0.66	Average
Finescale dace	0.62	Average
Slimy sculpin	0.38	Below Average
Longnose dace	0.12	None
Northern redbelly dace	0.62	Average
Pearl dace	0.62	Average

3.2 BASELINE CASE FOR REGIONAL STUDY AREA

The Baseline Case for the RSA consists of data collected by the Regional Aquatics Monitoring Program (RAMP) in the MacKay River, downstream of the LSA and upstream of all existing development. Table 15 and Figure 5 provide the locations of the RAMP sampling stations for water quality, sediment quality and benthic invertebrates (RAMP 2005, 2010, 2011). The Baseline Case for fish resources consists of FWMIS data for the MacKay River watershed (ASRD 2011).

Table 15 Location of water and sediment quality and benthic invertebrate sampling on the MacKay River, downstream of the LSA, within the RSA.

RAMP Component	RAMP Station	Location	Years Monitored	UTM (Zone 12 NAD 83)	
				Easting	Northing
Water Quality	MAR-2A	Upstream of Suncor Dover	2009	449741	6320046
Sediment Quality	MAR-2	Upstream of Suncor MacKay	2002, 2004	444882	6314088
Benthic Invertebrates	MAR-E3	Upstream of Suncor Dover	2010	449741	6320046

3.2.1 Water Quality

RAMP annually samples water quality at one location on the MacKay River in the RSA of the Phase 2 Project, and upstream of all other development (Table 15). Table 16 provides a summary of the existing water quality data for the MacKay River watershed, upstream of other development and within the RSA for the Phase 2 Project.

3.2.2 Sediment Quality

Sediment quality data have been collected by RAMP in 2002 and 2004 at one location on the MacKay River, within the RSA and upstream of all other development in the watershed (Table 15, RAMP 2005). Table 17 provides a summary of the existing sediment quality data for the MacKay River watershed, upstream of other development and within the RSA for the Phase 2 Project. Given the MacKay River consists predominantly of erosional habitat, sediment quality sampling was discontinued in the MacKay River in 2005.

Table 16 **Summary of existing water quality data for the MacKay River, downstream of the LSA, within the RSA (RAMP 2010).**

Water Quality Category	Water Quality Variable	Units	Guideline	Detection Limit	RAMP Station MAR-2a			
					Fall	Spring	Summer	Winter
Conventional variables	Conductivity	µS/cm		0.2	268	102	183	615
	Dissolved Organic Carbon	mg/L		1	24.7	30.7	29.1	27
	Hardness (as $CaCO_3$)	mg/L		-	116	42.8	78.3	232
	pH	pH	6.5 - 9.0[c]	0.1	8.25	7.83	8.05	7.90
	Total Alkalinity	mg/L		5	122	42.1	80.4	268
	Total Dissolved Solids	mg/L		10	244	123	182	424
	Total Organic Carbon	mg/L		1	25.4	27.9	29.1	26
	Total Suspended Solids	mg/L		3	3	93	7	<3
	True Colour	TCU		2	186	170	155	79
General Organics	Naphthenic acids	mg/L		0.02	0.1782	0.16	0.06	0.2
	Total phenolics	mg/L		0.001	0.0091	0.0101	0.0084	0.006
	Total Recoverable Hydrocarbons	mg/L	-	1	<1	<1	<1	<1
Major Ions	Bicarbonate (HCO_3)	mg/L	-	5	148	51.4	98.1	327
	Calcium (Ca)	mg/L	-	0.5	31.3	11.4	20.6	59.2
	Carbonate (CO_3)	mg/L	-	5	<5	<5	<5	<5
	Chloride (Cl)	mg/L	230, 860[f]	0.5	0.6	5	0.5	6
	Hydroxide (OH)	mg/L	-	5	<5	<5	<5	<5
	Magnesium (Mg)	mg/L	-	0.1	9.13	3.48	6.53	20.4
	Potassium (K)	mg/L	-	0.5	0.94	1.39	0.64	2.3
	Sodium (Na)	mg/L	-	1	15.1	6.8	10.2	45
	Sulphate (SO_4)	mg/L	100[o]	0.5	18.4	7.91	11.5	60.9
	Sulphide	mg/L	2[r]	0.002	0.0125	0.0205	0.0081	0.009
Nutrients and BOD	Ammonia-N	mg/L	1.37[b]	0.05	<0.05	<0.05	<0.05	<0.05
	Biochemical Oxygen Demand	mg/L	-	2	<2	<2	0	<2
	Nitrate (as N)	mg/L	13	0.05	<0.05	<0.05	<0.05	-
	Nitrate+Nitrite (as N)	mg/L	1.3	0.071	<0.071	<0.071	<0.071	0.5
	Nitrite (as N)	mg/L	0.06	0.05	<0.05	<0.05	<0.05	-
	Phosphorus, Total Dissolved	mg/L	0.05[q]	0.001	0.0342	0.03	0.0263	0.046
	Phosphorus, Total	mg/L	0.05	0.001	0.0434	0.141	0.0446	**0.09**
	Total Kjeldahl Nitrogen	mg/L	1[1]	0.2	**1.7**	**1.5**	**1.5**	**1.1**
	Total nitrogen	mg/L	1	0.271	**1.8**	**1.5**	**1.6**	**1.6**
Metal - Dissolved	Aluminum	mg/L	-[a]	0.001	0.0166	0.0627	0.0257	0.00808
	Antimony	mg/L	0.02	0.000001	0.0000493	0.0000648	0.0000436	0.0000388
	Arsenic	mg/L	0.005	0.00006	0.000965	0.000492	0.000691	0.00134
	Barium	mg/L	5[h]	0.0001	0.0233	0.0149	0.0163	0.0453
	Beryllium	mg/L	-	0.00001	0.000012	0.0000174	0.0000121	0.0000038
	Bismuth	mg/L	-	0.00001	<0.00001	0.0000089	0.0000062	0.0000017
	Boron	mg/L	1.2[d]	0.0008	0.0707	0.0356	0.0547	0.16
	Cadmium	mg/L	[e]	0.000006	0.000006	0.0000036	0.0000056	0.0000076
	Calcium	mg/L	-	0.1	34.2	10.7	20.3	50.6
	Chlorine	mg/L	-	0.3	0.73	<0.3	0.277	52
	Chromium	mg/L	0.001[g]	0.0003	0.000351	0.000195	0.000217	0.000659
	Cobalt	mg/L	0.11	0.00001	0.00015	0.000134	0.000108	0.00011
	Copper	mg/L	[i]	0.0001	0.000684	0.000786	0.0008	0.001
	Iron	mg/L	0.3	0.004	**0.847**	**0.428**	**0.392**	**1**
	Lead	mg/L	-	0.000006	0.0000954	0.000105	0.0000621	0.0000511
	Lithium	mg/L	2.5	0.0002	0.0182	0.00706	0.0132	0.0333
	Manganese	mg/L	[p]	0.00003	0.0166	0.00526	0.00385	0.00954
	Molybdenum	mg/L	0.073	0.000008	0.000556	0.000192	0.000368	0.000614
	Nickel	mg/L	[m]	0.00006	0.00102	0.00123	0.000767	0.000594
	Selenium	mg/L	0.001	0.0002	<0.0002	<0.0003	<0.0003	0.00171
	Silver	mg/L	0.0001	0.000005	<0.000005	0.0000032	0.0000016	<0.000005
	Strontium	mg/L	-	0.000008	0.167	0.0567	0.114	0.357
	Sulphur	mg/L	-	0.6	7.07	2.41	4.17	18.9
	Thallium	mg/L	0.0008[c]	0.000003	0.0000036	0.0000034	0.0000052	<0.000003
	Thorium	mg/L	-	0.00003	0.0000375	0.0000541	0.000027	0.0000166
	Tin	mg/L	-	0.00007	<0.00007	<0.00007	<0.00007	<0.00007
	Titanium	mg/L	0.1	0.00007	0.00172	0.00443	0.00179	0.00258
	Uranium	mg/L	0.03[h]	0.000003	0.000267	0.0000774	0.000122	0.000609
	Vanadium	mg/L	-	0.00005	0.000442	0.000394	0.00035	0.000509
	Zinc	mg/L	-	0.0002	0.000687	0.000963	0.00131	0.00131
Total metals	Aluminum	mg/L	0.1[a]	0.002	**0.116**	**2.59**	**0.302**	0.0936
	Antimony	mg/L	0.02	0.000001	0.0000498	0.0000655	0.000044	0.0000392
	Arsenic	mg/L	0.005	0.00006	0.00112	0.00137	0.000854	0.00142
	Barium	mg/L	5[h]	0.0001	0.0255	0.0411	0.0211	0.0458
	Beryllium	mg/L	-	0.00001	0.0000175	0.000102	0.0000157	0.0000063
	Bismuth	mg/L	-	0.00001	<0.00001	0.0000221	0.0000099	<0.00001
	Boron	mg/L	1.2[d]	0.0008	0.0719	0.0399	0.0553	0.161
	Cadmium	mg/L	[e]	0.000006	0.000006	<0.0000225	0.0000071	0.0000136
	Calcium	mg/L	-	0.1	34.4	11.4	20.4	55.5
	Chlorine	mg/L	-	0.3	0.737	<0.3	0.28	52.6
	Chromium	mg/L	0.001[g]	0.0003	0.000418	0.00353	0.000526	0.000666
	Cobalt	mg/L	0.11	0.00001	0.000188	0.00117	0.000234	0.000138
	Copper	mg/L	[i]	0.0001	0.000757	0.00234	0.00081	0.00101
	Iron	mg/L	0.3	0.004	**1.26**	**3.44**	**0.817**	**2.04**
	Lead	mg/L	-	0.000006	0.000161	0.00148	0.000178	0.00013
	Lithium	mg/L	-	0.0002	0.0184	0.00999	0.0134	0.0343
	Manganese	mg/L	[p]	0.00003	0.0357	0.0851	0.0582	0.015
	Mercury (ultra-trace)	mg/L	5, 13[l]	1.2	2.6	6.4	<1.2	<1.2
	Molybdenum	mg/L	0.073	0.000008	0.000562	0.000194	0.000378	0.000625
	Nickel	mg/L	[m]	0.00006	0.0011	0.00322	0.000835	0.000759
	Selenium	mg/L	0.001	0.0002	<0.0002	<0.000157	<0.0003	0.00173
	Silver	mg/L	0.0001	0.000005	0.0000091	0.0000227	0.0000143	0.000005
	Strontium	mg/L	-	0.000008	0.168	0.0612	0.119	0.38
	Sulphur	mg/L	-	0.6	7.2	2.43	4.21	22.2
	Thallium	mg/L	0.0008[c]	0.000003	0.000004	0.0000354	0.0000061	<0.000003
	Thorium	mg/L	-	0.00003	0.0000503	0.000524	0.0000706	0.0000432
	Tin	mg/L	-	0.00007	<0.00007	<0.0000315	<0.00007	<0.00007
	Titanium	mg/L	0.1	0.00007	0.00277	0.0425	0.00674	0.00399
	Uranium	mg/L	0.033, 0.015	0.000003	0.000275	0.000217	0.000135	0.000656
	Vanadium	mg/L	-	0.00005	0.000763	0.00699	0.00104	0.000564
	Zinc	mg/L	0.03	0.0002	0.00118	0.0092	0.00203	0.0021

Values in bold indicate concentrations exceeding guidelines for the protection of aquatic life.

[1] Guideline is for total nitrogen.

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Table 17 Summary of existing sediment quality data for the MacKay River, downstream of the LSA, within the RSA (RAMP 2005).

Analyte	Units	Guideline ISQG[1]	RAMP Station MAR-2			
			N	Min	Median	Max
AEP Total extractable hydrocarbons (C11-C30)	mg/kg	-	2	10	37	64
AEP Total recoverable hydrocarbons	mg/kg	-	2	100	100	100
AEP Total volatile hydrocarbons (C5-C10)	mg/kg	-	2	0.50	0.85	1.20
Benzene	mg/kg	-	1	0.01	0.01	0.01
CCME Fraction 1 (BTEX)	mg/kg	-	1	5	5	5
CCME Fraction 1 (C6-C10)	mg/kg	30[2]	1	5	5	5
CCME Fraction 2 (C10-C16)	mg/kg	150[2]	1	5	5	5
CCME Fraction 3 (C16-C34)	mg/kg	400[2]	1	6	6	6
CCME Fraction 4 (C34-C50)	mg/kg	2800[2]	1	5	5	5
CCME Total hydrocarbons (C6-C50)	mg/kg	-	1	6	6	6
Ethylbenzene	mg/kg	-	1	0.01	0.01	0.01
Toluene	mg/kg	-	1	0.01	0.01	0.01
Xylenes	mg/kg	-	1	0.01	0.01	0.01
% Moisture_PAH sample	%	-	2	17.30	27.65	38.00
Acenaphthene	mg/kg	-	2	0.00014	0.000148	0.000156
Acenaphthylene	mg/kg	-	2	0.000085	0.000097	0.000108
Anthracene	mg/kg	-	2	0.000059	0.000086	0.000112
Benzo[a]pyrene	mg/kg	-	2	0.000991	0.001496	0.002
Benz[a]anthracene	mg/kg	-	2	0.000234	0.000247	0.00026
Benz[a]anthracene/Chrysene	mg/kg	-	-	-	-	-
Biphenyl	mg/kg	-	2	0.0001	0.000234	0.000368
C1-Benzofluoranthenes/Benzopyrenes	mg/kg	-	2	0.00453	0.007015	0.0095
C1-Benzo[a]anthracenes/Chrysenes	mg/kg	-	2	0.00797	0.023485	0.039
C1-Dibenzothiophenes	mg/kg	-	2	0.00051	0.000588	0.000666
C1-Fluoranthenes/Pyrenes	mg/kg	-	2	0.003	0.00345	0.0039
C1-Fluorenes	mg/kg	-	2	0.000585	0.000623	0.00066
C1-Naphthalenes	mg/kg	-	2	0.0008	0.000975	0.00115
C1-Phenanthrenes/Anthracenes	mg/kg	-	2	0.00152	0.00191	0.0023
C2-Benzofluoranthenes/Benzopyrenes	mg/kg	-	2	0.0012	0.002	0.0028
C2-Benzo[a]anthracenes/Chrysenes	mg/kg	-	2	0.00369	0.006345	0.009

[1] Freshwater sediment quality guidelines (CCME 2002).
[2] Guideline is for residential/parkland coarse (median grain size > 75µm) surface soils (CCME 2001).
Guideline exceedances are shown in bold.

Table 17 (Cont'd.)

Analyte	Units	Guideline ISQG[1]	RAMP Station MAR-2			
			N	Min	Median	Max
C2-Dibenzothiophenes	mg/kg	-	2	0.00192	0.00211	0.0023
C2-Fluoranthenes/Pyrenes	mg/kg	-	2	0.00437	0.006735	0.0091
C2-Fluorenes	mg/kg	-	2	0.0027	0.00336	0.00402
C2-Naphthalenes	mg/kg	-	2	0.0011	0.002065	0.00303
C2-Phenanthrenes/Anthracenes	mg/kg	-	2	0.00244	0.00262	0.0028
C3-Dibenzothiophenes	mg/kg	-	2	0.00205	0.002425	0.0028
C3-Fluoranthenes/Pyrenes	mg/kg	-	2	0.00203	0.002915	0.0038
C3-Fluorenes	mg/kg	-	2	0.0026	0.003305	0.00401
C3-Naphthalenes	mg/kg	-	2	0.00088	0.001915	0.00295
C3-Phenanthrenes/Anthracenes	mg/kg	-	2	0.00197	0.001985	0.002
C4-Dibenzothiophenes	mg/kg	-	2	0.0045	0.004705	0.00491
C4-Naphthalenes	mg/kg	-	2	0.00058	0.001305	0.00203
C4-Phenanthrenes/Anthracenes	mg/kg	-	2	0.0015	0.00519	0.00888
Chrysene	mg/kg	-	2	0.000646	0.001123	0.0016
Dibenzothiophene	mg/kg	-	2	0.000088	0.000094	0.0001
Dimethyl-Biphenyl	mg/kg	-	2	0.000078	0.000594	0.00111
Fluoranthene	mg/kg	-	2	0.000386	0.000648	0.00091
Fluorene	mg/kg	-	2	0.00014	0.000151	0.000162
Methyl Acenaphthene	mg/kg	-	2	0.000092	0.000121	0.00015
Methyl-Biphenyl	mg/kg	-	2	0.00005	0.000148	0.000245
Naphthalene	mg/kg	-	2	0.00065	0.001055	0.00146
Phenanthrene	mg/kg	-	2	0.000435	0.000588	0.00074
Pyrene	mg/kg	-	2	0.000284	0.000437	0.00059
Retene	mg/kg	-	2	0.00365	0.011825	0.02
% Clay	%	-	2	2	3	4
% Moisture	%	-	1	19	19	19
% Sand	%	-	2	90	93	95
% Silt	%	-	2	3	5	6
Inorganic Carbon	%	-	2	0.21	0.23	0.25
Total carbon by combustion	%	-	2	0.30	0.45	0.60
Total organic carbon	%	-	2	0.10	0.25	0.40
Total Aluminum (Al)	mg/kg	-	1	2340	2340	2340

1 Freshwater sediment quality guidelines (CCME 2002).

2 Guideline is for residential/parkland coarse (median grain size > 75µm) surface soils (CCME 2001).

Guideline exceedances are shown in bold.

Table 17 (Cont'd.)

Analyte	Units	Guideline ISQG[1]	RAMP Station MAR-2			
			N	Min	Median	Max
Total Antimony (Sb)	mg/kg	-	-	-	-	-
Total Arsenic (As)	mg/kg	5.9	2	2.8	3.2	3.6
Total Barium (Ba)	mg/kg	-	2	22.4	37.2	52.0
Total Beryllium (Be)	mg/kg	-	2	0.2	0.2	0.2
Total Bismuth (Bi)	mg/kg	-	1	0.5	0.5	0.5
Total Boron (B)	mg/kg	-	1	11	11	11
Total Cadmium (Cd)	mg/kg	0.6	2	0.1	0.1	0.1
Total Calcium (Ca)	mg/kg	-	1	2900	2900	2900
Total Chromium (Cr)	mg/kg	37.3	2	2.2	3.8	5.3
Total Cobalt (Co)	mg/kg	-	2	1.4	2.1	2.8
Total Copper (Cu)	mg/kg	35.7	2	1.8	3.9	6.0
Total Iron (Fe)	mg/kg	-	1	11400	11400	11400
Total Lead (Pb)	mg/kg	35	2	1.4	2.3	3.2
Total Magnesium (Mg)	mg/kg	-	1	1950	1950	1950
Total Manganese (Mn)	mg/kg	-	1	189	189	189
Total Mercury (Hg)	mg/kg	0.17	2	0.05	0.05	0.05
Total Molybdenum (Mo)	mg/kg	-	2	0.2	0.2	0.2
Total Nickel (Ni)	mg/kg	-	2	2.3	3.6	4.9
Total Phosphorus (P)	mg/kg	-	-	-	-	-
Total Potassium (K)	mg/kg	-	1	670	670	670
Total Selenium (Se)	mg/kg	-	2	0.2	0.2	0.2
Total Silver (Ag)	mg/kg	-	2	0.10	0.15	0.20
Total Sodium (Na)	mg/kg	-	1	110	110	110
Total Strontium (Sr)	mg/kg	-	2	9	15	21
Total Sulphur (S)	mg/kg	-	-	-	-	-
Total Thallium (Tl)	mg/kg	-	2	0.05	0.06	0.07
Total Tin (Sn)	mg/kg	-	1	2	2	2
Total Titanium (Ti)	mg/kg	-	1	19.8	19.8	19.8
Total Uranium (U)	mg/kg	-	2	0.11	0.21	0.30
Total Vanadium (V)	mg/kg	-	2	5.7	7.9	10.1
Total Zinc (Zn)	mg/kg	123	2	11	18	25

[1] Freshwater sediment quality guidelines (CCME 2002).
[2] Guideline is for residential/parkland coarse (median grain size > 75µm) surface soils (CCME 2001).
Guideline exceedances are shown in bold.

3.2.3 Benthic Invertebrate Communities

Benthic invertebrate data have been collected by RAMP in 2010 at one reach on the MacKay River, within the RSA and upstream of other development in the watershed (Table 15, RAMP 2011). Given the MacKay River running through the LSA is dominated by erosional habitat, the existing benthic data represents benthic communities in erosional habitat. A summary of measurement endpoint values (abundance, richness, diversity, evenness, and percentage *Ephemeroptera*, *Trichoptera* and *Plecoptera* [%EPT]) for this reach is provided in Table 18.

Table 18 Summary of existing benthic invertebrate indices for the MacKay River, downstream of the LSA, within the RSA (RAMP 2011).

Taxon	RAMP Reach MAR-E3
	2010
Total Abundance (No./m^2)	4,300
Richness	35
Simpson's Diversity	0.81
Evenness	0.83
% EPT	22

3.2.4 Fish Resources

The RSA for the Phase 2 Project is the MacKay River, downstream of the LSA. Table 9 indicates that a total of 15 fish species are documented in the MacKay River, which is the only sixth order stream in the watershed.

While information on fish health specific to the MacKay River watershed is not available, there is some information for other watersheds in the Fort McMurray region. The majority of information on fish health comes from studies conducted in the Athabasca or Clearwater Rivers, and the data presented here is based on data collected for RAMP. RAMP (2009) reported that:

- mean mercury concentrations across all size classes in walleye and lake whitefish in the Athabasca River were below the Health Canada guideline for subsistence fishers indicating a negligible-low risk to human health;

- a negligible-low risk to the health of walleye and lake whitefish were identified given all metals in composite samples were below sublethal effects and no-effects criteria; and

- all tainting compounds in walleye and lake whitefish muscle tissue from the Athabasca River were below guideline concentrations indicating a negligible-Low influence on fish palatability.

3.3 BASELINE CASE FOR ACID SENSITIVITY OF SURFACE AQUATIC RESOURCES

Acid-sensitive lakes occur in areas with little or no capacity to neutralize acidic deposition. This capacity is determined by basin soil characteristics (e.g., soil chemistry, composition, and depth), extent and type of vegetation cover, and drainage patterns (Holowaychuk and Fessenden 1987, Lucas and Cowell 1984). Typically, these lakes occur in areas of moderate to high elevation and high relief, with severe, short-term changes in hydrology, small drainage systems, and minimal contact between drainage waters and basin soils or geologic materials.

Acid-sensitive surface waters typically exhibit low pH (<6.5), low concentrations of all major ions (i.e., specific conductance is <25 µS/cm), low organic acid concentrations (i.e., DOC concentration is typically less than 3 to 5 mg/L), and low acid neutralizing capacity (i.e., ANC <200 µeq/L) (Sullivan *et al.* 1989).

Lakes are not present in the surface aquatic resources LSA or RSA for the Project. Therefore, an assessment of acid sensitivity was conducted using lakes within the Air Quality RSA (AQRSA). In the AQRSA, there are 36 lakes that have been designated as acid-sensitive based on the characteristics of these lakes (RAMP 2011). Of the 36 lakes, Baseline Case PAI inputs for 14 of the lakes exceeded the Critical Load by approximately 0.5% to 80%. These lakes are primarily located southeast of the Phase 2 project.

4.0 EFFECTS ASSESSMENT

4.1 EFFECTS ON SURFACE AQUATIC RESOURCES THROUGH SURFACE DISTURBANCE AND CONSTRUCTION ACTIVITIES

4.1.1 Description of Effects and Assessment of Validity of Impact Pathways

A number of surface disturbance and construction activities will take place within the LSA during construction, reclamation and decommissioning phases of the Phase 2 Project that may give rise to increased sediment loading in watercourses and waterbodies. These activities may have consequent effects on water quality, aquatic habitat and fish populations and include:

- vegetation clearing and overburden stripping for access roads and utility corridor construction, borrow pit development, and well pad construction;
- management of soil stockpiles;
- dismantling of all Project facilities; and
- re-grading and re-vegetation of reclamation areas.

These Project disturbances will be located in the drainage basin of the MacKay River and within a number of sub-basins of tributaries to the MacKay River. The linkage between surface disturbance and construction activities and potential changes in sediment yield is; therefore, assessed as valid.

4.1.2 Mitigation Measures to be Implemented

The Phase 2 Project will implement a number of well-established mitigation measures which will effectively prevent or reduce to acceptable levels the effects from surface disturbance Project activities. A range of different measures will be implemented including:

- the requirement for earthworks contractors to utilize an effective sediment control plan;

- sediment control measures such as those described in the *Alberta Code of Practice for Watercourse Crossings* (AENV 2000) and associated guidelines will be implemented for earthworks which take place within or in close proximity to watercourses. These measures may include, as required: the use of cutoff trenches, silt fences, flow barriers, temporary and/or permanent sediment control ponds and/or traps, and ditches to minimize or eliminate sediment transport from exposed soil areas into receiving watercourses and waterbodies;

- whenever possible, surface disturbance activities in close proximity to watercourses will be carried out during periods of relatively low surface runoff in late fall, winter and early spring (from October to April). A 30 m buffer (vegetation) strip will be left between disturbance sites and watercourses except at stream crossings and diversions;

- the time interval between clearing/grubbing and subsequent earthworks will be minimized, particularly at or in the vicinity of watercourses or in areas susceptible to erosion;

- where relevant, slope grading and stabilization techniques will be adopted. Slopes will be contoured to produce moderate slope angles to reduce erosion risk. Other stabilization techniques used to control erosion may include: ditching above the cutslope to channel surface runoff away from the cutslope, leaving buffer (vegetation) strips between the disturbance area and a watercourse, placing large rock rip rap to stabilize slopes;

- where required, surface runoff collection and treatment systems will be used to direct surface runoff from both disturbed areas and constructed areas (well pads and roads) into settling impoundments/sumps for removal of settleable solids;

- progressive disturbance and reclamation will be undertaken to reduce the amount of disturbed area at any given time. A primary objective of the progressive reclamation program will be to quickly re-establish, permanent plant cover. Soil erosion will therefore be reduced by minimizing the time that reclaimed surfaces are left bare; and

- where necessary, interim erosion/sediment control measures will be utilized until long-term protection can be effectively implemented.

4.1.3 Impact Analysis

With strict implementation of the mitigation measures summarized above and other measures described in detail for this Project, potential impacts of surface disturbance activities are predicted to be low for the following reasons:

- impacts from construction activities which have been identified as potentially adverse are mitigable using standard engineering and environmental design applications;

- potential adverse effects associated with sedimentation will be localized, that is, they will occur mainly during periods of construction and reclamation and will be confined to the immediate and downstream areas of the surface disturbance activities;

- surface run-off from active areas such as well pads and roads will be managed in a manner in which erosion from surface water runoff will be minimized. Ditches will be designed to avoid ponding of water along the road surface. Flows will be maintained across drainages and wetlands with the appropriate use of culverts; and

- construction of well pads and associated infrastructure will be phased with progressive reclamation in order to minimize the amount of area disturbed at any one time.

4.1.4 Residual Effects Classification

The residual (after mitigation) effects of the Project on aquatic resources through surface disturbance and construction activities are assessed as ***Low Impact*** in the LSA:

- **Magnitude** – magnitude of effects will be ***Low.*** With the effective application of well-accepted and regulated mitigation measures, changes are expected to be within established protective standards and to cause no detectable change in surface water or aquatic habitat quality beyond occasional, local effects;

- **Geographic Extent** – effects will be ***Local,*** within the LSA;

- **Duration of Impact** – effects will be ***Long,*** occurring over the life of the project from development and ongoing reclamation through to decommissioning;

- **Frequency** – effects will be ***Occasional,*** occurring intermittently and sporadically over assessment period;

- **Ability for Recovery –** effects will be ***reversible in the short-term*** and will diminish upon cessation of activities;

- **Project Contribution** – ***Negative***, there will be some localized, periodic negative effects on surface water quality from Project surface disturbance activities;

- **Confidence Rating** – ***High,*** the mitigation measures to be applied are well-accepted and there is good evidence from previous studies that the effective application of these measures in accordance with operating procedures will mitigate any effects of surface disturbance activities; and

- **Probability of Occurrence** – ***High***, based on experience from previous similar projects.

Because the residual effects of the Project on surface aquatic resources through surface disturbance and construction activities are assessed as ***Low Impact*** in the LSA, these residual effects: these residual effects are also assessed as ***Low Impact*** for the RSA.

4.2 EFFECTS ON SURFACE AQUATIC RESOURCES THROUGH INSTREAM CONSTRUCTION ACTIVITIES

4.2.1 Description of Effects and Assessment of Validity on Impact Pathways

Direct changes and physical loss of aquatic habitat may occur during instream construction works, such as watercourse crossing sites (roads or utilities) by the direct disturbance of the streambed, banks or riparian areas. Direct habitat effects can include alteration or loss of specific habitat features, such as pools, aquatic vegetation and bed materials, that ultimately lead to loss or impairment of habitat functions, such as overwintering, spawning and rearing. The specific effects will depend on the type of habitat at the crossing site, the type of crossing method used and the timing of the construction period.

There are 28 potential watercourse crossings in the Phase 2 Project area with three crossings situated on watercourses with fish and fish habitat (Figure 5). The linkage between instream construction activities and effects on surface aquatic resources is therefore assessed as valid.

4.2.2 Mitigation Measures to be Implemented

The Phase 2 Project will implement a number of well-established mitigation measures which will effectively prevent or reduce to acceptable levels the effects on aquatic habitat from instream construction activities. These measures include:

- whenever possible, instream construction activities will be carried out during periods of relatively low surface runoff in late fall, winter and early spring (from October to April);
- all crossings of watercourses with fish and fish habitat will be clear span and constructed in accordance with the DFO Alberta Operational Statement for Clear Span Bridges; and
- all watercourse crossings will be designed and constructed in compliance with the *Alberta Code of Practice for Watercourse Crossings* (AENV 2000) and associated guidelines. For watercourse crossings these requirements include: aquatic and biological assessments; watercourse crossing design and construction; post-construction clean-up and reclamation; contingency measures; and watercourse crossing site monitoring. Implementation of appropriate mitigation measures means that all stream crossings constructed and operated for the Phase 2 Project will meet regulatory requirements for the protection of fish resources and aquatic habitat and will subsequently mitigate against effects on surface water quality.

4.2.3 Impact Analysis

With strict implementation of the mitigation measures summarized above, potential impacts of instream construction activities are predicted to be low for the following reasons:

- Impacts from instream construction are mitigable using standard engineering and environmental design applications and adhering to work timing windows;
- potential adverse effects associated with sedimentation will be temporary, short-term and localized, that is, they will occur mainly during periods of construction and reclamation and will be confined to the immediate and downstream areas of the surface disturbance activities;
- a minimum 100 m buffer will be maintained from the edge of the MacKay River and all construction activities proposed to take place; and
- a minimum 50 m buffer will be maintained from the edge of the stream bank for all other construction activities which are proposed to take place near watercourses with defined channels.

4.2.4 Residual Effects Classification

The residual (after mitigation) effects of the Project on aquatic resources through in-stream construction activities are assessed as ***Low Impact*** in the LSA:

- **Magnitude** – magnitude of effects will be ***Low.*** With the effective application of well-accepted and regulated mitigation measures, changes are expected to be within established protective standards and to cause no detectable change in aquatic habitat quality beyond occasional, local effects;
- **Geographic Extent** – effects will be ***Local,*** within the LSA;
- **Duration of Impact** – effects will be ***Long,*** occurring over the life of the project from development and ongoing reclamation through to decommissioning;
- **Frequency** – effects will be ***Occasional,*** occurring intermittently and sporadically over assessment period;
- **Ability for Recovery –** effects will be ***reversible in the short-term*** and will diminish upon cessation of activities;
- **Project Contribution** – ***Negative***, there will be some localized, periodic negative effects on surface water quality from Project surface disturbance activities;
- **Confidence Rating** – ***High,*** the mitigation measures to be applied are well-accepted and there is good evidence from previous studies that the effective application of these measures in accordance with operating procedures will mitigate any effects of in-stream construction activities; and
- **Probability of Occurrence** – ***High***, based on experience from previous similar projects.

Because the residual effects of the Project on surface aquatic resources through in-stream construction activities are assessed as ***Low Impact*** in the LSA, these residual effects are also assessed as ***Low Impact*** for the RSA.

4.3 EFFECTS ON SURFACE AQUATIC RESOURCES THROUGH CHANGES IN SURFACE WATER QUALITY

4.3.1 Description of Effects and Assessment of Validity Impact Pathways

The following Project activities may negatively affect surface water quality, and may give rise to resultant changes to aquatic habitat and fish populations:

- discharge of Project-affected water to natural watercourses;
- accidental spills of hydrocarbons, chemicals and waste products used and stored within Project Development Area; and
- changes in shallow groundwater quality.

The linkage between these Project activities and potential changes in surface water quality is considered valid.

4.3.2 Mitigation Measures to be Implemented

Discharge of Project-affected waters: The steam condensate and water used in the SAGD process will be recycled as much as possible. A produced water recycling rate of 97% is expected, making the Phase 2 Project a near zero liquid discharge operation. The waste stream of concentrated brine from the evaporation-distillation process will be trucked or pipelined to approved disposal wells. No planned discharges of process-affected waters will take place from the Phase 2 Project, hence impact to natural watercourses is considered low and no mitigation measures are proposed.

Surface water run-off from the plant site will be directed to a storm water retention pond which will be constructed in accordance with relevant energy utilities board (EUB) and AENV regulations. All surface runoff will be collected in the settling pond and released to the surrounding watershed if it meets the quality requirements outlined in the operating approval. However, it is anticipated that occasionally, depending upon site and operating conditions, the surface runoff collected in the settling pond may be returned to the CPF for use as plant makeup water.

All storage tanks, except boiler feed water and source water tanks, will be equipped with secondary containment and leak detection equipment to minimize the occurrence of product leaks, hence under normal operating conditions, surface run-off from the plant to the retention pond is not anticipated to contain any process related chemicals.

The storm water retention pond will function as a sedimentation pond and will settle particulates to reduce levels of any sediment-associated chemicals, such as metals, nutrients and organics. To mitigate against potential adverse impacts to surrounding watercourses, retention pond water will always be tested prior to discharge and will only be released in accordance with the terms and conditions of the operating approval. Based on the anticipated management of runoff waters and the controlled rate of water releases from the stormwater ponds, the release of runoff waters on nearby surface waters is predicted to have a negligible effect on water quality.

Accidental spills: The facilities or locations where potentially contaminating materials are handled, transferred or stored include the well pad during drilling of production wells and the CPF.

Management and disposal of all drilling waste will be in accordance with all regulations and will be implemented under the Phase 2 Project's waste management plan. Disposal options for liquid drilling waste include disposal at a licensed third party waste disposal facility or pump off. Solid drilling waste, which is largely composed of bentonite clay, will be stored in remote sump locations for chemical testing. Depending on hydrocarbon levels, these drill wastes will either be disposed of on-site using the mix-bury-cover method or will be disposed of at an approved waste disposal facility. The remote sump locations will be selected and constructed after soil sampling to ensure the base material meets the required permeability limits to mitigate against accidental leakage from the sumps.

A range of potentially contaminating materials are handled or stored within the CPF. All storage tanks, except boiler feed water and source water tanks, will be equipped with secondary containment and leak detection equipment to mitigate against product leaks. Additionally, an Integrated Environmental Health and Safety Management Plan will be prepared for the Project. This Plan will include an Emergency Response Plan; a Substance Release Control and Monitoring Plan and a Loss Control and Environmental Compliance Program which will describe the contingency plans for responses to accidental releases. Collectively, the secondary containment and leak detection measures, along with management and response plans will minimize the risk of substance release into watercourses and waterbodies and resultant negative impacts to aquatic resources.

4.3.3 Impact Analysis

With strict implementation of the mitigation measures summarized above, potential impacts to aquatic resources through changes in surface water quality and discharge of Project-affected water into natural watercourses are predicted to be low for the following reasons:

- no planned discharges of process-affected waters will take place from the Project;
- occasional releases from the storm water retention pond may take place, but water will always be tested prior to discharge and will only be released in strict accordance with the terms and conditions of the operating approval;
- design features, management practices, mitigation plans and emergency response procedures will minimize the potential for accidental release of substances into waterbodies or watercourses; and
- shallow groundwater quality is not expected to be significantly impacted by Project activities; therefore resultant changes to surface water are not expected.

4.3.4 Residual Effects Classification

The residual (after mitigation) effects of the Project on aquatic resources due to changes in surface water quality are assessed as ***Low Impact*** in the LSA:

- **Magnitude** – magnitude of effects will be ***Low to Moderate.*** There may be changes in surface water quality as a result of accidental releases. With the effective application of well-accepted and regulated mitigation measures and contingency plans, these changes are expected to be generally within established protective standards and to cause no detectable change in surface water quality beyond occasional, local effects. However, under upset conditions, it is predicted that some disturbances may cause short-term detectable changes in background ecological parameters;

- **Geographic Extent** – effects will be ***Local,*** within the LSA;
- **Duration of Impact** – effects will be ***Long,*** occurring over the life of the project from development and ongoing reclamation through to decommissioning;
- **Frequency** – effects will be ***Occasional to accidental,*** occurring intermittently and sporadically or rarely over assessment period;
- **Ability for Recovery –** effects will be ***reversible in the short-term*** and will diminish upon cessation of activities;
- **Project Contribution** – ***Negative***, there will be some localized, occasional negative effects on surface water quality from Project activities;
- **Confidence Rating** – ***High,*** the management practices and mitigation measures to be applied are well-accepted and there is good evidence from previous studies that the effective application of these measures will mitigate any effects of Project activities on surface water quality. The level of confidence in the groundwater assessment is dependent of the reliability and robustness of the hydrogeological analyses of Project effects as described in MEMS (2011a); and
- **Probability of Occurrence –** ***Medium,*** possible - based on experience from previous similar projects.

Because the residual effects of the Project on surface aquatic resources through changes in surface water quality are assessed as ***Low Impact*** in the LSA, these residual effects are also assessed as ***Low Impact*** for the RSA.

4.4 EFFECTS ON SURFACE AQUATIC RESOURCES THROUGH CHANGES TO SURFACE FLOW RATES AND LEVELS

4.4.1 Description of Effects and Assessment of Validity Impact Pathways

Changes in stream flow can affect:

- spawning, rearing, feeding, migration and overwintering habitats of fish-bearing streams and rivers through reduced stream area and shallow depth, reducing dissolved oxygen under the ice;
- watercourse productivity and availability of food for fish (e.g., benthic invertebrates); and
- the presence of macrophytes, which provide cover, spawning material or food for fish.

Changes to surface water flow rates could result from:

- surface disturbance activities altering natural run-off and drainage patterns;

- surface water withdrawal activities required to meet water requirements for the Project's SAGD process;
- release of process affected waters to natural waterbodies; and
- changes in the amount of shallow groundwater reporting to surface water.

The linkage between these Project activities and potential changes in surface water flow rates is considered valid.

4.4.2 Mitigation Measures to be Implemented

Changes to natural run-off and drainage patterns due to surface disturbance activities: Mitigation measures to minimize potential impacts include diverting runoff from disturbed areas into the natural environment, away from the existing stream networks and phasing reclamation activities such that they commence before the entire Project is developed.

Changes to surface water flow rates due to surface water withdrawal activities: Water requirements for Phase 2 process will be met through groundwater withdrawals. There will be no surface water withdrawals for the Project process activities, with the exception of the potential use of water collected in the stormwater retention pond, short-term withdrawals for winter ice road construction and summer road dust suppression. These withdrawals will meet water license requirements to ensure that any adverse impacts to surface water flow rates are mitigated.

Changes to surface water flow rates due to release of Project process-affected water: No planned discharges of process-affected waters will take place from the Project. Occasional releases may take place from the storm water retention pond to the environment. Such releases will be undertaken at a controlled rate, in strict accordance with the terms and conditions of the operating approval, in order to mitigate against adverse impacts to surface water flow rates.

Changes to surface water flow rates due to changes in the amount of groundwater reporting to surface water: The Hydrogeology Assessment (MEMS 2011a) for the Phase 2 project indicates that all Project process water requirements will be met through groundwater withdrawals from the Quaternary formation. No other Project activities have been identified (e.g., excavation works) that are expected to impact on shallow groundwater/surface water interactions, therefore minimal impact to the amount of shallow groundwater reporting to surface water is expected.

4.4.3 Impact Analysis

Potential impacts to aquatic resources through changes in surface water flow rates are predicted to be low:

- only small increases in surface water runoff volumes are predicted as a result of surface disturbances. The Hydrology assessment (nhc 2011) predicts maximum changes in average runoff volume of between 8.9%

below and 8.3% above Baseline Case conditions in the unnamed watercourses in the LSA. Minor changes in peak annual flows and low flow rates in winter are anticipated in streams in the LSA.

- no planned discharges of Process-affected waters will take place from the Phase 2 Project therefore no consequent changes to surface water flow rates are expected.
- occasional releases from the storm water retention pond may take place, but water will be released at a controlled rate in accordance with the terms and conditions of the operating approvals.
- shallow groundwater levels are not expected to be materially affected by Project activities and therefore no resulting changes to surface water flow rates are expected.

4.4.4 Residual Effects Classification

The residual (after mitigation) effects of the Project on surface aquatic resources due to changes in surface water flow rates are assessed as ***Low Impact*** in the LSA:

- **Magnitude** – magnitude of effects will be ***Low*. **Changes are expected to be generally within established protective standards and to cause no detectable change to surface water flow rates beyond occasional, local effects;
- **Geographic Extent** – effects will be ***Local,*** within the LSA;
- **Duration of Impact** – effects will be ***Long,*** occurring over the life of the project from development and ongoing reclamation through to decommissioning;
- **Frequency** – effects will be ***Occasional and Seasonal,*** occurring intermittently and sporadically over assessment period, and in the case of changes to water flows and levels due to surface disturbance;
- **Ability for Recovery –** effects to water flows and levels due to surface disturbance will be ***reversible in the long-term,*** all other effects will be ***reversible in the short-term*** and will diminish upon cessation of activities;
- **Project Contribution** – *Negative*, there will be some localized, occasional, minor negative effects on surface water flow rates from Project activities;
- **Confidence Rating** – ***High,*** The level of confidence in this assessment is dependent of the reliability and robustness of the hydrological and hydrogeological analyses of Project effects as described in nhc (2011) and MEMS (2011); and
- **Probability of Occurrence** – ***High***, based on experience from previous similar projects.

Because the residual effects of the Project on surface aquatic resources through changes in surface water flow rates are assessed as ***Low Impact*** in the LSA, these residual effects: are also assessed as ***Low Impact*** for the RSA.

4.5 EFFECTS ON SURFACE AQUATIC RESOURCES FROM IMPROVED OR ALTERED ACCESS TO FISH BEARING WATERBODIES

4.5.1 Description of Effects and Assessment of Validity of Impact Pathways

Improved access and increased workforce in the area as a result of the Phase 2 Project could increase fishing pressure and fish harvest in local fish-bearing waterbodies and watercourses. This could, in turn, result in a decreased abundance of sportfish if fishing pressure and/or fish harvest were not appropriately managed.

The linkage between these altered access and potential increases in fishing pressure is considered valid.

4.5.2 Mitigation Measures to be Implemented

STP will work with ASRD (the government resource agency mandated to manage provincial fisheries resources) to ensure the fisheries resources in the study area, particularly the lakes, do not become over-exploited as a result of increased sportfishing. Possible initiatives include:

- raising awareness among the STP Project workers of the existing ASRD regulations for the species found in the study area lakes; and
- discouraging fishing by Project employees within the LSA.

4.5.3 Impact Analysis

While many fish populations in the RSA, particularly the MacKay River, are sensitive to angling pressure, and while the workforce may potentially catch additional fish, it is expected that the mitigation and management measures described above will mean that these effects of increased angling on LSA fish populations will be low.

The watercourses in the Phase 2 Project area contain primarily small-bodied fish species or juvenile life stages of large-bodied and sportfish species. Therefore, it is also expected that fishing pressure will be low given the Project is in an area primarily consisting of lower-order streams with few sportfish species reaching length-classes that meet ASRD regulations for catch limits.

4.5.4 Residual Effects Classification

The residual (after mitigation) effects of the Project on aquatic resources from improved or altered access to fish bearing watercourses are assessed as ***Low Impact*** in the LSA:

- **Magnitude** – magnitude of effects will be ***Low.*** With the effective application of mitigation and management measures, changes to fisheries resources are expected to be well within established or accepted protective standards;
- **Geographic Extent** – effects will be ***Local,*** within the LSA;
- **Duration of Impact** – effects will be ***Long,*** occurring over the life of the project from development and ongoing reclamation through to decommissioning;
- **Frequency** – effects will be ***Occasional,*** occurring intermittently and sporadically over assessment period;
- **Ability for Recovery –** effects will be ***reversible in the short-term,*** being reversible and diminishing upon cessation of activities;
- **Project Contribution** – ***Negative,*** there may be a net loss to fish resources;
- **Confidence Rating** – ***High,*** the mitigation and management measures to be applied are well-accepted and there is good evidence from previous studies that the effective application of these measures in accordance will ensure the potential for over-fishing is minimized; and
- **Probability of Occurrence** – ***Medium to High,*** depending on the level of management measures implemented.

Because the residual effects of the Project on surface aquatic resources through improved or altered access to fish-bearing watercourses are assessed as ***Low Impact*** in the LSA, these residual effects are also assessed as ***Low Impact*** for the RSA given the migratory patterns of sportfish in the watershed.

4.6 EFFECTS ON FISH HEALTH, INCLUDING FISH TAINTING THROUGH CHANGES IN WATER QUALITY

4.6.1 Description of Effects and Assessment of Validity of Impact Pathways

Changes in water quality have the potential to affect the health of fish and other aquatic organisms and the linkage between potential changes in water quality and fish health for this Project is assessed as valid.

4.6.2 Mitigation Measures to be Implemented

Section 4.1.2, Section 4.2.2 and Section 4.3.2 outlines mitigation measures to address potential sedimentation of surface waters, as well as any releases of process-affected water and accidental spills of contaminants to surface waters; these mitigation measures are applicable to this issue as well.

4.6.3 Impact Analysis

With implementation of the mitigation measures summarized in Section 4.1.2, Section 4.2.2 and Section 4.3.2 potential impacts to fish health through potential changes in water quality are predicted to be low.

4.6.4 Residual Effects Classification

The residual (after mitigation) effects of the Project on fish health through changes in water quality are assessed as ***Low Impact*** in the LSA:

- **Magnitude** – magnitude of effects will be ***Low.*** With the effective application of well-accepted and regulated mitigation measures, changes are expected to be well within established protective standards and to cause no detectable change in fish health;

- **Geographic Extent** – effects will be ***Regional*** given the migratory behavior of some fish species documented in the LSA;

- **Duration of Impact** – effects will be ***Long,*** occurring over the life of the project from development and ongoing reclamation through to decommissioning;

- **Frequency** – effects will be ***Occasional to Accidental,*** occurring intermittently and sporadically or rarely over the assessment period;

- **Ability for Recovery –** effects will be ***Reversible in the short-term*** and will diminish upon cessation of activities;

- **Project Contribution** – *Negative*;

- **Confidence Rating** – ***High***, The mitigation measures to be applied are well-accepted and there is good evidence from previous studies that the effective application of these measures in accordance with operating procedures will mitigate effects of in-stream construction activities such that they are *Low Impact*; and

- **Probability of Occurrence** – ***Low***, unlikely based on the results of longer term fish health monitoring programs in the Athabasca oil sands region (RAMP 2011).

Because the residual effects of the Project on surface aquatic resources on fish health are assessed as ***Low Impact*** in the LSA, these residual effects are also assessed as ***Low Impact*** for the RSA.

4.7 EFFECTS ON SURFACE AQUATIC RESOURCES FROM ACIDIFYING EMISSIONS

4.7.1 Description of Effects and Assessment of Validity of Impact Pathways

The Phase 2 Project will result in the release of acidifying emissions as described in the Air Quality Assessment (MEMS 2011b); the potential for acidifying emissions from the Project to affect surface aquatic resources in both the Air Quality RSA is considered a valid impact pathway.

4.7.2 Mitigation Measures to be Implemented

The Air Quality Assessment Report (MEMS 2011b) describes a series of mitigation measures to be implemented in the Phase 2 Project that will minimize acidifying emissions.

4.7.3 Impact Analysis

4.7.3.1 Application Case

The predicted annual input of acidifying substances (PAI) for Baseline and Application cases (MEMS 2011b) for acid-sensitive lakes in the AQRSA is presented in Table 19. With the exception of three lakes to the northeast of Fort McMurray, predicted PAI values at all lakes are below Alberta's Clean Air Strategic Alliance (CASA) target level of 0.25 keq H^+/ha/yr (AEP 1997) for the Baseline and Application cases.

PAI values for fourteen lakes exceed critical load values in both the Baseline and Application cases; there are no lakes that exceed the critical load value in just the Application Case.

The area within the Air Quality Regional Study Area (AQRSA) which receives PAI in excess of 0.25 keq H+/ha/yr for the Application Case is predicted to remain the same as the Baseline Case at 6.2 km^2. This affected area represents less than 1% of the total area of the AQRSA (82,350 km^2). No increases in potential for acidification are predicted to result from the Project within the AQRSA in the Application Case.

4.7.3.2 Planned Development Case

One lake in the Birch Mountains subregion of the acid-sensitive lakes in the AQRSA has a predicted PAI value that exceeds the Critical Load for the Planned Development Case but not the Baseline and Application cases (Lake 199, Table 19) (MEMS 2011b). There are no additional lakes with predicted PAI values that exceed the Alberta's Clean Air Strategic Alliance (CASA) target level of 0.25 keq H^+/ha/yr (AEP 1997) for the Planned Development Case compared to the Baseline and Application cases.

Table 19 Comparison of estimated PAI inputs in Baseline, Application and Planned Development cases and Critical Load for AQRSA lakes.

RAMP Lake ID (RAMP 2011)	Original Name	Lake Area (km²)	UTM Coordinates (NAD83, Zone12)		Distance from Lake Center to AQ Receptor (m)	Sensitivity to Acidification (from Saffran and Trew 1996)	Annual Average PAI (keq/ha/yr)			Critical Load (RAMP 2011)
			Easting	Northing			Baseline Case	Application Case	Planned Develop-ment Case	
Stony Mountains Sub-Region										
168	A21	1.38	483819	6235130	222	High	0.063	0.063	0.096	-0.137
169	A24	1.45	484387	6230872	4,146	High	0.063	0.063	0.096	-0.254
170	A26	0.71	489502	6230877	6,101	High	0.066	0.066	0.108	-0.049
167	A29	1.05	466180	6224950	2,181	High	0.050	0.050	0.072	-0.278
287	25	2.18	487594	6229281	5,590	High	0.048	0.048	0.077	-0.260
289	27	1.83	477248	6228400	4,702	High	0.049	0.049	0.077	0.008
290	28	0.54	487068	6225576	3,122	High	0.048	0.048	0.077	-0.032
Birch Mountains Sub-Region										
436	L18/Namur	43.39	402704	6368016	3,283	Low	0.073	0.073	0.101	3.055
442	L23/Otasan	3.44	417321	6396959	3,856	Moderate	0.057	0.057	0.069	0.245
444	L25/Legend	16.8	383849	6364923	170	Low	0.070	0.071	0.092	1.088
447	L28	1.3	382996	6414339	1,202	High	0.050	0.050	0.058	0.162
448	L29/Clayton	0.65	424694	6435790	1,052	High	0.047	0.048	0.058	-0.483
454	L46/Bayard	1.2	416941	6404239	3,038	Moderate	0.055	0.055	0.066	0.391
455	L47	4.37	396500	6395456	2,541	Moderate	0.053	0.053	0.064	1.227
457	L49	2.61	404995	6403111	2,135	High	0.052	0.053	0.063	0.569
464	L60	0.91	403796	6392247	2,461	Moderate	0.054	0.054	0.065	0.498
175	P13	0.38	416003	6353212	2,216	Low	0.089	0.090	0.123	0.526
199	P49	2.61	446002	6394961	2,002	High	0.093	0.094	0.159	0.105
Northeast of Fort McMurray Sub-Region										
452	L4 (A-170)	0.61	508990	6334305	5,038	High	0.206	0.207	0.248	0.080
470	L7	0.33	461006	6368512	4,615	High	0.603	0.604	1.158	0.210
471	L8	0.56	460931	6369481	5,431	Moderate	0.603	0.604	1.158	0.428
400	L39/E9/A-150	1.12	536495	6424234	2,610	Moderate	0.067	0.067	0.083	0.851
268	E15	1.87	506092	6305335	2,119	Moderate	0.138	0.139	0.195	2.310
182	P23	0.28	509000	6346712	5,285	Least	0.221	0.222	0.266	3.188
185	P27	0.09	508300	6333712	4,489	High	0.206	0.207	0.248	0.051
209	P7	0.15	515399	6343212	2,270	High	0.209	0.209	0.242	1.323
270	4	3.44	506113	6291421	4,156	Least	0.102	0.102	0.143	5.369
271	6	4.31	549064	6277789	5,669	Least	0.046	0.046	0.065	3.638
418	Kearl	5.34	485939	6349881	5,252	Least	2.897	2.898	7.362	2.082

Table 19 (Cont'd.)

RAMP Lake ID (RAMP 2011)	Original Name	Lake Area (km^2)	UTM Coordinates (NAD83, Zone12)		Distance from Lake Center to AQ Receptor (m)	Sensitivity to Acidification (from Saffran and Trew 1996)	Annual Average PAI (keq/ha/yr)			Critical Load (RAMP 2011)
			Easting	Northing			Baseline Case	Application Case	Planned Develop-ment Case	
West of Fort McMurray Sub-Region										
165	A42	3.2	365015	6247322	2,534	Low	0.069	0.069	0.099	1.943
171	A47	0.47	367321	6235430	3,349	Moderate	0.065	0.065	0.084	0.180
223	P94	0.03	440557	6334112	1,411	Low	0.163	0.164	0.197	0.158
225	P96	0.21	444002	6295513	198	Low	0.160	0.164	0.205	0.556
226	P97	0.16	456002	6296463	1,802	Moderate	0.205	0.208	0.255	0.470
227	P98	0.08	451762	6293513	438	Low	0.181	0.185	0.229	1.675
267	1	2.22	441917	6290884	477	Low	0.126	0.128	0.161	0.348

Note: Critical Loads calculated based on the relationship between acid neutralizing capacity (ANC), base cation concentrations, and annual catchment runoff using Henriksen's steady state water chemistry model (RAMP 2011), PAI values from MEMS (2011).

Note: Shaded values denote PAI values that exceed the critical load for the lake.

4.7.4 Residual Impact Classification

The residual (after mitigation) effects of the Project in the Application Case and Planned Development Cases on surface aquatic resources through acidifying emissions are assessed as ***Low Impact***:

- **Magnitude** – magnitude of the effects of the Project will be ***Low***;
- **Duration of Impact** – effects will be ***Long,*** occurring over the life of the Project from development and during operation of the facility;
- **Frequency** – effects will be ***Continuous,*** occurring continually over assessment periods;
- **Ability for Recovery –** effects will be ***reversible in the long-term***, they will remain after cessation of activities but will diminish with time;
- **Project Contribution** – *Negative*, there will be some net loss to the quality of aquatic resources;
- **Confidence Rating** – *Moderate,* predictions of impacts to aquatic resources resulting from Project related acidifying emissions are subject to uncertainty, resulting from the uncertainty in the estimation of critical loads, due to incomplete understanding of chemical and physical processes in lakes and calculation of critical loads based on limited data. The relationship between acidic deposition and acidification of surface waters depends in part on complex interactions between various chemical constituents of the drainage basin and surface waters, and variability in these interactions over space and time. Lack of scientific knowledge and understanding regarding these phenomena is reflected in the inability to quantitatively assess impacts of acidifying emissions on surface water chemical characteristics. Instead, current scientific understanding permits only the identification of potential impacts; and
- **Probability of Occurrence** – *High*, based on experience from previous similar projects.

The residual effects of the Project on surface aquatic resources from changes in acidifying emissions are assessed as ***Low Impact*** for both the Application and Planned Development Cases.

4.8 SUMMARY ASSESSMENT

A summary of the significance of potential impacts and effects on valued environmental components (VECs) for the different assessment cases is provided in Table 20.

4.9 ENVIRONMENTAL MONITORING

4.9.1 Construction Monitoring

Contractors will be required to submit environmental management plans as part of construction agreements that will outline acceptable methods for each activity as well as for the post-construction period. Routine audits and associated surface aquatic resources monitoring will be conducted during construction periods.

4.9.2 Effects Monitoring

STP will conduct monitoring at specific locations in specific drainages to assess how surface aquatic resources (water quality, fish, and fish habitat) are changing with the Phase 2 Project implementation and to ensure environmental quality guidelines are being met. Monitoring requirements will be carried out in accordance with the terms and conditions of all approvals.

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Table 20 Summary of impact rating on VECs for aquatic resources.

VEC	Nature of Potential Impact or Effect	Mitigation/ Protection Plan	Type of Impact or Effect	Geographical Extent of Impact or Effect[1]	Duration of Impact or Effect[2]	Frequency of Impact or Effect[3]	Ability for Recovery from Impact or Effect[4]	Magnitude of Impact or Effect[5]	Project Contribution[6]	Confidence Rating[7]	Probability of Impact or Effect Occurrence[8]	Significance[9]
NOTE: VEC 1: Water Quality; VEC 2: Fish Resources												
VEC 1 and VEC 2	Changes to water quality and aquatic habitat and resources from surface disturbance and construction activities.	1) Implement sediment and erosion control plan and sediment control measures in line with the *Alberta Code of Practice for Watercourse Crossings*; 2) Observe timing windows and maintain 30m vegetation strip where possible; 3) Manage surface water runoff from disturbed areas; and 4) Adopt slope stabilization techniques and progressive reclamation techniques where needed.	Application	Local	Long	Occasional	Reversible in short term	Low	Negative	High	High	Low Impact
VEC 2	Changes to fish and fish habitat due to instream construction activities.	1) Watercourse crossings to comply with *Alberta Code of Practice for Watercourse Crossings*; 2) Observe timing windows; and 3) Apart from watercourse crossings, avoid construction activities within 30m of stream bank.	Application	Local	Long	Occasional	Reversible in short term	Low	Negative	High	High	Low Impact
VEC 1	Changes in surface water quality.	1) Collect surface water run-off from plant site to a storm water retention pond. Discharge from pond only after testing and meeting operating approvals; 2) Handle and dispose of drilling waste and chemicals in accordance. with management plans; and 3) Comply with integrated Environmental Health and Safety Management Plan and contingency plans for responses to accidental releases.	Application	Local	Long	Occasional to accidental	Reversible in short term	Low to Moderate	Negative	High	Medium	Low Impact

[1] Local, Regional, Provincial, National, Global.
[2] Short, Long, Extended, Residual.
[3] Continuous, Isolated, Periodic, Occasional (Accidental, Seasonal).
[4] Reversible in short term, Reversible in long term, Irreversible – Rare.
[5] Nil, Low, Moderate, High.
[6] Neutral, Positive, Negative.
[7] Low, Moderate, High.
[8] Low, Medium, High.
[9] No Impact, Low Impact, Moderate Impact, High Impact.

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Table 20 (Cont'd.)

VEC	Nature of Potential Impact or Effect	Mitigation/ Protection Plan	Type of Impact or Effect	Geographical Extent of Impact or Effect[1]	Duration of Impact or Effect[2]	Frequency of Impact or Effect[3]	Ability for Recovery from Impact or Effect[4]	Magnitude of Impact or Effect[5]	Project Contribution[6]	Confidence Rating[7]	Probability of Impact or Effect Occurrence[8]	Significance[9]
NOTE: VEC 1: Water Quality; VEC 2: Fish Resources												
VEC 2	Changes to surface water flow rates and levels	1) Discharge runoff into natural environment, away from streams; 2) Phase reclamation activities prior to Project completion; 3) Return Project area to natural state when Project completed; and 4) Discharge from storm water retention pond at a controlled rate in accordance with operating approval.	Application	Local	Long	Occasional to seasonal	Reversible in the long term	Low	Negative	High	High	Low Impact
			Cumulative	No change expected from Application Case	Long	Occasional	Reversible in short term	Low	Negative	High	Medium to High	Low Impact
VEC 2	Changes to fish health, including fish tainting	1) Sediment and erosion control mitigation measures as outlined in *Surface Disturbance and In-Stream Construction Activities* section above; and 2) Mitigation measures and management practices as outlined in *Changes in surface water quality* section above.	Application	Regional	Long	Occasional to accidental	Reversible in short term	Low	Negative	High	Low	Low Impact
VEC1	Changes local fish populations due to changes in angling pressure	1) Raising awareness among the Project workers of the existing ASRD regulations for the species found in the lakes and watercourses in the LSA; 2) Educating the Project workforce on the benefits of the practice of catch-and-release angling; and 3) Discourage fishing by Project employees within the LSA	Application	Local	Long	Occasional	Reversible in short term	Low	Negative	High	High	Low Impact
VEC 1 and VEC 2	Changes to surface aquatic resources from acidifying emissions	1) Specific process design and project operations to minimize acidifying emissions.	Application and Planned Development	Local and Regional	Long	Continuous	Reversible in long term	Low	Negative	Moderate	High	Low Impact

[1] Local, Regional, Provincial, National, Global.
[2] Short, Long, Extended, Residual.
[3] Continuous, Isolated, Periodic, Occasional, Accidental, Seasonal.
[4] Reversible in short term, Reversible in long term, Irreversible – Rare.
[5] Nil, Low, Moderate, High.
[6] Neutral, Positive, Negative.
[7] Low, Moderate, High.
[8] Low, Medium, High.
[9] No Impact, Low Impact, Moderate Impact, High Impact.

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5.0 CLOSURE

We trust the above information meets your requirements. If you have any questions or comments, please contact the undersigned.

HATFIELD CONSULTANTS:

Approved by: ______________________ October 28, 2011

Heather Keith
Project Manager

Date

Approved by: ______________________ October 28, 2011

Peter McNamee
Project Director

Date

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Figure 1 Location of STP McKay Thermal Project - Phase 2.

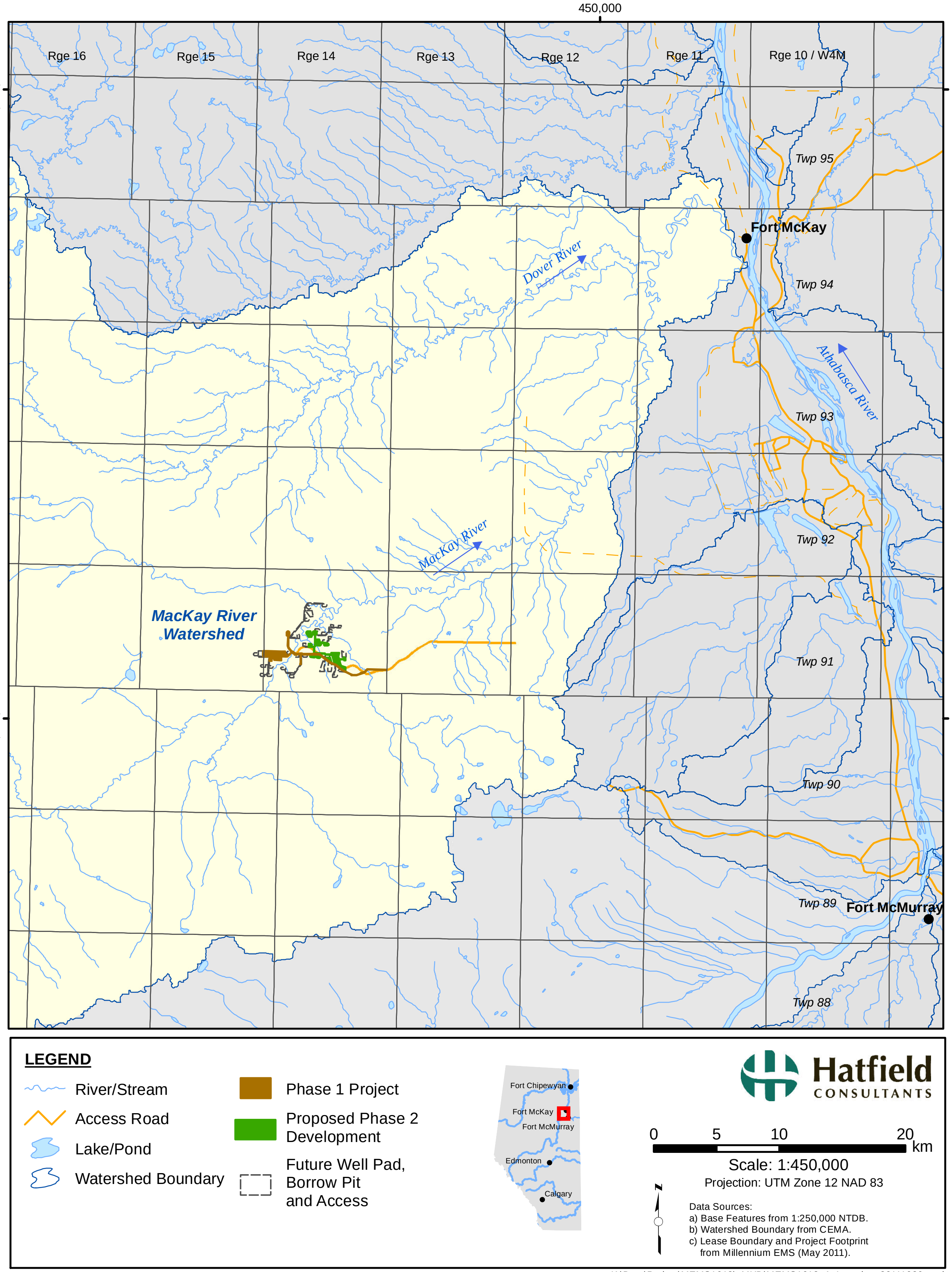

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Figure 2 STP McKay Thermal Project Phase 2 footprint.

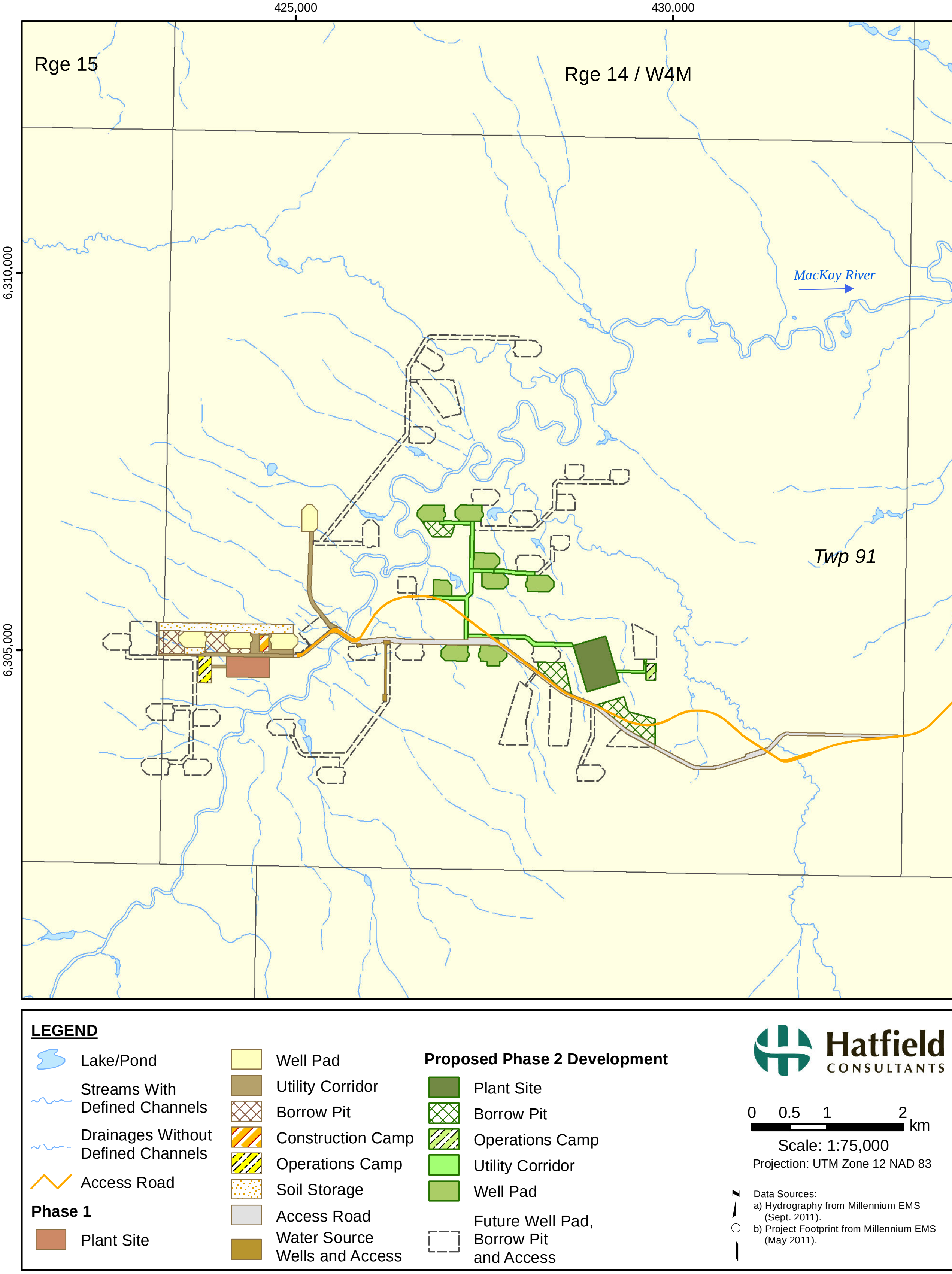

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Figure 3 Aquatic resources local and regional study areas.

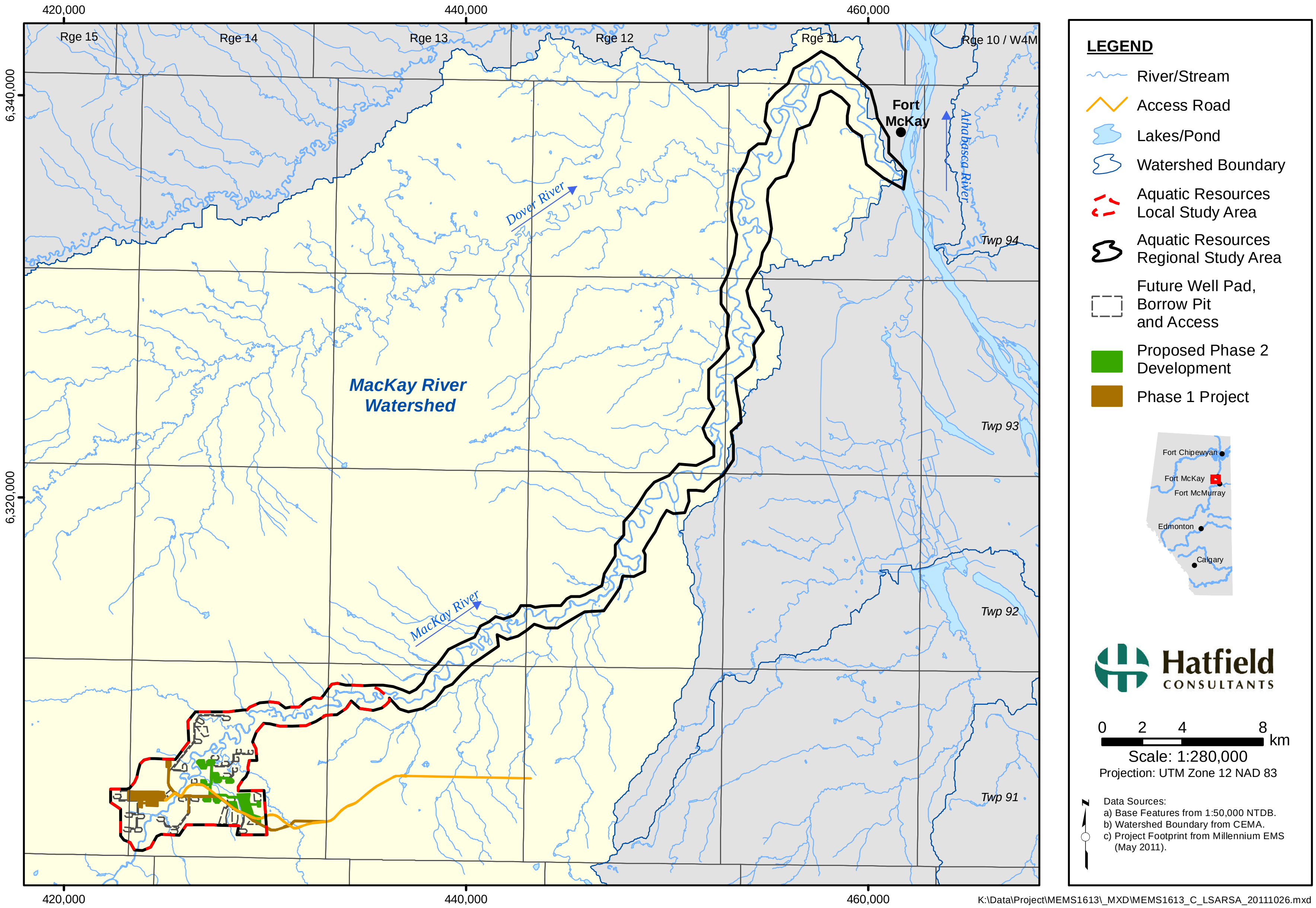

Figure 4 Regional study areas for assessing potential effects of acidifying emissions.

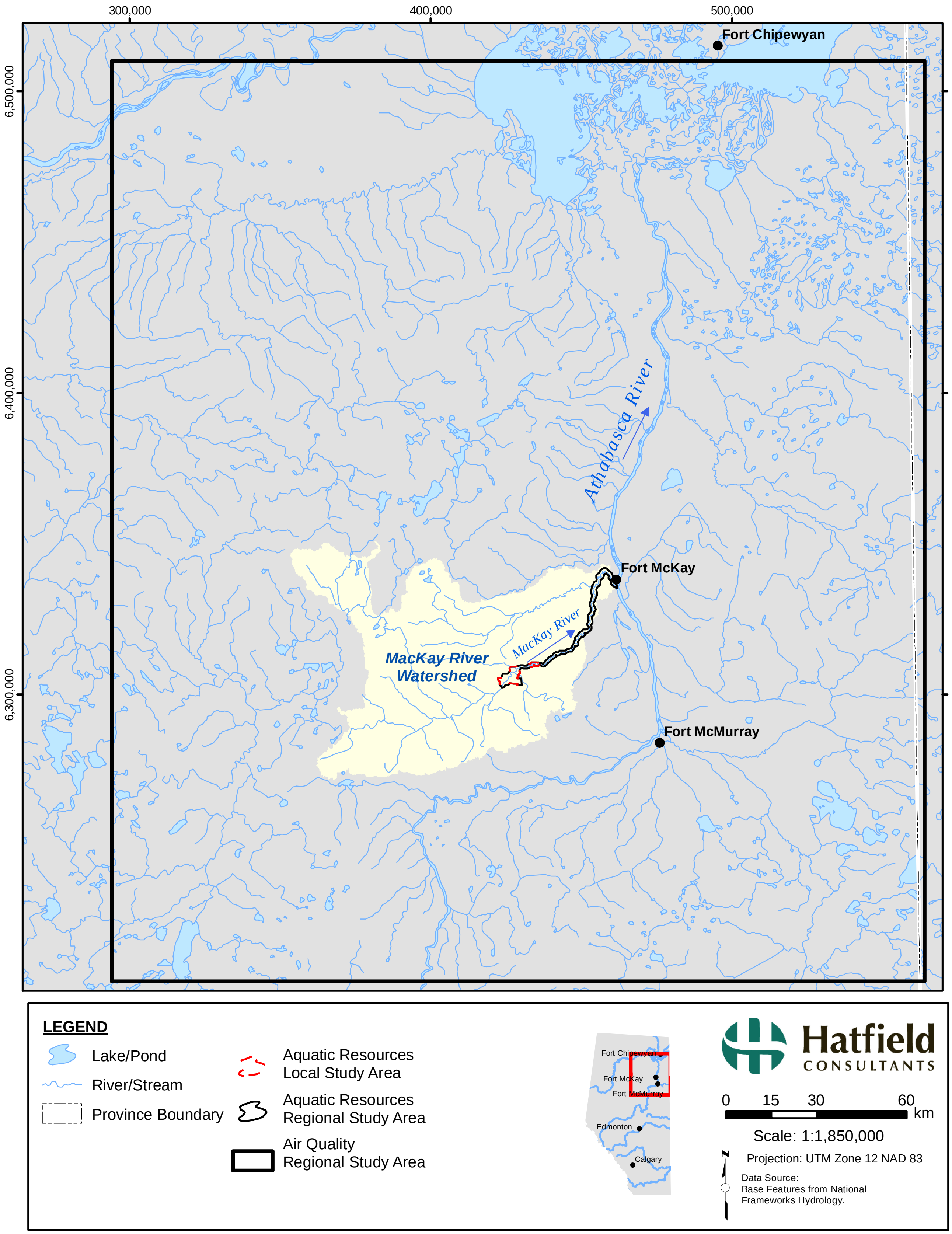

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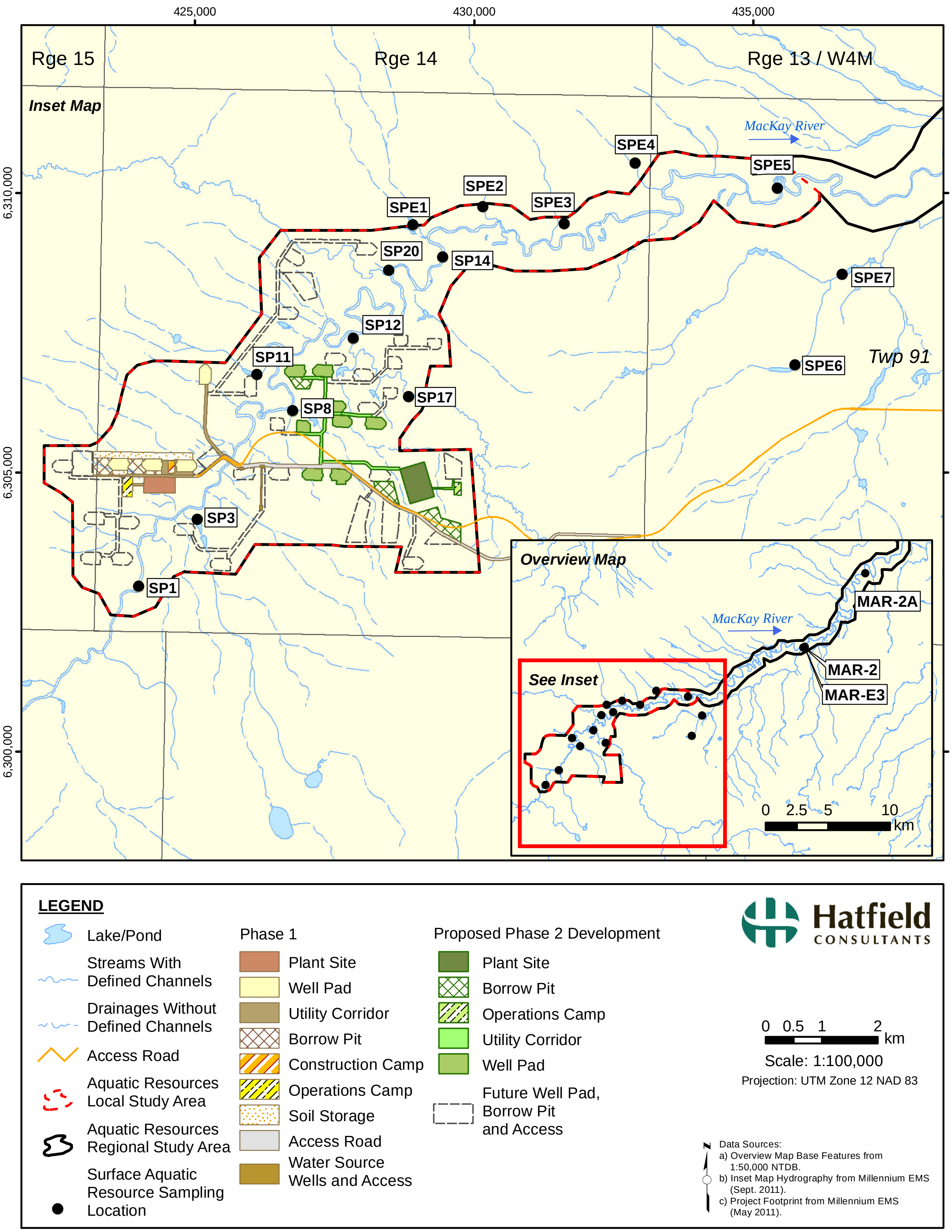
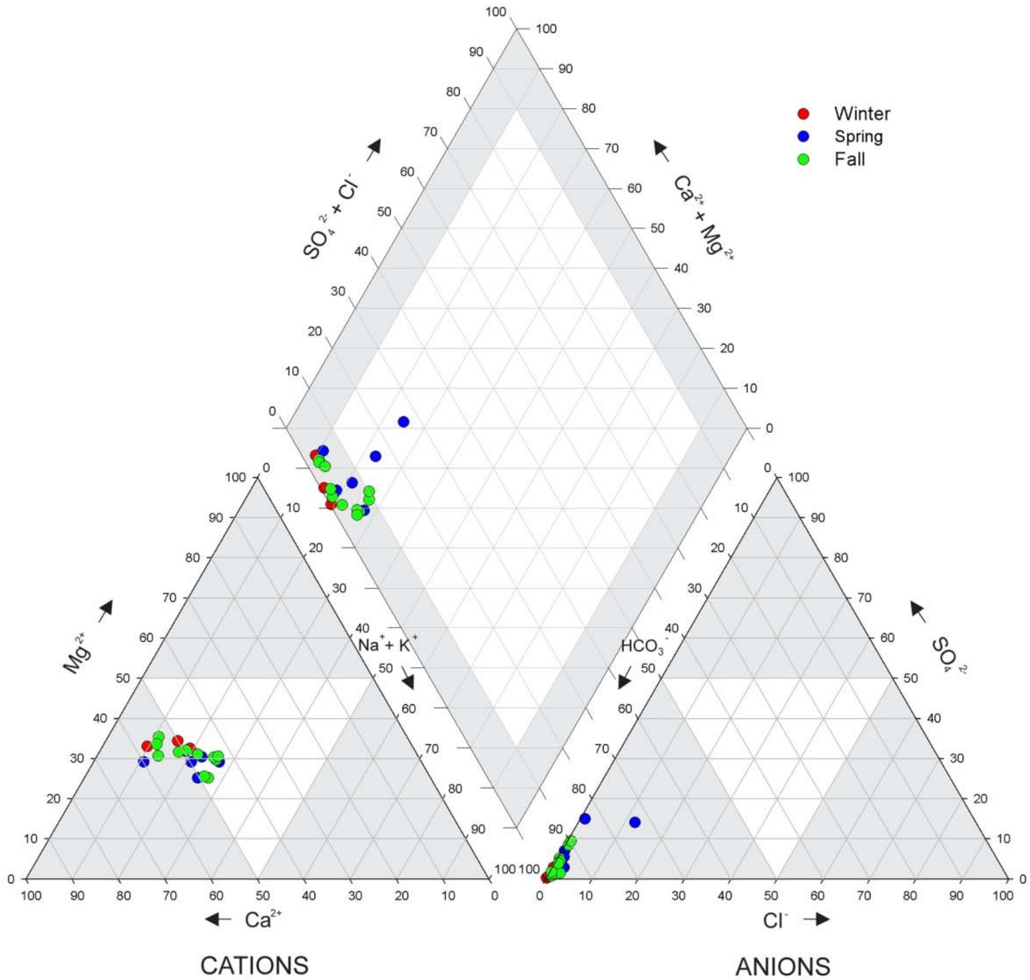
Figure 5 Surface aquatic resource sampling locations.



K:\Data\Project\MEMS1613_MXD\MEMS1613_D_Samples_20111025.mxd

Figure 6 Ionic characteristics of surface water in the LSA.



APPENDICES

Appendix A1

Field Work Activities and Methodology – Water Quality

A1.0 FIELD WORK ACTIVITIES AND METHODOLOGY – WATER QUALITY

Water quality sampling for analytical testing was conducted at five sites in spring 2010; thirteen sites in fall 2010; and three sites in winter 2011. *In situ* water quality testing was conducted at seven sites in spring 2010; seven sites in summer 2010; fifteen sites in fall 2010; and three sites in winter 2011.

RAMP Standard Operating Procedures (SOPs, RAMP 2009) were used as the water quality sampling protocols. Water sampling involved collection of single grab samples by submerging sample bottles to a depth of approximately 30 cm (where possible), uncapping and filling the bottle, recapping at depth.

In situ measurements of pH, dissolved oxygen, temperature and conductivity were collected using a YSI Model 650 multi-probe water meter, or a LaMotte Tracer Pocketester. Dissolved oxygen titrations were performed in the field using a LaMotte Winkler titration kit (Code 5860). Winter sampling required drilling a hole through the ice with a Stihl BT 121 ice auger to provide a measure of ice thickness.

Samples were collected, preserved, and shipped according to protocols specified by consulting laboratories. Standard water quality variables and organics/hydrocarbons were analyzed by ALS Laboratory Group (ALS) in Fort McMurray and Edmonton, with naphthenic acids and metals (dissolved and total, including ultra-trace mercury) analyzed by Alberta Innovates Technology Futures (AITF, formerly ARC) in Vegreville, Alberta. A field blank, trip blank, and field duplicate were also collected for QA/QC purposes in each water quality sampling season.

QA/QC analyses for water quality are provided in Table A1.1 to Table A1.5 and are discussed in Section A1.2. Results of analytical and *in situ* water quality testing are provided in Appendix A2.

A1.1 QUALITY ASSURANCE AND QUALITY CONTROL FOR WATER QUALITY DATA

The quality assurance (QA) procedures that were used in the gathering and analysis of water samples followed the QA procedures used in the Regional Aquatics Monitoring Program (RAMP 2009).

Quality control (QC) procedures are used to estimate potential contamination of samples during collection, handling, and transport with field blanks and trip blanks. Field blanks were used to assess potential contamination from sample handling, and were prepared in the field by filling sample bottles with deionized water provided by the analytical laboratory. Trip blanks are also comprised of deionized water and were prepared in the analytical laboratory prior to sampling. These samples were kept sealed for the duration of the sampling trip, and were used to evaluate potential contamination from the sample container and the efficacy of sample preservation and storage conditions. Field blanks and trip blanks were analyzed for the same variables as the actual samples. Field blanks were labeled with dummy-style codes to ensure "blind" laboratory analysis. Trip blanks were labeled as "Trip Blank".

Field and trip blank analytical results were compared to analytical detection limits. Water quality variable concentrations that are greater than five times the detection limit in the blank samples may demonstrate potential contamination of samples during sample collection or analysis or analytical error. Blanks with water quality variable concentrations below or near detection limits represent samples that were collected, handled, and analyzed without contamination or potential errors.

QC procedures used to assess analytical precision of the laboratory involved the collection of a split sample in which a single sample was "split" into two separate samples. Analytical results for the split samples were compared, and relative percent difference (difference between data values/average of data values, multiplied by 100%) was calculated for each water quality variable. Relative percent differences of greater than 20% were noted as potentially unacceptable levels of precision. However, because precision decreases as the water quality variable concentration approaches the detection limit, relative percent differences greater than 20% were considered to be of significance only if water quality variable concentrations in both samples were greater than five times the detection limit.

A1.2 QUALITY CONTROL ANALYSIS RESULTS

A1.2.1 Field and Trip Blanks

Concentrations of water quality variables in the field and trip blanks are shown in Table A1.1 and Table A1.2. A field blank and trip blank were collected during each of the three field trips when analytical water samples were collected in support of the Project. The results were:

- Concentrations of all physical variables, nutrients, ions, and organics/ hydrocarbons were less than five times the detection limits in both the field and trip blanks in all sampling seasons;

- In the spring 2010 season, concentrations of total and dissolved strontium, and total barium and lead exceeded five times their detection limit in the field blank; total lead and strontium exceeded five times their detection limit in the trip blank. In the fall 2010 season, the concentration of two dissolved metals (barium and manganese) and four total metals (barium, boron, calcium, and manganese) exceeded five times their detection limit in the field blank; total barium, boron and thallium exceeded five times their detection limit in the trip blank. In the winter 2011 season, the concentration of two dissolved metals and six total metals exceeded five times their detection limit in the field blank, representing 6% and 19% of the total number of metals analyzed; no exceedances were observed in the trip blank; and

- With the exception of winter 2010, the majority of water quality variables in the trip blank that had concentrations that exceeded five times the detection limit were also similarly elevated in the field blank, suggesting that these exceedances may resulted from a source consistent across samples rather than accidental contamination in the field (Table A1.1 and Table A1.2).

Table A1.1 Water quality results: field blanks.

Parameter	Units	Guideline	Detection Limit	Field Blanks		
				SPS21	SP4	SP5
				June-10	October-10	January-11
Alkalinity, Total (as $CaCO_3$)	mg/L		5	<5	<5	<5
Ammonia-N	mg/L	1.37	0.05	<0.05	<0.05	<0.05
Bicarbonate (HCO_3)	mg/L		5	<5	<5	<5
Biochemical Oxygen Demand	mg/L		2	<2	<2	<2
Calcium (Ca)-Dissolved	mg/L		0.5	<0.5	<0.5	<0.5
Carbonate (CO_3)	mg/L		5	<5	<5	<5
Chloride (Cl)	mg/L	230, 860[3]	0.5	<0.5	<0.5	<0.5
Color, True	T.C.U.		2	<2	<2	<2
Conductivity (EC)	µS/cm		0.2	0.44	0.32	0.83
Dissolved Organic Carbon	mg/L		1	2.1	1	1.3
Hardness (as $CaCO_3$)	mg/L			<1	<1	<1
Hydrocarbons, Recoverable (I.R.)	mg/L		1			<1
Hydroxide (OH)	mg/L		5	<5	<5	<5
Magnesium (Mg)-Dissolved	mg/L		0.1	<0.1	<0.1	<0.1
Naphthenic Acids	mg/L		0.02	0	0	0
Nitrate (as N)	mg/L	2.9	0.05	<0.05	<0.05	<0.05
Nitrate and Nitrite as N	mg/L	1.3	0.071	<0.071	<0.071	<0.071
Nitrite (as N)	mg/L	0.06	0.05	<0.05	<0.05	<0.05
Oil & Grease-(IR)	mg/L		1	<1	<1	
pH	pH	6.5-9.0	0.1	5.96	5.88	5.73
Phenols (4AAP)	mg/L	4	0.001	<0.001	<0.001	<0.001
Phosphorus, Total	mg/L	0.05	0.001	<0.001	<0.001	<0.001
Phosphorus, Total Dissolved	mg/L	0.052	0.001	<0.001	<0.001	<0.001
Potassium (K)-Dissolved	mg/L		0.5	<0.5	<0.5	<0.5
Sodium (Na)-Dissolved	mg/L		1	<1	<1	<1
Sulfate (SO_4)	mg/L	50, 100[4]	0.5	<0.5	<0.5	<0.5
Sulphide	mg/L	27	0.002	<0.002	<0.002	<0.002
Total Dissolved Solids	mg/L		10	<10	<10	22
Total Kjeldahl Nitrogen	mg/L	1[2]	0.2	<0.2	<0.2	<0.2
Total Organic Carbon	mg/L		1	<1	<1	1
Total Suspended Solids	mg/L	1[1]	3	<3	4	<3

# Indicates sample concentration is greater than five times the detection limit.
Guidelines are CCME (2007), BC MOE (2003) or AENV (1999) unless otherwise noted.
Values in bold indicate concentrations exceeding guidelines for the protection of aquatic life.
Chromium and selenium were analyzed against two detection limits.

[1] AENV guideline: TSS is not to be increased by more than 10 mg/L over background value.
[2] Guideline is for total analyte (no guideline for dissolved species).
[3] U.S. EPA Guideline for Continuous and Maximum Concentration, respectively (U.S. EPA 2006).
[4] B.C. maximum concentration guideline for sulphate (B.C. Approved Water Quality Guideline, B.C. 2006).
[5] B.C. ambient water quality guideline for boron (B.C. 2003).
[6] Draft AENV guidelines for chronic and acute total mercury concentrations, respectively (AENV 1999).
[7] B.C. Working Water Quality Guideline for sulphide as H_2S, Total Barium and Total Thallium (B.C. 2006).

Table A1.1 (Cont'd.)

Parameter	Units	Guideline	Detection Limit	Field Blanks		
				SPS21	SP4	SP5
				June-10	October-10	January-11
Dissolved Metals						
Mercury	mg/L		0.00001	<0.00001	<0.00001	<0.00001
Aluminum	mg/L	0.12	0.0002	<0.0002	<0.0002	<0.0002
Antimony	mg/L	0.02	0.0000005	0.00000175	0.0000016	0.0000027
Arsenic	mg/L	0.005	0.000002	<0.000020	0.0000028	<0.000002
Barium	mg/L	5[7]	0.000004	<0.000004	0.0000259	0.0000086
Beryllium	mg/L		0.000003	<0.000003	<0.000003	<0.000003
Bismuth	mg/L		0.000001	<0.000001	<0.000001	<0.000001
Boron	mg/L	1.2	0.00003	0.000132	<0.00003	0.0000681
Cadmium	mg/L	Calculated - DL above guideline	0.000002	<0.000002	<0.000002	<0.000002
Calcium	mg/L		0.004	0.0043	0.0146	<0.004
Chlorine	mg/L		0.1	<0.1	<0.1	<0.1
Chromium	mg/L	0.001	0.00003	<0.00004	<0.00003	<0.00003
Cobalt	mg/L	0.11	0.000001	<0.000001	<0.000001	<0.000001
Copper	mg/L	Calculated	0.00005	0.0000612	0.0000544	<0.00005
Iron	mg/L	0.3	0.002	<0.002	<0.002	<0.002
Lead	mg/L		0.000001	<0.000001	0.0000014	<0.000001
Lithium	mg/L	2.5	0.00002	<0.00002	<0.00002	0.0000286
Manganese	mg/L		0.000003	0.0000103	0.0000294	0.0000108
Molybdenum	mg/L	0.073	0.000001	<0.000001	0.0000011	0.000001
Nickel	mg/L	Calculated	0.000005	<0.000005	0.0000116	<0.000005
Selenium	mg/L	0.001	0.00004	<0.00004	<0.00010	<0.00010
Silver	mg/L	0.0001	0.0000005	<0.0000005	<0.0000005	<0.0000005
Strontium	mg/L		0.000004	0.0000261	0.0000111	0.0000148
Sulphur	mg/L		0.2	<0.2	0.82	<0.2
Thallium	mg/L	0.0008[7]	0.0000003	<0.0000003	0.0000004	<0.0000003
Thorium	mg/L		0.0000003	0.0000006	<0.0000003	<0.0000003
Tin	mg/L		0.00003	<0.00003	<0.00003	<0.00003
Titanium	mg/L	0.1	0.00004	<0.00004	<0.00004	<0.00004
Uranium	mg/L	0.033, 0.015	0.0000001	<0.0000001	<0.0000001	<0.0000001
Vanadium	mg/L		0.000005	0.0000116	<0.000005	<0.000005
Zinc	mg/L		0.00005	0.000112	0.00024	0.000257

\# Indicates sample concentration is greater than five times the detection limit.

Guidelines are CCME (2007), BC MOE (2003) or AENV (1999) unless otherwise noted.

Values in bold indicate concentrations exceeding guidelines for the protection of aquatic life.

Chromium and selenium were analyzed against two detection limits.

1 AENV guideline: TSS is not to be increased by more than 10 mg/L over background value.

2 Guideline is for total analyte (no guideline for dissolved species).

3 U.S. EPA Guideline for Continuous and Maximum Concentration, respectively (U.S. EPA 2006).

4 B.C. maximum concentration guideline for sulphate (B.C. Approved Water Quality Guideline, B.C. 2006).

5 B.C. ambient water quality guideline for boron (B.C. 2003).

6 Draft AENV guidelines for chronic and acute total mercury concentrations, respectively (AENV 1999).

7 B.C. Working Water Quality Guideline for sulphide as H_2S, Total Barium and Total Thallium (B.C. 2006).

Table A1.1 (Cont'd.)

Parameter	Units	Guideline	Detection Limit	Field Blanks		
				SPS21	SP4	SP5
				June-10	October-10	January-11
Total Metals						
Mercury	mg/L	0.00005	0.00001	<0.00001	<0.00001	<0.00001
Aluminum	mg/L	0.1	0.0005	<0.0005	<0.0005	<0.0005
Antimony	mg/L	0.02	0.0000005	0.0000018	0.0000016	0.0000027
Arsenic	mg/L	0.005	0.000002	0.0000021	0.0000096	0.0000023
Barium	mg/L	5[7]	0.000004	0.0000554	0.0000302	0.0000326
Beryllium	mg/L		0.000003	<0.000003	<0.000003	0.0000038
Bismuth	mg/L		0.000001	<0.000001	<0.000001	<0.000001
Boron	mg/L	1.2	0.00005	0.0002	0.00045	0.000749
Cadmium	mg/L	Calculated	0.000002	<0.000002	<0.000002	<0.000002
Calcium	mg/L		0.004	0.0136	0.0228	0.0103
Chlorine	mg/L		0.1	<0.1	<0.1	<0.1
Chromium	mg/L	0.001	0.00003	<0.00004	<0.00003	<0.00003
Cobalt	mg/L	0.11	0.000001	<0.000001	<0.000001	<0.000001
Copper	mg/L	Calculated	0.00005	0.000062	0.0000549	<0.00005
Iron	mg/L	0.3	0.002	<0.002	<0.002	<0.002
Lead	mg/L		0.000001	0.00001	0.0000015	<0.000001
Lithium	mg/L		0.00002	<0.00002	<0.00002	0.0000289
Manganese	mg/L		0.000003	0.0000104	0.0000315	0.0000332
Mercury (ultra-trace)	ng/L	5, 13[6]	0.6	<0.6	<0.6	<0.6
Molybdenum	mg/L	0.073	0.000001	<0.000001	0.0000011	0.0000301
Nickel	mg/L	Calculated	0.000005	<0.000005	0.0000117	<0.000005
Selenium	mg/L	0.001	0.0001	<0.0001	<0.0001	<0.0001
Silver	mg/L	0.0001	0.0000005	<0.0000005	<0.0000005	0.0000014
Strontium	mg/L		0.000004	0.0000265	0.0000112	0.0000241
Sulphur	mg/L		0.2	<0.2	0.82	<0.2
Thallium	mg/L	0.0008[7]	0.0000003	<0.0000003	0.0000014	<0.0000003
Thorium	mg/L		0.0000003	0.0000006	<0.0000003	<0.0000003
Tin	mg/L		0.00003	<0.00003	<0.00003	<0.00003
Titanium	mg/L	0.1	0.00004	0.000092	0.000049	<0.00004
Uranium	mg/L	0.033, 0.015	0.0000001	0.0000004	0.0000001	0.0000003
Vanadium	mg/L		0.000005	0.0000132	<0.000005	<0.000005
Zinc	mg/L	0.03	0.0001	0.000219	0.000242	0.000321

\# Indicates sample concentration is greater than five times the detection limit.

Guidelines are CCME (2007), BC MOE (2003) or AENV (1999) unless otherwise noted.

Values in bold indicate concentrations exceeding guidelines for the protection of aquatic life.

Chromium and selenium were analyzed against two detection limits.

1 AENV guideline: TSS is not to be increased by more than 10 mg/L over background value.

2 Guideline is for total analyte (no guideline for dissolved species).

3 U.S. EPA Guideline for Continuous and Maximum Concentration, respectively (U.S. EPA 2006).

4 B.C. maximum concentration guideline for sulphate (B.C. Approved Water Quality Guideline, B.C. 2006).

5 B.C. ambient water quality guideline for boron (B.C. 2003).

6 Draft AENV guidelines for chronic and acute total mercury concentrations, respectively (AENV 1999).

7 B.C. Working Water Quality Guideline for sulphide as H_2S, Total Barium and Total Thallium (B.C. 2006).

Table A1.2 Water quality results: trip blanks.

Parameter	Units	Guideline	Detection Limit	Trip Blanks		
				SPE25	SP2	SP6
				June-10	October-10	January-11
Alkalinity, Total (as $CaCO_3$)	mg/L		5	<5	<5	<5
Ammonia-N	mg/L	1.37	0.05	<0.05	<0.05	<0.05
Bicarbonate (HCO_3)	mg/L		5	<5	<5	<5
Biochemical Oxygen Demand	mg/L		2	<2	<2	<2
Calcium (Ca)-Dissolved	mg/L		0.5	<0.5	<0.5	<0.5
Carbonate (CO_3)	mg/L		5	<5	<5	<5
Chloride (Cl)	mg/L	230, 860[3]	0.5	<0.5	<0.5	<0.5
Color, True	T.C.U.		2	<2	<2	<2
Conductivity (EC)	µS/cm		0.2	<0.2	0.57	0.78
Dissolved Organic Carbon	mg/L		1	<1	<1	<1
Hardness (as $CaCO_3$)	mg/L			<1	<1	<1
Hydrocarbons, Recoverable (I.R.)	mg/L		1	<1		<1
Hydroxide (OH)	mg/L		5	<5	<5	<5
Magnesium (Mg)-Dissolved	mg/L		0.1	0.1	0.1	0.1
Naphthenic Acids	mg/L		0.02	0	0	0
Nitrate (as N)	mg/L	2.9	0.05	<0.05	<0.05	<0.05
Nitrate and Nitrite as N	mg/L	1.3	0.071	<0.071	<0.071	<0.071
Nitrite (as N)	mg/L	0.06	0.05	<0.05	<0.05	<0.05
Oil & Grease-(IR)	mg/L		1		<1	
Oilsands Acid Extractable	mg/L		0.1			0
pH	pH	6.5-9.0	0.1	6.81	6.16	5.65
Phenols (4AAP)	mg/L	4	0.001	<0.001	<0.001	<0.001
Phosphorus, Total	mg/L	0.05	0.001	<0.001	<0.001	<0.001
Phosphorus, Total Dissolved	mg/L	0.052	0.001	<0.001	<0.001	<0.001
Potassium (K)-Dissolved	mg/L		0.5	<0.5	<0.5	<0.5
Sodium (Na)-Dissolved	mg/L		1	<1	<1	<1
Sulfate (SO_4)	mg/L	50, 100[4]	0.5	<0.5	<0.5	<0.5
Sulphide	mg/L	27	0.002	<0.002	<0.002	<0.002
Total Dissolved Solids	mg/L		10	<10	<10	25
Total Kjeldahl Nitrogen	mg/L	1[2]	0.2	<0.2	<0.2	<0.2
Total Organic Carbon	mg/L		1	<1	<1	1.1
Total Suspended Solids	mg/L	1[1]	3	<3	3	<3

# Indicates sample concentration is greater than five times the detection limit.

Guidelines are CCME (2007), BC MOE (2003) or AENV (1999) unless otherwise noted.

Values in bold indicate concentrations exceeding guidelines for the protection of aquatic life.

Chromium and selenium were analyzed against two detection limits.

* Total nitrogen = Nitrate + nitrite plus total Kjeldahl nitrogen (TKN); Non-detectable results were assumed to be equal to the detection limit for calculating total nitrogen.

1 AENV guideline: TSS is not to be increased by more than 10 mg/L over background value.

2 Guideline is for total analyte (no guideline for dissolved species).

3 U.S. EPA Guideline for Continuous and Maximum Concentration, respectively (U.S. EPA 2006).

4 B.C. maximum concentration guideline for sulphate (B.C. Approved Water Quality Guideline, B.C. 2006).

5 B.C. ambient water quality guideline for boron (B.C. 2003).

6 Draft AENV guidelines for chronic and acute total mercury concentrations, respectively (AENV 1999).

7 B.C. Working Water Quality Guideline for sulphide as H2S, Total Barium and Total Thallium (B.C. 2006).

Table A1.2 (Cont'd.)

Parameter	Units	Guideline	Detection Limit	Trip Blanks		
				SPE25	SP2	SP6
				June-10	October-10	January-11
Dissolved Metals						
Mercury	mg/L		0.00001	<0.00001	<0.00001	<0.00001
Aluminum	mg/L	0.12	0.0002	<0.0002	<0.0002	<0.0002
Antimony	mg/L	0.02	0.0000005	0.0000008	0.0000007	<0.0000005
Arsenic	mg/L	0.005	0.000002	<0.00002	<0.000002	<0.000002
Barium	mg/L	5[7]	0.000004	<0.000004	<0.000004	<0.000004
Beryllium	mg/L		0.000003	<0.000003	<0.000003	<0.000003
Bismuth	mg/L		0.000001	<0.000001	<0.000001	<0.000001
Boron	mg/L	1.2	0.00003	0.000105	0.0000645	<0.00003
Cadmium	mg/L	Calculated-DL above guideline	0.000002	<0.000002	<0.000002	<0.000002
Calcium	mg/L		0.004	<0.004	<0.004	<0.004
Chlorine	mg/L		0.1	<0.1	<0.1	<0.1
Chromium	mg/L	0.001	0.00003		<0.00003	<0.00003
			0.00004	<0.00004		
Cobalt	mg/L	0.11	0.000001	<0.000001	<0.000001	<0.000001
Copper	mg/L	Calculated	0.00005	<0.00005	0.0000541	<0.00005
Iron	mg/L	0.3	0.002	<0.002	<0.002	<0.002
Lead	mg/L		0.000001	<0.000001	<0.000001	0.0000028
Lithium	mg/L	2.5	0.00002	<0.00002	<0.00002	0.000034
Manganese	mg/L		0.000003	<0.000003	<0.000003	<0.000003
Molybdenum	mg/L	0.073	0.000001	<0.000001	0.0000028	0.0000021
Nickel	mg/L	Calculated	0.000005	<0.000005	0.0000111	<0.000005
Selenium	mg/L	0.001	0.0001	<0.0001	<0.0001	<0.0001
Silver	mg/L	0.0001	0.0000005	0.0000005	<0.0000005	0.0000023
Strontium	mg/L		0.000004	0.0000162	0.0000094	0.0000088
Sulphur	mg/L		0.2	<0.2	0.66	<0.2
Thallium	mg/L	0.0008[7]	0.0000003	<0.0000003	<0.0000003	<0.0000003
Thorium	mg/L		0.0000003	0.0000006	<0.0000003	<0.0000003
Tin	mg/L		0.00003	<0.00003	<0.00003	<0.00003
Titanium	mg/L	0.1	0.00004	0.0000427	<0.00004	<0.00004
Uranium	mg/L	0.033, 0.015	0.0000001	0.0000002	<0.0000001	<0.0000001
Vanadium	mg/L		0.000005	<0.000005	<0.000005	<0.000005
Zinc	mg/L		0.00005	<0.00005	<0.00005	0.0000585

\# Indicates sample concentration is greater than five times the detection limit.

Guidelines are CCME (2007), BC MOE (2003) or AENV (1999) unless otherwise noted.

Values in bold indicate concentrations exceeding guidelines for the protection of aquatic life.

Chromium and selenium were analyzed against two detection limits.

1 AENV guideline: TSS is not to be increased by more than 10 mg/L over background value.

2 Guideline is for total analyte (no guideline for dissolved species).

3 U.S. EPA Guideline for Continuous and Maximum Concentration, respectively (U.S. EPA 2006).

4 B.C. maximum concentration guideline for sulphate (B.C. Approved Water Quality Guideline, B.C. 2006).

5 B.C. ambient water quality guideline for boron (B.C. 2003).

6 Draft AENV guidelines for chronic and acute total mercury concentrations, respectively (AENV 1999).

7 B.C. Working Water Quality Guideline for sulphide as H2S, Total Barium and Total Thallium (B.C. 2006).

Table A1.2 (Cont'd.)

Parameter	Units	Guideline	Detection Limit	Trip Blanks		
				SPE25	SP2	SP6
				June-10	October-10	January-11
Total Metals						
Mercury	mg/L	0.00005	0.00001	<0.00001	<0.00001	<0.00001
Aluminum	mg/L	0.1	0.0005	<0.0005	<0.0005	<0.0005
Antimony	mg/L	0.02	0.0000005	0.0000008	0.0000007	<0.0000005
Arsenic	mg/L	0.005	0.000002 0.00002	<0.000002	0.0000066	0.0000068
Barium	mg/L	5[7]	0.000004	0.0000192	0.0000249	0.0000046
Beryllium	mg/L		0.000003	<0.000003	<0.000003	<0.000003
Bismuth	mg/L		0.000001	<0.000001	<0.000001	<0.000001
Boron	mg/L	1.2	0.00005	0.000204	0.00094	0.00024
Cadmium	mg/L	Calculated	0.000002	<0.000002	<0.000002	<0.000002
Calcium	mg/L		0.004	0.0048	0.0123	<0.004
Chlorine	mg/L		0.1	<0.1	<0.1	<0.1
Chromium	mg/L	0.001	0.00003	<0.00004	<0.00003	<0.00003
Cobalt	mg/L	0.11	0.000001	<0.000001	0.0000013	<0.000001
Copper	mg/L	Calculated	0.00005	0.000054	0.0000782	<0.00005
Iron	mg/L	0.3	0.002	<0.002	<0.002	<0.002
Lead	mg/L		0.000001	0.000008	0.0000021	<0.000001
Lithium	mg/L		0.00002	<0.00002	<0.00002	0.0000343
Manganese	mg/L		0.000003	0.0000059	0.0000071	<0.000003
Mercury (ultra-trace)	ng/L	5, 13[6]	0.6	<0.6	<0.6	<0.6
Molybdenum	mg/L	0.073	0.000001	0.0000012	0.000003	0.0000044
Nickel	mg/L	Calculated	0.000005	<0.000005	0.0000202	<0.000005
Selenium	mg/L	0.001	0.00004	<0.00004	<0.0001	<0.0001
Silver	mg/L	0.0001	0.0000005	<0.0000005	<0.0000005	<0.0000005
Strontium	mg/L		0.000004	0.0000414	0.0000115	0.0000159
Sulphur	mg/L		0.2	<0.2	0.66	<0.2
Thallium	mg/L	0.0008[7]	0.0000003	<0.0000003	0.0000018	<0.0000003
Thorium	mg/L		0.0000003	0.0000006	<0.0000003	<0.0000003
Tin	mg/L		0.00003	<0.00003	<0.00003	<0.00003
Titanium	mg/L	0.1	0.00004	0.00005	<0.00004	<0.00004
Uranium	mg/L	0.033, 0.015	0.0000001	0.00000021	0.0000001	<0.0000001
Vanadium	mg/L		0.000005	0.0000051	<0.000005	<0.000005
Zinc	mg/L	0.03	0.0001	0.000259	<0.0001	0.000113

\# Indicates sample concentration is greater than five times the detection limit.
Guidelines are CCME (2007), BC MOE (2003) or AENV (1999) unless otherwise noted.
Values in bold indicate concentrations exceeding guidelines for the protection of aquatic life.
Chromium and selenium were analyzed against two detection limits.

1 AENV guideline: TSS is not to be increased by more than 10 mg/L over background value.
2 Guideline is for total analyte (no guideline for dissolved species).
3 U.S. EPA Guideline for Continuous and Maximum Concentration, respectively (U.S. EPA 2006).
4 B.C. maximum concentration guideline for sulphate (B.C. Approved Water Quality Guideline, B.C. 2006).
5 B.C. ambient water quality guideline for boron (B.C. 2003).
6 Draft AENV guidelines for chronic and acute total mercury concentrations, respectively (AENV 1999).
7 B.C. Working Water Quality Guideline for sulphide as H2S, Total Barium and Total Thallium (B.C. 2006).

A1.2.2 Field Duplicates

Concentrations of water quality variables in the field duplicates are shown in Table A1.3 to Table A1.5. The relative percent difference in concentrations was greater than 20% for several total and dissolved metals in all seasons; BOD and TSS in spring; sulphide in fall, and TSS in winter. There were no water quality variables with concentrations greater than five times the detection limit with a relative percent difference greater than 20%.

Table A1.3 Water quality results: field duplicates, June 2010.

Parameter	Units	Guideline	Detection Limit	Duplicate SPS20	SPE3	Relative Percent Difference (%)[1]
Conventional Parameters						
Alkalinity, Total (as $CaCO_3$)	mg/L		5	83.5	83.2	0.4
Biochemical Oxygen Demand	mg/L		2	3.8	4.9	**25.3**
Color, True	T.C.U.		2	189	187	1.1
Conductivity (EC)	µS/cm		0.2	180	180	0.0
Dissolved Organic Carbon	mg/L		1	38.2	39.2	2.6
Hardness (as $CaCO_3$)	mg/L			89.2	88	1.4
pH	pH	6.5-9.0	0.1	7.96	7.93	0.4
Total Dissolved Solids	mg/L		10	179	191	6.5
Total Organic Carbon	mg/L		1	39	37.2	4.7
Total Suspended Solids	mg/L	1[2]	3	<3	5	**50.0**
General Organics						
Naphthenic Acids	mg/L		0.02	0.99	0.9	9.5
Oil & Grease-(IR)	mg/L		1	<1	<1	0.0
Phenols (4AAP)	mg/L	4	0.001	0.0086	0.008	7.2
Nutrients						
Ammonia-N	mg/L	1.37	0.05	<0.05	<0.05	0.0
Nitrate (as N)	mg/L	2.9	0.05	<0.05	<0.05	0.0
Nitrate and Nitrite as N	mg/L	1.3	0.071	<0.071	<0.071	0.0
Nitrite (as N)	mg/L	0.06	0.05	<0.05	<0.05	0.0
Total Kjeldahl Nitrogen	mg/L	1[3]	0.2	1.94	2.28	16.1
Phosphorus, Total	mg/L	0.05	0.001	0.0342	0.0299	13.4
Phosphorus, Total Dissolved	mg/L	0.052	0.001	0.0239	0.02	17.8
Major Ions						
Bicarbonate (HCO_3)	mg/L		5	102	102	0.0
Calcium (Ca)-Dissolved	mg/L		0.5	22.5	22.2	1.3
Carbonate (CO_3)	mg/L		5	<5	<5	0.0
Chloride (Cl)	mg/L	230, 860[4]	0.5	0.5	0.5	0.0
Hydroxide (OH)	mg/L		5	<5	<5	0.0

[1] Relative percent difference (RPD) = (difference between sample 1 and 2)/(average of sample 1 and 2) x 100%. RPD for undetectable analytes (i.e., < detection limit) was calculated assuming a concentration equal to the detection limit.

Precision is influenced by how close the analytical value is to the method detection limit. Thus, assessing percent mean differences is valid only for analytical values that are at least five times the detection limit.

# (grey)	Analytes differ by > 20% between duplicates but 1 or both concentrations are < 5 times the detection limit.
# (black)	Analytes differ by > 20% between duplicates and concentrations are > 5 times the detection limit.

Guidelines are CCME (2007), BC MOE (2003) or AENV (1999) unless otherwise noted.

Values in bold indicate concentrations exceeding guidelines for the protection of aquatic life.

[2] AENV guideline: TSS is not to be increased by more than 10 mg/L over background value.

[3] Guideline is for total analyte (no guideline for dissolved species).

[4] U.S. EPA Guideline for Continuous and Maximum Concentration, respectively (U.S. EPA 2006).

[5] B.C. maximum concentration guideline for sulphate (B.C. Approved Water Quality Guideline, B.C. 2006).

[6] B.C. ambient water quality guideline for boron (B.C. 2003).

[7] Draft AENV guidelines for chronic and acute total mercury concentrations, respectively (AENV 1999).

[8] B.C. Working Water Quality Guideline for sulphide as H_2S, Total Barium and Total Thallium (B.C. 2006).

Table A1.3 (Cont'd.)

Parameter	Units	Guideline	Detection Limit	Duplicate SPS20	SPE3	Relative Percent Difference (%)[1]
Major Ions (Cont'd.)						
Magnesium (Mg)-Dissolved	mg/L		0.1	8.01	7.9	1.4
Potassium (K)-Dissolved	mg/L		0.5	1.16	1.24	6.7
Sodium (Na)-Dissolved	mg/L		1	10.3	10.1	2.0
Sulfate (SO_4)	mg/L	50, 100[5]	0.5	6.3	6.1	3.2
Sulphide	mg/L	27	0.002	0.0095	0.0099	4.1
Dissolved Metals						
Mercury	mg/L		0.00001	<0.00001	<0.00001	0.0
Aluminum	mg/L	0.12	0.0002	0.0171	0.017	0.6
Antimony	mg/L	0.02	5E-07	0.0000388	0.0000402	3.5
Arsenic	mg/L	0.005	0.00002	0.000444	0.000458	3.1
Barium	mg/L	5[8]	0.000004	0.0181	0.0177	2.2
Beryllium	mg/L		0.000003	0.0000128	0.0000049	**89.3**
Bismuth	mg/L		0.000001	<0.000001	0.000001	0.0
Boron	mg/L	1.2	0.00003	0.0743	0.0756	1.7
Cadmium	mg/L	Calculated-DL above guideline	0.000002	<0.000002	<0.000002	0.0
Calcium	mg/L		0.004	16.4	16.6	1.2
Chlorine	mg/L		0.1	<0.1	<0.1	0.0
Chromium	mg/L	0.001	0.00004	0.00021	0.000219	4.2
Cobalt	mg/L	0.11	0.000001	0.0000607	0.0000642	5.6
Copper	mg/L	Calculated	0.00005	0.000399	0.000421	5.4
Iron	mg/L	0.3	0.002	0.319	**0.324**	1.6
Lead	mg/L		0.000001	0.0000017	0.0000027	**45.5**
Lithium	mg/L	2.5	0.00002	0.0109	0.0107	1.9
Manganese	mg/L		0.000003	0.00653	0.00649	0.6
Molybdenum	mg/L	0.073	0.000001	0.00015	0.000151	0.7
Nickel	mg/L	Calculated	0.000005	0.000833	0.000858	3.0

[1] Relative percent difference (RPD) = (difference between sample 1 and 2)/(average of sample 1 and 2) x 100%. RPD for undetectable analytes (i.e., < detection limit) was calculated assuming a concentration equal to the detection limit.

Precision is influenced by how close the analytical value is to the method detection limit. Thus, assessing percent mean differences is valid only for analytical values that are at least five times the detection limit.

#	Analytes differ by > 20% between duplicates but 1 or both concentrations are < 5 times the detection limit.
#	Analytes differ by > 20% between duplicates and concentrations are > 5 times the detection limit.

Guidelines are CCME (2007), BC MOE (2003) or AENV (1999) unless otherwise noted.

Values in bold indicate concentrations exceeding guidelines for the protection of aquatic life.

[2] AENV guideline: TSS is not to be increased by more than 10 mg/L over background value.

[3] Guideline is for total analyte (no guideline for dissolved species).

[4] U.S. EPA Guideline for Continuous and Maximum Concentration, respectively (U.S. EPA 2006).

[5] B.C. maximum concentration guideline for sulphate (B.C. Approved Water Quality Guideline, B.C. 2006).

[6] B.C. ambient water quality guideline for boron (B.C. 2003).

[7] Draft AENV guidelines for chronic and acute total mercury concentrations, respectively (AENV 1999).

[8] B.C. Working Water Quality Guideline for sulphide as H_2S, Total Barium and Total Thallium (B.C. 2006).

Table A1.3 (Cont'd.)

Parameter	Units	Guideline	Detection Limit	Duplicate SPS20	SPE3	Relative Percent Difference (%)[1]
Dissolved Metals (Cont'd.)						
Selenium	mg/L	0.001	0.00004	0.000047	0.0000707	**40.3**
Silver	mg/L	0.0001	5E-07	0.0000018	0.0000011	**48.3**
Strontium	mg/L		0.000004	0.114	0.114	0.0
Sulphur	mg/L		0.2	3.04	2.91	4.4
Thallium	mg/L	0.0008[8]	3E-07	0.0000013	0.0000016	**20.7**
Thorium	mg/L		3E-07	0.0000241	0.0000244	1.2
Tin	mg/L		0.00003	<0.00003	<0.00003	0.0
Titanium	mg/L	0.1	0.00004	0.000814	0.000797	2.1
Uranium	mg/L	0.033, 0.015	1E-07	0.0000226	0.0000241	6.4
Vanadium	mg/L		0.000005	0.000152	0.000167	9.4
Zinc	mg/L		0.00005	0.00073	0.00086	16.4
Total Metals						
Mercury	mg/L	0.00005	0.00001	<0.00001	<0.00001	0.0
Aluminum	mg/L	0.1	0.0005	0.038	0.0299	**23.9**
Antimony	mg/L	0.02	5E-07	0.0000392	0.0000406	3.5
Arsenic	mg/L	0.005	0.00002	0.00051	0.000523	2.5
Barium	mg/L	5[8]	0.000004	0.0193	0.0194	0.5
Beryllium	mg/L		0.000003	0.0000144	0.0000163	12.4
Bismuth	mg/L		0.000001	0.0000017	0.000001	**51.9**
Boron	mg/L	1.2	0.00005	0.0801	0.0769	4.1
Cadmium	mg/L	Calculated	0.000002	<0.000002	<0.000002	0.0
Calcium	mg/L		0.004	17.3	17.1	1.2
Chlorine	mg/L		0.1	<0.1	0.13	**26.1**
Chromium	mg/L	0.001	0.00004	0.000217	0.000222	2.3
Cobalt	mg/L	0.11	0.000001	0.0000871	0.0000885	1.6
Copper	mg/L	Calculated	0.00005	0.000403	0.000425	5.3

[1] Relative percent difference (RPD) = (difference between sample 1 and 2)/(average of sample 1 and 2) x 100%. RPD for undetectable analytes (i.e., < detection limit) was calculated assuming a concentration equal to the detection limit.

Precision is influenced by how close the analytical value is to the method detection limit. Thus, assessing percent mean differences is valid only for analytical values that are at least five times the detection limit.

# (grey)	Analytes differ by > 20% between duplicates but 1 or both concentrations are < 5 times the detection limit.
# (black)	Analytes differ by > 20% between duplicates and concentrations are > 5 times the detection limit.

Guidelines are CCME (2007), BC MOE (2003) or AENV (1999) unless otherwise noted.

Values in bold indicate concentrations exceeding guidelines for the protection of aquatic life.

[2] AENV guideline: TSS is not to be increased by more than 10 mg/L over background value.

[3] Guideline is for total analyte (no guideline for dissolved species).

[4] U.S. EPA Guideline for Continuous and Maximum Concentration, respectively (U.S. EPA 2006).

[5] B.C. maximum concentration guideline for sulphate (B.C. Approved Water Quality Guideline, B.C. 2006).

[6] B.C. ambient water quality guideline for boron (B.C. 2003).

[7] Draft AENV guidelines for chronic and acute total mercury concentrations, respectively (AENV 1999).

[8] B.C. Working Water Quality Guideline for sulphide as H_2S, Total Barium and Total Thallium (B.C. 2006).

Table A1.3 (Cont'd.)

Parameter	Units	Guideline	Detection Limit	Duplicate SPS20	SPE3	Relative Percent Difference (%)[1]
Total Metals (Cont'd.)						
Iron	mg/L	0.3	0.002	0.497	0.499	0.4
Lead	mg/L		0.000001	0.0000178	0.000102	**140.6**
Lithium	mg/L		0.00002	0.0113	0.011	2.7
Manganese	mg/L		0.000003	0.0217	0.0221	1.8
Mercury (ultra-trace)	ng/L	5, 13[7]	0.6	1.8	1.9	5.4
Molybdenum	mg/L	0.073	0.000001	0.000159	0.000157	1.3
Nickel	mg/L	Calculated	0.000005	0.000878	0.000945	7.4
Selenium	mg/L	0.001	0.00004	0.000069	0.000076	9.7
Silver	mg/L	0.0001	5E-07	0.0000026	0.000003	14.3
Strontium	mg/L		0.000004	0.12	0.12	0.0
Sulphur	mg/L		0.2	3.04	2.91	4.4
Thallium	mg/L	0.0008[8]	3E-07	0.000002	0.0000016	**22.2**
Thorium	mg/L		3E-07	0.0000243	0.0000246	1.2
Tin	mg/L		0.00003	<0.00003	<0.00003	0.0
Titanium	mg/L	0.1	0.00004	0.00103	0.000986	4.4
Uranium	mg/L	0.033, 0.015	1E-07	0.0000228	0.0000243	6.4
Vanadium	mg/L		0.000005	0.000188	0.000185	1.6
Zinc	mg/L	0.03	0.0001	0.000862	0.000918	6.3

1 Relative percent difference (RPD) = (difference between sample 1 and 2)/(average of sample 1 and 2) x 100%. RPD for undetectable analytes (i.e., < detection limit) was calculated assuming a concentration equal to the detection limit.

Precision is influenced by how close the analytical value is to the method detection limit. Thus, assessing percent mean differences is valid only for analytical values that are at least five times the detection limit.

# (grey)	Analytes differ by > 20% between duplicates but 1 or both concentrations are < 5 times the detection limit.
# (black)	Analytes differ by > 20% between duplicates and concentrations are > 5 times the detection limit.

Guidelines are CCME (2007), BC MOE (2003) or AENV (1999) unless otherwise noted.

Values in bold indicate concentrations exceeding guidelines for the protection of aquatic life.

2 AENV guideline: TSS is not to be increased by more than 10 mg/L over background value.

3 Guideline is for total analyte (no guideline for dissolved species).

4 U.S. EPA Guideline for Continuous and Maximum Concentration, respectively (U.S. EPA 2006).

5 B.C. maximum concentration guideline for sulphate (B.C. Approved Water Quality Guideline, B.C. 2006).

6 B.C. ambient water quality guideline for boron (B.C. 2003).

7 Draft AENV guidelines for chronic and acute total mercury concentrations, respectively (AENV 1999).

8 B.C. Working Water Quality Guideline for sulphide as H_2S, Total Barium and Total Thallium (B.C. 2006).

Table A1.4 Water quality results: field duplicates, October 2010.

Parameter	Units	Guideline	Detection Limit	Duplicate SP6	SPS2	Relative Percent Difference (%)[1]
Conventional Parameters						
Alkalinity, Total (as $CaCO_3$)	mg/L		5	42.5	42.6	0.2
Biochemical Oxygen Demand	mg/L		2	<2	<2	0.0
Color, True	T.C.U.		2	117	116	0.9
Conductivity (EC)	µS/cm		0.2	89.6	90.5	1.0
Dissolved Organic Carbon	mg/L		1	29.2	32.6	11.0
Hardness (as $CaCO_3$)	mg/L			46.4	46.2	0.4
pH	pH	6.5-9.0	0.1	7.69	7.73	0.5
Total Dissolved Solids	mg/L		10	103	119	14.4
Total Organic Carbon	mg/L		1	28.9	29.9	3.4
Total Suspended Solids	mg/L	1[2]	3	<3	<3	0.0
General Organics						
Naphthenic Acids	mg/L		0.02	1.18	1.25	5.8
Oil & Grease-(IR)	mg/L		1	<1	<1	0.0
Phenols (4AAP)	mg/L	4	0.001	0.0076	0.0065	15.6
Nutrients						
Ammonia-N	mg/L	1.37	0.05	<0.05	<0.05	0.0
Nitrate (as N)	mg/L	2.9	0.05	<0.05	<0.05	0.0
Nitrate and Nitrite as N	mg/L	1.3	0.071	<0.071	<0.071	0.0
Nitrite (as N)	mg/L	0.06	0.05	<0.05	<0.05	0.0
Total Kjeldahl Nitrogen	mg/L	1[3]	0.2	0.95	0.98	3.1
Phosphorus, Total	mg/L	0.05	0.001	0.0165	0.0172	4.2
Phosphorus, Total Dissolved	mg/L	0.052	0.001	0.0119	0.0133	11.1
Major Ions						
Bicarbonate (HCO_3)	mg/L		5	51.8	52	0.4
Calcium (Ca)-Dissolved	mg/L		0.5	12.5	12.4	0.8
Carbonate (CO_3)	mg/L		5	<5	<5	0.0
Chloride (Cl)	mg/L	230, 860[4]	0.5	<0.5	<0.5	0.0
Hydroxide (OH)	mg/L		5	<5	<5	0.0
Magnesium (Mg)-Dissolved	mg/L		0.1	3.68	3.71	0.8
Potassium (K)-Dissolved	mg/L		0.5	<0.5	<0.5	0.0
Sodium (Na)-Dissolved	mg/L		1	2.7	2.8	3.6
Sulfate (SO_4)	mg/L	50, 100[5]	0.5	<0.5	<0.5	0.0
Sulphide	mg/L	27	0.002	<0.002	0.0094	**129.8**

[1] Relative percent difference (RPD) = (difference between sample 1 and 2)/(average of sample 1 and 2) x 100%. RPD for undetectable analytes (i.e., < detection limit) was calculated assuming a concentration equal to the detection limit.

Precision is influenced by how close the analytical value is to the method detection limit. Thus, assessing percent mean differences is valid only for analytical values that are at least five times the detection limit.

#	Analytes differ by > 20% between duplicates but 1 or both concentrations are < 5 times the detection limit.
#	Analytes differ by > 20% between duplicates and concentrations are > 5 times the detection limit.

Table A1.4 (Cont'd.)

Parameter	Units	Guideline	Detection Limit	Duplicate SP6	SPS2	Relative Percent Difference (%)[1]
Dissolved Metals						
Mercury	mg/L		0.00001	<0.00001	<0.00001	0.0
Aluminum	mg/L	0.12	0.0002	0.0123	0.011	11.2
Antimony	mg/L	0.02	0.0000005	0.000012	0.0000129	7.2
Arsenic	mg/L	0.005	0.000002	0.00045	0.00042	6.9
Barium	mg/L	5	0.000004	0.0081	0.00726	10.9
Beryllium	mg/L		0.000003	<0.000003	0.0000043	**35.6**
Bismuth	mg/L		0.000001	0.000008	<0.000001	**155.6**
Boron	mg/L	1.2	0.00003	0.0135	0.0123	9.3
Cadmium	mg/L	Calculated-DL above guideline	0.000002	<0.000002	<0.000002	0.0
Calcium	mg/L		0.004	9.72	10.1	3.8
Chlorine	mg/L		0.1	0.141	0.163	14.5
Chromium	mg/L	0.001	0.00004	0.000113	0.0000959	16.4
Cobalt	mg/L	0.11	0.000001	0.0000426	0.0000414	2.9
Copper	mg/L	Calculated	0.00005	0.00011	0.000123	11.2
Iron	mg/L	0.3	0.002	0.196	0.177	10.2
Lead	mg/L		0.000001	0.000007	0.0000044	**45.6**
Lithium	mg/L	2.5	0.00002	0.00319	0.00285	11.3
Manganese	mg/L		0.000003	0.00139	0.00122	13.0
Molybdenum	mg/L	0.073	0.000001	0.0000236	0.0000205	14.1
Nickel	mg/L	Calculated	0.000005	0.000235	0.00021	11.2
Selenium	mg/L	0.001	0.00004	<0.0001	<0.0001	0.0
Silver	mg/L	0.0001	0.0000005	<0.0000005	<0.0000005	0.0
Strontium	mg/L		0.000004	0.0441	0.0394	11.3
Sulphur	mg/L		0.2	0.463	0.954	**69.3**
Thallium	mg/L	0.0008	0.0000003	0.000009	0.0000012	**152.9**
Thorium	mg/L		0.0000003	0.0000387	<0.0000003	**196.9**
Tin	mg/L		0.00003	<0.00003	<0.00003	0.0
Titanium	mg/L	0.1	0.00004	0.000583	0.000438	**28.4**
Uranium	mg/L	0.033, 0.015	0.0000001	0.0000047	0.0000043	8.9
Vanadium	mg/L		0.000005	0.0000963	0.0000838	13.9
Zinc	mg/L		0.00005	0.0017	0.00151	11.8

[1] Relative percent difference (RPD) = (difference between sample 1 and 2)/(average of sample 1 and 2) x 100%. RPD for undetectable analytes (i.e., < detection limit) was calculated assuming a concentration equal to the detection limit.

Precision is influenced by how close the analytical value is to the method detection limit. Thus, assessing percent mean differences is valid only for analytical values that are at least five times the detection limit.

# (grey)	Analytes differ by > 20% between duplicates but 1 or both concentrations are < 5 times the detection limit.
# (black)	Analytes differ by > 20% between duplicates and concentrations are > 5 times the detection limit.

Table A1.4 (Cont'd.)

Parameter	Units	Guideline	Detection Limit	Duplicate SP6	SPS2	Relative Percent Difference (%)[1]
Total Metals						
Mercury	mg/L	0.00005	0.00001	<0.00001	<0.00001	0.0
Aluminum	mg/L	0.1	0.0005	0.0468	0.0344	**30.5**
Antimony	mg/L	0.02	0.0000005	0.0000121	0.000013	7.2
Arsenic	mg/L	0.005	0.00002	0.000494	0.00045	9.3
Barium	mg/L	5	0.000004	0.00921	0.00809	12.9
Beryllium	mg/L		0.000003	<0.000003	0.0000044	**37.8**
Bismuth	mg/L		0.000001	0.000008	<0.000001	
Boron	mg/L	1.2	0.00005	0.0154	0.0133	14.6
Cadmium	mg/L	Calculated	0.000002	<0.000002	<0.000002	0.0
Calcium	mg/L		0.004	10.4	10.6	1.9
Chlorine	mg/L		0.1	0.371	0.165	**76.9**
Chromium	mg/L	0.001	0.00003	0.00016	0.0000969	**49.1**
Cobalt	mg/L	0.11	0.000001	0.000101	0.0000795	**23.8**
Copper	mg/L	Calculated	0.00005	0.000111	0.000124	11.1
Iron	mg/L	0.3	0.002	0.334	0.281	17.2
Lead	mg/L		0.000001	0.0000224	0.0000178	**22.9**
Lithium	mg/L		0.00002	0.00366	0.00287	**24.2**
Manganese	mg/L		0.000003	0.0212	0.0149	**34.9**
Mercury (ultra-trace)	ng/L	5, 13[7]	0.6	<0.6	<0.6	0.0
Molybdenum	mg/L	0.073	0.000001	0.0000319	0.0000216	**38.5**
Nickel	mg/L	Calculated	0.000005	0.000262	0.000243	7.5
Selenium	mg/L	0.001	0.00004	0.000119	0.000246	**69.6**
Silver	mg/L	0.0001	0.0000005	<0.0000005	<0.0000005	0.0
Strontium	mg/L		0.000004	0.0468	0.0405	14.4
Sulphur	mg/L		0.2	0.463	0.954	**69.3**
Thallium	mg/L	0.0008	0.0000003	0.0000091	0.0000012	**153.4**
Thorium	mg/L		0.0000003	0.0000391	<0.0000003	**197.0**
Tin	mg/L		0.00003	<0.00003	<0.00003	0.0
Titanium	mg/L	0.1	0.00004	0.0017	0.000955	**56.1**
Uranium	mg/L	0.033, 0.015	0.0000001	0.0000064	0.0000051	**22.6**
Vanadium	mg/L		0.000005	0.000181	0.00013	**32.8**
Zinc	mg/L	0.03	0.0001	0.00211	0.00159	**28.1**

[1] Relative percent difference (RPD) = (difference between sample 1 and 2)/(average of sample 1 and 2) x 100%. RPD for undetectable analytes (i.e., < detection limit) was calculated assuming a concentration equal to the detection limit.

Precision is influenced by how close the analytical value is to the method detection limit. Thus, assessing percent mean differences is valid only for analytical values that are at least five times the detection limit.

#	Analytes differ by > 20% between duplicates but 1 or both concentrations are < 5 times the detection limit.
#	Analytes differ by > 20% between duplicates and concentrations are > 5 times the detection limit.

Table A1.5 Water quality results: field duplicates, January 2011.

Parameter	Units	Guideline	Detection Limit	Duplicate-SP7	SP17	Relative Percent Difference (%)[1]
Conventional Parameters						
Alkalinity, Total (as $CaCO_3$)	mg/L		5	143	143	0.0
Biochemical Oxygen Demand	mg/L		2	<2	<2	0.0
Color, True	T.C.U.		2	175	178	1.7
Conductivity (EC)	µS/cm		0.2	272	271	0.4
Dissolved Organic Carbon	mg/L		1	35.4	36	1.7
Hardness (as $CaCO_3$)	mg/L			129	145	11.7
pH	pH	6.5-9.0	0.1	7.92	7.9	0.3
Total Dissolved Solids	mg/L		10	230	239	3.8
Total Organic Carbon	mg/L		1	36.1	35.3	2.2
Total Suspended Solids	mg/L	1[2]	3	5	4	**22.2**
General Organics						
Naphthenic Acids	mg/L		0.02	1.68	1.6	4.9
Oilsands Acid Extractable	mg/L		0.1	4.96	5.02	1.2
Hydrocarbons, Recoverable (I.R.)	mg/L		1	<1	<1	0.0
Phenols (4AAP)	mg/L	4	0.001	0.0082	0.0086	4.8
Nutrients						
Ammonia-N	mg/L	1.37	0.05	0.342	0.327	4.5
Nitrate (as N)	mg/L	2.9	0.05	0.067	0.065	3.0
Nitrate and Nitrite as N	mg/L	1.3	0.071	<0.071	<0.071	0.0
Nitrite (as N)	mg/L	0.06	0.05	<0.05	<0.05	0.0
Total Kjeldahl Nitrogen	mg/L	1[3]	0.2	1.37	1.27	7.6
Phosphorus, Total	mg/L	0.05	0.001	0.135	0.133	1.5
Phosphorus, Total Dissolved	mg/L	0.052	0.001	0.0973	0.0983	1.0
Major Ions						
Bicarbonate (HCO_3)	mg/L		5	175	174	0.6
Calcium (Ca)-Dissolved	mg/L		0.5	32.8	36.8	11.5
Carbonate (CO_3)	mg/L		5	<5	<5	0.0
Chloride (Cl)	mg/L	230, 860[4]	0.5	<0.5	<0.5	0.0
Hydroxide (OH)	mg/L		5	<5	<5	0.0
Magnesium (Mg)-Dissolved	mg/L		0.1	11.5	12.9	11.5
Potassium (K)-Dissolved	mg/L		0.5	0.88	1.02	14.7
Sodium (Na)-Dissolved	mg/L		1	6	6.6	
Sulfate (SO_4)	mg/L	50, 100[5]	0.5	4.11	3.99	3.0
Sulphide	mg/L	27	0.002	0.0112	0.0111	0.9

[1] Relative percent difference (RPD) = (difference between sample 1 and 2)/(average of sample 1 and 2) x 100%. RPD for undetectable analytes (i.e., < detection limit) was calculated assuming a concentration equal to the detection limit.

Precision is influenced by how close the analytical value is to the method detection limit. Thus, assessing percent mean differences is valid only for analytical values that are at least five times the detection limit.

# (grey)	Analytes differ by > 20% between duplicates but 1 or both concentrations are < 5 times the detection limit.
# (black)	Analytes differ by > 20% between duplicates and concentrations are > 5 times the detection limit.

Table A1.5 (Cont'd.)

Parameter	Units	Guideline	Detection Limit	Duplicate-SP7	SP17	Relative Percent Difference (%)[1]
Dissolved Metals						
Mercury	mg/L		0.00001	<0.00001	<0.00001	0.0
Aluminum	mg/L	0.12	0.0002	0.0235	0.023	2.2
Antimony	mg/L	0.02	5E-07	0.0000157	0.0000228	**36.9**
Arsenic	mg/L	0.005	0.000002	0.00053	0.000518	2.3
Barium	mg/L	5	0.000004	0.0313	0.0318	1.6
Beryllium	mg/L		0.000003	0.0000036	0.000003	18.2
Bismuth	mg/L		0.000001	0.0000012	0.0000016	**28.6**
Boron	mg/L	1.2	0.00003	0.03	0.0276	8.3
Cadmium	mg/L	Calculated-DL above guideline	0.000002	0.0000024	0.0000025	4.1
Calcium	mg/L		0.004	32.6	33	1.2
Chlorine	mg/L		0.1	0.213	0.254	17.6
Chromium	mg/L	0.001	0.00003	0.000347	0.000349	0.6
Cobalt	mg/L	0.11	0.000001	0.000443	0.000452	2.0
Copper	mg/L	Calculated	0.00005	0.000416	0.000293	**34.7**
Iron	mg/L	0.3	0.002	2.33	2.33	0.0
Lead	mg/L		0.000001	0.0000725	0.0000464	**43.9**
Lithium	mg/L	2.5	0.00002	0.0128	0.00968	**27.8**
Manganese	mg/L		0.000003	0.225	0.224	0.4
Molybdenum	mg/L	0.073	0.000001	0.0000591	0.0000663	11.5
Nickel	mg/L	Calculated	0.000005	0.000236	0.000296	**22.6**
Selenium	mg/L	0.001	0.0001	<0.0001	<0.0001	0.0
Silver	mg/L	0.0001	5E-07	<0.0000005	<0.0000005	0.0
Strontium	mg/L		0.000004	0.162	0.162	0.0
Sulphur	mg/L		0.2	2.17	1.83	17.0
Thallium	mg/L	0.0008	3E-07	0.0000011	0.0000014	**24.0**
Thorium	mg/L		3E-07	0.0000183	0.0000189	3.2
Tin	mg/L		0.00003	<0.00003	<0.00003	0.0
Titanium	mg/L	0.1	0.00004	0.00211	0.00209	1.0
Uranium	mg/L	0.033, 0.015	1E-07	0.0000881	0.0000843	4.4
Vanadium	mg/L		0.000005	0.000319	0.000341	6.7
Zinc	mg/L		0.00005	0.00219	0.00219	0.0

[1] Relative percent difference (RPD) = (difference between sample 1 and 2)/(average of sample 1 and 2) x 100%. RPD for undetectable analytes (i.e., < detection limit) was calculated assuming a concentration equal to the detection limit.

Precision is influenced by how close the analytical value is to the method detection limit. Thus, assessing percent mean differences is valid only for analytical values that are at least five times the detection limit.

# (grey)	Analytes differ by > 20% between duplicates but 1 or both concentrations are < 5 times the detection limit.
# (black)	Analytes differ by > 20% between duplicates and concentrations are > 5 times the detection limit.

Table A1.5 (Cont'd.)

Parameter	Units	Guidelines	Detection Limit	Duplicate-SP7	SP17	Relative Percent Difference (%)[1]
Total Metals						
Mercury	mg/L	0.00005	0.00001	<0.00001	<0.00001	0.0
Aluminum	mg/L	0.1	0.0005	0.0679	0.073	7.2
Antimony	mg/L	0.02	5E-07	0.0000159	0.000023	**36.5**
Arsenic	mg/L	0.005	0.000002	0.000607	0.000606	0.2
Barium	mg/L	5	0.000004	0.0343	0.0351	2.3
Beryllium	mg/L		0.000003	0.0000037	0.0000101	
Bismuth	mg/L		0.000001	0.0000016	0.0000022	**31.6**
Boron	mg/L	1.2	0.00005	0.0311	0.0306	1.6
Cadmium	mg/L	Calculated	0.000002	0.0000028	0.0000118	**123.3**
Calcium	mg/L		0.004	33.6	33.7	0.3
Chlorine	mg/L		0.1	0.297	0.279	6.2
Chromium	mg/L	0.001	0.00003	0.000351	0.000353	0.6
Cobalt	mg/L	0.11	0.000001	0.000512	0.00052	1.6
Copper	mg/L	Calculated	0.00005	0.000475	0.00052	9.0
Iron	mg/L	0.3	0.002	3.04	3.07	1.0
Lead	mg/L		0.000001	0.0000732	0.000238	**105.9**
Lithium	mg/L		0.00002	0.0134	0.012	11.0
Manganese	mg/L		0.000003	0.249	0.257	3.2
Mercury (ultra-trace)	ng/L	5, 13[6]	0.6	<0.6	<0.6	0.0
Molybdenum	mg/L	0.073	0.000001	0.0000679	0.0000716	5.3
Nickel	mg/L	Calculated	0.000005	0.00028	0.000474	**51.5**
Selenium	mg/L	0.001	0.0001	<0.0001	<0.0001	0.0
Silver	mg/L	0.0001	5E-07	0.0000066	0.0000036	**58.8**
Strontium	mg/L		0.000004	0.166	0.168	1.2
Sulphur	mg/L		0.2	2.17	1.83	17.0
Thallium	mg/L	0.0008	3E-07	0.0000017	0.0000021	**21.1**
Thorium	mg/L		3E-07	0.0000233	0.0000229	1.7
Tin	mg/L		0.00003	<0.00003	<0.00003	0.0
Titanium	mg/L	0.1	0.00004	0.00352	0.00282	**22.1**
Uranium	mg/L	0.033, 0.015	1E-07	0.0000904	0.000091	0.7
Vanadium	mg/L		0.000005	0.0004	0.000416	3.9
Zinc	mg/L	0.03	0.0001	0.00258	0.00654	**86.8**

[1] Relative percent difference (RPD) = (difference between sample 1 and 2)/(average of sample 1 and 2) x 100%. RPD for undetectable analytes (i.e., < detection limit) was calculated assuming a concentration equal to the detection limit.

Precision is influenced by how close the analytical value is to the method detection limit. Thus, assessing percent mean differences is valid only for analytical values that are at least five times the detection limit.

# (grey)	Analytes differ by > 20% between duplicates but 1 or both concentrations are < 5 times the detection limit.
# (black)	Analytes differ by > 20% between duplicates and concentrations are > 5 times the detection limit.

Appendix A2

Surface Water Quality Data

A2.0 SURFACE WATER QUALITY DATA

Table A2.1 Water quality data by site and season.

Parameter Name	Units	Guideline	Detection Limit	SP1	SP11	SP17		SP20	SP3	SP8	SPE1		SPE3		SPE5		SPE6			SPE7		
				Oct 10	Oct 10	Oct 10	Jan 11	Oct 10	Oct 10	Oct 10	June 10	Oct 10	June 10	Oct 10	June 10	Oct 10	June 10	Oct 10	Jan 11	June 10	Oct 10	Jan 11
Conventional Parameters																						
Conductivity (EC)	µS/cm		0.2	160	130	98.4	271	125	107	211	105	136	180	337	146	161	111	140	389	127	139	308
Dissolved Organic Carbon	mg/L		1	36.3	36	32.7	36	32.3	40.1	34.2	29.9	32.8	39.2	41.3	27.9	36	36.2	48	54.8	41.4	46	53.4
Hardness (as $CaCO_3$)	mg/L			64	68.3	56.7	145	61.3	61.8	91.8	56.6	64.6	88	162	64.5	69.3	53.3	63.5	187	62.2	58.4	153
pH	pH	6.5-9.0	0.1	7.79	7.73	7.66	7.9	7.88	7.5	7.94	7.87	7.76	7.93	7.83	8.05	8.04	7.69	7.44	7.35	7.65	7.57	7.43
Alkalinity, Total (as $CaCO_3$)	mg/L		5	70.1	61	45.7	143	58.1	48.2	100	50.8	65.6	83.2	174	59.4	68.7	49.2	60.9	220	50.3	61.9	163
Total Dissolved Solids	mg/L		5	158	154	137		144	128	188		144		282		170		173			181	
			10				239				120		191		152		164		358	186		306
Total Organic Carbon	mg/L		1	38.3	35.8	34.6	35.3	32.1	36.9	36.6	30.1	34	37.2	44.4	29.7	37.8	39.3	53.9	55.5	45.1	47.5	57.4
Total Suspended Solids	mg/L	[1]	3	9	<3	<3	4	4	<3	10	8	<3	5	20	5	<3	9	14	13	12	98	11
Color, True	T.C.U.		2	214	138	175	178	140	166	138	131	118	187	172	166	195	217	238	468	280	292	282
General Organics																						
Naphthenic Acids	mg/L		0.02	0.77	1.29	0.93	1.6	0.86	1.51	1.6	0.47	0.92	0.9	1.04	0.89	1.57	0.94	1.77	1.3	1.32	1.28	1.56
Phenols (4AAP)	mg/L	4	0.001	0.0091	0.0067	0.0078	0.0086	0.0081	0.0105	0.0059	0.0061	0.0066	0.008	0.0147	0.0064	0.0089	0.0097	0.0158	0.0172	0.0121	0.0142	0.0137
Hydrocarbons, Recoverable (IR)	mg/L		1	<1	<1	<1	<1	<1	<1	<1		<1		<1		<1		<1	<1		<1	<1
Oil & Grease (IR)	mg/L		1								<1		<1		<1		<1			<1		
Oilsands Acid Extractable	mg/L		0.1				5.02												4.66			5.7
Major Ions																						
Bicarbonate (HCO_3)	mg/L		5	85.5	74.4	55.7	174	70.9	58.9	122	62	80.1	102	213	72.4	83.8	60	74.3	269	61.4	75.6	199
Calcium (Ca)-Dissolved	mg/L		0.5	16.8	16.5	14.1	36.8	14.8	16	22	13.8	15.7	22.2	40	17.2	18.2	12.8	15.1	44.9	15.1	13.7	36.2
Carbonate (CO_3)	mg/L		5	<5	<5	<5	<5	<5	<5	<5	<5	**<5**	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5
Chloride (Cl)	mg/L	230, 860[3]	0.5	0.5	<0.5	<0.5	<0.5	<0.5	0.9	<0.5	<0.5	0.5	<0.5	0.82	7.09	<0.5	0.52	<0.5	<0.5	<0.5	<0.5	0.63
Hydroxide (OH)	mg/L		5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5
Magnesium (Mg)-Dissolved	mg/L		0.1	5.36	6.59	5.23	12.9	5.9	5.3	8.96	5.37	6.16	7.9	15	5.24	5.79	5.18	6.26	18.3	5.95	5.88	15.1
Potassium (K)-Dissolved	mg/L		0.5	<0.5	<0.5	0.64	1.02	1.15	0.57	0.97	<0.5	<0.5	1.24	1.97	0.78	0.64	0.72	<0.5	0.86	3.13	1.44	3.62
Sodium (Na)-Dissolved	mg/L		1	10.5	3.6	3	6.6	7.1	4	14.5	5.7	6.5	10.1	14.3	9.2	10.7	8.7	9.7	20	6.6	8.7	10.9
Sulfate (SO_4)	mg/L	50, 100[4]	0.5	6.27	1.44	0.8	3.99	0.97	0.74	5.17	1.09	<0.5	6.1	2.9	10.9	6.98	2.8	2.73	<0.5	8.61	2.39	0.94
Sulphide	mg/L	2[7]	0.002	0.0168	0.0078	0.0096	0.0111	0.0075	0.0135	0.0148	0.0029	0.0034	0.0099	0.0942	0.0189	0.0208	0.021	0.0134	0.0755	0.0237	0.0213	0.0478
Nutrients																						
Ammonia-N	mg/L	1.37	0.05	<0.05	<0.05	<0.05	0.327	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	0.579	0.053	<0.05	0.826
Biochemical Oxygen Demand	mg/L		2	<2	<2	<2	<2	<2	<2	<2	6.7	<2	4.9	3.4	2.2	<2	3.3	7.3	12.5	2.7	2.8	6.7
Nitrate (as N)	mg/L	2.9	0.05	<0.05	<0.05	<0.05	0.065	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Nitrate and Nitrite as N	mg/L	1.3	0.071	<0.071	<0.071	<0.071	<0.071	<0.071	<0.071	<0.071	<0.071	<0.071	<0.071	<0.071	<0.071	<0.071	<0.071	<0.071	<0.071	<0.071	<0.071	<0.071
Nitrite (as N)	mg/L	0.06	0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Phosphorus, Total	mg/L	0.05	0.001	**0.0512**	0.0062	0.0267	**0.133**	0.0238	0.0199	0.0284	0.0084	0.0064	0.0299	**0.366**	0.0484	0.0403	0.0355	**0.199**	**0.217**	**0.0987**	**0.0691**	**0.347**
Phosphorus, Total Dissolved	mg/L	0.05[2]	0.001	0.0331	0.0024	0.0198	**0.0983**	0.0141	0.0087	0.0228	0.0056	0.0038	0.02	0.0478	0.0324	0.025	0.0251	0.0132	**0.186**	**0.0502**	0.0214	**0.238**
Total Kjeldahl Nitrogen	mg/L	1[2]	0.2	**1.26**	0.92	0.90	**1.27**	1	**1.16**	1	**1.13**	0.92	**2.28**	**4.92**	**1.74**	**1.12**	**1.85**	**3.71**	**2.14**	**1.94**	**1.47**	**2.59**
Total Nitrogen	mg/L	1*	-	**1.33**	0.99	0.97	**1.34**	10.7	**1.23**	**1.07**	**1.20**	0.99	**2.35**	**4.99**	**1.81**	**1.19**	**1.92**	**3.78**	**2.21**	**2.01**	**1.54**	**2.66**

Guidelines are CCME (2007) or AENV (1999) unless otherwise noted.

Values in bold indicate concentrations exceeding guidelines for the protection of aquatic life.

* Total nitrogen = Nitrate + nitrite plus total Kjeldahl nitrogen (TKN).

Non-detectable results were assumed to be equal to the detection limit for calculating total nitrogen.

[1] AENV guideline: TSS is not to be increased by more than 10 mg/L over background value.

[2] Guideline is for total analyte (no guideline for dissolved species).

[3] U.S. EPA Guideline for Continuous and Maximum Concentration, respectively (U.S. EPA 2006).

[4] B.C. maximum concentration guideline for sulphate (B.C. Approved Water Quality Guideline, B.C. 2006).

[5] B.C. ambient water quality guideline for boron (B.C. 2003).

[6] Draft AENV guidelines for chronic and acute total mercury concentrations, respectively (AENV 1999).

[7] B.C. Working Water Quality Guideline for sulphide as H_2S (B.C. 2006).

Table A2.1 (Cont'd.)

Parameter Name	Units	Guideline	Detection Limit	SP1	SP11	SP17		SP20	SP3	SP8	SPE1		SPE3		SPE5		SPE6			SPE7		
				Oct 10	Oct 10	Oct 10	Jan 11	Oct 10	Oct 10	Oct 10	June 10	Oct 10	June 10	Oct 10	June 10	Oct 10	June 10	Oct 10	Jan 11	June 10	Oct 10	Jan 11
Dissolved Metals																						
Mercury	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	<0.00001	<0.00001	0.0000126	0.000011
Aluminum	mg/L	0.1[2]	0.0002	0.0317	0.019	0.0213	0.023	0.0135	0.0151	0.0419	0.013	0.00953	0.017	0.00639	0.0312	0.0293	0.025	0.0348	0.0241	0.0552	0.0396	0.0451
Antimony	mg/L	0.02	0.0000005	0.0000265	0.0000217	0.0000113	0.0000228	0.0000125	0.000013	0.0000377	2.59E-05	0.000028	4.02E-05	0.0000544	3.69E-05	0.0000275	2.05E-05	0.0000277	0.0000408	3.17E-05	0.0000355	0.0000361
Arsenic	mg/L	0.005	0.000002	0.0006	0.000376	0.000374	0.000518	0.000529	0.00037	0.000481		0.000427		0.000677		0.000609		0.000511	0.00185		0.00066	0.00107
		0.005	0.00002								0.000299		0.000458		0.000637		0.000491			0.000849		
Barium	mg/L	5[7]	0.000004	0.0115	0.00828	0.0103	0.0318	0.00729	0.00837	0.00964	0.00625	0.0066	0.0177	0.0386	0.0139	0.012	0.00986	0.00981	0.0358	0.0132	0.0124	0.0356
Beryllium	mg/L		0.000003	0.0000109	0.0000036	0.000004	<0.000003	<0.000003	0.0000067	0.0000104	<0.000003	<0.000003	4.9E-06	0.0000045	1.57E-05	0.000011	9.8E-06	0.0000097	0.0000107	3.01E-05	0.0000128	0.0000109
Bismuth	mg/L		0.000001	0.0000023	<0.000001	<0.000001	0.0000016	<0.000001	<0.000001	<0.000001	1.4E-06	<0.000001	0.000001	<0.000001	1.5E-06	<0.000001	0.000002	<0.000001	0.0000018	2.4E-06	0.0000021	0.0000033
Boron	mg/L	1.2	0.00003	0.0386	0.0316	0.0133	0.0276	0.0264	0.0241	0.0473	0.0251	0.0191	0.0756	0.067	0.0496	0.0373	0.0408	0.0315	0.0412	0.04	0.0231	0.0191
Cadmium	mg/L	DL above guideline- see below	0.000002	<0.000002	<0.000002	<0.000002	0.0000025	<0.000002	<0.000002	<0.000002	<0.000002	<0.000002	<0.000002	<0.000002	4.7E-06	0.000004	2.8E-06	<0.000002	<0.000002	5.8E-06	0.0000025	0.0000026
Calcium	mg/L		0.004	12.8	12.3	9.84	33	9.76	11.3	15.8	9.35	13.2	16.6	34.7	12.8	15.2	9.37	12	38.3	11	12.6	31.8
Chlorine	mg/L		0.1	0.439	0.251	0.159	0.254	0.291	0.254	0.328	<0.1	<0.1	<0.1	0.483	0.149	0.257	<0.1	0.277	0.379	0.119	0.408	0.99
Chromium	mg/L	0.001	0.00003	0.000175	0.000167	0.000131	0.000349	0.0000765	0.000122	0.000166		0.000104		0.00013		0.000185		0.000126	0.000594		0.000446	0.000724
		0.001	0.00004								0.000261		0.000219		0.000137		0.00015			0.000283		
Cobalt	mg/L	0.11	0.000001	0.0000951	0.0000411	0.000053	0.000452	0.0000582	0.0000437	0.0000498	0.000046	0.0000339	6.42E-05	0.0000725	9.84E-05	0.000113	8.34E-05	0.0000589	0.00098	0.000141	0.0000825	0.00387
Copper	mg/L	See below	0.00005	0.00043	0.000152	0.000175	0.000293	0.000215	0.000148	0.000357	0.00031	0.000174	0.000421	0.00065	0.000648	0.000463	0.000322	0.000314	0.000312	0.000652	0.000416	0.000263
Iron	mg/L	0.3	0.002	**0.512**	0.106	0.295	**2.33**	0.246	0.197	0.175	0.0626	0.0938	**0.324**	**1**	**0.445**	**0.505**	**0.495**	0.262	**6.46**	**0.697**	**0.467**	**3.96**
Lead	mg/L		0.000001	0.0000361	0.0000038	0.0000242	0.0000464	0.0000109	0.0000066	0.0000053	0.000009	0.0000042	2.7E-06	0.0000158	4.96E-05	0.0000387	0.000015	0.0000091	0.0000256	4.16E-05	0.0000257	0.0000451
Lithium	mg/L	2.5	0.00002	0.00984	0.00865	0.00492	0.00968	0.00865	0.00697	0.0185	0.00589	0.00679	0.0107	0.0163	0.0103	0.00893	0.00979	0.0104	0.015	0.00645	0.00476	0.00635
Manganese	mg/L		0.000003	0.00957	0.000806	0.00465	0.224	0.00285	0.00161	0.0148	0.00188	0.00109	0.00649	0.00251	0.00865	0.011	0.0117	0.0024	0.252	0.00819	0.00551	2.13
Molybdenum	mg/L	0.073	0.000001	0.000144	0.0000374	0.000024	0.0000663	0.0000427	0.0000271	0.0000667	3.91E-05	0.0000331	0.000151	0.000158	0.000299	0.000145	3.02E-05	0.0000393	0.0000419	8.39E-05	0.0000396	0.0000297
Nickel	mg/L	AENV see below	0.000005	0.000616	0.000321	0.000303	0.000296	0.000246	0.000215	0.000589	0.000341	0.000276	0.000858	0.000889	0.000912	0.000681	0.000472	0.000487	0.000933	0.00161	0.00108	0.0016
Selenium	mg/L	0.001	0.00004								<0.00004		7.07E-05		<0.00004		<0.00004			0.000085		
		0.001	0.0001	0.000122	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001		<0.0001		<0.0001		<0.0001		<0.0001	0.00015		0.000203	0.00019
Silver	mg/L	0.0001	0.0000005	<0.0000005	<0.0000005	<0.0000005	<0.0000005	<0.0000005	<0.0000005	<0.0000005	5.2E-07	<0.0000005	1.1E-06	<0.0000005	0.000003	<0.0000005	1.3E-06	<0.0000005	0.0000043	2.5E-06	<0.0000005	0.0000107
Strontium	mg/L		0.000004	0.0835	0.0654	0.0506	0.162	0.061	0.0615	0.105	0.0442	0.058	0.114	0.215	0.0803	0.086	0.0489	0.0584	0.256	0.0525	0.0579	0.165
Sulphur	mg/L		0.2	2.58	0.697	0.475	1.83	0.587	0.866	2.22	0.647	4.03	2.91	9.32	4.43	25.4	1.79	8.22	0.663	3.17	1.89	1.13
Thallium	mg/L	0.0008[7]	0.0000003	0.0000064	0.0000021	0.0000018	0.0000014	0.0000017	0.0000012	0.0000016	0.000002	0.0000006	1.6E-06	0.0000021	1.7E-06	0.000004	9E-07	0.0000007	0.0000006	1.7E-06	0.0000054	0.0000006
Thorium	mg/L		0.0000003	0.0000472	0.0000038	0.0000087	0.0000189	0.0000074	0.0000023	0.0000109	1.17E-05	0.0000089	2.44E-05	0.0000275	3.01E-05	0.0000341	2.46E-05	0.0000166	0.0000407	5.65E-05	0.0000591	0.0000666
Tin	mg/L		0.00003	<0.00003	<0.00003	<0.00003	<0.00003	<0.00003	<0.00003	<0.00003	<0.00003	<0.00003	<0.00003	<0.00003	<0.00003	<0.00003	<0.00003	<0.00003	<0.00003	<0.00003	<0.00003	<0.00003
Titanium	mg/L	0.1	0.00004	0.00173	0.0011	0.000898	0.00209	0.00105	0.000733	0.00147	0.000707	0.000805	0.000797	0.00135	0.00171	0.00169	0.000891	0.000835	0.00211	0.00115	0.000823	0.00241
Uranium	mg/L	0.033, 0.015	0.0000001	0.0000555	0.000019	0.0000135	0.0000843	0.0000143	0.0000055	0.000031	1.35E-05	0.0000109	2.41E-05	0.0000586	8.63E-05	0.0000656	5.59E-05	0.000036	0.000194	6.98E-05	0.0000381	0.0000996
Vanadium	mg/L		0.000005	0.000235	0.000155	0.000157	0.000341	0.000127	0.000127	0.000224	0.000217	0.000133	0.000167	0.000169	0.000311	0.00025	0.000255	0.000213	0.000877	0.000564	0.000361	0.000875
Zinc	mg/L		0.00005	0.00129	0.000725	0.00187	0.00219	0.00154	0.001	0.00099	0.000811	0.000544	0.00086	0.00179	0.000816	0.00103	0.00119	0.00104	0.00118	0.00252	0.00725	0.00106

Guidelines are CCME (2007) or AENV (1999) unless otherwise noted.

Values in bold indicate concentrations exceeding guidelines for the protection of aquatic life.

* Total nitrogen = Nitrate + nitrite plus total Kjeldahl nitrogen (TKN).

Non-detectable results were assumed to be equal to the detection limit for calculating total nitrogen.

[1] AENV guideline: TSS is not to be increased by more than 10 mg/L over background value.

[2] Guideline is for total analyte (no guideline for dissolved species).

[3] U.S. EPA Guideline for Continuous and Maximum Concentration, respectively (U.S. EPA 2006).

[4] B.C. maximum concentration guideline for sulphate (B.C. Approved Water Quality Guideline, B.C. 2006).

[5] B.C. ambient water quality guideline for boron (B.C. 2003).

[6] Draft AENV guidelines for chronic and acute total mercury concentrations, respectively (AENV 1999).

[7] B.C. Working Water Quality Guideline for sulphide as H_2S (B.C. 2006).

Table A2.1 (Cont'd.)

Parameter Name	Units	Guideline	Detection Limit	SP1	SP11	SP17		SP20	SP3	SP8	SPE1		SPE3		SPE5		SPE6			SPE7		
				Oct 10	Oct 10	Oct 10	Jan 11	Oct 10	Oct 10	Oct 10	June 10	Oct 10	June 10	Oct 10	June 10	Oct 10	June 10	Oct 10	Jan 11	June 10	Oct 10	Jan 11
Total Metals																						
Mercury	mg/L	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	0.00001	<0.00001	0.0000111	<0.00001	<0.00001	**0.000206**	0.0000111
Aluminum	mg/L	0.1	0.0005	**0.415**	0.0354	**0.103**	0.073	**0.114**	0.0371	0.0812	**0.107**	0.0282	0.0299	**0.336**	**0.441**	**0.254**	**0.101**	**0.278**	0.0546	**0.194**	**1.09**	0.0704
Antimony	mg/L	0.02	0.0000005	0.0000268	0.0000219	0.0000114	0.000023	0.0000126	0.0000131	0.0000381	2.62E-05	0.0000283	4.06E-05	0.000055	3.73E-05	0.0000278	2.07E-05	0.000028	0.0000412	0.000032	0.0000359	0.0000365
Arsenic	mg/L	0.005	0.000002	0.00081	0.000396	0.000464	0.000606	0.000629	0.000404	0.000528		0.000488		0.0011		0.000752		0.000983	0.00321		0.00235	0.00135
		0.005	0.00002								0.000392		0.000523		0.000807		0.000575			0.000925		
Barium	mg/L	5[7]	0.000004	0.0156	0.00866	0.012	0.0351	0.00907	0.00937	0.0107	0.00772	0.00718	0.0194	0.0561	0.0185	0.0136	0.012	0.0189	0.0556	0.0148	0.0631	0.0438
Beryllium	mg/L		0.000003	0.0000134	0.0000036	0.0000085	0.0000101	0.0000074	0.0000068	0.0000105	5.7E-06	<0.000003	1.63E-05	0.000025	3.52E-05	0.0000182	9.9E-06	0.0000153	0.0000183	3.03E-05	0.0000371	0.000011
Bismuth	mg/L		0.000001	0.0000037	<0.000001	<0.000001	0.0000022	<0.000001	<0.000001	<0.000001	2.4E-06	<0.000001	0.000001	<0.000001	4.9E-06	<0.000001	2.1E-06	0.0000024	0.0000021	3.2E-06	0.0000097	0.0000048
Boron	mg/L	1.2	0.00005	0.0465	0.0318	0.0146	0.0306	0.0309	0.0254	0.0502	0.0281	0.0211	0.0769	0.088	0.0521	0.0381	0.0421	0.0342	0.0428	0.0402	0.0326	0.022
Cadmium	mg/L	See below	0.000002	0.000004	<0.000002	<0.000002	0.0000118	<0.000002	<0.000002	0.0000032	2.5E-06	<0.000002	<0.000002	0.0000202	0.000008	0.000004	3.7E-06	0.0000051	0.0000039	6.9E-06	**0.0000303**	0.0000039
Calcium	mg/L		0.004	13.7	12.3	10.5	33.7	11	11.9	16.4	10.4	14.1	17.1	35.1	13.4	15.2	10	13.3	41.2	11.3	13.7	33.4
Chlorine	mg/L		0.1	1.09	0.273	0.18	0.279	0.352	0.275	0.34	<0.1	<0.1	0.13	0.488	0.174	0.26	0.177	0.297	0.405	0.153	0.547	1
Chromium	mg/L	0.001	0.00003	0.000628	0.000182	0.00022	0.000353	0.000233	0.000133	0.000192		0.000116		0.000483		0.00048		0.000448	0.0006		**0.00138**	0.000731
		0.001	0.00004								0.000308		0.000222		0.000496		0.000215			0.000417		
Cobalt	mg/L	0.11	0.000001	0.000224	0.0000597	0.000108	0.00052	0.000109	0.0000656	0.0000923	7.74E-05	0.0000616	8.85E-05	0.000566	0.00024	0.000173	0.000278	0.000848	0.00539	0.000308	0.00598	0.00418
Copper	mg/L	See below	0.00005	0.000473	0.000154	0.000177	0.00052	0.000217	0.000149	0.000361	0.000313	0.000176	0.000425	0.000793	0.000683	0.000496	0.000325	0.000735	0.000315	0.000719	0.00103	0.000969
Iron	mg/L	0.3	0.002	**0.947**	0.124	**0.474**	**3.07**	**0.442**	0.265	0.262	0.13	0.124	**0.499**	**2.74**	**0.925**	**0.815**	**0.79**	**2.25**	**16.2**	**0.967**	**5.63**	**7.61**
Lead	mg/L		0.000001	0.000174	0.0000095	0.0000415	0.000238	0.0000682	0.000183	0.0000172	0.000117	0.0000315	0.000102	0.000156	0.000184	0.000101	6.81E-05	0.000166	0.0000778	8.29E-05	0.000644	0.0000839
Lithium	mg/L		0.00002	0.0107	0.00874	0.00529	0.012	0.0101	0.00704	0.0193	0.00626	0.00755	0.011	0.0165	0.0111	0.00956	0.00993	0.0106	0.015	0.00652	0.00524	0.00705
Manganese	mg/L		0.000003	0.0468	0.00646	0.018	0.257	0.0228	0.0136	0.0702	0.0041	0.00481	0.0221	0.538	0.0509	0.0342	0.0947	0.245	2.49	0.0335	**2.55**	**2.28**
Mercury (ultra-trace)	ng/L	5, 13[6]	0.6	1	<0.6	<0.6	<0.6	<0.6	<0.6	<0.6	1.5	<0.6	1.9	<0.6	2.3	<0.6	2.4	<0.6	<0.6	2.8	<0.6	<0.6
Molybdenum	mg/L	0.073	0.000001	0.000152	0.0000418	0.0000274	0.0000716	0.0000447	0.0000318	0.0000674	4.56E-05	0.0000334	0.000157	0.000209	0.000314	0.000146	3.29E-05	0.00012	0.00006	8.52E-05	0.000149	0.000042
Nickel	mg/L	See below	0.000005	0.000839	0.000324	0.000341	0.000474	0.000308	0.000229	0.000614	0.000446	0.000316	0.000945	0.00127	0.00117	0.000738	0.00058	0.000948	0.00112	0.00173	0.00213	0.00163
Selenium	mg/L	0.001	0.00004								<0.00004		0.000076		0.000049		7.93E-05			0.000086		
		0.001	0.0001	0.000181	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001		0.000139		0.000257		**0.00351**		0.000156	0.000183		0.000303	0.000232
Silver	mg/L	0.0001	0.0000005	<0.0000005	<0.0000005	<0.0000005	0.0000036	<0.0000005	<0.0000005	<0.0000005	2.9E-06	<0.0000005	0.000003	<0.0000005	7.6E-06	<0.0000005	1.9E-06	<0.0000005	0.0000077	3.5E-06	0.0000121	0.0000141
Strontium	mg/L		0.000004	0.0904	0.0654	0.0538	0.168	0.0678	0.0642	0.111	0.0493	0.0628	0.12	0.224	0.084	0.0866	0.0508	0.0791	0.282	0.0525	0.0819	0.175
Sulphur	mg/L		0.2	2.58	0.697	0.475	1.83	0.587	0.866	2.22	0.647	4.03	2.91	9.32	4.43	25.4	1.79	8.22	0.663	3.17	1.89	1.13
Thallium	mg/L	0.0008[7]	0.0000003	0.0000078	0.0000021	0.0000027	0.0000021	0.0000019	0.0000017	0.000002	2.2E-06	0.0000006	1.6E-06	0.0000046	5.5E-06	0.0000041	1.4E-06	0.0000028	0.0000007	0.000002	0.0000142	0.0000015
Thorium	mg/L		0.0000003	0.0000796	0.0000038	0.0000088	0.0000229	0.0000095	0.0000023	0.000011	2.22E-05	0.000009	2.46E-05	0.0000681	7.32E-05	0.0000509	2.92E-05	0.0000321	0.0000661	6.36E-05	0.000195	0.0000694
Tin	mg/L		0.00003	<0.00003	<0.00003	<0.00003	<0.00003	<0.00003	<0.00003	<0.00003	<0.00003	<0.00003	<0.00003	<0.00003	<0.00003	<0.00003	<0.00003	<0.00003	<0.00003	<0.00003	<0.00003	<0.00003
Titanium	mg/L	0.1	0.00004	0.0112	0.00121	0.00258	0.00282	0.0034	0.00106	0.00268	0.00202	0.00107	0.000986	0.00638	0.00867	0.0043	0.00177	0.00537	0.00339	0.00269	0.0208	0.0032
Uranium	mg/L	0.033, 0.015	0.0000001	0.00007	0.0000192	0.0000183	0.000091	0.000019	0.0000074	0.0000334	1.84E-05	0.0000119	2.43E-05	0.000086	0.000102	0.0000689	6.15E-05	0.0000794	0.000238	7.64E-05	0.0000953	0.000114
Vanadium	mg/L		0.000005	0.000951	0.00018	0.000332	0.000416	0.000347	0.000177	0.000324	0.000371	0.000179	0.000185	0.000869	0.00106	0.000706	0.000435	0.00135	0.00171	0.000838	0.00362	0.00121
Zinc	mg/L	0.03	0.0001	0.00216	0.000732	0.0021	0.00654	0.00225	0.00101	0.001	0.000925	0.00055	0.000918	0.0101	0.00183	0.00182	0.00169	0.00602	0.00119	0.00328	0.0281	0.00107
		Cadmium guideline:		2.25587E-05	2.3856E-05	2.0327E-05	4.558E-05	2.1738E-05	2.189E-05	3.0764E-05	2.03E-05	2.274E-05	2.97E-05	5.014E-05	2.27E-05	2.4156E-05	1.93E-05	2.2407E-05	5.673E-05	2.2E-05	2.085E-05	4.773E-05
		Manganese guideline:		1.24528	1.292666	1.164834	2.1379	1.215526	1.221036	1.551636	1.163732	1.251892	1.50976	2.32524	1.25079	1.303686	1.127366	1.23977	2.60074	1.225444	1.183568	2.22606
		Nickel guideline:		0.065	0.065	0.025	0.11	0.065	0.065	0.065	0.025	0.065	0.065	0.11	0.065	0.065	0.025	0.065	0.15	0.065	0.025	0.11
		Copper guideline:		0.002	0.002	0.002	0.003	0.002	0.002	0.002	0.002	0.002	0.002	0.003	0.002	0.002	0.002	0.002	0.004	0.002	0.002	0.003
		Lead guideline:		0.002	0.002	0.001	0.004	0.002	0.002	0.002	0.001	0.002	0.002	0.004	0.002	0.002	0.001	0.002	0.007	0.002	0.001	0.004

Guidelines are CCME (2007) or AENV (1999) unless otherwise noted.

Values in bold indicate concentrations exceeding guidelines for the protection of aquatic life.

* Total nitrogen = Nitrate + nitrite plus total Kjeldahl nitrogen (TKN).

Non-detectable results were assumed to be equal to the detection limit for calculating total nitrogen.

1 AENV guideline: TSS is not to be increased by more than 10 mg/L over background value.

2 Guideline is for total analyte (no guideline for dissolved species).

3 U.S. EPA Guideline for Continuous and Maximum Concentration, respectively (U.S. EPA 2006).

4 B.C. maximum concentration guideline for sulphate (B.C. Approved Water Quality Guideline, B.C. 2006).

5 B.C. ambient water quality guideline for boron (B.C. 2003).

6 Draft AENV guidelines for chronic and acute total mercury concentrations, respectively (AENV 1999).

7 B.C. Working Water Quality Guideline for sulphide as H_2S, Total Barium and Total Thallium (B.C. 2006).

Appendix A3

Field Work Activities and Methodology – Fish Inventory

A3.0 FIELD WORK ACTIVITIES AND METHODOLOGY – FISH INVENTORY

Fish inventories were conducted at five sites in spring 2010; two sites in summer 2010; and thirteen sites in fall 2010. A Fisheries Research License (FRL #10-0410) was obtained from Alberta Sustainable Resource Development (ASRD) prior to the commencement of all fish inventory activities. Fishing gear consisted of:

- minnow traps deployed around the perimeter of beaver ponds or along the stream bank. The geographic location and start and end time of deployment of each minnow trap was recorded; and
- electrofishing conducted on some watercourses using a Smith-Root Model 12B backpack electrofisher.

All fish captured were enumerated and identified to the species level when possible. Fork lengths and weights of all fish were recorded. Particular conditions (gravid females, spawning markings and coloration) were noted and recorded. All fish were returned to the location where they were captured.

Calculating a body condition index is a common practice in fisheries research because it provides a non-lethal estimate of health that can be correlated to various environmental components and provides a consistent comparative index over time and between populations (Craig *et al.* 2005, Colautti *et al.* 2006). Condition for fish captured in this study was calculated as:

$$Z = (y/\ x^3) \times 10^5$$

Where:

Z is condition, $\boldsymbol{y}$ is weight (g) and $\boldsymbol{x}$ is length (mm).

This equation does not take body shape or natural history into consideration and therefore it is important to recognize that the values are only comparative, assuming normal distribution, within species but between the groups of interest (e.g., differences of brook stickleback inhabiting rivers and lakes).

A3.1 SUMMARY OF HABITAT LIMITING FACTORS FOR MODELED SPECIES

Brook Stickleback - Habitat was considered average for watercourses of the MacKay River watershed:

- Nesting material is limiting in the watercourses, in terms of submergent plants suitable to brook stickleback; and
- Watercourses in both watersheds are dominated by runs, considered to have average habitat value for brook stickleback. There are some beaver ponds in the LSA, which were included in the habitat assessments but not of substantial quantity to increase habitat suitability.

Finescale Dace - Habitat suitability was average for watercourses of the MacKay River watershed:

- Finescale dace prefer finer substrate; however, the similar co-dominance of cobble and boulder with finer substrates in the watercourses limited the available habitat for this species; and
- High proportion of run-type habitat in watercourses of both watersheds; finescale dace prefer pool-type habitat.

Lake Chub - Habitat suitability was found to be below average for watercourses in the MacKay River watershed:

- Lake Chub prefer coarser substrate; however, most beaver ponds and watercourses have approximately equal proportions of finer substrates, which limits the suitability of the habitat for this species.

Longnose Dace - Habitat suitability was found to be below for watercourses of the MacKay River watershed:

- Longnose dace prefer no instream cover and all watercourses are dominated by instream vegetation.

Pearl Dace - Habitat suitability was found to be average for watercourses in the MacKay River watershed:

- Pearl dace prefer sand and gravel substrate, which although is present in high proportions, does not dominate the habitat in all watercourses.

Northern Redbelly Dace - Habitat suitability was found to be average for watercourses in the MacKay River watershed:

- Northern redbelly dace prefer pooled habitat. Most watercourses are limited by a high proportion of run habitat.

White Sucker - Habitat suitability was found to be average for watercourses in the MacKay River watershed:

- Most watercourses are dominated by runs, considered to have average habitat value for white sucker. Beaver ponds are common in the watershed but not in high proportions relative to watercourses; and
- The watercourses had high proportions of organic material and fines, which provides very little habitat value to white sucker.

Table A3.1 Habitat suitability of streams in the MacKay River Watershed for Brook Stickleback.

Habitat Requirement	Data Used and Assumptions	SI Value
Substrate	The watershed is dominated by silt, organic material and sand (73%), considered excellent habitat materials, with smaller fractions (27%) of sediments with average habitat value.	0.92
Nesting Materials	Good nesting material is in high proportion in the watershed. Instream vegetation is typically emergent plants and considered to have above average habitat value (74%) with smaller fractions of excellent nesting materials (submergent plants 3%) and poorer nesting materials (inundated vegetation 4% and woody debris 7%).	0.74
Channel Unit	The watershed was dominated by runs (59%), with smaller proportions of riffles (12%) and pools (30%). Pools and backwater areas are considered to have excellent habitat value for brook stickleback.	0.63
% Instream Cover	The average amount of instream cover (35%) comprised of small fractions of grasses, woody debris and detritus.	0.75
Late Winter Dissolved Oxygen (mg/L)	Average DO concentration was measured in January 2011 at 6.4 mg/L. A late winter DO value above 1.0 mg/L is considered excellent.	1.0
pH	Median seasonal pH was calculated to determine suitability. Excellent (95%) and Average (5%) pH values occurred over the sampling period.	0.95
	HSI value For Brook Stickleback, the HSI is set to the lowest of the SI values for the variables included in the model.	**0.63**

Table A3.2 Habitat suitability of streams in the MacKay River Watershed for lake chub and finescale dace.

Habitat Requirement	Data Used and Assumptions	Lake Chub SI Value	Finescale Dace SI Value
Substrate	The watershed is dominated by silt, organic material and sand (73%), considered excellent habitat materials, with smaller fractions (27%) of sediments with average habitat value. Finescale Dace prefer habitats with fine sediment types; Lake Chub prefer coarser substrate material.	0.50	0.64
Instream Cover	Submergent vegetation is abundant in all watercourses, typically comprised of grasses (33%). Additionally, lower quality vegetation is present in the form of woody debris (20%) and sticks and detritus (20%). Substrate also comprises a proportion of instream cover (24%).	0.57	0.98
Channel Unit	The watershed was dominated by runs (59%), with smaller proportions of riffles (12%) and pools (30%). Runs and pools are considered to have excellent habitat value for lake chub whereas pools and backwater areas are considered excellent habitat value for finescale dace.	0.94	0.62
% Instream Cover	The average amount of instream cover (35%) comprised of small fractions of grasses, woody debris and detritus. Finescale Dace require less instream cover than Lake Chub.	1.00	0.75
Late Winter Dissolved Oxygen (mg/L)	Winter dissolved oxygen (6.4 mg/L) was sampled in January 2011. Values above 1.0 mg/L are considered excellent.	1.00	1.00
pH	Median seasonal pH was calculated to determine suitability. Excellent (95%) and Average (5%) pH values occurred over the sampling period.	0.95	0.95
	HSI value For Lake Chub and Finescale Dace, the HSI is set to the lowest of the SI values for the variables included in the model.	**0.50**	**0.62**

Table A3.3 Habitat suitability of streams in the MacKay River Watershed for slimy sculpin.

Habitat Requirement	Data Used and Assumptions		SI Value
Substrate	Observations of river bed material indicate that most watercourses are comprised of sand, silt, and clay (76%) with little cobble, gravel, and boulder (24%), preferred by slimy sculpin.		0.38
Instream Cover	Submergent vegetation is abundant in all watercourses, typically comprised of grasses (33%). Additionally, lower quality vegetation is present in the form of woody debris (20%) and sticks and detritus (20%). Substrate also comprises a proportion of instream cover (24%). Substrate and woody debris is considered excellent habitat for slimy sculpin.		0.42
Channel Unit	The watershed was dominated by runs (59%), with smaller proportions of riffles (12%) and pools (30%). Runs and riffles are considered to have excellent habitat value for slimy sculpin.		0.78
% Instream Cover	The average amount of instream cover (35%) comprised of small fractions of grasses, woody debris and detritus. Values greater than 30% are considered excellent.		1.00
Late Winter Dissolved Oxygen (mg/L)	Winter dissolved oxygen (6.4 mg/L) was sampled in January 2011. Values above 1.0 mg/L are considered excellent.		1.00
	HSI value	For slimy sculpin, the HSI is set to the lowest of the SI values for the variables included in the model.	**0.38**

Table A3.4 Habitat suitability of streams in the MacKay River Watershed for longnose dace.

Habitat Requirement	Data Used and Assumptions	SI Value
Substrate	Observations of river bed material indicate that most watercourses are comprised of sand, silt, and clay (76%) with little cobble, gravel, and boulder (24%). Longnose dace prefer a combination of boulder and finer materials.	0.58
Instream Cover	Submergent vegetation is abundant in all watercourses, typically comprised of grasses (33%). Additionally, lower quality vegetation is present in the form of woody debris (20%) and sticks and detritus (20%). Substrate also comprises a proportion of instream cover (24%). Woody debris and all other instream cover are considered above average and average habitat for longnose dace with no cover preferred.	0.12
Channel Unit	The watershed was dominated by runs (59%), with smaller proportions of riffles (12%) and pools (30%). Runs and riffles are considered to have excellent habitat value for longnose dace.	0.86
% Instream Cover	The average amount of instream cover (35%) comprised of small fractions of grasses, woody debris and detritus. Values greater 30% are considered below average.	0.25
Late Winter Dissolved Oxygen (mg/L)	Winter dissolved oxygen (6.4 mg/L) was sampled in January 2011. Values above 1.0 mg/L are considered excellent.	1.00
pH	Median seasonal pH was calculated to determine suitability. Excellent (95%) and Average (5%) pH values occurred over the sampling period.	0.95
	HSI value For longnose dace, the HSI is set to the lowest of the SI values for the variables included in the model.	**0.12**

Table A3.5 Habitat suitability of streams in the MacKay River Watershed for northern redbelly dace.

Habitat Requirement	Data Used and Assumptions	SI Value
Substrate	Observations of river bed material indicate that most watercourses are comprised of sand, silt, and clay (76%). Gravel, sand and clay/silt are considered excellent habitat for northern redbelly dace.	0.64
Instream Cover	Submergent vegetation is abundant in all watercourses, typically comprised of grasses (33%). Additionally, lower quality vegetation is present in the form of woody debris (20%) and sticks and detritus (20%). Substrate also comprises a proportion of instream cover (24%). Instream vegetation and woody debris are considered excellent habitat for northern redbelly dace.	0.98
Channel Unit	The watershed was dominated by runs (59%), with smaller proportions of riffles (12%) and pools (30%). Pools and backwater areas are considered to have excellent habitat value for northern redbelly dace.	0.62
% Instream Cover	The average amount of instream cover (35%) comprised of small fractions of grasses, woody debris and detritus. Values between 30% and 50% are considered above average for northern redbelly dace.	0.75
Late Winter Dissolved Oxygen (mg/L)	Winter dissolved oxygen (6.4 mg/L) was sampled in January 2011. Values above 1.0 mg/L are considered excellent.	1.00
pH	Median seasonal pH was calculated to determine suitability. Excellent (95%) and Average (5%) pH values occurred over the sampling period.	0.95
	HSI value For northern redbelly dace, the HSI is set to the lowest of the SI values for the variables included in the model.	**0.62**

Table A3.6 Habitat suitability of streams in the MacKay River Watershed for pearl dace.

Habitat Requirement	Data Used and Assumptions		Pearl Dace SI Value
Substrate	Observations of river bed material indicate that most watercourses are comprised of sand, silt, and clay (76%) with little cobble, gravel, and boulder (24%). Gravel, sand and clay/silt are considered excellent habitat for pearl dace.		0.62
Instream Cover	Submergent vegetation is abundant in all watercourses, typically comprised of grasses (33%). Additionally, lower quality vegetation is present in the form of woody debris (20%) and sticks and detritus (20%). Substrate also comprises a proportion of instream cover (24%). Instream vegetation and woody debris are considered excellent habitat for pearl dace.		0.98
Channel Unit	The watershed was dominated by runs (59%), with smaller proportions of riffles (12%) and pools (30%). Pools and backwater areas are considered to have excellent habitat value for pearl dace.		0.94
% Instream Cover	The average amount of instream cover (35%) comprised of small fractions of grasses, woody debris and detritus. Values between 20% and 50% are considered excellent for pearl dace.		1.00
Late Winter Dissolved Oxygen (mg/L)	Winter dissolved oxygen (6.4 mg/L) was sampled in January 2011. Values above 1.0 mg/L are considered excellent.		1.00
pH	Median seasonal pH was calculated to determine suitability. Excellent (95%) and Average (5%) pH values occurred over the sampling period.		0.95
	HSI value	For Pearl Dace, the HSI is set to the lowest of the SI values for the variables included in the model.	**0.62**

Table A3.7 Habitat suitability of lakes and streams in the MacKay River Watershed for white sucker.

Habitat Requirement	Data Used and Assumptions	SI Value
Maximum monthly average turbidity (NTU)	Model requests this value be assumed non-limiting. Therefore a value of 1.0 is applied.	1.00
Average pH	Average pH measures similar across waterbody types.	0.75
Minimum dissolved oxygen levels (mg/L) during May through August	Model requests this value be assumed non-limiting. Therefore a value of 1.0 is applied.	1.00
Average of mean weekly water temperature (°C)	This variable is divided into three different parameters:	
	July and August (for adults and juveniles);	1.00
	July and August (for fry); and	1.00
	April through July (for spawning and incubation).	1.00
Average riffle velocity (cm/s) during spawning and incubation	If any riffles with suitable spawning substrates are present, this parameter is assigned a value of 1.0. If no riffles with suitable material are present, this parameter is given a value of 0.5. Riffles were encountered in the MacKay River and near the mouths of some of the tributaries. The assumption was made that they were suitable for spawning.	1.00
Average riffle depth (cm) during spawning and incubation	As above: Assumption was made that the MacKay River and some tributaries had suitable areas for spawning	1.00
Percent instream and overhanging shoreline cover	All watercourses in the watershed have similar amounts of instream (46%) and overhanging (40%) vegetation.	0.40
Percent pools during average summer flows	Watersheds are dominated by run-type habitat (50%) with smaller proportions of pool habitat (35%).	0.35
HSI value	For White Sucker, the HSI is calculated using an equation with the following inputs:	
	Minimum of water quality component (C_{WQ});	**0.75**
	Minimum of reproduction component (C_R); and	**1.00**
	Streams only–Average of cover component (C_C).	**0.38**
	Streams: HSI = $(C_{WQ}*C_R*C_C)^{1/3}$.	**0.66**

A3.2 METHODOLOGY FOR FWMIS ANALYSIS AND ASSIGNING STREAM ORDERS

FWMIS data was reviewed to determine the presence of fish within the MacKay River watershed. The overall objective of analyzing the FWMIS data was to extrapolate this presence of fish into un-sampled watercourses within the LSA and RSA and to make assumptions about the probability of particular species of fish occurring in the LSA and RSA.

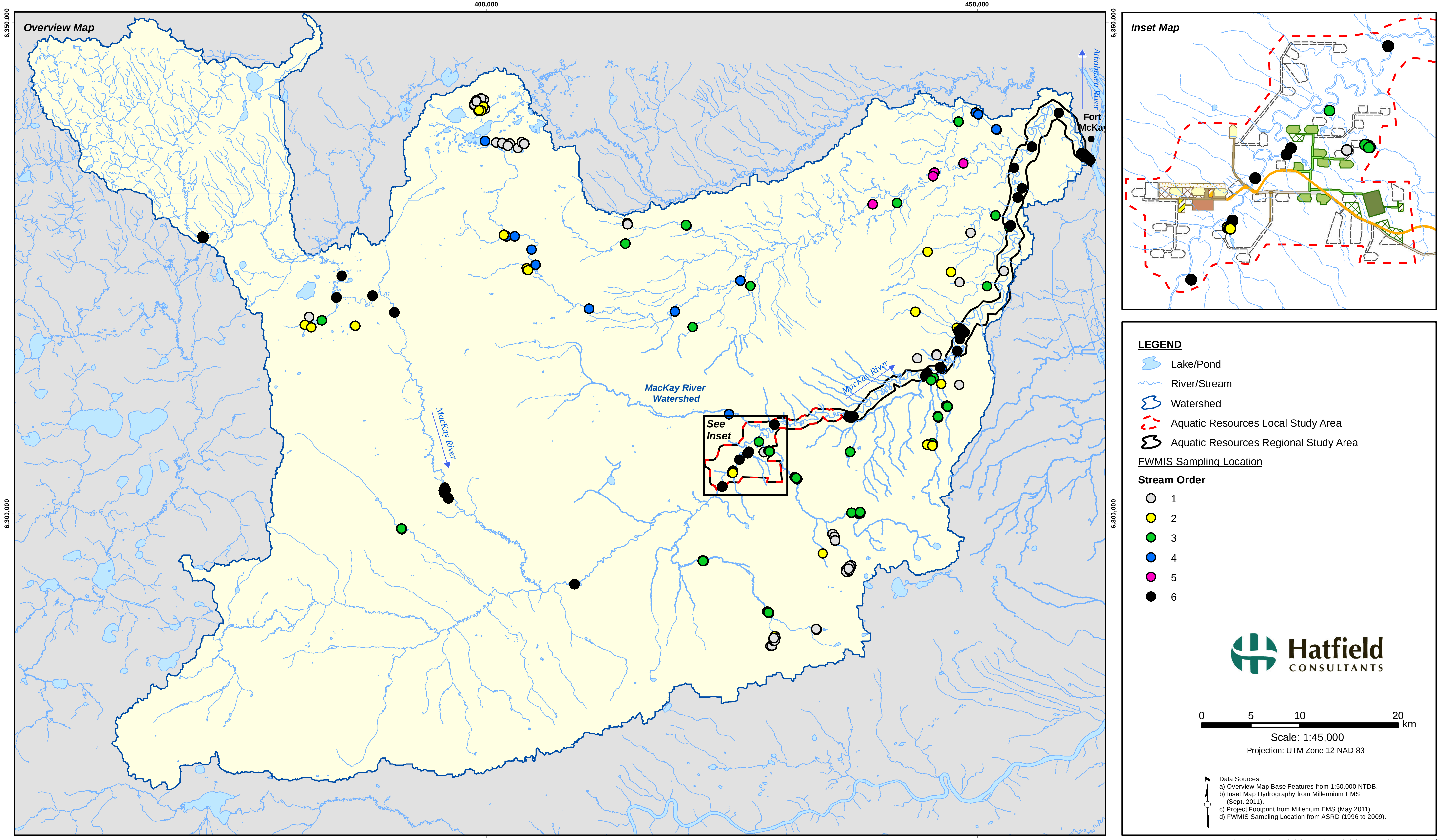
To define where fish were captured within the MacKay River watershed, ArcGIS 9.2 was used to display the FWMIS data and the hydrological network on a 1:50,000 scale map and a hard copy was produced.

The next step was to assign stream orders to the watercourses where fish were captured. Stream orders were assigned manually based on the degree of complexity of the watercourse. To determine this, labels were assigned to the watercourses starting at 1 for the lowest complexity or furthest out watercourse in the system and increased as the watercourse approached the main channel in the system. To increase in complexity, two order 1 channels would have to join to create a second order and two order 2 channels would join to create a third order channel. When a first and second order channel joined the higher complexity channel would take priority so the resulting channel would be second order.

Once the orders had been assigned to each stream, each FWMIS point was assigned a corresponding stream order number. The assigned numbers were added to a new column in the dataset attribute table. This table was then exported in ArcGIS to DBF format, which can be read in Excel.

The resulting excel file allowed us to select all the recorded watercourses across the two watersheds sampled for each stream order. Processing the data using a filter shows which species are dominant at each stream order level. This correlated data can be extrapolated to nearby un-sampled watercourses to determine the probability of presence of certain species.

Figure A3.1 Location of FWMIS data points within the MacKay River watershed and the Local and Regional Study Areas for the McKay SAGD project.



K:\Data\Project\MEMS1613_MXD\MEMS1613_F_FWMISO_20111025.mxd

Appendix A4

Fish Inventory Data

A4.0 FISH INVENTORY DATA

Table A4.1 Fish inventory data by site and season.

	Site Code	Start UTM (NAD83, Zone 12) E	Start UTM (NAD83, Zone 12) N	End UTM (NAD83, Zone 12) E	End UTM (NAD83, Zone 12) N	Gear Type	No. of Traps	Effort (trap-hours or EF secs)	Total No. Fish Caught	Species[1]	No. Fish Caught by Species	CPUE	Average Length (mm)	Average Weight (g)
Rivers														
Spring	SPE5	435434	6310089	434978	6309874	EF		2,232 s	30	LNSC	2	1.34	54.00	4.00
										PRDC	6		40.17	1.00
										SLSC	4		45.75	2.00
										WHSC	18		40.94	1.60
	SPE1	429142	6309220	428971	6309409	EF		1,170s	2	FNDC	1	0.002	67.00	0.40
										NRDC	1			
Summer	SPE5	436683	6308634	436828	6308708	EF		1,976 s	135	LKCH	38	6.83	38.29	0.70
										LNDC	30		43.10	1.27
										SLSC	55		38.67	1.11
										TRPR	3		44.33	1.23
										WHSC	9		43.78	1.06
Fall	SP20	428472	6308613	428400	6308540	MT	8	5 hrs 33 mins	23	LKCH	20	4.14	56.90	1.99
										NRDC	1		57.00	1.70
										PRDC	1		49.00	1.40
										WHSC	1		49.00	1.30
	SP3	425036	6304155	424979	6304192	MT	8	18 hrs 34 mins	66	BRST	12	3.55	54.42	1.62
										LKCH	26		60.42	2.33
										PRDC	22		58.68	2.16
										WHSC	6		54.83	2.15
	SP1	424024	6303401	423988	6302952	EF		2,588 s	19	LNDC	2	0.73	35.00	0.60
										NRPK	1		140.00	18.20
										PRDC	9		32.00	0.58
										SLSC	1		41.00	0.90
										TRPR	2		37.00	0.90
										WHSC	4		40.25	1.08
	SPE5	435481	6309992	435081	6309858	EF		2,895 s	133	LNDC	9	4.59	30.00	0.25
										PRDC	45		36.98	0.59
										SLSC	50		38.96	0.94
										TRPR	13		42.50	0.83
										WHSC	16		44.00	3.41
Beaver Ponds														
Spring	SPE3	431069	6309454	431690	6309298	MT	10	11 hrs 9 mins	37	FNDC	37	3.32	67.00	4.09
	SPE7	436592	6308547	436776	6308690	MT	10	5 hrs 37 mins	83	BRST	14	14.78	50.00	1.90
										FNDC	69		64.80	3.75
Summer	SPE7	436625	6308572	436831	6308711	MT	8	7 hrs 26 mins	10	BRST	10	1.35	51.70	1.48
Fall	SPE7	436683	6308634	436828	6308708	MT	10	19 hrs 15 mins	295	BRST	50	15.32	56.22	1.55
										NRDC	245		58.65	2.46
	SPE3	431621	6309427	431680	6309335	MT	2	6 hrs 6 mins	9	NRDC	9	1.48	7.30	4.90
	SPE6	435732	6306909	435795	6306943	MT	2	18 hrs 5 mins	12	NRDC	2	0.66	63.50	2.40
										BRST	10		65.10	2.38

[1] Species Codes: BRST-brook stickleback; LKCH-lake chub; LNSC-longnose sucker; EMSH-emerald shiner; SLSC-slimy sculpin; WHSC-white sucker; LNDC-longnose dace.

Note: No fish were caught at SP8 and SP11 during Fall sampling, nor SPE6 during Spring sampling.

Appendix A5

Field Work Activities and Methodology – Aquatic Habitat

A5.0 FIELD WORK ACTIVITIES AND METHODOLOGY – AQUATIC HABITAT

Habitat Surveys

Aquatic habitat surveys were undertaken at seven watercourses over 4 sampling seasons. Habitat survey procedures developed and used extensively by the British Columbia Ministry of Fisheries were used to characterize habitats at each site. This survey procedure evaluates specific habitat elements to provide an overall description of fish habitat. This methodology takes into consideration survey and assessment procedures recommended in a number of Alberta environmental codes of practice, including: (i) Code of Practice for Pits (AENV 2000); (ii) Code of Practice for Pipelines and Telecommunication Lines Crossing a Waterbody (AENV 2000); and (iii) Code of Practice for Watercourse Crossings (AENV 2000); as well as their associated guidelines. Surveys documented dominant and sub-dominant vegetation cover types and sources of instream cover, channel morphology, and blank shape, texture and vegetation. Detailed habitat cards are provided below.

A5.1 HABITAT CARDS

Referencing Information			
Watershed:	Tributary to MacKay River		
Map Location:	SPE1		
Date Assessed :	8 June 2010	23 Aug 2010	3 Oct 2010
Time Assessed:	0828	0733	0938
UTM (NAD83, 12V):	429070E, 6309241N		
Access:	Helicopter		
Water Quality			
	Spring	Summer	Fall
Temperature (°C):	-	11.49	4.71
Dissolved Oxygen (mg/L):	-	7.88	25.80
pH:	-	7.98	5.60
Conductivity (µS/cm):	-	196.5	0.08
Channel Characteristics			
	Spring	Summer	Fall
Channel Width (m):	-	11.93	1.46
Wetted Width (m):	-	6.23	1.11
Residual Pool Depth (m):	0.18	0.60	0.20
Flow Velocity (m/s):	-	0.05	0.13
Morphology:	run	run	riffle
Cover and Streambanks			
	Spring	Summer	Fall
Crown Cover %:	46	-	-
Dominant Overhanging Vegetation (%):	-	Grasses (25)	Grasses (28)
2ary Overhanging Vegetation (%):	-	Shrubs (10)	Trees (25)
Sources of Instream Cover:	None	-	-
Dominant Cover Type (%):	-	Logs (5)	Logs (20)
2ary Cover Type (%):	-	Substrate (5)	Substrate (10)
Undercut Banks (%):	25	1.75	0.75
Aquatic Vegetation:	Rooted emergent, periphyton, moss, rooted submergent		
Bank Slope (°):	L33.75/R14.38	L71.25/R82.5	L23.75/R2.85
Bank Texture:	-	-	-
Bank Riparian Vegetation:	Mixed forest, grasses, shrubs		
Channel Morphology			
Dominant Bed Material:	Sand (>50%)		
Sub-Dominant Bed Material:	Gravel		
Disturbance Indicators:	Beaver dam and collapsed dam		
Islands:	-		
Bars:	-		
Comments			
SPE1 is a defined channel. There is a beaver pond habitat at the upstream end of the reach and it confluences with the MacKay River at the downstream end.			

June 2010

June 2010

August 2010

October 2010

Referencing Information			
Watershed:	Tributary to MacKay River		
Map Location:	SPE2		
Date Assessed :	12 June 2010	23 Aug 2010	8 Oct 2010
Time Assessed:	1146	0945	1237
UTM (NAD83, 12V):	430162E, 6309758N		
Access:	Helicopter		

Water Quality	Spring	Summer	Fall
Temperature (°C):	-	10.9	6.9
Dissolved Oxygen (mg/L):	-	8.85	26.48
pH:	-	8.17	7.65
Conductivity (µS/cm):	-	289.75	0.13

Channel Characteristics	Spring	Summer	Fall
Channel Width (m):	-	1.59	2.61
Wetted Width (m):	-	1.17	1.1
Residual Pool Depth (m):	0.11	0.60	0.20
Flow Velocity (m/s):	-	0.01	0.10
Morphology:	run	run	run

Cover and Streambanks	Spring	Summer	Fall
Crown Cover %:	67	-	-
Dominant Overhanging Vegetation (%):	-	Shrubs, trees, grasses (5)	Litter >150 mm (14)
2ary Overhanging Vegetation (%):	-	Shrubs (10)	Shrubs (7.5)
Sources of Instream Cover:	-	-	-
Dominant Cover Type (%):	Logs (5-10)	Substrate (10)	Logs (9)
2ary Cover Type (%):	Twigs/sticks (5-10)	Twigs/stick, vegetation (5)	Detritus (5)
Undercut Banks (%):	5	5	2
Aquatic Vegetation:	Rooted emergent, rooted submergent, rooted floating		
Bank Slope (°):	L47.25	L67.5/R67.5	L70/R63.75
Bank Texture:	-	-	-
Bank Riparian Vegetation:	mixed forest, grasses, re-growth forest, cutlines, shrubs, roads		

Channel Morphology		
Dominant Material:	Bed	Silt/Sand
Sub-Dominant Material:	Bed	Boulder
Disturbance Indicators:		Beaver pond and cutblock
Islands:		-
Bars:		-

Comments

SPE2 is located upstream of an old cutblock road in a mature forest.


June 2010


August 2010


October 2010


October 2010

Referencing Information			
Watershed:	Tributary to MacKay River		
Map Location:	SPE3		
Date Assessed :	10 June 2010	23 Aug 2010	5 Oct 2010
Time Assessed:	1445	1350	1304
UTM (NAD83, 12V):	431621E, 6309427N		
Access:	Helicopter		
Water Quality			
	Spring	Summer	Fall
Temperature (°C):	-	12.4	8.48
Dissolved Oxygen (mg/L):	-	2.60	4.55
pH:	-	7.42	7.23
Conductivity (µS/cm):	-	399	0.23
Channel Characteristics			
	Spring	Summer	Fall
Channel Width (m):	-	0.6	NA
Wetted Width (m):	-	0.38	40
Residual Pool Depth (m):	0.12	0.16	>1
Flow Velocity (m/s):	-	0.01	NA
Morphology:	-	run/pool	pool/pond
Cover and Streambanks			
	Spring	Summer	Fall
Crown Cover %:	50	-	-
Dominant Overhanging Vegetation (%):	-	Grasses (33)	Trees (20)
2ary Overhanging Vegetation (%):	-	Shrubs (12)	Grasses, shrubs (10)
Sources of Instream Cover:	-	-	-
Dominant Cover Type (%):	Twigs/sticks (5)	Trace vegetation	Logs (40)
2ary Cover Type (%):	Logs (0-5)		Vegetation (30)
Undercut Banks (%):	no	no	no
Aquatic Vegetation:	Rooted emergent, flooded terrestrial		
Bank Slope (°):	-	L67.5/R67.5	L70-5/R0-5
Bank Texture:	-	-	-
Bank Riparian Vegetation:	mixed forest, grasses, re-growth forest, shrubs, sedges, cutlines		
Channel Morphology			
Dominant Bed Material:	Organics/Silt		
Sub-Dominant Bed Material:	Boulder		
Disturbance Indicators:	Beaver pond and old cutblock		
Islands:	-		
Bars:	-		
Comments			
There is a beaver dam on SPE3 about 10 m upstream from the MacKay River confluence.			

June 2010

August 2010

August 2010

October 2010

Referencing Information			
Watershed:	Tributary to MacKay River		
Map Location:	SPE4		
Date Assessed :	8 June 2010	23 Aug 2010	3 Oct 2010
Time Assessed:	1657	1145	1446
UTM (NAD83, 12V):	432882E, 6310531N		
Access:	Helicopter		
Water Quality			
	Spring	Summer	Fall
Temperature (°C):	-	12.88	7.65
Dissolved Oxygen (mg/L):	-	4.78	4.16
pH:	-	7.46	6.99
Conductivity (µS/cm):	-	204.25	0.19
Channel Characteristics			
	Spring	Summer	Fall
Channel Width (m):	-	1.08	1.00
Wetted Width (m):	-	0.58	0.72
Residual Pool Depth (m):	0.15	-	0.31
Flow Velocity (m/s):	-	0.01	0.04
Morphology:	-	run	run
Cover and Streambanks			
	Spring	Summer	Fall
Crown Cover %:	30-40	-	-
Dominant Overhanging Vegetation (%):	-	Grasses (17)	Shrubs (28)
2ary Overhanging Vegetation (%):	-	Overhead litter >150 mm (12)	Trees (15)
Sources of Instream Cover:	-	-	-
Dominant Cover Type (%):	Twigs/sticks (10)	Logs (3)	Vegetation(16)
2ary Cover Type (%):	Logs (5)	Twigs/stick, vegetation (3)	Twigs/sticks (6)
Undercut Banks (%):	10	5	2.5
Aquatic Vegetation:	Rooted emergent, rooted submergent, algae, flooded terrestrial		
Bank Slope (°):	L41.25/R23.75	L60/R60	L45.6/R45.6
Bank Texture:	-	-	-
Bank Riparian Vegetation:	mixed forest, grasses, re-growth forest, cutlines, shrubs		
Channel Morphology			
Dominant Bed Material:	Silt (>65%)		
Sub-Dominant Bed Material:	Organics/gravel		
Disturbance Indicators:	Old cutblock, beaver pond		
Islands:	-		
Bars:	-		
Comments			
SPE4 is located in a mature forest and has very low flow because of a beaver dam located on the river.			


June 2010


June 2010


August 2010


October 2010

Referencing Information			
Watershed:	MacKay River, downstream of Phase 2 Project Area		
Map Location:	SPE5		
Date Assessed :	10 June 2010	27 Aug 2010	4 Oct 2010
Time Assessed:	1215	0941	0922
UTM (NAD83, 12V):	434978E, 6309874N		
Access:	Helicopter		
Water Quality			
	Spring	Summer	Fall
Temperature (°C):	15.13	15.2	6.79
Dissolved Oxygen (mg/L):	10.66	7.45	6.33
pH:	7.25	8.14	7.61
Conductivity (μS/cm):	115	182.75	0.10
Channel Characteristics			
	Spring	Summer	Fall
Channel Width (m):	27.42	56.75	43.33
Wetted Width (m):	22.5	36	32.67
Residual Pool Depth (m):	0.87	-	0.6
Flow Velocity (m/s):	0.19	5.0	0.5
Morphology:	run/riffle	run	run
Cover and Streambanks			
	Spring	Summer	Fall
Crown Cover %:	-	-	-
Dominant Overhanging Vegetation (%):	Trace	Grasses (4)	Shrubs (1.3)
2ary Overhanging Vegetation (%):	-	Shrubs (3)	Trees (1.25)
Sources of Instream Cover:	-	-	-
Dominant Cover Type (%):	Substrate (64)	Substrate (5)	Substrate (3)
2ary Cover Type (%):	Vegetation (3)	Twigs/sticks, vegetation (Trace)	Vegetation (1)
Undercut Banks (%):	5	5	-
Aquatic Vegetation:	Rooted emergent		
Bank Slope (°):	L15/R48.75	L71.25/R63.75	L70/R63.3
Bank Texture:	-	-	-
Bank Riparian Vegetation:	mixed forest, grasses, re-growth forest, shrubs, sedges, burn, cutblock		
Channel Morphology			
Dominant Bed Material:	Sand/Cobble		
Sub-Dominant Bed Material:	Gravel		
Disturbance Indicators:	Cutblock/burn area		
Islands:	-		
Bars:	grass bar 5 x 0.5-1.5 m		
Comments			
SPE5 is on the MacKay River, during both the August and October field programs fish were observed in this river (fry and a northern pike).			


June 2010


August 2010


October 2010


October 2010

Referencing Information			
Watershed:	Tributary to the MacKay River		
Map Location:	SPE6		
Date Assessed :	9 June 2010	27 Aug 2010	4 Oct 2010
Time Assessed:	0801	0943	0812
UTM (NAD83, 12V):	435749E, 6306918N		
Access:	Helicopter		

Water Quality	Spring	Summer	Fall
Temperature (°C):	-	12.15	6.06
Dissolved Oxygen (mg/L):	-	-	28.1
pH:	-	7.04	6.99
Conductivity (µS/cm):	-	202.5	0.09

Channel Characteristics	Spring	Summer	Fall
Channel Width (m):	-	40-60	-
Wetted Width (m):	-	30-40	-
Residual Pool Depth (m):	0.52	0.5- >1.0	>1.0
Flow Velocity (m/s):	-	-	-
Morphology:	pool	pool	pool

Cover and Streambanks	Spring	Summer	Fall
Crown Cover %:	34	-	-
Dominant Overhanging Vegetation (%):	-	Grasses (20)	Grasses/ shrubs (20)
2[ary] Overhanging Vegetation (%):	-	Shrubs (18)	-
Sources of Instream Cover:	-	-	-
Dominant Cover Type (%):	Twigs/ sticks(0-5)	Vegetation (34)	Vegetation (40)
2[ary] Cover Type (%):	Logs (Trace)	Substrate (5)	Logs (5)
Undercut Banks (%):	-	-	-
Aquatic Vegetation:	Rooted emergent, rooted submergent, rooted floating, flooded terrestrial plants		
Bank Slope (°):	-	-	-
Bank Texture:	Organic	-	-
Bank Riparian Vegetation:	grasses, coniferous forest, shrubs, sedges		

Channel Morphology	
Dominant Bed Material:	Organics (100 %)
Sub-Dominant Bed Material:	-
Disturbance Indicators:	Cutline, old burn, beaver dam
Islands:	-
Bars:	-

Comments

SPE6 is a series of beaver ponds that end in a flooded willow area. There is no defined channel. Water is stagnant, and there is no visible flow.

June 2010

August 2010

August 2010

October 2010

Referencing Information			
Watershed:	Tributary to the MacKay River		
Map Location:	SPE7		
Date Assessed :	9 June 2010	24 Aug 2010	4 Oct 2010
Time Assessed:	1228	0730	1453
UTM (NAD83, 12V):	436751E, 6308662N		
Access:	Helicopter		
Water Quality			
	Spring	Summer	Fall
Temperature (°C):	-	11.73	9.58
Dissolved Oxygen (mg/L):	-	0.63	4.82
pH:	-	7.39	7.03
Conductivity (µS/cm):	-	145.33	0.10
Channel Characteristics			
	Spring	Summer	Fall
Channel Width (m):	-	-	>50
Wetted Width (m):	-	-	>40
Residual Pool Depth (m):	0.70	0.85	>1.0
Flow Velocity (m/s):	-	-	-
Morphology:	-	ponds	pool
Cover and Streambanks			
	Spring	Summer	Fall
Crown Cover %:	2.80	-	-
Dominant Overhanging Vegetation (%):	-	Grasses, shrubs, overhead litter >150mm (trace)	Grasses (20)
2ary Overhanging Vegetation (%):	-		Shrubs (10)
Sources of Instream Cover:	-	-	-
Dominant Cover Type (%):	Twigs/ sticks, logs (trace)	Twigs/ sticks, logs (trace)	Vegetation (30)
2ary Cover Type (%):	-	-	Detritus (10)
Undercut Banks (%):	-	-	-
Aquatic Vegetation:	Rooted emergent, free-floating, floating algae		
Bank Slope (°):	-	0-5	-
Bank Texture:	Organic	Organic	-
Bank Riparian Vegetation:	grasses, coniferous forest, shrubs, sedges		
Channel Morphology			
Dominant Bed Material:	Organics (100 %)		
Sub-Dominant Bed Material:	-		
Disturbance Indicators:	Cutblock, beaver dams		
Islands:	-		
Bars:	-		
Comments			
SPE7 is a series of beaver ponds linked together, adjacent to a cutblock.			


June 2010


August 2010


October 2010


October 2010

Referencing Information	
Watershed:	MacKay River upstream of Phase 1 Project Area
Map Location:	SP1
Date Assessed:	7 October, 2010
Time Assessed:	0942
UTM (NAD83, 12V):	424024, 6303401N
Access:	Helicopter

Water Quality	
Temperature (°C):	7.47
Dissolved Oxygen (mg/L):	4.67
pH:	5.88
Conductivity (µS/cm):	0.11

Channel Characteristics	
Channel Width (m):	35
Wetted Width (m):	30.5
Residual Pool Depth (m):	0.70
Flow Velocity (m/s):	0.18
Morphology:	run

Cover and Streambanks	
Crown Cover %:	-
Dominant Overhanging Vegetation (%):	Overhead litter </>150 mm, trees, shrubs, grasses (1)
2^{ary} Overhanging Vegetation (%):	
Sources of Instream Cover:	
Dominant Cover Type (%):	Detritus, logs, twigs/sticks (1)
2^{ary} Cover Type (%):	
Undercut Banks (%):	1
Aquatic Vegetation:	-
Bank Slope (°):	L90/R86
Bank Texture:	-
Bank Riparian Vegetation:	grasses, coniferous forest, deciduous forest, shrubs

Channel Morphology	
Dominant Bed Material:	Clay
Sub-Dominant Bed Material:	Sand/silt
Disturbance Indicators:	-
Islands:	-
Bars:	-

Comments

SP1 is located upstream of the Phase 1 Project Area on the MacKay River.


October 2010


October 2010

Referencing Information	
Watershed:	Tributary to the MacKay River
Map Location:	SP3
Date Assessed:	7 October, 2010
Time Assessed:	1533
UTM (NAD83, 12V):	425039, 6304162N
Access:	Helicopter
Water Quality	
Temperature (°C):	10.1
Dissolved Oxygen (mg/L):	4.2
pH:	6.73
Conductivity (µS/cm):	0.08
Channel Characteristics	
Channel Width (m):	3
Wetted Width (m):	3
Residual Pool Depth (m):	>2.0
Flow Velocity (m/s):	-
Morphology:	run/pool
Cover and Streambanks	
Crown Cover %:	-
Dominant Overhanging Vegetation (%):	Grasses (30)
2ary Overhanging Vegetation (%):	Shrubs (10)
Sources of Instream Cover:	
Dominant Cover Type (%):	Vegetation (30)
2ary Cover Type (%):	Twigs/sticks (10)
Undercut Banks (%):	-
Aquatic Vegetation:	-
Bank Slope (°):	L0.5/R0.5
Bank Texture:	-
Bank Riparian Vegetation:	grasses, shrubs
Channel Morphology	
Dominant Bed Material:	Organics (100%)
Sub-Dominant Bed Material:	-
Disturbance Indicators:	Beaver dam
Islands:	-
Bars:	-
Comments	
SP3 is a tributary to the MacKay River.	

October 2010

October 2010

Referencing Information	
Watershed:	Tributary to the MacKay River
Map Location:	SP8
Date Assessed:	8 October, 2010
Time Assessed:	1223
UTM (NAD83, 12V):	426751, 6306101N
Access:	Helicopter
Water Quality	
Temperature (°C):	7.15
Dissolved Oxygen (mg/L):	20.38
pH:	7.31
Conductivity (µS/cm):	0.16
Channel Characteristics	
Channel Width (m):	0.82
Wetted Width (m):	0.61
Residual Pool Depth (m):	0.17
Flow Velocity (m/s):	0.03
Morphology:	riffle
Cover and Streambanks	
Crown Cover %:	-
Dominant Overhanging Vegetation (%):	Shrubs (50)
2ary Overhanging Vegetation (%):	Trees (20)
Sources of Instream Cover:	
Dominant Cover Type (%):	Twigs/sticks (28)
2ary Cover Type (%):	Logs (20)
Undercut Banks (%):	-
Aquatic Vegetation:	Rooted emergent
Bank Slope (°):	L28.8/R33.2
Bank Texture:	-
Bank Riparian Vegetation:	mixed forest, shrubs
Channel Morphology	
Dominant Bed Material:	Sand (89%)
Sub-Dominant Bed Material:	Organics (11%)
Disturbance Indicators:	-
Islands:	-
Bars:	-

Comments

SP8 is a narrow and shallow creek that follows the toe of a hill and empties into the MacKay River.


October 2010


October 2010


October 2010

Referencing Information	
Watershed:	Tributary to the MacKay River
Map Location:	SP11
Date Assessed:	7 October, 2010
Time Assessed:	1344
UTM (NAD83, 12V):	426111, 6308613N
Access:	Helicopter
Water Quality	
Temperature (°C):	8.44
Dissolved Oxygen (mg/L):	5.4
pH:	6.84
Conductivity (µS/cm):	-
Channel Characteristics	
Channel Width (m):	2.25
Wetted Width (m):	2.25
Residual Pool Depth (m):	0.4-0.6
Flow Velocity (m/s):	-
Morphology:	run
Cover and Streambanks	
Crown Cover %:	-
Dominant Overhanging Vegetation (%):	Grasses (60)
2^{ary} Overhanging Vegetation (%):	-
Sources of Instream Cover:	
Dominant Cover Type (%):	Vegetation (60)
2^{ary} Cover Type (%):	Logs (5)
Undercut Banks (%):	-
Aquatic Vegetation:	Flooded terrestrial, attached algae
Bank Slope (°):	L10/R10
Bank Texture:	-
Bank Riparian Vegetation:	grasses, coniferous forest
Channel Morphology	
Dominant Bed Material:	Organics (100%)
Sub-Dominant Bed Material:	-
Disturbance Indicators:	Old beaver dams
Islands:	-
Bars:	-
Comments	
SP11 is a very grass channel, made up of a series of old beaver ponds (drained).	


October 2010


October 2010


October 2010

Referencing Information	
Watershed:	Tributary to the MacKay River
Map Location:	SP20
Date Assessed:	8 October, 2010
Time Assessed:	0900
UTM (NAD83, 12V):	428472, 6308613N
Access:	Helicopter
Water Quality	
Temperature (°C):	7.09
Dissolved Oxygen (mg/L):	4.95
pH:	7.39
Conductivity (µS/cm):	0.08
Channel Characteristics	
Channel Width (m):	10
Wetted Width (m):	4
Residual Pool Depth (m):	0.3
Flow Velocity (m/s):	0.4
Morphology:	run
Cover and Streambanks	
Crown Cover %:	-
Dominant Overhanging Vegetation (%):	Overhead litter >150 mm (20)
2ary Overhanging Vegetation (%):	Shrubs (5)
Sources of Instream Cover:	
Dominant Cover Type (%):	Logs(40)
2ary Cover Type (%):	Twigs/sticks (10)
Undercut Banks (%):	5
Aquatic Vegetation:	Rooted emergent
Bank Slope (°):	L30/R90
Bank Texture:	-
Bank Riparian Vegetation:	mixed forest, grasses, shrubs
Channel Morphology	
Dominant Bed Material:	Gravel (60%)
Sub-Dominant Bed Material:	Cobble (40%)
Disturbance Indicators:	-
Islands:	-
Bars:	-
Comments	
SP20 is a well defined channel that drains into the MacKay River.	


October 2010


October 2010


October 2010