

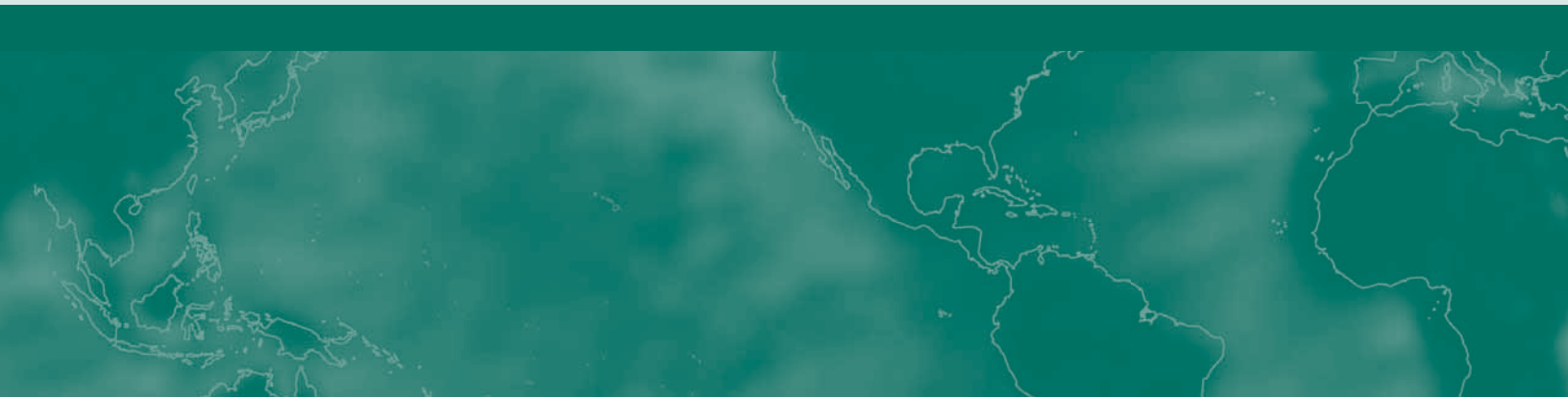


Connacher Great Divide SAGD Expansion Project: Surface Aquatic Resources Report

May 2010

Prepared for:

Connacher Oil Gas Ltd.
Calgary, Alberta





CONNACHER GREAT DIVIDE SAGD EXPANSION PROJECT: SURFACE AQUATIC RESOURCES REPORT

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MAY 2010

COG1291-111.2



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LIST OF ACRONYMS

AENV	Alberta Environment
AEPEA	Alberta Environmental Protection and Enhancement Act
AQLSA	Air Quality Local Study Area
AQRSA	Air Quality Regional Study Area
ASRD	Alberta Sustainable Resource Development
BCMOE	British Columbia Ministry of Environment
CASA	Clean Air Strategic Alliance
CCME	Canadian Council of Ministers of the Environment
CEMA	Cumulative Environmental Management Association
CL	Critical Load
COSEWIC	Committee on the Status of Endangered Wildlife
CPFs	Central Processing Facilities
CWQG	Canadian Water Quality Guidelines
DOC	Dissolved Organic Carbon
EIA	Environmental Impact Assessment
EPEA	Environmental Protection and Enhancement Act
EUB	Energy and 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	Project Public Disclosure Document
QA/QC	Quality Assurance/Quality Control
RAMP	Regional Aquatic Monitoring Program
RSA	Regional Study Area
SAGD	Surface Water Quality, Fish Resources and Aquatic Habitat for the Proposed Great Divide
TCUs	True Colour Units
TDS	Total Dissolved Solids
TEK	Traditional Environmental Knowledge
TLU	Traditional Land Use
TOR	Final Terms of Reference
TSS	Total Suspended Solids
USEPA	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 Great Divide SAGD Expansion Project (the Project) south of Fort McMurray, Alberta in the Athabasca oil sands region. The report was prepared by Hatfield Consultants Partnership (Hatfield) for Connacher Oil and Gas Ltd. (Connacher) and was prepared as a component of an integrated formal application by Connacher for the Project.

1.2 TERMS OF REFERENCE

The format and contents of this Project report are guided by the Final Terms of Reference (ToR) for the Environmental Impact Assessment Report for the Project issued in July 2009 (AENV 2009). The final ToR was developed following release of the Project Public Disclosure Document (PDD) in March 2009 (Connacher 2009); 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](#)).

1.3 PROJECT LOCATION AND SCOPE

The Project will be located approximately 70 km south of Fort McMurray, Alberta. The Project will be located both to the east and to the west of Highway No. 63, and within Townships 81 to 83, Ranges 11 to 12, W4M ([Figure 1](#)). The Project is located in the Christina and Horse River watersheds and lies within the Wabasca Lowland Ecoregion, which is part of the Boreal Plains Ecozone.

The Project will consist of an expansion of the productive capacity of existing and approved Connacher oil sands production facilities ([Figure 2](#)) by an additional 24,000 barrels per day (bbl/d) of bitumen. Connacher's existing Great Divide Pod One SAGD project (Pod One) is currently operational and is designed to produce 10,000 bbl/d. The Algar SAGD project (Algar) has also been approved to produce 10,000 bbl/day and construction activities have commenced. Once the Great Divide SAGD Expansion Project is complete and operational, the combined production capacity for the Project will be approximately 44,000 bbl/d of bitumen.

1.4 SUMMARY PROJECT DESCRIPTION

The Project will occur in three phases over a period of 25 years. Phases 1, 2, and 3 will require an additional nine, twelve, and nineteen well pads, respectively ([Figure 2](#)). Well pads in Phase 1 will increase production, while well pads in Phases 2 and 3 will replace well pads that have ended production in the Pod One and Algar projects in order to maintain the 44,000 bbl/day production rate throughout the anticipated twenty five year economic life of the Project. The total disturbance area will be approximately 738 ha, consisting of 521 ha for the Expansion Project, 99.9 ha for Pod One, and 117.7 ha for Algar. 426 ha (58%) of the total Project footprint will be located in the Christina River watershed and approximately 312 ha (42%) will be located in the Horse River watershed.

Key components of the 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.

A full description of the Project is provided in [Connacher 2010, Section B](#).

Table 1 Terms of Reference sections applicable to this assessment.

Final ToR for Project (from AENV 2009)	Report Section
3.5 Surface Water Quality	
3.5.1 Baseline Information	Section 3
[A] Describe the baseline water quality of watercourses and waterbodies. Discuss the effects of seasonal variations, flow and other factors on water quality.	3.3.1, 3.4.1
3.5.2 Impact Assessment	Section 4
[A] Identify Project components that may influence or impact surface water quality.	4.1, 4.2
[B] Describe the potential impacts of the Project on surface water quality:	
a) discuss any changes in water quality resulting from the Project that may exceed the <i>Surface Water Quality Guidelines for Use in Alberta or Canadian Water Quality Guidelines</i> ;	4.1.1, 4.1.2, 4.1.3, 4.1.4, 4.1.5, 4.1.6, 4.1.7, 4.2.1
b) discuss the significance of any impacts on water quality and implications to aquatic resources (e.g., biota, biodiversity, and habitat);	4.1.1, 4.1.2, 4.1.3, 4.1.4, 4.1.5, 4.1.6, 4.1.7, 4.2
c) discuss seasonal variation and potential effects on surface water quality;	4.1.1, 4.1.2, 4.1.3, 4.1.4, 4.1.5, 4.1.6, 4.1.7, 4.2
d) assess the potential Project related and cumulative impacts of acidifying and other air emissions on surface water quality; and	4.1.7, 4.2
e) discuss the effect of changes in surface runoff or groundwater discharge on water quality in surface waterbodies.	4.1.1, 4.1.4
[C] Describe proposed mitigation measures to maintain surface water quality during all stages of the Project.	4.1.1, 4.1.2, 4.1.3, 4.1.4, 4.1.5, 4.1.6, 4.1.7, 4.2
[D] Describe the residual effects of the Project on surface water quality and Connacher's plans to manage those effects.	4.1.1, 4.1.2, 4.1.3, 4.1.4, 4.1.5, 4.1.6, 4.1.7, 4.2, 4.3, 4.4
3.5.3 Monitoring	
[A] Describe the monitoring programs proposed to assess any Project impacts to surface water quality and to measure the effectiveness of mitigation measures. Discuss the location of monitoring sites, the frequency of monitoring, the parameters to be monitored, the implementation of quality assurance programs, and the numerical methodology.	4.4

Table 1 (Cont'd.)

Final ToR for Project (from AENV 2009)	Report Section
3.6 Aquatic Ecology	
3.6.1 Baseline Information	Section 3
[A] Describe the existing fish and other aquatic resources (e.g., benthic invertebrates). Identify species composition, distribution, relative abundance, movements, and general life history parameters.	3.3.2 to 3.3.6, 3.4.2
[B] Describe and map, as appropriate, the fish habitat, and aquatic resources of the lakes, rivers, ephemeral water bodies and other waters and identify:	
a) key indicator species and provide the rationale and selection criteria use	2.6
b) critical or sensitive areas such as spawning, rearing, and over-wintering habitats. Discuss seasonal habitat use including migration and spawning routes; and	3.3.6
c) current and potential use of the fish resources by aboriginal, sport, or commercial fisheries.	2.3.1
3.6.2 Impact Assessment	Section 4
[A] Describe the potential impacts to fish, fish habitat, and other aquatic resources (e.g., stream alterations and changes to substrate conditions, water quality, and quantity) considering:	4.1.1, 4.1.2, 4.1.3, 4.1.4, 4.1.5, 4.1.6, 4.1.7, 4.2
a) fish tainting, survival of eggs and fry, chronic or acute health effects, and increased stress on fish populations from release of contaminants, sedimentation, flow alterations, temperature, and habitat changes;	4.1.6
b) potential impacts on riparian areas that could impact aquatic biological resources and productivity;	4.1.1, 4.1.2
c) the potential for increased fishing pressures in the region that could arise from the increased workforce and improved access as a result of the Project. Identify the implications on the fish resource and describe any mitigation strategies that might be planned to minimize these effects, including any plans to restrict employee and visitor access; and	4.1.8
d) changes to benthic invertebrate communities that may affect food quality and availability for fish.	4.1.1, 4.1.2, 4.1.3, 4.1.4, 4.1.5, 4.1.6, 4.1.7, 4.2
[B] Discuss the design, construction, and operational factors to be incorporated into the Project to minimize effects to fish and fish habitat and protect aquatic resources during all stages of the Project.	4.1.1, 4.1.2, 4.1.3, 4.1.4, 4.1.5, 4.1.6, 4.1.7, 4.2
[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
[D] Describe the effects of any surface water withdrawals considered including cumulative effects on aquatic resources during all stages of the Project.	4.1.4
[E] Describe the residual effects of the Project on fish, fish habitat, and other aquatic resources and discuss their significance in the context of local and regional fisheries. Describe Connacher's plans to manage those effects.	4.1.1, 4.1.2, 4.1.3, 4.1.4, 4.1.5, 4.1.6, 4.1.7, 4.2
3.6.3 Monitoring	
[A] Describe the monitoring programs proposed to assess any Project impacts to fish, fish habitat, and other aquatic resources and to measure the effectiveness of mitigation measures.	4.4

Figure 1 Great Divide SAGD Expansion Project location.

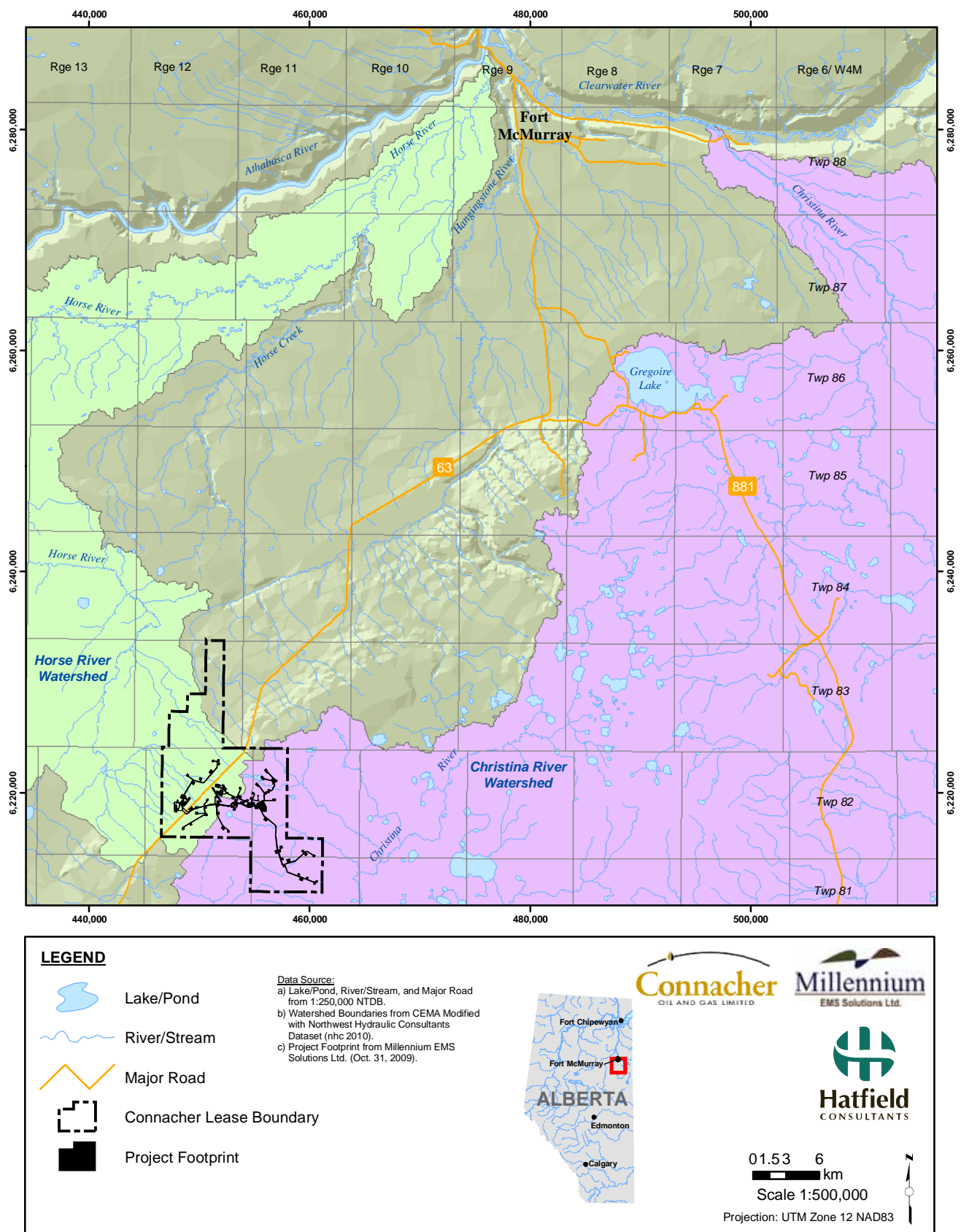
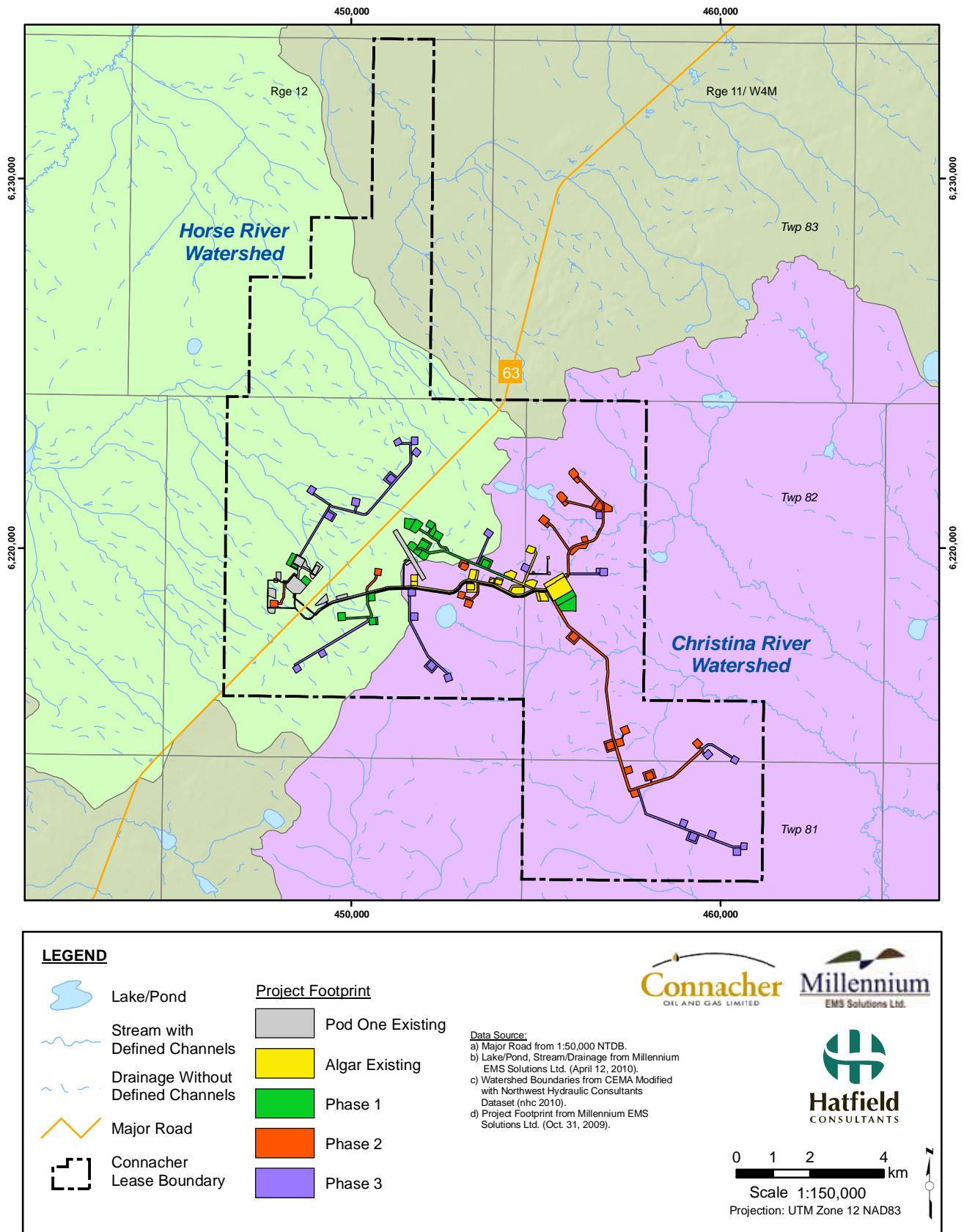


Figure 2 Great Divide SAGD Expansion Project footprint and development phases.



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 (USEPA 1999), Canada Health and the British Columbia Ministry of Environment (BCMOE 2003, 2006).

1.6 DATA SOURCES

Data sources used in the preparation of this report include:

- Previous EA reports completed for the Great Divide SAGD (Pod One) Project (Connacher 2005) and the Great Divide Algar SAGD project (Connacher 2007);
- Aquatic environment assessment reports prepared for four proposed stream crossings in the Pod One and Algar Project areas (Hatfield 2008a, 2008b, 2008c and 2009);
- 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, and 2009) and various working groups of the Cumulative Environmental Management Association (CEMA);
- Other existing literature sources related to surface water quality, fish and fish habitat in the Christina and Horse River watersheds, including, where available, EIA reports for existing oil sands operators in these watersheds;
- Baseline surface water hydrology conditions and impact assessments as described in the *Surface Water Hydrology Report* of this Application Northwest Hydraulic Consultants (nhc 2010);
- Baseline groundwater conditions and impact assessments as described in the *Hydrogeology Report* of this Application Millennium EMS Solutions Ltd. (MEMS 2010a);
- Baseline air quality conditions and impact assessments as described in the *Air Quality Report* of this Application (MEMS 2010b); and
- Information obtained from stakeholder consultations, described in Connacher (2010), [Section F](#).

2.0 SCOPE OF ENVIRONMENTAL ASSESSMENT

2.1 STUDY AREAS

2.1.1 Local Study Area

The Local Study Area (LSA) for the Project was selected based on the Project footprint and the local drainage patterns of lakes, rivers, ephemeral and other waterbodies within the spatial extent of potential direct or indirect Project effects (Figure 3). The LSA encompasses portions of the Horse River watershed and the Christina River watershed within approximately 1 km of the RDA and the downstream portion of the watercourses, within approximately 4 km to the nearest confluence with a larger watercourse. The Christina River watershed within the LSA contains five fish-bearing lakes and a series of third- and lower-order streams, while the Horse River watershed within the LSA contains first- and second-order streams.

2.1.2 Regional Study Area

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

- drainage patterns in the Christina and Horse River watersheds;
- spatial extent of potential impacts from the Project and all other development projects in the Athabasca oil sands region south of Fort McMurray; and
- 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 and the main stem of the Christina and Horse rivers downstream to their confluence to a major watercourse. For the Christina River this is the Clearwater River and for the Horse River this is the Athabasca River. Within the RSA, the Christina River is a fourth- to sixth-order watercourse, while the Horse River is a third- to fifth-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 Project description (Connacher 2010, [Section B](#));
- results and information obtained from stakeholder consultations conducted as part of this Application (Connacher 2010, [Section F](#)), including Traditional Environmental Knowledge (TEK) and Traditional Land Use (TLU);
- the scope and findings of environmental assessments and studies conducted for the Great Divide SAGD (Pod One) Project (Connacher 2005), the Algar SAGD project (Connacher 2007) and elsewhere in the region; 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 Project are considered, as well as all possible indirect effects.

Table 2 Aquatic resource issues considered in this report.

Issue/Description of Potential Effect	Project Activities
Changes in surface water quality	Construction, operation, reclamation and decommissioning Project activities giving rise to:
Changes in fish health and fish tissue, including fish tainting	<ul style="list-style-type: none">▪ 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/loss of fish resources and aquatic habitat	Construction, operation, reclamation and decommissioning Project activities giving rise to: <ul style="list-style-type: none">▪ changes in surface water quality;▪ physical changes in stream channel morphology;▪ changes in surface water flow rates; and▪ modified access to and increased recreational angling in fish-bearing watercourses and waterbodies.

Figure 3 Local and regional study area boundaries.

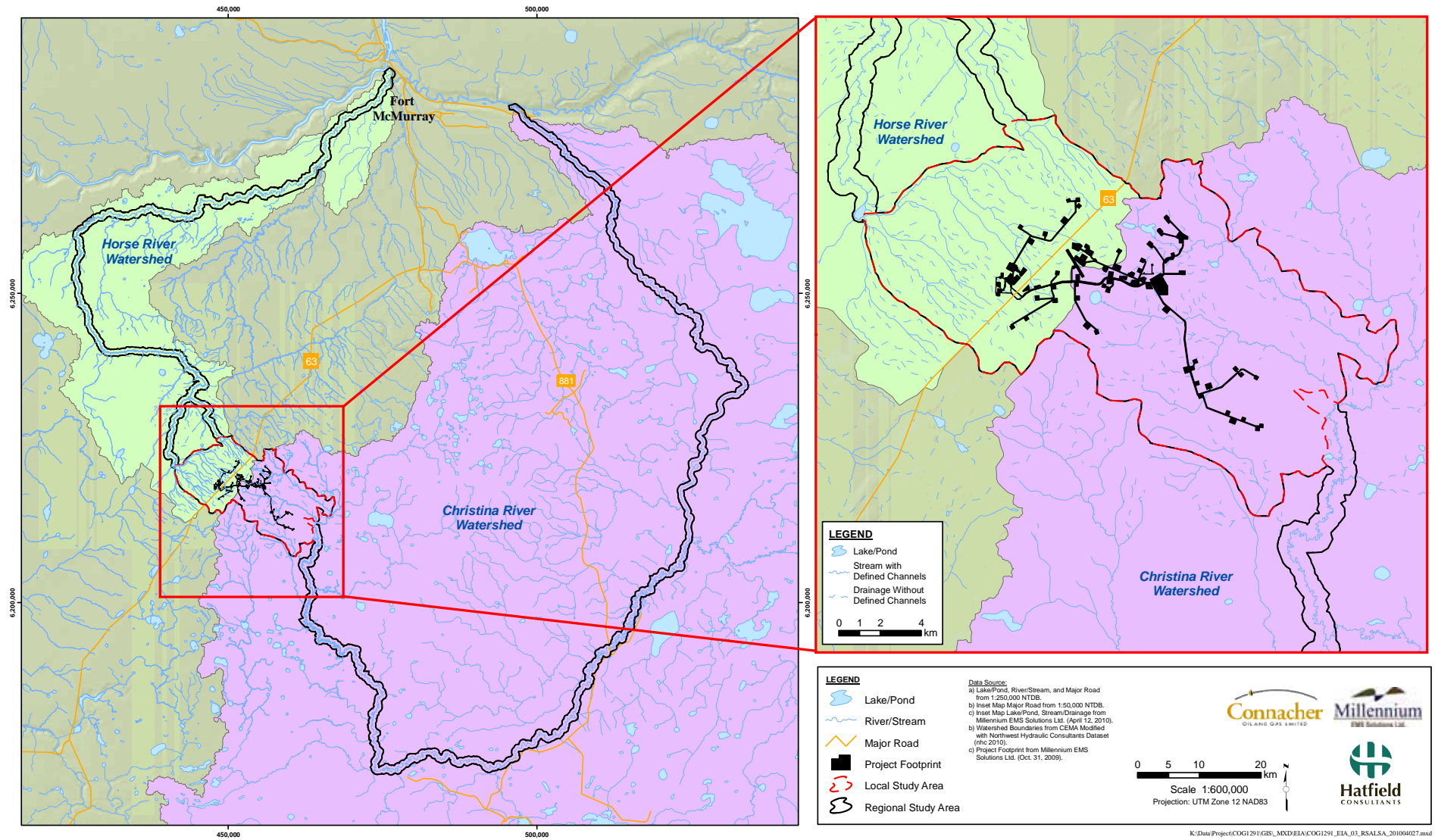
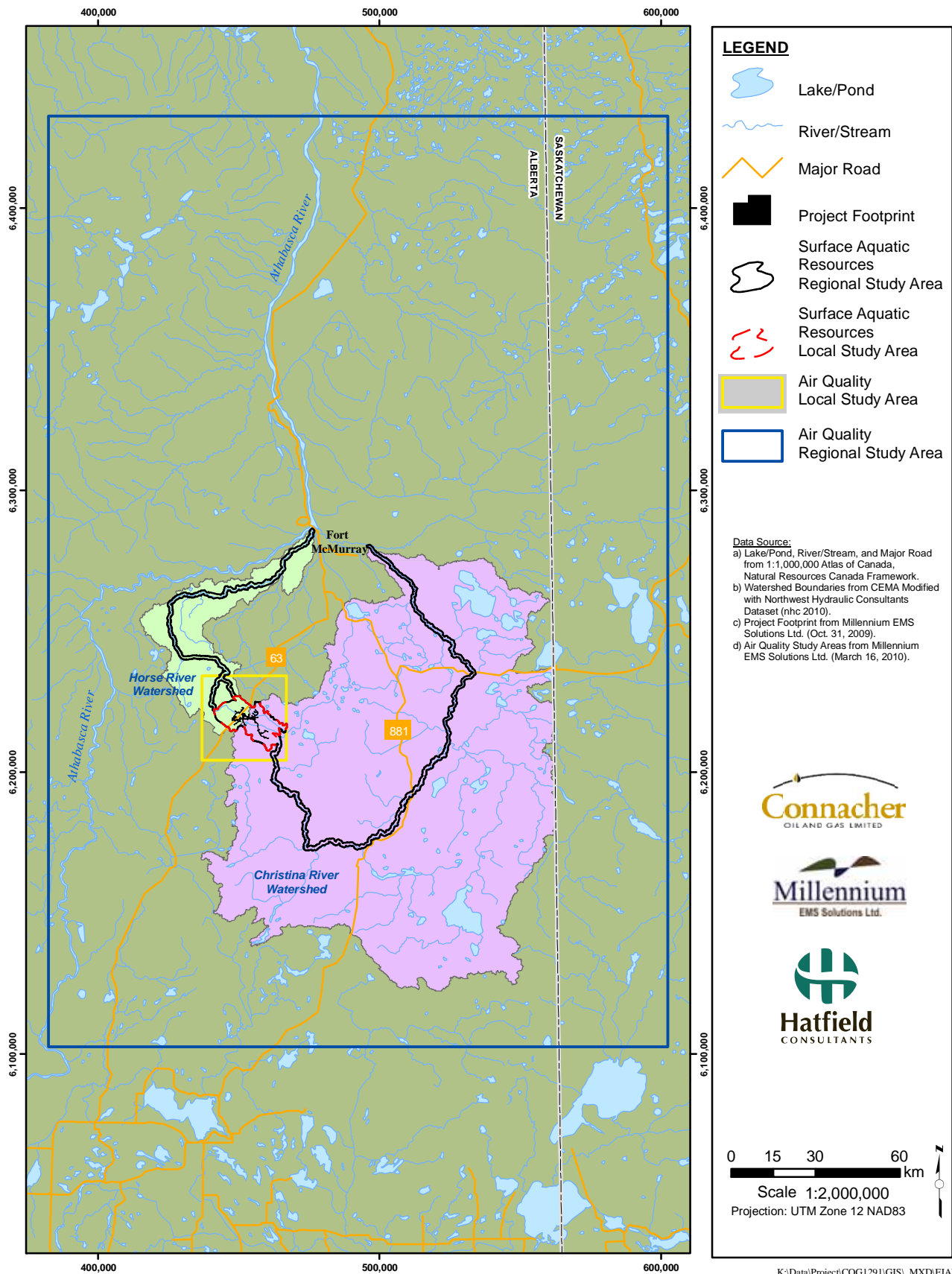


Figure 4 Local and regional study area for the effects of acidifying emissions.



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 this Project (Table 3) was guided by a review of:

- requirements of the ToR for this EIA;
- 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);
- water quality concerns and issues raised during the public consultation conducted during the preparation of this EIA; and
- various water quality variables required for interpretation of effects on other aquatic components, particularly fish populations and human health.

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 2006 to 2008 field programs for the baseline studies;
- 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 2008);
- key indicator species or guild status as defined by other approved oil sands projects, research studies and monitoring programs in the region such as Golder (2004) and RAMP (2005);
- 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 3 Variables used to characterize surface water quality.

Group	Water Quality Variables	Rationale
Conventional variables	Colour; Total Organic Carbon; Dissolved Organic Carbon; Total Dissolved Solids; Total Suspended Solids; pH; conductivity; total alkalinity; total hardness; dissolved oxygen; turbidity.	<p>pH - an indicator of acidity.</p> <p>TSS - a variable strongly associated with several other water quality variables, including total phosphorus, total aluminum and numerous other metals.</p> <p>TDS and DOC - indicators of total ion concentrations and dissolved organic matter (particularly humic acids), respectively.</p> <p>Total alkalinity - an indicator of the buffering capacity and acid sensitivity of waters.</p>
Major ions	Bicarbonate; calcium; chloride; magnesium; potassium; sodium; sulphate; sulphide.	Indicators of ion balance, which could be affected by discharges or seepages from project activities or by changes in the water table and changes in the relative influence of groundwater.
Nutrients	Ammonia nitrogen; Nitrate+Nitrite; Total Kjeldahl Nitrogen; Total Phosphorus; Chlorophyll a.	Indicators of nutrient status.
Organics and Hydrocarbons	Phenols; Hydrocarbons (recoverable); Naphthenic Acids.	Naphthenic acids - relatively-labile hydrocarbons associated with oil sands deposits and processing that have been identified as a potential toxicity concern.
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.	<p>Total and dissolved aluminum - is mentioned as a variable of interest in previous oil sands EIAs, by CEMA, and in RAMP (2004). Total aluminum, for which water quality guidelines exist, has been demonstrated to be strongly associated with TSS (Golder 2003). Dissolved aluminum more accurately represents biologically available forms of aluminum that may be toxic to aquatic organisms (Butcher 2001).</p> <p>Total boron, total molybdenum, total strontium - three metals found in predominantly-dissolved form in waters of the Athabasca oil sands region and which may be indicators of groundwater influence in surface waters (RAMP 2004).</p> <p>Total arsenic and total mercury - metals of potential importance to the health of aquatic life and human health.</p>

Table 4 Summary of fish key indicator species.

Key Indicator Species	CEMA ¹	RAMP ²	Recovered in FWMIS Database		Captured in Baseline Field Studies		Traditional Ecological Knowledge ³	Status of Special Concern ⁴
			Christina	Horse	Christina	Horse		
Northern pike	√	√	√	√	√		√	
Arctic grayling	√		√	√	√			√
Burbot	√		√					
Walleye	√	√	√	√			√	
Yellow perch			√					
Goldeye	√	√	√	√				
Lake whitefish	√	√	√				√	
Mountain whitefish			√	√				
Longnose sucker		√	√	√				
White sucker		√	√	√	√			
Forage fish guild	√		√	√	√	√		

¹ from CEMA (2004).

² from RAMP (2003).

³ from [Connacher Oil and Gas Ltd. \(2010\), Appendix 7.](#)

⁴ from http://www.cosewic.gc.ca/eng/sct3/index_e.cfm.

2.4 ASSESSMENT CASES

2.4.1 Baseline Case

The Baseline Case consists of the existing and approved developments described in Connacher 2010, [Section B](#), which may be influencing aquatic resources in the vicinity of the project. The Baseline Case, described in [Section 3.0](#) of this report, assumes that: (i) any effects of the existing projects on aquatic resources are already reflected in the data gathered to establish the baseline conditions; (ii) these existing projects will not cause any different effects on aquatic resources in the future; and (iii) the Baseline Case defined in [Section 3.0](#) therefore includes the influences of all existing projects.

2.4.2 Application Case

The Application Case is an assessment of the incremental environmental effects of the 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 Project are added to existing environmental conditions.

2.4.3 Planned Development Case

The Planned Development Case is an assessment of the incremental environmental effects of the 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. A list of these projects is provided in Connacher 2010, [Section C](#).

3.0 AQUATIC RESOURCES BASELINE CASE

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

3.1 EXISTING AQUATIC RESOURCES INFORMATION

3.1.1 Surface Water Quality

Existing water quality information consists of *in situ* water quality measurements of headwater streams in the Horse River drainage collected in support of the Great Divide SAGD (Pod One) Project (Connacher 2005), water quality data for lakes and streams in both the Christina and Horse watersheds collected in support of the Algar SAGD project (Hatfield 2007), and a review of water quality results gathered for the Christina River watershed as part of RAMP (RAMP 2010)¹.

3.1.2 Fish Resources

Existing fisheries resources information includes fish inventories and fish habitat assessments conducted in:

- the upper drainage of the Horse River watershed collected in support of the Great Divide SAGD Project (Connacher 2005). No fish were recovered in this study;
- lakes and streams in the Christina River watershed in support of the Algar SAGD Project (Connacher 2007); and
- the Horse and Christina River watersheds at a number of stream crossing locations (Hatfield 2008a, 2008b and 2008c).

In addition, the Fisheries and Wildlife Management Information System (FWMIS) database (ASRD 2008) was reviewed and analyzed for both the Christina and Horse River watersheds within the LSA and RSA to determine fish presence, distribution and probability of occurrence within the aquatic resources study areas.

3.2 DESCRIPTION OF BASELINE AQUATIC RESOURCES FIELD PROGRAM

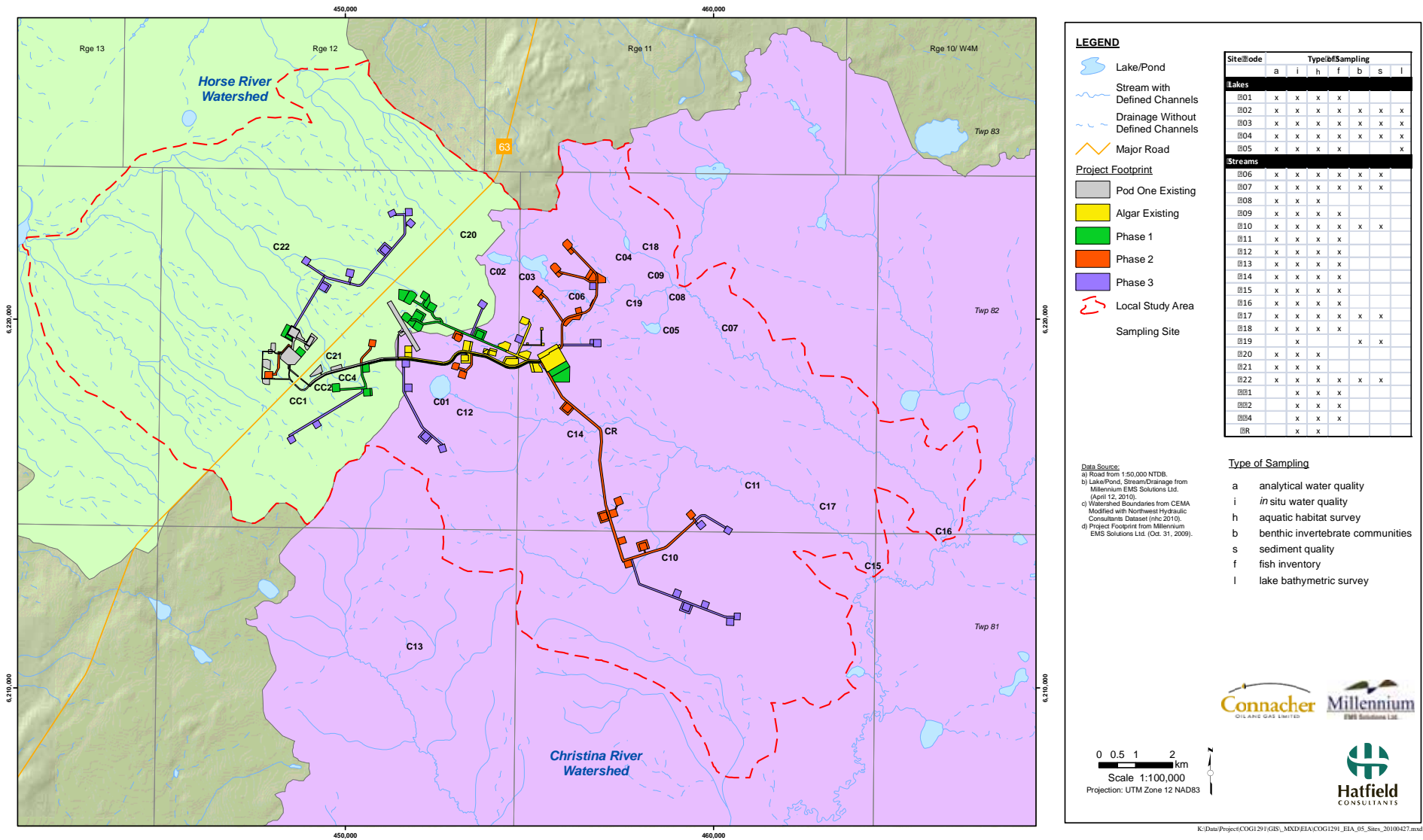
Table 5 and Figure 5 contain a summary of the baseline aquatic resources field program conducted in support of this EIA.

¹ Two Christina River water quality monitoring stations are maintained by RAMP within the RSA boundary. They are located approximately 120 and 280 km downstream of the LSA boundary. Sampling has been conducted at these locations since fall 2006. located approximately 120 and 280 km downstream of the LSA boundary. Sampling has been conducted at these locations since fall 2006.

Table 5 Summary of sampling conducted for the baseline aquatic resources field program.

Site Code	Location	Study Area	Drainage	UTM (Zone 12 NAD 83)		Season						
				E	N	Fall 2006	Winter 2007	Spring 2007	Summer 2007	Fall 2007	Spring 2008	Fall 2009
Lakes												
C01	Unnamed Lake (UL-1)	LSA	Christina	452637	6218116	ahi		afhi	ah^i	afhi		
C02	Unnamed Lake (UL-2)	LSA	Christina	454144	6221610	afhi	ai	afhi	ah^i	sbi		
C03	Unnamed Lake (UL-3)	LSA	Christina	455179	6221480	afhi	ai	afhi	ah^i	sbi		
C04	Unnamed Lake (UL-4)	LSA	Christina	457634	6221997	fl	ai	afhi	ah^i	sbi		
C05	Unnamed Lake (UL-5)	LSA	Christina	458403	6219733	afhi	ai	afhi	ah^i			
Streams												
C06	Watercourse draining UL-3	LSA	Christina	456548	6220526	afhi		afhi	ah^i	sbi		
C07	Christina River tributary	LSA	Christina	460122	6219754	ahi	ai	afhi	ah^i	sbhi		
C08	Watercourse draining UL2 and UL-3	LSA	Christina	458840	6220865	ah^i	ai					
C09	Watercourse draining UL-4	LSA	Christina	458809	6221234	ahi		afhi	ah^i			
C10	East flowing watercourse to Christina River tributary	LSA	Christina	458413	6213744	i		afhi	ah^i	asbi		
C11	Christina River tributary	LSA	Christina	460868	6215796		ai			afh		
C12	Main watercourse draining UL-1 to east	LSA	Christina	453248	6217794			afhi	ah^i	ai		
C13	Christina River tributary within RSA	RSA	Christina	451704	6211504			afhi	ah^i			
C14	Christina River tributary	LSA	Christina	456364	6217213					afhi		
C15	Confluence of tributary with Christina River	LSA	Christina	464395	6212973			afhi	ah^i	ai		
C16	Confluence of tributary with Christina River	LSA	Christina	466237	6213828			afhi	ah^i	ai		
C17	Christina River tributary	LSA	Christina	462694	6214992			afhi	ah^i	asbi		
C18	Christina River tributary	LSA	Christina	458309	6221658	fhi		afhi	ah^i			
C19	Christina River tributary	LSA	Christina	457852	6220703					sbi		
C20	Tributary to Horse Creek	LSA	Horse	452934	6222307	hi		ah	ah^i	ai		
C21	Tributary to Horse River	LSA	Horse	449361	6218814			ah	ah^i	ai		
C22	Tributary to Horse River	LSA	Horse	447899	6221877			afhi	ah^i	asbi		
CC1-100U	100m upstream of CC1	LSA	Horse	448973	6218023						fhi	
CC1-50U	50m upstream of CC1	LSA	Horse	448945	6218066						fhi	
CC1	Possible Horse River stream crossing	LSA	Horse	448913	6218102						fhi	
CC1-100D	100m downstream of CC1	LSA	Horse	448897	6218191						fhi	
CC1-200D	200m downstream of CC1	LSA	Horse	448982	6218248						fhi	
CC1-300D	300m downstream of CC1	LSA	Horse	449016	6218341						fhi	
CC2-100U	100m upstream of CC2	LSA	Horse	449250	6218480						fhi	
CC2-50U	50m upstream of CC2	LSA	Horse	449299	6218498						fhi	
CC2	Possible Horse River stream crossing	LSA	Horse	449350	6218505						fhi	
CC2-100D	100m downstream of CC2	LSA	Horse	449419	6218575						fhi	
CC2-200D	200m downstream of CC2	LSA	Horse	449417	6218673						fhi	
CC4-100U	100m upstream of CC4	LSA	Horse	449620	6218465						hi	
CC4-50U	50m upstream of CC4	LSA	Horse	449603	6218514						fhi	
CC4	Possible Horse River stream crossing	LSA	Horse	449577	6218575						fhi	
CC4-100D	100m downstream of CC4	LSA	Horse	449444	6218699						fhi	
CR-100U	100m upstream of CR	LSA	Christina	456838	6216985							hi
CR	Possible Christina River stream crossing	LSA	Christina	456884	6217055							hi
CR-100D	100m downstream of CR	LSA	Christina	456953	6217138							hi
CR-200D	200m downstream of CR	LSA	Christina	456994	6217075							hi
CR-300D	300m downstream of CR	LSA	Christina	457053	6217153							hi
a analytical water quality i in situ water quality												
b benthic invertebrate communities l lake bathymetric survey												
f fish inventory s sediment quality												
h aquatic habitat survey ^ only simple habitat survey conducted												

Figure 5 Surface Aquatic Resource sampling locations.



3.3 BASELINE CASE FOR LOCAL STUDY AREA

3.3.1 Water Quality

Water quality sampling was undertaken:

- at 15 watercourses (sites C06 to C22 on [Figure 5](#)) over five seasons between fall 2006 and fall 2007;
- in spring 2008 and summer 2007 at an additional 20 locations on three watercourses as part of stream crossing assessments (in situ water quality measurement only at sites CC1, CC2, CC3 and CR on [Figure 5](#)); and
- at four lakes in fall 2006 and winter 2007, at five lakes in spring and summer 2007 and one lake in the fall 2007 (sites C01 to C05 on [Figure 5](#)).

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

Detailed water quality information for watercourses is provided in [Appendix A2](#). Table 6 provides the sources of the water quality guidelines used all surface water quality tables throughout this report. [Table 7](#) and [Table 8](#) provide a summary of seasonal and total median, minimum and maximum concentrations for surface water quality variables measured in watercourses and lakes, respectively, within the LSA.

The water quality of watercourses and lakes in the LSA is generally characteristic of highly-coloured brown-water systems with a median true color level of 330 TCU and DOC concentration of 46 mg/L for watercourses and 150 TCU and a DOC concentration of 22 mg/L for lakes. Surface water in the LSA is slightly hard, with median hardness of 35 mg/L and 20 mg/l in watercourses and lakes, respectively. Water in watercourses and lakes of the LSA generally have circumneutral pH, with a higher range of pH in spring than in other seasons.

Surface water in the LSA has low concentrations of TDS (median value of 90 mg/L and 60 mg/L for watercourses and lakes, respectively) and conductivity (median value of 55 µS/cm and 33 µS/cm for watercourses and lakes, respectively) compared with TDS and conductivity in watercourses in the Athabasca oil sands region (RAMP 2010).

Median concentrations of TSS are 7.5 mg/L and range from below detection limits to 51 mg/L in LSA watercourses; the median TSS concentration in lakes is below detection limits, with maximum-measured concentrations of 9mg/L.

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

Notation in Water Quality Tables	Description/Explanation
1	Alberta Environment Guidelines for the Protection of Freshwater Aquatic Life (1999), unless otherwise specified.
a	at pH ≥ 6.5 ; Hardness $\geq 4\text{mg/L}$; DOC $\geq 2\text{mg/L}$ (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 $10(0.86 \cdot \text{LOG}(\text{Hardness}) - 3.2)$ (CCME 2007).
f	Set to US Environmental Protection Agency continuous 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). Most stringent guideline (0.001 mg/L) is used.
h	BC working water quality guidelines (BC MOE 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 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 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.
o	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."
p	BC approved water quality guideline (BC MOE 2006).
q	BC Acute guideline is hardness-dependent: 0.8mg/L at hardness= 0 to 25mg/L; 1.1mg/L at hardness= 25 to 50mg/L;1.6mg/L at hardness= 50 to 100mg/L; 2.2mg/L at hardness= 100 to 150mg/L;3.8mg/L at hardness= 150 to 300mg/L (BC MOE 2006).
r	Guideline is for chronic total (organic and inorganic) phosphorus (AENV 1999).
s	US Environmental Protection Agency continuous concentration guideline (as H ₂ S). (USEPA 1999).
t	AENV (1999) acute and chronic guideline for suspended solids states: "Not to be increased by more than 10 mg/L over background value."
u	US Environmental Protection Agency continuous concentration guideline. (USEPA 1999).

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

Water Quality Variable	Units	Guideline ¹	Detection Limit	All Seasons			Fall			Winter			Spring			Summer							
				Number of Samples	Minimum	Median	Maximum	Number of Samples	Minimum	Median	Maximum	Number of Samples	Minimum	Median	Maximum	Number of Samples	Minimum	Median	Maximum	Number of Samples	Minimum	Median	Maximum
Alkalinity, Total (as CaCO ₃)	mg/L	20 ^a	5	43	<5	25	169	14	5	25.5	87	3	22	29	83	13	6	22	103	13	11	38	169
Ammonia-N	mg/L	1.37 ^b	0.05	43	<0.05	<0.05	0.26	14	<0.05	<0.05	0.17	3	0.2	0.25	0.26	13	<0.05	<0.05	0.08	13	<0.05	<0.05	0.14
Bicarbonate (HCO ₃)	mg/L	-	5	43	<5	31	206	14	<5	31.5	107	3	27	35	101	13	7	26	125	13	14	46	206
Biochemical Oxygen Demand	mg/L	-	2	43	<2	<2	17	14	<2	<2	3	3	<2	<2	<2	13	<2	<2	4	13	<2	<2	17
Calcium (Ca)	mg/L	-	0.5	43	3.3	9	46.4	14	3.3	10.05	26.9	3	7.5	9	23.6	13	3.9	7.7	28.8	13	5.4	11.7	46.4
Carbonate (CO ₃)	mg/L	-	5	43	<5	<5	<5	14	<5	<5	<5	3	<5	<5	<5	13	<5	<5	<5	13	<5	<5	<5
Chloride (Cl)	mg/L	230 ^d	1	43	<1	2	6	14	<1	2	6	3	1	2	2	13	<1	2	5	13	1	2	4
Chlorophyll a	µg/L	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Color, True	T.C.U.	-	2.5	43	61	200	330	14	120	177.5	300	3	170	280	290	13	88	170	230	13	61	250	330
Conductivity (EC)	µS/cm	-	0.2	63	11.5	48.5	313	14	23.5	58.25	193	3	53.7	63.9	163	28	11.5	30.35	209	18	35.5	55	313
Dissolved Organic Carbon	mg/L	-	1	43	17	29	46	14	23	28.5	46	3	23	31	33	13	17	24	31	13	19	32	45
Dissolved oxygen (acute)	mg/L	5 ^f	-	63	0.7	6.17	9.02	16	3	6.5	8.6	4	0.7	2.95	6.17	26	4.5	6.65	9	17	0.8	5.09	9.02
Dissolved oxygen (chronic)	mg/L	9 ^f	-	63	0.7	6.17	9.02	16	3	6.5	8.6	4	0.7	2.95	6.17	26	4.5	6.65	9	17	0.8	5.09	9.02
Hardness (as CaCO ₃)	mg/L	-	-	43	12	35	165	14	12	37.5	96	3	28	35	87	13	14	29	104	13	17	40	165
Hydrocarbons, Recoverable (I.R.)	mg/L	-	1	42	<0.5	<1	<1	13	<1	<1	<1	3	<1	<1	<1	13	<1	<1	<1	13	<0.5	<1	<1
Hydroxide (OH)	mg/L	-	5	43	<5	<5	<5	14	<5	<5	<5	3	<5	<5	<5	13	<5	<5	<5	13	<5	<5	<5
Magnesium (Mg)	mg/L	-	0.1	43	0.6	2.5	12	14	0.9	2.95	7.1	3	2.3	3	6.8	13	0.6	2.4	7.8	13	0.8	2.6	12
Naphthenic Acids	mg/L	-	1	43	<1	<1	<1	14	<1	<1	<1	3	<1	<1	<1	13	<1	<1	<1	13	<1	<1	<1
Nitrate+Nitrite-N	mg/L	ⁿ	0.1	43	<0.1	<0.1	0.8	14	<0.1	<0.1	<0.1	3	<0.1	0.7	0.8	13	<0.1	<0.1	<0.1	13	<0.1	<0.1	0.2
pH	pH	6.5-9.0 ^d	0.1	63	4.83	7.02	8.1	14	6.2	7.25	8	3	6.4	6.5	7.4	28	4.83	6.55	8.1	18	6.4	7.195	8.1
Phenols (4AAP)	mg/L	0.001 ^c	0.001	43	<0.001	0.013	0.03	14	<0.001	0.0135	0.022	3	0.019	0.029	0.03	13	<0.001	<0.001	0.013	13	0.006	0.013	0.029
Phosphorus, Total	mg/L	0.05 ^e	0.001	43	0.012	0.063	0.5	14	0.015	0.085	0.286	3	0.077	0.087	0.092	13	0.012	0.033	0.5	13	0.018	0.063	0.422
Potassium (K)	mg/L	-	-	43	0.5	0.6	2	14	<0.5	0.65	1	3	<0.5	0.6	0.7	13	<0.5	0.6	1.6	13	0.5	0.5	2
Sodium (Na)	mg/L	-	1	43	<1	<1	10	14	<1	1	6	3	1	1	6	13	<1	1	7	13	<1	1	10
Sulfate (SO ₄)	mg/L	100 ^g	0.5	43	<0.5	1.4	4.5	14	0.6	1.25	3	3	0.9	1	1.1	13	<0.5	1.4	4.1	13	1.1	2.3	4.5
Sulphide	mg/L	0.014 ^h	0.003	43	<0.003	0.011	0.029	14	0.003	0.0115	0.017	3	0.014	0.016	0.017	13	<0.003	0.005	0.012	13	<0.003	0.017	0.029
Temperature (in situ)	°C	-	63	0.28	10.28	23	16	5.8	9.81	13.9	4	0.28	5.45	1.7	26	2.6	7.835	16.72	17	7.23	16.62	23	23
Total Dissolved Solids	mg/L	-	10	43	42	91	182	14	60	95.5	148	3	90	90	120	13	42	82	150	13	60	91	182
Total Kjeldahl Nitrogen	mg/L	1	0.2	43	0.4	0.7	3.4	14	0.5	0.7	1.4	3	0.8	1.1	1.3	13	0.4	0.5	1.7	13	0.7	0.9	3.4
Total Organic Carbon	mg/L	-	1	43	17	29	46	14	23	30.5	46	3	24	32	35	13	17	25	35	13	18	32	42
Total Suspended Solids	mg/L	+10 mg/L ⁱ	3	43	<3	<3	51	14	<3	<3	18	3	<3	<3	<3	13	<3	<3	44	13	<3	6	51
Turbidity (in situ)	NTU	-	54	0.23	1.92	137	10	0.5	3.215	137	10	-	-	-	-	26	0.23	0.98	6.17	18	1.04	3.115	14
Total Metals																							
Aluminum	mg/L	0.1 ^a	0.002	42	0.0449	0.155	0.51	14	0.0449	0.1535	0.396	3	0.0725	0.167	0.394	13	0.0669	0.152	0.51	12	0.0626	0.149	0.306
Antimony	mg/L	0.02 ^b	0.00001	42	0.0000104	0.00002065	0.0000213	14	0.0000104	0.0000207	0.0000362	3	0.0000194	0.0000204	0.0000213	13	0.0000105	0.0000189	0.0000336	12	0.0000155	0.00002535	0.0000649
Arsenic	mg/L	0.005 ^c	0.00004	42	0.000358	0.0007755	0.0162	14	0.000361	0.000712	0.00366	3	0.000769	0.00101	0.00106	13	0.000358	0.000561	0.00469	12	0.000738	0.001505	0.0162
Barium	mg/L	5 ^b	0.001	42	0.00732	0.0173	0.0807	14	0.00762	0.0158	0.0373	3	0.0181	0.0187	0.0285	13	0.00732	0.0151	0.04	12	0.0146	0.0237	0.0807
Beryllium	mg/L	0.0053 ^b	0.00001	42	<0.00001	0.0000118	0.0000423	14	<0.00001	0.0000123	0.0000289	3	0.00001	0.000012	0.0000262	13	0.00001	0.0000116	0.0000423	12	0.00001	0.00001305	0.0000253
Bismuth	mg/L	-	0.00001	42	<0.00001	<0.00001	0.0000204	14	<0.00001	<0.00001	0.0000105	3	0.00001	0.00001	0.0000107	13	0.00001	0.00001	0.0000204	12	0.00001	0.00001	0.0000147
Boron	mg/L	1.2 ^d	0.0008	42	0.00179	0.007525	0.0484	14	0.00179	0.00511	0.021	3	0.00515	0.0069	0.0145	13	0.00523	0.0098	0.0376	12	0.00497	0.00756	0.0484
Cadmium	mg/L	0.000006	0.000006	42	<0.000006	0.00001105	0.0000654	14	<0.000006	0.00001015	0.0000377	3	0.0000111	0.0000136	0.0000531	13	<0.000006	<0.000006	0.0000436	12	0.0000103	0.00002035	0.0000654
Calcium	mg/L	-	0.1	42	3.28	8.54	41.5	14	3.28	8.4	23.3	3	8.25	9.51	23.9	13	3.52	7.52	28.1	12	5.59	11.2	41.5
Chlorine	mg/L	-	0.3	42	<0.3	0.3	5.98	14	<0.3	<0.3	3.89	3	<0.3	<0.3	<0.3	13	<0.3	<0.3	5.98	12	<0.3	<0.3	3.64
Chromium	mg/L	0.001 ^a	0.0003	42	<0.0003	0.000338	0.000833	14	0.0003	0.0003315	0.000749	3	0.0003	0.000346	0.000764	13	0.0003	0.000314	0.000833	12	0.0003	0.000385	0.000643
Cobalt	mg/L	0.0009 ^d	0.00001	42	0.000119	0.000384	0.00497	14	0.000119	0.0003455	0.0113	3	0.0019	0.00211	0.00333	13	0.000135	0.000185	0.00221	12	0.000317	0.0006655	0.00497
Copper	mg/L	0.0001 ⁱ	0.0001	42	<0.0001	0.000258	0.00201	14	<0.0001	0.0001875	0.000692	3	0.00019	0.000276	0.00174	13	0.0001	0.000261	0.00108	12	0.000131	0.0003165	0.00201
Iron	mg/L	0.3	0.004	42	0.342	1.335	20	14	0.432	1.335	2.51	3	2.29	3.43	4.41	13	0.342	0.606	5.08	12	0.83	1.79	20
Lead	mg/L	0.00006	0.00006	42	0.0000066	0.00009275	0.000877	14	0.0000066	0.00007925	0.000584	3	0.0000824	0.000398	0.000877	13	0.0000265	0.0000682	0.00041	12	0.0000345	0.000146	0.00461
Lithium	mg/L	0.87 ^c	0.0002	42	<0.0002	0.0014	0.0137	14	0.0002	0.00136	0.00531	3	0.00138	0.00199	0.00594	13	0.00043	0.00142	0.00808	12	0.000251	0.00125	0.0137
Manganese	mg/L	0.00003	0.00003	42	0.0137	0.0693	1.31	14	0.0137	0.0634	0.11	3	0.397	0.737	1.31	13	0.0143	0.0517	0.491	12	0.031	0.149	1.16

Table 8 Surface water quality by season for lakes in the LSA.

Water Quality Variable	Units	Guideline ¹	Detection Limit	All Seasons			Fall			Winter			Spring			Summer							
				Number of Samples	Minimum	Median	Maximum	Number of Samples	Minimum	Median	Maximum	Number of Samples	Minimum	Median	Maximum	Number of Samples	Minimum	Median	Maximum				
Alkalinity, Total (as CaCO ₃)	mg/L	20 ^a	5	19	<5	11	35	5	<5	10	24	4	16	21.5	35	5	<5	8	16	5	<5	12	22
Ammonia-N	mg/L	1.37 ^b	0.05	19	<0.05	<0.05	0.4	5	<0.05	<0.05	<0.05	4	0.12	0.325	0.4	5	<0.05	<0.05	0.06	5	<0.05	<0.05	<0.05
Bicarbonate (HCO ₃)	mg/L	-	5	19	<5	14	43	5	<5	13	30	4	19	26	43	5	<5	10	20	5	<5	15	27
Biochemical Oxygen Demand	mg/L	-	2	19	<2	<2	4	5	<2	<2	2	4	<2	<2	<2	5	<2	<2	3	5	<2	<2	4
Calcium (Ca)	mg/L	-	0.5	19	1.8	5	11.2	5	3.1	5.2	7.1	4	7.4	7.65	11.2	5	2.5	3.6	5.1	5	1.8	3.8	5.5
Carbonate (CO ₃)	mg/L	-	5	19	<5	<5	<5	5	<5	<5	<5	4	<5	<5	<5	5	<5	<5	<5	5	<5	<5	<5
Chloride (Cl)	mg/L	230 ^d	1	19	<1	2	2	5	1	2	2	4	1	2	2	5	1	2	2	5	<1	<1	2
Chlorophyll a	ug/L	-	1	9	2	5	29	4	5	6	11	-	-	-	-	-	-	-	-	5	2	3	29
Color, True	T.C.U.	-	2.5	19	50	150	310	5	50	125	250	4	130	220	310	5	87	150	200	5	70	150	220
Conductivity (EC)	µS/cm	-	0.2	19	17.9	33.3	78.6	5	20.8	35.2	51.5	4	52	56.9	78.6	5	17.9	24.5	38.5	5	22	28.3	45.1
Dissolved Organic Carbon	mg/L	-	1	19	16	22	39	5	16	19	32	4	27	30.5	39	5	16	20	24	5	17	18	24
Dissolved oxygen (acute)	mg/L	g ⁱ	22	0.69	7.95	11		8	6.8	8.4	11	4	0.69	6.225	6.59	5	8.4	9.11	9.8	5	6.2	7.01	7.2
Dissolved oxygen (chronic)	mg/L	g ⁱ	22	0.69	7.95	11		8	6.8	8.4	11	4	0.69	6.225	6.59	5	8.4	9.11	9.8	5	6.2	7.01	7.2
Hardness (as CaCO ₃)	mg/L	-	19	4	20	44	5	11	21	30	4	28	29	44	5	8	14	20	5	4	14	20	
Hydrocarbons, Recoverable (I.R.)	mg/L	-	1	19	<1	<1	<1	5	<1	<1	<1	4	<1	<1	<1	5	<1	<1	<1	5	<1	<1	<1
Hydroxide (OH)	mg/L	-	5	19	<5	<5	<5	5	<5	<5	<5	4	<5	<5	<5	5	<5	<5	<5	5	<5	<5	<5
Magnesium (Mg)	mg/L	-	0.1	19	<0.1	1.5	4	5	0.8	1.8	2.9	4	2.2	2.4	4	5	0.5	1.2	1.8	5	<0.1	0.9	1.5
Naphthenic Acids	mg/L	-	1	19	<1	<1	<1	5	<1	<1	<1	4	<1	<1	<1	5	<1	<1	<1	5	<1	<1	<1
Nitrate+Nitrite-N	mg/L	n	0.1	19	<0.1	<0.1	1	5	<0.1	<0.1	<0.1	4	<0.1	0.4	1	5	<0.1	<0.1	<0.1	5	<0.1	<0.1	0.3
pH	pH	6.5-9.0 ^e	0.1	19	5.9	6.9	7.7	5	5.9	7	7.7	4	6	6.9	7.1	5	5.9	6.9	7.2	5	6.4	6.9	7.5
Phenols (4AAP)	mg/L	0.05 ^c	0.001	19	<0.001	0.01	0.037	5	<0.001	<0.001	0.021	4	0.021	0.0235	0.037	5	<0.001	<0.001	0.012	5	0.01	0.01	0.018
Phosphorus, Total	mg/L	0.05 ^f	0.001	19	0.012	0.024	0.096	5	0.013	0.023	0.096	4	0.018	0.038	0.081	5	0.012	0.018	0.033	5	0.017	0.024	0.055
Potassium (K)	mg/L	-	19	<0.5	0.8	1.5	5	<0.5	0.9	1	5	4	<0.5	0.7	0.9	5	0.7	0.8	0.8	5	0.8	0.9	1.5
Sodium (Na)	mg/L	-	1	19	<1	<1	2	5	<1	1	1	4	1	1.5	2	5	<1	<1	<1	5	<1	<1	1
Sulfate (SO ₄)	mg/L	100 ^g	0.5	19	<0.5	1.5	5.7	5	1	1.5	2.1	4	1	1.6	1.9	5	<0.5	<0.5	1.2	5	1.3	2.4	5.7
Sulphide	mg/L	0.014 ^h	0.003	19	<0.003	0.005	0.023	5	0.003	0.004	0.01	4	0.007	0.0095	0.023	5	<0.003	<0.003	0.004	5	<0.003	0.009	0.01
Temperature (in situ)	°C	-	22	1.03	12.75	23.6	8	7.86	9.85	12.8	4	1.03	1.095	2.5	5	14.43	16.24	18.3	5	22.3	23.1	23.6	
Total Dissolved Solids	mg/L	-	10	19	23	60	90	5	40	60	70	4	70	80	90	5	45	57	65	5	23	28	62
Total Kjeldahl Nitrogen	mg/L	1	0.2	19	0.5	0.8	1.2	5	0.6	0.7	0.9	4	1	1.2	1.2	5	0.5	0.8	1.1	5	0.6	0.6	1.2
Total Organic Carbon	mg/L	-	1	19	17	23	40	5	17	21	33	4	28	30.5	40	5	18	20	26	5	17	19	25
Total Suspended Solids	mg/L	+10 mg/L ⁱ	3	19	<3	<3	9	5	<3	<3	4	4	<3	<3	<3	5	<3	3	9	5	<3	3	7
Turbidity (in situ)	NTU	-	10	0.65	1.215	3.56	3	0.65	1.11	2.83	-	-	-	-	-	5	1.05	1.32	3.56	2	1.06	1.23	1.4
Total Metals																							
Aluminum	mg/L	0.1 ^a	0.002	19	0.0311	0.0906	0.161	5	0.0344	0.0714	0.161	4	0.0725	0.10995	0.149	5	0.048	0.0906	0.16	5	0.0311	0.102	0.148
Antimony	mg/L	0.02 ^b	0.00001	19	0.0000108	0.0000155	0.0000983	5	0.000013	0.0000148	0.0000159	4	0.0000236	0.00003105	0.0000983	5	0.0000108	0.0000137	0.000017	5	0.0000139	0.000016	0.0000272
Arsenic	mg/L	0.005 ^c	0.00004	19	0.0000286	0.0000511	0.000101	5	0.0000357	0.0000535	0.000085	4	0.0000516	0.0000773	0.000101	5	0.0000286	0.0000338	0.0000541	5	0.0000359	0.0000464	0.0000581
Barium	mg/L	5 ^d	0.0001	19	0.00635	0.0117	0.0299	5	0.00902	0.0123	0.0156	4	0.0165	0.0211	0.0299	5	0.00635	0.00807	0.0122	5	0.0085	0.00927	0.0148
Beryllium	mg/L	0.0053 ^b	0.00001	19	<0.00001	0.00001	0.0000184	5	0.00001	0.00001	0.0000107	4	0.00001	0.00001285	0.0000176	5	0.00001	0.00001	0.0000184	5	<0.00001	0.00001	0.000011
Bismuth	mg/L	-	0.00001	19	<0.00001	0.00001	0.0000148	5	<0.00001	0.00001	0.00001	4	0.00001	0.00001	0.0000148	5	0.00001	0.00001	0.00001	5	0.00001	0.00001	0.00001
Boron	mg/L	1.2 ^d	0.0008	19	0.00371	0.00743	0.014	5	0.00394	0.00723	0.0101	4	0.00371	0.01155	0.014	5	0.00567	0.00677	0.00929	5	0.00492	0.00835	0.00888
Cadmium	mg/L	*	0.000006	19	<0.000006	0.000006	0.0000349	5	<0.000006	0.000006	0.0000202	4	0.000006	0.0000139	0.0000349	5	<0.000006	<0.000006	0.0000062	5	0.000006	0.0000095	0.0000233
Calcium	mg/L	-	0.1	19	2.29	4.37	12.2	5	2.86	4.49	8.08	4	8.18	8.69	12.2	5	2.33	3.61	5.27	5	2.29	3.82	5.35
Chlorine	mg/L	-	0.3	19	<0.3	0.3	0.94	5	<0.3	0.31	0.567	4	<0.3	<0.3	0.3	5	<0.3	<0.3	0.94	5	<0.3	0.303	0.692
Chromium	mg/L	0.001 ^a	0.0003	19	0.0003	0.0003	0.000374	5	0.0003	0.0003	0.000323	4	0.0003	0.000314	0.000374	5	0.0003	0.0003	0.000374	5	0.0003	0.0003	0.000304
Cobalt	mg/L	0.0009 ^b	0.00001	19	0.0000288	0.000178	0.00108	5	0.0000288	0.000206	0.000274	4	0.0000975	0.000683	0.00108	5	0.0000383	0.0000958	0.000178	5	0.0000414	0.000199	0.000235
Copper	mg/L	1	0.0001	19	0.0001	0.000184	0.000731	5	0.0001	0.00015	0.000228	4	0.000187	0.000454	0.000731	5	0.0001	0.000115	0.000185	5	0.000118	0.000194	0.000266
Iron	mg/L	0.3	0.004	19	0.107	0.424	2.32	5	0.107	0.498	0.683	4	0.603	1.2045	2.32	5	0.21	0.353	0.419	5	0.155	0.424	0.515
Lead	mg/L	^h	0.000006	19	0.0000235	0.0000879	0.000322	5	0.0000405	0.0000879	0.000612	4	0.000082	0.0003535	0.000322	5	0.0000364	0.0000779	0.000157	5	0.0000235	0.0000531	0.000123
Lithium	mg/L	0.87 ^h	0.0002	19	<0.0002	0.00122	0.00391	5	0.0002	0.00139	0.00229	4	0.00122	0.00228	0.00391	5	0.0000538	0.000781	0.00182	5	0.000293	0.000715	0.00128
Manganese	mg/L	^g	0.00003	19	0.00976	0.03	0.289	5	0.0109	0.0271	0.0332	4	0.0789	0.1365	0.289	5	0.00976	0.0119	0.0316	5	0.0166		

Watercourses in the LSA are classified as eutrophic based on summer total phosphorus concentrations (Dodds *et al.* 1998). Total phosphorus concentrations are indicative of mesotrophic to eutrophic conditions for lakes in the LSA².

The ionic composition of the watercourses and lakes in the LSA is dominated by calcium-magnesium and bicarbonate (Figure 6) and is similar to the ionic composition of shallow groundwater in the LSA which is characterized as a 'calcium-magnesium bicarbonate' type water in the Hydrogeology Assessment prepared for this Application (MEMS 2010a). Both surface water and shallow groundwater exhibit similar characteristics of a 'calcium-magnesium bicarbonate' type water, with a few number of shallow groundwater samples and lake samples showing predominantly 'sodium-potassium sulfate' ionic composition. In general, the similarities in chemical composition between surface water and shallow groundwater indicate that there are likely direct connections between surface water and the shallow groundwater system in the LSA.

Most of the cases in which concentrations of water quality variables exceed their guidelines in the watercourses and lakes of the LSA are attributable to total iron, total aluminum, total phosphorus, and dissolved oxygen (Table 9, Table 10). Concentrations of total iron, total aluminum and total phosphorus are generally above their water quality guidelines throughout the Athabasca oil sands region and are positively correlated with concentrations of TSS (Golder 2003, RAMP 2006). Concentrations of dissolved oxygen in watercourses and lakes in the LSA are often below the chronic guideline for the protection of aquatic life and in some watercourses and seasons (particularly winter for both watercourses and lakes as well as summer for watercourses) were below the acute guideline. The rest of the water quality guideline exceedances in the watercourses and lakes of the LSA were occasional exceedances of sulfide, pH, nitrate and nitrite, total Kjeldahl nitrogen and cobalt.

Concentrations of a number of water quality variables, including selenium, total mercury, and phenols, were never above their water quality guidelines in the watercourses and lakes of the LSA, while concentrations of total arsenic were below water quality guidelines in all but two cases in LSA watercourses. In addition, concentrations of naphthenic acids and total recoverable hydrocarbons were below detection limits across all seasons in both watercourses and lakes.

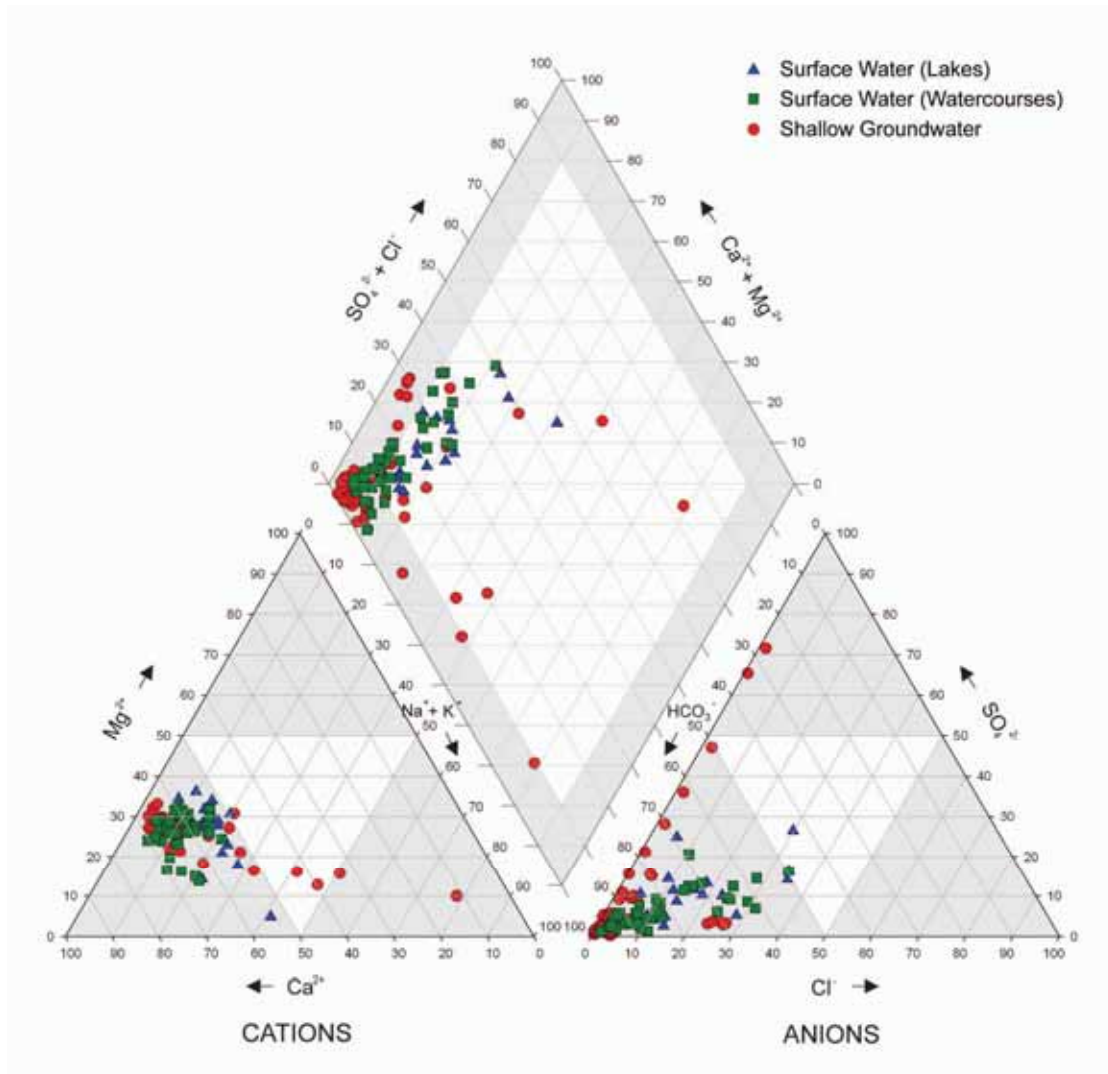
3.3.2 Fish Resources

3.3.2.1 Expected Fish Resources

Table 11 lists the fish species found in the FWMIS database within the lakes and watercourses, by stream order, in the Christina and Horse River watersheds, while Table 12 indicates the probability of capturing small-bodied, large-bodied, or sport fish species by stream order and watershed (a description of the methods by which data from the FWMIS database were analyzed is provided in Appendix A1).

² http://www3.gov.ab.ca/env/soe/water_indicators/images/LakeChlaTP1980to03.pdf

Figure 6 Comparison of ionic characteristics of surface water and shallow groundwater.



The watercourses in the LSA consist of first order to third order streams. The analysis of FWMIS dataset indicates a low probability of first order streams containing small-bodied fish in the LSA. In addition, there is a low probability of first order and second order streams in the LSA containing either large-bodied fish or sport fish species, and that if these fish groups are found in first order and second order streams, the fish species are likely to be white sucker, northern pike, and Arctic grayling. Third order streams in the LSA can be expected to have a much higher probability of all types of fish and much more diverse species assemblage than lower order streams.

Table 9 **Frequencies of guideline exceedance for watercourses in the Local Study Area.**

Water Quality Variable	Units	Guideline ¹	Detection Limit	All Data		Fall		Winter		Spring		Summer	
				Number of Samples	Frequency of Exceedance	Number of Samples	Frequency of Exceedance	Number of Samples	Frequency of Exceedance	Number of Samples	Frequency of Exceedance	Number of Samples	Frequency of Exceedance
Ammonia-N	mg/L	1.37 ^b	0.05	43	0%	14	0%	3	0%	13	0%	13	0%
Chloride (cl)	mg/L	230 ^f	1	43	0%	14	0%	3	0%	13	0%	13	0%
Dissolved oxygen (acute)	mg/L	5 ^j	-	63	25%	16	25%	4	75%	26	4%	17	47%
Dissolved oxygen (chronic)	mg/L	9 ^j	-	63	95%	16	100%	4	100%	26	92%	17	94%
Nitrate+Nitrite-N	mg/L	ⁿ	0.1	43	0%	14	0%	3	0%	13	0%	13	0%
pH	pH	6.5-9.0 ^o	0.1	63	29%	14	21%	3	33%	28	46%	18	6%
Phenols (4AAP)	mg/L	0.05 ^c	0.001	43	0%	14	0%	3	0%	13	0%	13	0%
Phosphorus, Total	mg/L	0.05 ^r	0.001	43	53%	14	57%	3	100%	13	31%	13	62%
Sulfate (SO ₄)	mg/L	100 ^p	0.5	43	0%	14	0%	3	0%	13	0%	13	0%
Sulphide	mg/L	0.014 ^s	0.003	43	30%	14	14%	3	67%	13	0%	13	69%
Total Kjeldahl Nitrogen	mg/L	1	0.2	43	17%	14	14%	3	67%	13	8%	13	23%
Total Suspended Solids	mg/L	+10 mg/L ^t	3	43	0%	14	0%	3	0%	13	0%	13	0%
Total Metals													
Aluminum	mg/L	0.1 ^a	0.002	42	71%	14	57%	3	67%	13	77%	12	83%
Arsenic	mg/L	0.005 ^c	0.00004	42	5%	14	0%	3	0%	13	0%	12	17%
Barium	mg/L	5 ^h	0.0001	42	0%	14	0%	3	0%	13	0%	12	0%
Beryllium	mg/L	0.0053 ^h	0.00001	42	0%	14	0%	3	0%	13	0%	12	0%
Boron	mg/L	1.2 ^d	0.0008	42	0%	14	0%	3	0%	13	0%	12	0%
Chromium	mg/L	0.001 ^g	0.0003	42	0%	14	0%	3	0%	13	0%	12	0%
Cobalt	mg/L	0.0009 ^h	0.00001	42	21%	14	7%	3	100%	13	8%	12	33%
Iron	mg/L	0.3	0.004	42	100%	14	100%	3	100%	13	100%	12	100%
Lithium	mg/L	0.87 ^h	0.0002	42	0%	14	0%	3	0%	13	0%	12	0%
Ultra-Trace Mercury	mg/L	13 ⁱ	1.2	43	0%	14	0%	3	0%	13	0%	13	0%
Molybdenum	mg/L	0.073 ^c	0.000008	42	0%	14	0%	3	0%	13	0%	12	0%
Selenium	mg/L	0.001 ^c	0.0002	42	0%	14	0%	3	0%	13	0%	12	0%
Silver	mg/L	0.0001 ^c	0.000005	42	0%	14	0%	3	0%	13	0%	12	0%
Thallium	mg/L	0.0008 ^c	0.000003	42	0%	14	0%	3	0%	13	0%	12	0%
Titanium	mg/L	0.1 ^h	0.00007	42	0%	14	0%	3	0%	13	0%	12	0%
Uranium	mg/L	0.3 ^h	0.000003	42	0%	14	0%	3	0%	13	0%	12	0%
Zinc	mg/L	0.03 ^c	0.0002	42	0%	14	0%	3	0%	13	0%	12	0%

¹ Refer to Table 6 for sources of surface water quality guidelines.

Table 10 **Frequencies of guideline exceedance for lakes in the Local Study Area.**

Water Quality Variable	Units	Guideline ¹	Detection Limit	All Data		Fall		Winter		Spring		Summer	
				Number of Samples	Frequency of Exceedance	Number of Samples	Frequency of Exceedance	Number of Samples	Frequency of Exceedance	Number of Samples	Frequency of Exceedance	Number of Samples	Frequency of Exceedance
Ammonia-N	mg/L	1.37 ^b	0.05	19	0%	5	0%	4	0%	5	0%	5	0%
Chloride (cl)	mg/L	230 ^f	1	19	0%	5	0%	4	0%	5	0%	5	0%
Dissolved oxygen (acute)	mg/L	5 ^j	-	22	5%	8	0%	4	25%	5	0%	5	0%
Dissolved oxygen (chronic)	mg/L	9 ^j	-	22	77%	8	75%	4	100%	5	40%	5	100%
Nitrate+Nitrite-N	mg/L	ⁿ	0.1	19	0%	5	0%	4	0%	5	0%	5	0%
pH	pH	6.5-9.0 ^o	0.1	19	21%	5	20%	4	25%	5	20%	5	20%
Phenols (4AAP)	mg/L	0.05 ^c	0.001	19	0%	5	0%	4	0%	5	0%	5	0%
Phosphorus, Total	mg/L	0.05 ^r	0.001	19	21%	5	20%	4	50%	5	20%	5	20%
Sulfate (SO ₄)	mg/L	100 ^p	0.5	19	0%	5	0%	4	0%	5	0%	5	0%
Sulphide	mg/L	0.014 ^s	0.003	19	5%	5	0%	4	25%	5	0%	5	0%
Total Kjeldahl Nitrogen	mg/L	1	0.2	19	26%	5	0%	4	75%	5	20%	5	20%
Total Suspended Solids	mg/L	+10 mg/L ^t	3	19	0%	5	0%	4	0%	5	0%	5	0%
Total Metals													
Aluminum	mg/L	0.1 ^a	0.002	19	47%	5	40%	4	50%	5	40%	5	60%
Arsenic	mg/L	0.005 ^c	0.00004	19	0%	5	0%	4	0%	5	0%	5	0%
Barium	mg/L	5 ^h	0.0001	19	0%	5	0%	4	0%	5	0%	5	0%
Beryllium	mg/L	0.0053 ^h	0.00001	19	0%	5	0%	4	0%	5	0%	5	0%
Boron	mg/L	1.2 ^d	0.0008	19	0%	5	0%	4	0%	5	0%	5	0%
Chromium	mg/L	0.001 ^g	0.0003	19	0%	5	0%	4	0%	5	0%	5	0%
Cobalt	mg/L	0.0009 ^h	0.00001	19	5%	5	0%	4	25%	5	0%	5	0%
Iron	mg/L	0.3	0.004	19	74%	5	80%	4	100%	5	60%	5	60%
Lithium	mg/L	0.87 ^h	0.0002	19	0%	5	0%	4	0%	5	0%	5	0%
Ultra-Trace Mercury	mg/L	13 ⁱ	1.2	19	0%	5	0%	4	0%	5	0%	5	0%
Molybdenum	mg/L	0.073 ^c	0.000008	19	0%	5	0%	4	0%	5	0%	5	0%
Selenium	mg/L	0.001 ^c	0.0002	19	0%	5	0%	4	0%	5	0%	5	0%
Silver	mg/L	0.0001 ^c	0.000005	19	0%	5	0%	4	0%	5	0%	5	0%
Thallium	mg/L	0.0008 ^c	0.000003	19	0%	5	0%	4	0%	5	0%	5	0%
Titanium	mg/L	0.1 ^h	0.00007	19	0%	5	0%	4	0%	5	0%	5	0%
Uranium	mg/L	0.3 ^h	0.000003	19	0%	5	0%	4	0%	5	0%	5	0%
Zinc	mg/L	0.03 ^c	0.0002	19	0%	5	0%	4	0%	5	0%	5	0%

¹ Refer to Table 6 for sources of surface water quality guidelines.

Table 11 Documented fish presence in Christina and Horse River watersheds.

Species	Stream Order						Lakes
	1	2	3	4	5	6	
Arctic Grayling	✓		✓	✓	✓		✓
Brassy Minnow				✓			
Brook Stickleback	✓	✓	✓	✓	✓		✓
Burbot			✓	✓	✓		✓
Emerald Shiner					✓		
Flathead Chub					✓		
Finescale Dace				✓			
Fathead Minnow			✓				
Goldeye				✓	✓	✓	
Iowa Darter				✓			
Lake Chub			✓	✓	✓	✓	✓
Lake Whitefish						✓	✓
Longnose Dace				✓		✓	
Longnose Sucker			✓	✓	✓	✓	
Mountain Whitefish					✓	✓	
Ninespine Stickleback							✓
Northern Pike	✓	✓	✓	✓	✓	✓	✓
Pearl Dace			✓	✓	✓		✓
Rainbow Trout							✓
Slimy Sculpin	✓	✓	✓	✓	✓	✓	
Spoonhead Sculpin			✓	✓			
Spottail Shiner				✓		✓	✓
Trout-perch				✓	✓	✓	✓
Tullibee (Cisco)							✓
Walleye			✓	✓	✓	✓	✓
White Sucker		✓	✓	✓	✓	✓	✓
Yellow Perch			✓	✓			✓
Total number of species present	4	4	13	19	15	12	15

Note: species in bold are sport fish. Information extracted from FWMIS database.

Results of Baseline Fish Inventories

Baseline fish inventories were conducted at 15 watercourse locations and in five lakes in the LSA (Table 5, Figure 5). In total, 590 fish comprising five species were captured in watercourses in the LSA (Table 13). The majority of fish captured (93%) were brook stickleback with fewer lake chub (4%), white sucker (3%), Arctic grayling (<1%) and finescale dace (<1%). Most of the fish were captured at site C12 in the Christina River watershed (76%). Arctic grayling were captured only in site C07 of the Christina River watershed, while finescale dace were captured only in site C22 in the Horse River watershed.

Table 12 Probability of capturing small bodied, large bodied, or sports fish by stream order for Christina River and Horse River watersheds.

Stream Order	Number of FWMIS Data Records	Probability of Capturing:		
		Small-Bodied Fish	Large-Bodied Fish	Sport Fish
1	84	44%	9%	5%
2	56	62%	12%	3%
3	91	72%	45%	23%
4	94	48%	59%	38%
5	30	46%	70%	46%
6	7	57%	57%	57%

Table 13 Summary of fish captured in watercourses in the Local Study Area.

Site	Drainage	Species					Total
		Arctic Grayling	Brook Stickleback	Finescale Dace	Lake Chub	White Sucker	
C06	Christina	-	12	-	-	-	12
C07	Christina	3	4	-	-	-	7
C09	Christina	-	7	-	-	-	7
C10	Christina	-	37	-	-	-	37
C11	Christina	-	10	-	10	9	29
C12	Christina	-	417	-	-	-	417
C14	Christina	-	10	-	10	-	20
C15	Christina	-	-	-	-	1	1
C16	Christina	-	-	-	-	4	4
C17	Christina	-	6	-	1	1	8
C18	Christina	-	15	-	-	-	15
C22	Horse	-	31	2	-	-	33
Total		3	549	2	21	15	590

Note: refer to Figure 5 for the sampling locations.

A total of 356 fish of three species were captured in the lakes in the LSA (Table 14). Brook stickleback was the only small-bodied fish captured in the lakes, while northern pike and white sucker were the large-bodied fish captured in these lakes. Northern pike was the only fish species captured in lakes C02 and C03 despite both lakes being sampled using both gillnets and minnow traps.

Table 14 Summary of fish captured in lakes in the Local Study Area.

Site	Species			Total
	Brook Stickleback	Northern Pike	White Sucker	
C01	37	-	-	37
C02	-	4	-	4
C03	-	10	-	10
C04	64	1	6	71
C05	231	-	3	234
	332	15	9	356

Note: refer to Figure 5 for the sampling locations.

3.3.3 Physical Aquatic Habitat

Detailed physical aquatic habitat surveys were conducted at 35 watercourse locations in the LSA, 20 of which were conducted in support of stream crossing assessments, as well as for five lakes (Table 5, Figure 5). Detailed results of these surveys are provided in Appendix A3 and Appendix A3.

The watercourses in the LSA have mostly a run morphology (Table 15). Vegetation bordering the sampled watercourses is comprised of grasses and shrubs with some muskeg and immature to established deciduous or mixed forest. Instream vegetation is minimal, but stream courses were often braided around small patches of vegetation. Woody debris is generally limited to complete and incomplete beaver dams, and the sparse canopy cover is limited to that provided by shrubs.

Instream cover in these watercourses is dominated by overhanging vegetation with approximately equal amounts of small and woody debris, deep pools, instream vegetation and undercut banks. Stream substrates are dominated by fines and organic material with lesser amounts of gravels, cobbles, and boulders.

Visual aerial observations of watercourses in LSA and RSA made during the baseline field studies suggest that most reaches in the watercourses have similar characteristics as those described above and presented in detail in Table 15 and Appendix A3. In particular, beaver dams, often well-established, are frequent in the watercourses of the LSA. Visual observations in fall 2006 (Appendix A3) indicated that water was not flowing over all of these beaver dams, suggesting that they form potential fish migration barriers for at least part of the year in some years.

Table 15 Physical aquatic habitat summary for watercourses in Local Study Area.

Streambed Material (% Streambed Area)		Crown Closure and Instream Cover	
		% Wetted Area with Crown Closure	15
Organic	22	% Wetted Area with Instream Cover	29
Fines	56	% Total Instream Cover as:	
Gravels	11	Small woody debris	13
Cobbles	4	Large woody debris	12
Boulders	4	Boulders	2
Rock	4	Undercut Banks	16
Anthropogenic Materials	-	Deep Pools	15
Bank Morphology (% Streambank Length)		Overhanging Vegetation	27
Undercut Banks	33	Instream Vegetation	15
Vertical	22	Riparian Vegetation (% Streambank Length)	
Sloping	39	No Riparian Vegetation	-
Overhanging	6	Grasses	42
Channel Morphology (% Stream Area)		Shrubs	37
Run	78	Coniferous Forest	-
Pool	17	Deciduous Forest	4
Riffle	6	Mixedwood Forest	2
Other	-	Wetland	15

Fall lake habitat characteristics were generally similar across all five lakes with respect to water depth, vegetation, cover and bed material. A minimal amount of submergent aquatic vegetation was present in all lakes surveyed, and limited observations of bed materials suggest that substrates in these lakes are dominated by fines and organics. Lake waters are typically surrounded by muskeg wetlands which may extend up to 100 m before terminating in forested shorelines. Shorelines are dominated by established black spruce, tamarack, jackpine forests. Evidence of current and past beaver activity is present at all lakes in the form of lodges and/or dams.

Fall water quality profiles are consistent across the four lakes for which these profiles were obtained (lakes C02 to C05, [Appendix A4](#)). No thermocline or chemocline was detected in any of the lakes in fall 2006 surveys with the possible exception of a decline in dissolved oxygen in lake C04 at about 1.5 m. This is not unexpected, given that the lakes are shallow and any autumn mixing would have likely already occurred by the time the fall 2006 sampling program took place.

Winter habitat quality with respect to fish overwintering was variable ([Table 16](#)). Lakes C02, C03, and C05 appear to have conditions suitable for successful overwintering of both large-bodied and small-bodied fish species. These three lakes had water depth below the ice in fall 2007 ranging from 125 cm (lake C03) to 200 cm

for lake C05 (Table 16) and dissolved oxygen profiles indicating fair dissolved oxygen levels in the winter 2007 season for overwintering fish species (Appendix A4). A literature review in AEP (1997) indicates dissolved oxygen concentrations resulting in short-term toxic effects to fish beginning at 0.25 mg/L to 3.4 mg/L, depending on the species. A substantial portion of the water column in lakes C02, C03, and C05 had measured dissolved oxygen levels above 3.4 mg/L in winter 2007 (Appendix A4). Dissolved oxygen levels causing acute effects on white sucker were not found in the scientific literature. Casselman and Lewis (1996) report that the upper range of the lower incipient lethal oxygen concentration is 0.5 to 1.5 mg/L; measured dissolved oxygen levels in most of the below-ice water columns in lakes C02, C03, and C05 were higher than these levels in winter 2007 (Appendix A4).

In contrast, lake C01 does not appear to contain suitable overwintering habitat for large-bodied fish as in winter 2007 it was almost completely frozen to depth (Table 16), with only 6 cm of water remaining unfrozen below the ice. Also, while lake C04 had 60 cm of water below the ice in winter 2007 (Table 16), its dissolved oxygen levels in winter 2007 throughout the below-ice water column were extremely low (i.e., below 0.5 mg/L).

Table 16 Winter 2007 ice conditions at selected locations in the Local Study Area.

Site	Total Depth (cm)	Ice Thickness (cm)	Water Depth Under Ice (cm)
Lakes			
C01	78	72	6
C02	230	50	180
C03	185	60	125
C04	95	35	60
C05	250	50	200
Watercourses			
C06	45	45	0
C07	185	35	150
C08	68	20	45
C10	55	50	5
C11	158	42	116
C12	70	70	0

Note: refer to Figure 5 for the sampling locations.

3.3.4 Sediment Quality

Sediment quality was assessed at three lakes and nine watercourse locations (Table 5, Figure 5), of which three sites were from lakes and six were from watercourses. A summary of sediment quality data is presented in Table 17 and Table 18; detailed results are provided in Appendix A5.

Table 17 Summary of sediment quality conditions for Local Study Area.

Analyte	Units	Guideline ISQG ¹	Lakes				Streams			
			N	Min	Median	Max	N	Min	Median	Max
% Clay	%		3	31	42	48	6	2	5	36
% Moisture	%		3	91	92	95	1	81	81	81
% Sand	%		3	13	23	26	6	35	63.5	83
% Silt	%		3	32	38	46	6	12	27	37
2-Bromobenzotrifluoride	%		3	39	72	74	1	103	103	103
Aluminum (Al)	mg/kg		0	-	-	-	2	2770	3585	4400
Antimony (Sb)	mg/kg		3	0.2	0.2	0.2	4	0.2	0.2	0.2
Arsenic (As)	mg/kg	5.9	3	2.5	2.7	3	6	0.7	1.4	9.9
Barium (Ba)	mg/kg		3	69	106	140	6	25	64	174
Benzene	mg/kg		3	0.01	0.06	0.07	1	0.03	0.03	0.03
Beryllium (Be)	mg/kg		3	1	1	1	6	0.2	1	1
Bismuth (Bi)	mg/kg		0	-	-	-	2	0.5	0.5	0.5
Boron (B)	mg/kg		0	-	-	-	2	3	4.5	6
CaCO3 Equivalent	%		3	0.7	0.9	1.5	6	0.7	0.7	5.4
Cadmium (Cd)	mg/kg	0.6	3	0.7	1.1	1.1	6	0.2	0.5	0.7
Calcium (Ca)	mg/kg		0	-	-	-	2	1900	5150	8400
Chromium (Cr)	mg/kg	37.3	3	5.8	7.2	9.9	6	3.4	4.7	6.8
Cobalt (Co)	mg/kg		3	4	5	5	6	2	3	16.6
Copper (Cu)	mg/kg	35.7	3	7	7	10	6	2.8	3.5	7
Ethylbenzene	mg/kg		3	0.1	0.1	0.2	1	0.05	0.05	0.05
F1 (C6-C10)	mg/kg	30 ²	3	5	5	5	1	5	5	5
F1-BTEX	mg/kg		3	5	5	5	1	5	5	5
F2 (C10-C16)	mg/kg	150 ²	3	5	5	5	1	5	5	5
F3 (C16-C34)	mg/kg	400 ²	3	240	490	2400	1	1100	1100	1100
F4 (C34-C50)	mg/kg	2800 ²	3	81	170	1900	1	610	610	610
Hexatriacontane	%		3	48	69	100	1	143	143	143
Inorganic Carbon	%		3	0.1	0.1	0.1	6	0.1	0.1	0.6
Iron (Fe)	mg/kg		0	-	-	-	2	6000	20850	35700
Lead (Pb)	mg/kg	35	3	5	6	7	6	3.2	5	5
Magnesium (Mg)	mg/kg		0	-	-	-	2	680	870	1060
Manganese (Mn)	mg/kg		0	-	-	-	2	155	657.5	1160
Mercury (Hg)	mg/kg	0.17	3	0.05	0.05	0.05	6	0.05	0.05	0.08
Molybdenum (Mo)	mg/kg		3	1	1	1	6	0.3	1	1
Nickel (Ni)	mg/kg		3	11	12	17	6	3.1	4.5	8.6
Potassium (K)	mg/kg		0	-	-	-	2	300	400	500
Selenium (Se)	mg/kg		3	0.7	0.8	1	6	0.2	0.35	1.1
Silver (Ag)	mg/kg		3	1	1	1	6	0.2	1	1
Sodium (Na)	mg/kg		0	-	-	-	2	100	100	100
Strontium (Sr)	mg/kg		0	-	-	-	2	14	26.5	39
Thallium (Tl)	mg/kg		3	1	1	1	6	0.08	1	1
Tin (Sn)	mg/kg		3	5	5	5	6	2	5	5
Titanium (Ti)	mg/kg		0	-	-	-	2	31	33	35
Toluene	mg/kg		3	0.1	0.1	0.1	1	0.05	0.05	0.05
Total Carbon by Combustion	%		3	23	23.8	26.2	6	1.3	7.2	16.7
Total Hydrocarbons (C6-C50)	mg/kg		3	320	660	4300	1	1700	1700	1700
Total Organic Carbon	%		3	23	23.8	26.2	6	1.3	7.1	16.5
Uranium (U)	mg/kg		3	2	2	2	6	0.55	2	2
Vanadium (V)	mg/kg		3	8	11	15	6	6	7.65	18.8
Xylenes	mg/kg		3	0.2	0.3	0.5	1	0.1	0.1	0.1
Zinc (Zn)	mg/kg	123	3	90	100	130	6	20	24	56

Table 18 Frequency and magnitude of exceedance of sediment quality guidelines.

Sediment Quality Variable	Units	Guideline ISQG ¹	Lakes			Watercourses		
			N	Frequency	Magnitude	N	Frequency	Magnitude
Arsenic (As)	mg/kg	5.9	3	-	-	6	33%	0.24
Cadmium (Cd)	mg/kg	0.6	3	100%	1.83	6	33%	0.83
F-3 (C16-C34) Hydrocarbons	mg/kg	400 ²	3	66%	1.23	1	100%	2.75
Zinc (Zn)	mg/kg	123	3	33%	0.81	6	-	-

¹ Freshwater sediment quality guidelines (CCME 2002).

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

Sediments in watercourses in the LSA are dominated by sand with smaller amounts of silt and clay, while sediments in lakes in the LSA are dominated by clays with smaller amounts of silt and sand. Concentrations of arsenic, cadmium, and F3 (C16-C34) hydrocarbons exceeded sediment quality guidelines in some watercourses. Concentrations of cadmium exceeded sediment quality guidelines in all sampled lakes, while concentrations of smaller amounts of silt and sand. Concentrations of arsenic, cadmium, and F3 (C16-C34) hydrocarbons and zinc exceeded sediment quality guidelines in two of three and one of three lakes sampled, respectively.

3.3.5 Benthic Invertebrate Communities

Benthic invertebrate samples were collected at nine sites in the Local Study Area in fall 2007, of which three sites were from lakes and six sites were from watercourses (Table 5, Figure 5). As watercourses in the LSA are dominated by depositional habitats, all six watercourse locations that were sampled for benthic invertebrate communities are depositional habitats. A summary of the benthic invertebrate community baseline for the LSA is provided in Table 19.

The abundance of benthic invertebrate communities in depositional watercourses in the LSA ranged from 1,000 organisms/m² to 89,870 organisms/m²; within the sampled lakes, density ranged from 889 organisms/m² to 10,710 organisms/m². From 6 to 20 taxa were enumerated at sampled watercourses, evenness ranged from 0.10 to 0.67, Simpson's diversity varied from 0.50 to 0.86, while no orders Ephemeroptera, Trichoptera and Plecoptera (taxa that are sensitive to environmental pollution) were recovered in any of the watercourses. In the lakes that were sampled, richness ranged from 9 to 13 taxa, evenness ranged from 0.32 to 0.72, Simpson's diversity ranged from 0.74 to 0.88, and %EPT ranged from 0% to 2.5%

The values of all these benthic invertebrate community indices are within the range of regional baseline values for these indices for depositional watercourse habitats and lakes in the RAMP study area (RAMP 2010).

Table 19 Summary of benthic invertebrate community indices for watercourses and lakes in the Local Study Area.

Variable	Lakes			Watercourses					
	C02	C03	C04	C06	C07	C10	C17	C19	C22
Total density (#/m ²)	889	10,710	4,551	20,884	14,681	13,710	6,507	1,000	89,870
Richness (total # taxa)	9	13	12	20	14	12	17	6	20
Simpson's Diversity	0.74	0.76	0.88	0.86	0.74	0.81	0.55	0.75	0.50
Evenness	0.43	0.32	0.72	0.35	0.27	0.44	0.13	0.67	0.10
% EPT ¹	1.6	0.0	2.5	0.0	0.0	0.0	0.0	0.0	0.0

¹ Percentage of all individuals made up of the orders Ephemeroptera, Trichoptera and Plecoptera.

3.3.6 Fish Habitat Suitability Assessment for Local Study Area

A number of habitat suitability index (HSI) models 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 as well as longnose sucker which, based on its distribution patterns identified in RAMP (2005), is expected to be present in the LSA. [Table 20](#) summarizes the results of the habitat suitability index models, while details of the application of the habitat suitability index models are provided in [Appendix A7](#).

Based on data available, the habitat suitability models suggest that the Christina River and Horse River watersheds are suitable for all life stages of the fish species captured and expected, particularly longnose sucker, brook stickleback, finescale dace, and white sucker. Most sites show average to above average suitability for all species assessed with the following exceptions:

1. Christina River watershed was considered to have excellent habitat for longnose sucker. This species was not captured during sampling, but was expected to be present;
2. Both watersheds were found to have below average suitability for brook stickleback, despite this species being the most abundant fish species captured in the baseline field studies of 2006 to 2008; and
3. Lake habitat of the Christina River watershed was found to have no suitable habitat for white sucker or Arctic grayling.

Fine sediments, low levels of aquatic vegetation in watercourses, constraints due to shallow lake depths, and high summer water temperatures generally reduced HSI values for many of the species considered. Additionally, low winter dissolved oxygen, and short frost-free seasons were assessed as reducing habitat suitability in the LSA for Arctic grayling and northern pike, respectively. An abundance of run-type habitat restricted habitat suitability for nearly all species modeled. Riffles, commonly used by fish as spawning habitat, were uncommon in both the Horse and Christina Rivers.

Table 20 Summary of HSI values for species captured or expected to be present in the Christina and Horse River watersheds.

Species	Habitat Suitability					
	Christina River				Horse River	
	Lakes		Watercourses		Watercourses	
Brook Stickleback	0.75	Above Average	0.34	Below Average	0.38	Below Average
Lake Chub	0.50	Average	0.55	Average	0.72	Above Average
Finescale Dace	0.75	Above Average	0.50	Average	0.50	Average
White Sucker	0.05	None	0.74	Above Average	0.69	Above Average
Northern Pike	0.42	Average	0.40	Average	0.40	Average
Longnose Sucker	0.62	Average	0.86	Excellent	0.77	Above Average
Arctic Grayling	0.00	None	0.50	Average	0.50	Average

3.4 BASELINE CASE FOR REGIONAL STUDY AREA

3.4.1 Water Quality

Water quality sampling occurred at one site (site C13) within the RSA in spring and summer 2007 (Table 5, Figure 5); detailed results are provided in Appendix A2. Water at site C13 in 2007 was highly-coloured (true colour measured at 160 and 250 TCU) and concentration of DOC measured at 29mg/L and 42mg/L. Water was slightly hard (average hardness of 29mg/L) and had low alkalinity (average alkalinity of 23mg/L). The concentration of TSS was below the detection limit in spring 2007 and 34mg/L in summer 2007. Concentrations of all water quality variables were below water quality guideline values at site C13 in spring and summer 2007 with the exception of total Kjeldahl nitrogen in summer 2007 and total aluminum and iron in spring 2007. The concentration of naphthenic acids and total recoverable hydrocarbons were below detection limits at site C13 in both spring and summer 2007.

RAMP annually samples water quality at two locations in the RSA for this Project: a baseline station approximately 120 km downstream of the LSA boundary, and a test station (i.e., downstream of RAMP-member oil sands development projects) and approximately 280 km downstream of the LSA boundary on the Christina River. As of 2009, water quality at the lower RAMP station in the Christina River was assessed as being moderately different from regional baseline conditions as a result of higher concentrations of total nitrogen, total boron, and several ions at this station compared to regional baseline ranges for these water quality variables. Water quality at the upper RAMP station on the Christina River was assessed as having negligible-low differences from regional baseline conditions.

There is no water quality information for the Horse River watershed except for 2009 water quality data collected on the upper Horse River (RAMP 2010), upstream of its confluence with Horse Creek. At this station, concentrations of a number of selected water quality measurement endpoints in fall 2009 were outside the range of regional *baseline* concentrations. In 2009, water quality at this station was assessed as being moderately different from regional baseline concentrations, primarily due to relatively high concentrations of nutrients (nitrogen and phosphorus) and total mercury.

3.4.2 Fish Resources

Site C13 in the RSA (Table 5, Figure 5) was sampled for fish in spring 2007. No fish were caught during this sampling session. Table 11 indicates that a total of 23 fish species are documented in fourth- and higher-order streams in the Christina and Horse River watersheds.

While information on fish health specific to the Christina and Horse River watersheds 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 (2010) reported that:

- mean mercury concentrations across all size classes in northern pike in the Clearwater 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 northern pike was identified given all metals in composite samples were below sublethal effects and no-effects criteria; and
- all tainting compounds in northern pike muscle tissue from the Clearwater River were below guideline concentrations indicating a negligible-Low influence on fish palatability.

3.5 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 2000).

Chemical characteristics of the lakes within the LSA are shown in Table 21. Using the alkalinity-based classification system developed by Saffran and Trew (1996), lake C01 is classified as having high sensitivity to acidification, lakes C02, C03, and C04 have moderate sensitivity, and lake C05 has low sensitivity to acidification. Baseline Case PAI inputs for lake C01 are also assessed as being approximately 5% greater than the Critical Load value for the lake.

Table 21 Acid-sensitivity of lakes in the Local Study Area.

Lake ID	pH (pH units)	Alkalinity (mg/L)	Conductivity (µS/cm)	TDS (mg/L)	DOC (mg/L)	Sensitivity to Acidification (from Saffran and Trew 1996)	Critical Load (keq H ⁺ / ha / y)	Baseline Case PAI (keq H ⁺ /ha/yr)
C01	6.28	6.3	24.2	54.8	26.8	High	0.080	0.0838
C02	7.10	16.0	39.9	50.0	19.8	Moderate	0.152	0.0810
C03	6.88	11.0	33.8	49.5	21.5	Moderate	0.127	0.0787
C04	6.53	11.3	35.1	71.3	28.3	Moderate	0.13	0.0728
C05	7.38	24.3	53.4	53.3	20.5	Low	0.196	0.0897

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 (CNRL 2002, RAMP 2005b),

PAI values from [MEMS 2010b](#).

4.0 EFFECTS ASSESSMENT

4.1 APPLICATION CASE

The Application case predicts the effects of existing, approved and Project developments on Aquatic Resources in the LSA and the RSA.

4.1.1 Effects on Surface Aquatic Resources through Surface Disturbance and Construction Activities

4.1.1.1 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 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 clearance and overburden stripping for access roads and utility corridor construction, borrow pit development, sump construction and well pad construction;
- Management of soil stockpiles;
- Dismantling of all project facilities; and
- Re-grading and re-vegetation of reclamation areas.

The project disturbances will be located in the drainage basins of both the Horse and Christina Rivers, with 38% of the disturbance occurring in the Horse River watershed and 62% occurring in the Christina River watershed. The linkage between surface disturbance and construction activities and potential changes in sediment yield is considered valid.

4.1.1.2 Mitigation Measures to be Implemented

The 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 submit a sediment control plan;
- Sediment control measures such as those described in the *Alberta Code of Practice for Watercourse Crossings* (AENV 2000a) 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. During reclamation, permanent plant cover and re-vegetation will be established. Soil erosion will 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.

4.1.1.3 Impact Analysis

With strict implementation of the mitigation measures summarized above and other measures described in detail in Connacher 2010, [Section E, Conservation and Reclamation Plan](#), potential impacts of surface disturbance activities are predicted to be insignificant 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 follow the schedules outlined in the phased development plan. These activities will be carried out sequentially and at intervals, before the development of new areas.

4.1.1.4 Residual Impact Classification

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

- **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;
- **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;
- **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 such that they are *Insignificant*; 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 *Insignificant* in the LSA, these residual effects: (i) are also assessed as *Insignificant* for the RSA; and (ii) are not assessed for the Planned Development Case (PDC).

4.1.2 Effects on Surface Aquatic Resources through In-stream Construction Activities

4.1.2.1 Description of Effects and Assessment of Validity of Impact Pathways

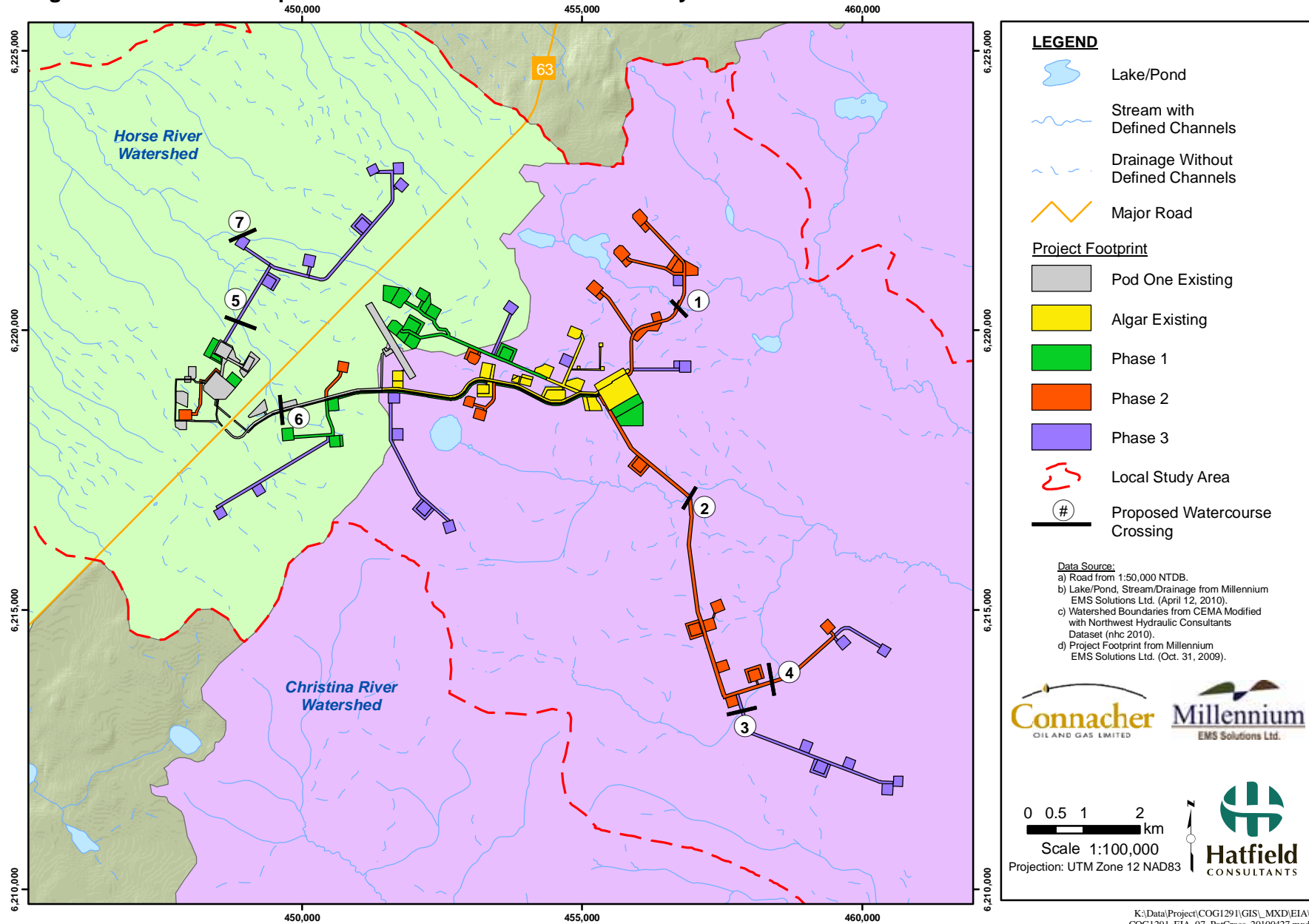
Direct changes and physical loss of aquatic habitat may occur during in-stream construction works, such as watercourse crossing sites (roads or utilities) by the direct disturbance of the streambed, banks or riparian areas. Direct habitat effects can include alteration or loss of specific habitat features, 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.

Six locations have been identified where road and utility corridors may cross watercourses with defined channels (Figure 7 and Table 22). One location has also been identified where the construction of a well pad may directly impinge upon a watercourse with a defined channel.

Table 22 Summary of potential in-stream construction activity locations.

Crossing Site	Watershed	Location	Construction Activity	Project Phase
1	Christina River	NW 20-82-11	Stream Crossing	Phase 2
2	Christina River	NW 8-82-11	Stream Crossing	Phase 2
3	Christina River	SE 32-81-11	Stream Crossing	Phase 2
4	Christina River	NW 33-81-11	Stream Crossing	Phase 3
5	Horse River	NW 21-82-12	Stream Crossing	Phase 3
6	Horse River	NE 16-82-12	Stream Crossing	Phase 3
7	Horse River	NW 28-82-12	Well Pad 106	Phase 3

Figure 7 Locations of potential in-stream construction activity.



4.1.2.2 Mitigation Measures to be Implemented

The 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 in-stream construction activities. These measures include:

- Whenever possible, in-stream 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 watercourse crossings will be designed and constructed in compliance with the *Alberta Code of Practice for Watercourse Crossings* (AENV 2000a) 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. Mitigation measures will be implemented once the exact location of stream crossings are finalized. Implementation of appropriate mitigation measures means that all stream crossings constructed and operated for the Project will meet regulatory requirements for the protection of fish resources and aquatic habitat and will subsequently mitigate against effects on surface water quality; and
- The existence and location of a defined stream channel at well pad 106 has not been confirmed through either aquatic resources or hydrology fieldwork. The nature of the stream should be assessed prior to well pad construction and where possible, construction works should aim to avoid direct impact to the watercourse and provide a minimum 30 m buffer from the edge of the stream bank.

4.1.2.3 Impact Analysis

With strict implementation of the mitigation measures summarized above, potential impacts of in-stream construction activities are predicted to be insignificant for the following reasons:

- Impacts from in-stream 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; and
- A minimum 30 m buffer will be maintained from the edge of the stream bank for all other construction activities which are proposed to take place in close vicinity to watercourses.

4.1.2.4 Residual Impact Classification

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

- **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;
- **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;
- **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 such that they are *Insignificant*; 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 *Insignificant* in the LSA, these residual effects: (i) are also assessed as *Insignificant* for the RSA; and (ii) are not assessed for the PDC.

4.1.3 Effects on Surface Aquatic Resources through Changes in Surface Water Quality

4.1.3.1 Description of Effects and Assessment of Validity of 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.

4.1.3.2 Mitigation Measures to be Implemented

Discharge of Project-affected waters: The water management plan provided in Connacher (2010), [Section B.7, Water Management](#) indicates that 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 system a near zero liquid discharge system. The waste stream of concentrated brine from the evaporation-distillation process will be trucked or pipelined to on-site disposal wells or an approved location off-site. No planned discharges of process-affected waters will take place from the Project, hence impact to natural watercourses is considered insignificant 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 EUB and AENV regulations. All surface runoff will be collected in the settling pond and returned to the central processing facility (CPF) for use as plant makeup water. However, it is anticipated that occasionally, depending upon site and operating conditions, the surface runoff collected in the settling pond may be released into the surrounding watershed receiving waters.

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 an insignificant 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 Central Processing Facility (CPF).

Management and disposal of all drilling waste will in accordance with regulations, as described in Connacher 2010, [Section B.4, Drilling Waste Management](#). Disposal options for liquid drill waste include disposal at a licensed third party waste disposal facility or pump off. Solid drill 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.

Changes in shallow groundwater quality: The Hydrogeology Assessment ([MEMS 2010a](#)) of this Application identifies that accidental releases may have the potential to effect shallow groundwater quality.

Design features at the CPF (several meters of sand close to the surface which is not suitable for surface grade at the plant and will be selectively removed and/or covered with low permeability compacted till) will provide for runoff control to a stormwater retention pond, mitigating against downward migration of potential contaminants and adverse effects to shallow groundwater. Further, in the event that a significant impact on groundwater quality is detected, a groundwater response plan will be implemented. The response plan typically includes determining the magnitude of the impact and undertaking remediation or a risk assessment and will be effective at avoiding a significant effect on groundwater quality, preventing impacted groundwater from reaching surface water bodies and restoring groundwater quality. As a result, accidental spills or leaks are not expected to have a significant impact on shallow groundwater quality.

Domestic sewage will be directed through an approved sewer system to a septic field or will be trucked to an approved disposal location. The septic system will be designed to meet all provincial and local codes such that it mitigates against adverse impacts to shallow groundwater.

4.1.3.3 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 insignificant 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.

4.1.3.4 Residual Impacts Classification

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

- **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;
- **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;

- **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 such that they are *Insignificant*. 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 \(2010a\)](#); 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 *Insignificant* in the LSA, these residual effects: (i) are also assessed as *Insignificant* for the RSA; and (ii) are not assessed for the PDC.

4.1.4 Effects on Surface Aquatic Resources through Changes to Surface Water Flow Rates and Levels

4.1.4.1 Description of Effects and Assessment of Validity of Impact Pathways

Changes in stream flow can affect spawning, rearing, feeding, migration and overwintering habitats of fish-bearing streams and rivers (i.e., reduced stream area and shallow depth, reducing dissolved oxygen under the ice), and can also affect the watercourse productivity and availability of food for fish (e.g., benthic invertebrates). Changes in stream flow can also alter the presence of macrophytes, which provide cover, spawning material or food for fish. Changes in lake levels can affect shoreline habitat for fish (e.g., area of littoral zone and macrophyte growth); overwintering capacity of fish-bearing waterbodies; primary productivity (i.e., effect on food for fish, including benthic invertebrates); and discharges to outlet creeks.

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.

4.1.4.2 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 the Expansion Project process activities are estimated at 0.56 million cubic metres per year, all of which will be met through groundwater withdrawals. There will be no surface water withdrawals for the Project process activities, with the exception of 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-affected water: No planned discharges of Project-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 2010a) of this Application indicates that all Project process water requirements will be met through groundwater withdrawals from the lower Grand Rapids non-saline formation (350m below ground level). Minor drawdown effects are expected within the deeper Grand Rapids formation, but not in shallow groundwater. No other Project activities have been identified (e.g., excavation works) that are expected to impact on shallow groundwater/surface water interactions, therefore no impact to the amount of shallow groundwater reporting to surface water is expected.

4.1.4.3 Impact Analysis

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

1. Only small increases in surface water runoff volumes are predicted as a result of surface disturbances. As described in the Hydrology assessment (nhc 2010), relatively small average increases in stream flow (maximum average increase in runoff volume of between 1.7 and 2.2% above Baseline Case conditions in the watersheds with the greatest effects) are predicted from surface disturbances associated with the Project. No perceptible impacts on the magnitude of peak annual flows are predicted and no significant changes to low flow rates are anticipated in most streams in the LSA, because they have little or no flow in winter.

2. No planned discharges of Project-affected waters will take place from the Project therefore no resultant changes to surface water flow rates are expected.
3. Occasional releases from the storm water retention pond may take place, but water will be released at a controlled rate in strict accordance with the terms and conditions of the operating approval.
4. Shallow groundwater levels are not expected to be affected by Project activities and therefore no resulting changes to surface water flow rates are expected.

4.1.4.4 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 *Insignificant* in the LSA:

- **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, and in the case of changes to water flows and levels due to surface disturbance - *Seasonal*;
- **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;
- **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;
- **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 \(2010\)](#) and [MEMS \(2010a\)](#); 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 *Insignificant* in the LSA, these residual effects: (i) are also assessed as *Insignificant* for the RSA; and (ii) are not assessed for the PDC.

4.1.5 Effects on Surface Aquatic Resources from Improved or Altered Access to Fish Bearing Waterbodies

4.1.5.1 Description of Effects and Assessment of Validity of Impact Pathways

Improved access and increased workforce in the area as a result of the 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 sport fish 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.

4.1.5.2 Mitigation Measures to be Implemented

Connacher will work closely 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 sport fishing. Possible initiatives include:

- raising awareness among the Great Divide Expansion Project workers of the existing ASRD regulations for the species found in the study area lakes;
- Educating the Project workforce on the benefits of the practice of catch-and-release angling; and
- discouraging fishing by Project employees within the LSA.

4.1.5.3 Impact Analysis

While many fish populations in the region 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 insignificant.

4.1.5.4 Residual Effects Classification

The residual (after mitigation) effects of the Project on aquatic resources from improved or altered access to fish bearing water courses and water bodies are assessed as *Insignificant* in the LSA:

- **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;

- **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;
- **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 and water bodies are assessed as *Insignificant* in the LSA, these residual effects: (i) are also assessed as *Insignificant* for the RSA; and (ii) are not assessed for the PDC.

4.1.6 Effects on Fish Health, including Fish Tainting through Changes in Water Quality

4.1.6.1 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.

4.1.6.2 Mitigation Measures to be implemented

[Section 4.1.1.2](#) and [Section 4.1.3.2](#) 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.

4.1.6.3 Impact Analysis

With implementation of the mitigation measures summarized in [Section 4.1.1.2](#) and [Section 4.1.3.2](#) potential impacts to fish health through potential changes in water quality are predicted to be insignificant.

4.1.6.4 Residual Effects Classification

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

- **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 the assessment period;
- **Ability for Recovery** – effects will be *Reversible in the short-term* and will diminish upon cessation of activities;
- **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;
- **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 *Insignificant*; and
- **Probability of Occurrence** – *Low*, unlikely based on the results of longer term fish health monitoring programs in the Athabasca oil sands region (RAMP 2010).

Because the residual effects of the Project on surface aquatic resources on fish health are assessed as *Insignificant* in the LSA, these residual effects: (i) are also assessed as *Insignificant* for the RSA; and (ii) are not assessed for the PDC.

4.1.7 Effects on Surface Aquatic Resources from Acidifying Emissions

4.1.7.1 Description of Effects and Assessment of Validity of Impact Pathways

The Project will result in the release of acidifying emissions, as described in the Air Quality Assessment in this Application (MEMS 2010b); therefore, the potential for acidifying emissions from the Project to affect surface aquatic resources in both the Air Quality LSA and RSA is considered a valid impact pathway.

4.1.7.2 Mitigation Measures to be Implemented

Connacher has chosen project components in the process design and project operation that minimize acidifying emissions. The resulting effects are described in the Air Quality Assessment Report (MEMS 2010b).

4.1.7.3 Impact Analysis

The predicted annual input of acidifying substances (PAI) for Baseline and Application cases (MEMS 2010b) is presented in Table 23. For Baseline and Application cases, predicted PAI values at all lakes are significantly below Alberta's Clean Air Strategic Alliance (CASA) target level of 0.25 keq H⁺/ha/yr.

PAI values are predicted to increase for the five lakes by between 1.3 and 1.8% from the Baseline Case to the Application Case. The predicted PAI for lake C01 in the Application Case is predicted to be 6% greater than its Critical Load; this compares to a predicted PAI for the Baseline Case for lake C01 that is 4% greater than its Critical Load. The predicted PAI in the Application Case for the other lakes in the AQLSA is lower than the Critical Loads for those lakes.

Table 23 Comparison of estimated PAI inputs in Application Case and Critical Load for five AQLSA lakes.

Lake	Critical Load (keq H ⁺ / ha / y)	Application Case PAI (keq H ⁺ /ha/yr)
C01	0.080	0.0849
C02	0.152	0.0825
C03	0.127	0.0800
C04	0.13	0.0738
C05	0.196	0.0913

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 (CNRL 2002, RAMP 2005b),

PAI values from [MEMS \(2010b\)](#).

The area within the Air Quality Regional Study Area (AQRSA) which receives PAI in excess of 0.25 keq H⁺/ha/yr is predicted to remain the same at 2800 km². This affected area represents less than 4% of the total area of the AQRSA (72,600 km²) and a very minor proportion of the Application PAI values are likely to be attributable to this Project. No increases in potential for acidification from Baseline to Application Case are predicted to result from the Project within the AQRSA.

4.1.7.4 Residual Impact Classification

The residual (after mitigation) effects of the Project in the Application Case on surface aquatic resources through acidifying emissions are assessed as *Insignificant* for both the AQLSA and AQRSA:

- **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;
- **Magnitude** – magnitude of the effects of the Project will be *Low* locally (AQLSA) and *None* regionally (AQRSA);
- **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: Uncertainty inherent in estimates of predicted PAI resulting from air quality modeling (as described in [MEMS \(2010b\)](#)); 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.

Because the residual effects of the Project on surface aquatic resources from changes in acidifying emissions are assessed as *Insignificant* for both the LSA and RSA, these effects are not assessed for the PDC.

4.2 PLANNED DEVELOPMENT CASE

The Planned Development Case (PDC) is a cumulative effects assessment of the incremental effects of the Application Case 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.

As indicated in previous sections, all of the effects of the Project on surface aquatic resources (water quality, fish, and fish habitat) within the LSA are expected to be insignificant after the application of suitable mitigation measures. Therefore, the effects of the Project on these surface aquatic resources within the RSA are also expected to be insignificant.

The only planned development within the LSA that may cumulatively impact upon surface aquatic resources is the expansion of Highway 63. It is expected that the highway drainage for the expansion will be designed according to current guidelines and best management practices and the mitigation measures implemented will minimize impacts to water quality, surface water flow rates, fish habitat and fish movement.

4.3 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 24.

Table 24 Summary of significance of impacts 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 <i>Alberta Code of Practice for Watercourse Crossings</i> ; 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 Planned Development	Local	Long	Occasional	Reversible in short term No change expected from Application Case	Low	Negative	High	High	Insignificant
VEC 2	Changes to fish and fish habitat due to in-stream construction activities.	1) Watercourse crossings to comply with <i>Alberta Code of Practice for Watercourse Crossings</i> ; 2) Observe timing windows; and 3) Apart from watercourse crossings, avoid construction activities within 30m of stream bank.	Application Planned Development Case	Local	Long	Occasional	Reversible in short term No change expected from Application Case	Low	Negative	High	High	Insignificant
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; and 2) Handle and dispose of drilling waste and chemicals in accordance with management plans. 3) Comply with integrated Environmental Health and Safety Management Plan and contingency plans for responses to accidental releases.	Application Planned Development	Local	Long	Occasional to accidental	Reversible in short term No change expected from Application Case	Low to Moderate	Negative	High	Medium	Insignificant

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 Insignificant, Significant.

Table 24 (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	Application	Local	Long	Occasional to seasonal	Reversible in the long term	Low	Negative	High	High	Insignificant
		2) Phase reclamation activities prior to Project completion.	Planned Development	No change expected from Application Case	Long	Occasional	Reversible in short term	Low	Negative	High	Medium to High	Insignificant
		3) Return Project area to natural state when Project completed.	Planned Development				No change from Application Case					
VEC 2	Changes to fish health, including fish tainting	4) Discharge from storm water retention pond at a controlled rate in accordance with operating approval.	Planned Development									
		1) Sediment and erosion control mitigation measures as outlined in <i>Surface Disturbance and In-Stream Construction Activities</i> section above.	Application	Local	Long	Occasional to accidental	Reversible in short term	Low	Negative	High	Low	Insignificant
		2) Mitigation measures and management practices as outlined in <i>Changes in surface water quality</i> section above.	Planned Development				No change expected from Application Case					
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.	Application	Local	Long	Occasional	Reversible in short term	Low	Negative	High	High	Insignificant
		2) Educating the Project workforce on the benefits of the practice of catch-and-release angling; and	Planned Development				No change expected from Application Case					
		3) Discourage fishing by Project employees within the LSA										
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	Local and Regional	Long	Continuous	Reversible in long term	Low	Negative	Moderate	High	Insignificant
			Planned Development				No change expected from Application Case					

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 Insignificant, Significant.

4.4 ENVIRONMENTAL MONITORING

4.4.1 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. In particular, suspended sediments will be routinely monitored (upstream and downstream) during construction periods for all in-stream construction activities.

4.4.2 Effects Monitoring

Connacher 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 Great Divide Expansion 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 the EPEA approval.

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:



Peter McNamee
Project Director



Date

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Appendix A1

Field Work Activities and Methodology - Water Quality

A1.1 FIELD WORK ACTIVITIES AND METHODOLOGY - WATER QUALITY

Water quality sampling for analytical testing was conducted at both lakes and streams including eight sites in fall 2006; seven sites in winter 2007; 18 sites in spring and summer 2007 and 11 sites in fall 2007. *In situ* water quality testing was conducted at 11 sites in fall 2006; seven sites in winter 2007; 16 sites in spring 2007; 18 sites in summer 2007; 16 sites in fall 2007; 15 sites in spring 2008 and five sites in fall 2009.

RAMP Standard Operating Procedures (SOPs, RAMP [2005]) 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, and recapping at depth. Each bottle was triple-rinsed using this procedure prior to the final sample collection.

In situ measurements of pH, dissolved oxygen, temperature and conductivity were collected using an 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 metals (dissolved and total, including ultra-trace total mercury) analyzed by the Alberta Research Council (ARC) in Vegreville, Alberta. A field blank, trip blank, and field split 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](#) and are discussed in [Section A1.2](#). Results of analytical and *insitu* water quality testing are provided in [Appendix A2](#).

A1.2 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; RAMP 2005).

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.

A1.3 QUALITY CONTROL ANALYSIS RESULTS

A1.3.1 Field and Trip Blanks

Concentrations of water quality variables in the field and trip blanks are shown in [Table A1.1](#). A field blank and trip blank were collected during each of the five field trips in support of this Project. The results were:

- With the exception of some conductivity values, 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 fall 2006 season, the concentration of eight total and six dissolved metals exceeded five times their detection limit in the trip and/or field blank. These represent 25% and 19% of the total and dissolved, metals analyzed, respectively. In the winter 2007 season, the concentration of seven total and six dissolved metals exceeding five times their detection limit in the trip and/or field blank, representing 22% and 19% of the total and dissolved, metals analyzed, respectively. In the spring 2007 season, the concentration of eight total and five dissolved metals exceeding five times their detection limit in the trip and/or field blank, representing 25% and 16% of the total and dissolved, metals analyzed, respectively. In the summer 2007 season, the concentration of twelve total and nine

dissolved metals exceeding five times their detection limit in the trip and/or field blank, representing 38% and 29% of the total and dissolved, metals analyzed, respectively. In the fall 2007 season, the concentration of five total and five dissolved metals exceeding five times their detection limit in the trip and/or field blank, representing 16% and 16% of the total and dissolved, metals analyzed, respectively.

- In all seasons seasons, the major of the 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](#)).

A1.3.2 Field Split

Concentrations of water quality variables in the field split are shown in [Table A1.2](#). The relative percent difference in concentrations was less than 20% for all physical variables, nutrients, ions, and organics/hydrocarbons except total phosphorus in fall 2006, and total Kjeldahl nitrogen in spring 2007. For water quality variables with concentrations greater than five times the detection limit, the percent difference was greater than 20% in concentrations of seven total and four dissolved metals in fall 2006, eleven total and eight dissolved metals in winter 2007, five total and seven dissolved metals in spring 2007, eight total and ten dissolved metals in summer 2007, and four total and two dissolved metals in fall 2007. These represent 22% and 13%, 34% and 8%, 16% and 7%, 25% and 10%, 13% and 6%, of the total and dissolved metals analyzed for each season, respectively.

Table A1.1 Water quality QA/QC results: field and trip blanks.

Water Quality Variable	Unit	Detection Limit	September 2006	September 2006	February 2007	February 2007	May 2007	May 2007	July 2007	July 2007	August 2007	August 2007
			Trip Blank	Field Blank	Trip Blank	Field Blank	Trip Blank	Field Blank	Trip Blank	Field Blank	Trip Blank	Field Blank
Physical Variables, Nutrients, Ions, and Organics/Hydrocarbons												
Alkalinity, Total (as CaCO ₃)	mg/L	5	<5	<5	<5	5	<5	<5	<5	<5	<5	<5
Ammonia-N	mg/L	0.05	<0.05	<0.05	<0.05	0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Bicarbonate (HCO ₃)	mg/L	5	<5	<5	<5	5	<5	<5	<5	<5	<5	<5
Biochemical Oxygen Demand	mg/L	2	<2	<2	<2	2	<2	<2	<2	<2	<2	<2
Calcium (Ca)	mg/L	0.5	<0.5	<0.5	<0.5	0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Carbonate (CO ₃)	mg/L	5	<5	<5	<5	5	<5	<5	<5	<5	<5	<5
Chloride (Cl)	mg/L	1	<1	<1	<1	1	1	1	<1	<1	<1	<1
Color, True	T.C.U.	2.5	<2.5	<2.5	<2	<2.5	2	<2	<2	<2	<2	<2
Conductivity (EC)	µS/cm	0.2	0.9	1.1	1.1	0.2	1.3	0.9	1	1	1.4	1.2
Dissolved Organic Carbon	mg/L	1	<1	1	<1	1	<1	<1	<1	2	<1	<1
Hardness (as CaCO ₃)	mg/L		<1	<1	<1	na	<1	<1	<1	<1	<1	<1
Hydrocarbons, Recoverable (I.R.)	mg/L	1	<1	<1	<1	1	<1	<1	<1	<1	<1	<1
Hydroxide (OH)	mg/L	5	<5	<5	<5	5	<5	<5	<5	<5	<5	<5
Magnesium (Mg)	mg/L	0.1	<0.1	<0.1	<0.1	0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Naphthenic Acids	mg/L	1	<1	<1	<1	1	<1	<1	<1	<1	<1	<1
Nitrate+Nitrite-N	mg/L	0.1	<0.1	<0.1	<0.1	0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Phenols (4AAP)	mg/L	0.001	<0.001	<0.001	<0.002	0.002	<0.001	0.006	<0.001	<0.001	<0.001	<0.001
Phosphorus, Total	mg/L	0.001	0.001	<0.001	0.001	0.001	0.001	0.001	<0.001	<0.001	0.001	0.001
Phosphorus, Total Dissolved	mg/L	0.001	<0.001	<0.001	0.001	0.001	<0.001	<0.001	<0.001	<0.001	0.001	0.001
Potassium (K)	mg/L	0.5	<0.5	<0.5	<0.5	0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Sodium (Na)	mg/L	1	<1	<1	<1	1	<1	<1	<1	<1	<1	<1
Sulfate (SO ₄)	mg/L	0.5	0.7	<0.5	<0.5	0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Sulphide	mg/L	0.003	<0.003	<0.003	<0.003	0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003
Total Dissolved Solids	mg/L	10	10	<10	<10	10	<5	5	<5	<5	<5	<5
Total Kjeldahl Nitrogen	mg/L	0.2	<0.2	<0.2	<0.2	0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Total Organic Carbon	mg/L	1	<1	3	<1	1	2	1	<1	<1	<1	<1
Total Suspended Solids	mg/L	3	<3	<3	<3	3	<3	<3	<3	<3	<3	<3
Total Metals												
Aluminum	µg/L	2.0	2	<2	<2	<2	2	<2	<2	<2	<2	<2
Antimony	µg/L	0.001	0.0027	0.0058	0.0037	<0.001	0.0036	0.0015	0.0046	0.0015	0.0037	0.0015
Arsenic	µg/L	0.04	<0.04	<0.04	0.04	<0.04	<0.04	<0.04	0.04	<0.04	<0.04	<0.04
Barium	µg/L	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Beryllium	µg/L	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Bismuth	µg/L	0.01	<0.01	0.01	<0.01	<0.01	<0.01	<0.01	0.0163	<0.01	<0.01	<0.01
Boron	µg/L	0.8	0.8	0.8	0.8	0.8	0.8	<0.8	0.8	<0.8	0.8	0.8
Cadmium	µg/L	0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006
Calcium	mg/L	0.1	<0.1	0.1	0.1	0.1	0.1	<0.1	0.1	<0.1	<0.1	<0.1
Chlorine	mg/L	0.3	0.3	<0.3	<0.3	<0.3	<0.3	0.342	<0.3	<0.3	<0.3	<0.3
Chromium	µg/L	0.3	0.3	<0.3	<0.3	<0.3	<0.3	0.3	0.3	<0.3	<0.3	<0.3
Cobalt	µg/L	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.01	<0.01	0.01	<0.01	<0.01
Copper	µg/L	0.1	0.529	0.146	<0.1	<0.1	<0.1	0.1	0.348	0.1	<0.1	<0.1
Iron	µg/L	4	<4	<4	<4	<4	<4	<4	<4	<4	<4	<4
Lead	µg/L	0.006	0.0325	0.0087	0.0104	0.0165	0.0075	0.006	0.0302	0.006	<0.006	0.006
Lithium	µg/L	0.2	<0.2	0.2	<0.2	<0.2	0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Manganese	µg/L	0.03	0.03	0.0318	<0.03	0.03	0.0329	0.03	0.03	0.03	0.0763	0.0834
Mercury	µg/L	0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Ultra-Trace Mercury	ng/L	1.2	<1.2	1.2	1.2	<1.2	<1.2	1.4	<1.2	1.4	<1.2	<1.2
Molybdenum	µg/L	0.008	0.0082	0.0152	<0.008	<0.008	<0.008	0.0105	0.008	0.0105	<0.008	<0.008
Nickel	µg/L	0.06	0.196	0.06	<0.06	0.06	<0.06	0.06	0.06	0.06	<0.06	<0.06
Selenium	µg/L	0.2	<0.2	<0.2	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3
Silver	µg/L	0.005	<0.005	<0.005	0.005	0.005	<0.005	<0.005	<0.005	<0.005	0.005	0.005
Strontium	µg/L	0.008	0.008	0.0157	0.0569	0.186	0.0399	0.008	0.122	0.008	0.01	0.027
Sulphur	mg/L	0.6	<0.6	<0.6	<0.6	<0.6	<0.6	<0.6	<0.6	<0.6	0.6	0.6
Thallium	µg/L	0.003	0.003	0.003	<0.003	<0.003	<0.003	<0.003	0.003	<0.003	<0.003	<0.003
Thorium	µg/L	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.0401	0.03	<0.03	<0.03
Tin	µg/L	0.07	<0.07	<0.07	0.07	0.07	<0.07	0.07	0.103	0.07	<0.07	<0.07
Titanium	µg/L	0.07	0.145	0.13	0.131	0.107	0.399	0.191	0.199	0.191	<0.07	<0.07
Uranium	µg/L	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.00699	<0.003
Vanadium	µg/L	0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	0.05	<0.05	<0.05	<0.05
Zinc	µg/L	0.2	0.3	0.43	0.464	0.375	0.338	0.377	0.381	0.377	0.281	0.306
Dissolved Metals												
Aluminum	µg/L	1	<1	<1	<1	1	<1	<1	<1	<1	<1	<1
Antimony	µg/L	0.001	0.0027	0.0058	0.0037	<0.001	0.00354	0.00147	0.0046	0.00147	0.00361	0.00148
Arsenic	µg/L	0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	0.04	<0.04	<0.04	<0.04
Barium	µg/L	0.1	0.1	0.1	0.1	0.1	0.1	<0.1	0.1	<0.1	<0.1	<0.1
Beryllium	µg/L	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Bismuth	µg/L	0.01	<0.01	0.01	<0.01	<0.01	<0.01	<0.01	0.0161	<0.01	<0.01	<0.01
Boron	µg/L	0.8	0.8	0.8	0.8	0.8	0.8	<0.8	0.8	<0.8	0.8	0.8
Cadmium	µg/L	0.006	<0.006	<0.006	<0.006	<0.006	0.1	<0.1	0.1	<0.1	<0.1	<0.1
Calcium	mg/L	0.1	<0.1	0.1	0.1	0.1	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006
Chlorine	mg/L	0.3	0.3	<0.3	<0.3	<0.3	<0.3	<0.3	0.3	<0.3	<0.3	<0.3
Chromium	µg/L	0.3	0.3	<0.3	<0.3	<0.3	<0.3	<0.3	0.3	<0.3	0.3	<0.3
Cobalt	µg/L	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.01	<0.01	<0.01	<0.01
Copper	µg/L	0.1	<0.1	0.1	<0.1	<0.1	<0.1	<0.1	0.182	<0.1	<0.1	<0.1
Iron	µg/L	4	<4	<4	<4	<4	<4	<4	<4	<4	<4	<4
Lead	µg/L	0.006	0.006	0.006	0.006	0.0163	0.006	<0.006	0.0258	<0.006	<0.006	<0.006
Lithium	µg/L	0.2	<0.2	0.2	<0.2	<0.2	0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Manganese	µg/L	0.03	0.03	0.03	<0.03	0.03	0.03	0.03	0.03	0.03	0.0716	0.059
Mercury	µg/L	0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Molybdenum	µg/L	0.008	<0.008	0.008	<0.008	<0.008	<0.008	0.008	0.008	0.008	<0.008	<0.008
Nickel	µg/L	0.06	0.06	<0.06	<0.06	<0.06	<0.06	<0.06	0.06	<0.06	0.06	<0.06
Selenium	µg/L	0.2	<0.2	<0.2	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3
Silver	µg/L	0.005	<0.005	<0.005	0.005	0.005	<0.005	<0.005	<0.005	<0.005	<0.005	0.005
Strontium	µg/L	0.008										

Table A1.2 Water quality QA/QC results: field splits.

Water Quality Variable	Units	Detection Limit	Fall 2006			Winter 2007			Spring 2007			Summer 2007			Fall 2007		
			C01	Split for C01	Relative Percent Difference	C02	Split for C02	Relative Percent Difference	C01	Split for C01	Relative Percent Difference	C09	Split for C09	Relative Percent Difference	C01	Split for C01	Relative Percent Difference
Physical Variables, Nutrients, Ions, and Organics/Hydrocarbons																	
Alkalinity, Total (as CaCO ₃)	mg/L	5	10	11	9.5	26	25	3.9	<5	<5	-	21	20	4.9	<5	<5	-
Ammonia-N	mg/L	0.05	<0.05	<0.05	-	0.32	0.33	3.1	0.05	<0.05	-	<0.05	<0.05	-	<0.05	<0.05	-
Bicarbonate (HCO ₃)	mg/L	5	13	14	7.4	31	31	0.0	<5	<5	-	26	25	3.9	<5	<5	-
Biochemical Oxygen Demand	mg/L	2	<2	<2	-	<2	<2	-	2	2	0.0	3	<2	-	2	2	0.0
Calcium (Ca)	mg/L	0.5	5.8	6.9	17.3	7.7	7.5	2.6	2.5	2.3	8.3	6.2	6.2	0.0	3.1	3.2	3.2
Carbonate (CO ₃)	mg/L	5	<5	<5	-	<5	<5	-	<5	<5	-	<5	<5	-	<5	<5	-
Chloride (Cl)	mg/L	1	2	2	0.0	2	1	66.7	2	2	0.0	2	2	0.0	2	2	0.0
Color, True	T.C.U.	2.5	150	150	0.0	130	130	0.0	200	200	0.0	230	230	0.0	250	250	0.0
Conductivity (EC)	µS/cm	0.2	36	36.1	0.3	60.9	59.8	1.8	17.9	17.6	1.7	39.2	39.3	0.3	20.8	20.8	0.0
Dissolved Organic Carbon	mg/L	1	32	30	6.5	27	24	11.8	24	25	4.1	29	30	3.4	28	28	0.0
Hardness (as CaCO ₃)	mg/L	1	22	26	16.7	30	29	3.4	8	8	0.0	20	20	0.0	11	11	0.0
Hydrocarbons, Recoverable (I.R.)	mg/L	1	<1	<1	-	<1	<1	-	<1	<1	-	<1	<1	-	<1	<1	-
Hydroxide (OH)	mg/L	5	<5	<5	-	<5	<5	-	<5	<5	-	<5	<5	-	<5	<5	-
Magnesium (Mg)	mg/L	0.1	1.8	2.1	15.4	2.6	2.6	0.0	0.5	0.5	0.0	1.1	1.2	8.7	0.8	0.8	0.0
Naphthenic Acids	mg/L	1	<1	<1	-	<1	<1	-	<1	<1	-	<1	<1	-	<1	<1	-
Nitrate+Nitrite-N	mg/L	0.1	<0.1	<0.1	-	<0.1	<0.1	-	<0.1	<0.1	-	<0.1	<0.1	-	<0.1	<0.1	-
pH	pH	0.1	6.9	7	1.4	7	7	0.0	5.9	5.7	3.4	7.1	7.1	0.0	5.9	5.9	0.0
Phenols (4AAP)	mg/L	0.001	<0.001	<0.001	-	0.021	0.022	4.7	<0.001	<0.001	-	0.015	0.015	0.0	0.021	0.019	10.0
Phosphorus, Total	mg/L	0.001	0.023	0.017	30.0	0.018	0.017	5.7	0.033	0.039	16.7	0.033	0.033	0.0	0.096	0.098	2.1
Phosphorus, Total Dissolved	mg/L	0.001	0.011	0.012	8.7	0.007	0.007	0.0	0.01	0.011	9.5	0.018	0.018	0.0	0.049	0.048	2.1
Potassium (K)	mg/L	0.5	<0.5	<0.5	-	0.9	1.1	20.0	0.8	0.8	0.0	<0.5	<0.5	-	0.9	0.9	0.0
Sodium (Na)	mg/L	1	<1	<1	-	2	1	66.7	<1	<1	-	<1	<1	-	<1	<1	-
Sulfate (SO ₄)	mg/L	0.5	1.5	2.2	37.8	1.5	1.6	6.5	1.1	1	9.5	1.9	2	5.1	1.3	1.3	0.0
Sulphide	mg/L	0.003	0.003	0.005	50.0	0.008	0.01	22.2	0.004	0.004	0.0	0.016	0.017	6.1	0.01	0.01	0.0
Total Dissolved Solids	mg/L	10	70	70	0.0	70	70	0.0	65	59	9.7	60	73	19.5	61	63	3.2
Total Kjeldahl Nitrogen	mg/L	0.2	0.8	0.9	11.8	1.2	1.2	0.0	1.1	0.7	44.4	0.8	0.8	0.0	0.9	0.9	0.0
Total Organic Carbon	mg/L	1	33	34	3.0	28	25	11.3	26	26	0.0	30	30	0.0	27	29	7.1
Total Suspended Solids	mg/L	3	<3	<3	-	<3	<3	-	9	8	11.8	3	3	0.0	4	<3	-
Total Metals																	
Aluminum	µg/L	2	131	132	0.8	83.9	85.6	2.0	160	158	1.3	124	126	1.6	161	161	0.0
Antimony	µg/L	0.001	0.0146	0.0142	2.8	0.0372	0.0299	21.8	0.0152	0.016	5.1	0.0155	0.0462	99.5	0.013	0.0136	4.5
Arsenic	µg/L	0.04	0.535	0.551	2.9	0.516	0.539	4.4	0.338	0.336	0.6	0.898	0.873	2.8	0.446	0.443	0.7
Barium	µg/L	0.1	12.3	12.4	0.8	29.9	30.1	0.7	7.7	8.02	4.1	14.6	15	2.7	9.02	9.1	0.9
Beryllium	µg/L	0.01	0.01	0.0161	46.7	0.01	0.015	40.0	0.01	0.0132	27.6	0.0115	0.0143	21.7	0.0107	0.01	6.8
Bismuth	µg/L	0.01	0.01	0.01	0.0	0.01	0.01	0.0	0.01	0.01	0.0	0.0142	0.01	34.7	<0.01	<0.01	-
Boron	µg/L	0.8	4.87	5.31	8.6	14	14.9	6.2	6.94	6.21	11.1	6.42	6.23	3.0	3.94	4.21	6.6
Cadmium	µg/L	0.006	0.0101	0.0078	25.7	0.006	0.0115	62.9	<0.006	<0.006	-	0.011	0.0106	3.7	0.0202	0.0171	16.6
Calcium	mg/L	0.1	5.78	5.9	2.1	8.96	8.95	0.1	2.33	2.39	2.5	6.51	6.63	1.8	2.86	2.82	1.4
Chlorine	mg/L	0.3	0.31	0.502	47.3	0.3	0.456	41.3	<0.3	<0.3	-	<0.3	<0.3	-	<0.3	<0.3	-
Chromium	µg/L	0.3	0.3	0.324	7.7	0.3	0.3	0.0	0.3	0.3	0.0	0.357	0.335	6.4	0.3	0.3	0.0
Cobalt	µg/L	0.01	0.274	0.294	7.0	0.0975	0.0934	4.3	0.178	0.173	2.8	0.317	0.331	4.3	0.206	0.205	0.5
Copper	µg/L	0.1	0.141	0.152	7.5	0.187	0.393	71.0	0.185	0.173	6.7	0.141	0.164	137.7	0.228	0.268	16.1
Iron	µg/L	4	693	708	2.1	603	599	0.7	353	351	0.6	1000	1080	7.7	498	501	0.6
Lead	µg/L	0.006	0.0714	0.0768	7.3	0.082	0.0768	6.5	0.157	0.112	33.5	0.0637	4.93	194.9	0.193	0.157	20.6
Lithium	µg/L	0.2	1.39	1.58	12.8	2.27	2.04	10.7	0.781	0.754	3.5	0.994	0.836	17.3	<0.2	<0.2	-
Manganese	µg/L	0.03	33.2	33.8	1.8	78.9	78	1.1	31.6	31.6	0.0	31	32.3	4.1	27.1	27.2	0.4
Mercury	µg/L	0.05	<0.05	<0.05	-	<0.05	<0.05	-	<0.05	<0.05	-	<0.05	<0.05	-	<0.05	<0.05	-
Ultra-Trace Mercury	ng/L	1.2	4	1.9	71.2	1.2	1.7	0.3	2.8	3.1	10.2	3.6	2.1	52.6	3.1	2.8	10.2
Molybdenum	µg/L	0.008	0.0907	0.0953	4.9	0.139	0.135	16.8	0.124	0.125	0.8	0.0904	0.0926	2.4	0.139	0.118	16.3
Nickel	µg/L	0.06	0.74	0.727	1.8	0.228	0.205	10.6	0.429	0.489	13.1	0.774	0.804	3.8	0.694	0.662	4.7
Selenium	µg/L	0.2	0.2	<0.2	-	<0.2	0.3	-	0.2	0.3	40.0	0.3	0.3	0.0	0.2	0.2	0.0
Silver	µg/L	0.005	0.005	0.005	0.0	0.005	0.005	0.0	0.005	0.005	0.0	0.005	<0.005	-	0.005	0.005	0.0
Strontium	µg/L	0.008	16.2	16.1	0.6	39.7	39.3	1.0	9.21	9.2	0.1	24.7	25.9	4.7	12	12	0.0
Sulphur	mg/L	0.6	<0.6	<0.6	-	0.789	1.03	26.5	0.622	0.73	16.0	<0.6	<0.6	-	<0.6	<0.6	-
Thallium	µg/L	0.003	0.0071	0.0064	10.4	0.0035	0.0036	2.8	0.003	0.003	0.0	0.0074	0.0057	26.0	0.0064	0.0068	6.1
Thorium	µg/L	0.03	0.03	0.03	0.0	0.03	0.03	0.0	0.03	0.03	0.0	0.0564	0.03	61.1	<0.03	<0.03	-
Tin	µg/L	0.07	<0.07	<0.07	-	<0.07	0.07	-	<0.07	<0.07	-	<0.07	0.07	-	0.356	<0.07	-
Titanium	µg/L	0.07	1.15	1.28	10.7	0.722	0.761	5.3	1.9	1.7	11.1	2.06	1.94	6.0	1.6	1.57	1.9
Uranium	µg/L	0.003	0.0173	0.0178	2.8	0.0198	0.0198	0.0	0.02	0.0207	3.4	0.0142	0.015	5.5	0.0228	0.0223	2.2
Vanadium	µg/L	0.05	0.32	0.303	5.5	0.191	0.184	3.7	0.755	0.742	1.7	0.397	0.383	3.6	0.414	0.413	0.2
Zinc	µg/L	0.2	11.7	3.65	104.9	3.4	6.37	60.8	5.1	7.37	36.4	4.04	5.74	34.8	6.81	5.49	21.5
Dissolved Metals																	
Aluminum	µg/L	1	108	110	1.8	82.1	75.8	8.0	132	132	0.0	91.1	95.1	4.3	143	141	1.4
Antimony	µg/L	0.001	0.0146	0.0142	2.8	0.0368	0.0296	21.7	0.015	0.0158	5.2	0.0153	0.0457	99.7	0.0129	0.0135	4.5
Arsenic	µg/L	0.04	0.452	0.478	5.6	0.488	0.499	2.2	0.296	0.273	8.1	0.784	0.767	2.2	0.391	0.412	5.2
Barium	µg/L	0.1	11.3	11.2	0.9	27.2	27.7	1.8	7.2	7.25	0.7	13.5	13.3	1.5	8.23	8.27	0.5
Beryllium	µg/L	0.01	0.01	0.01	0.0	0.01	0.01	0.0	0.01	0.0119	17.4	0.0114	0.0113	0.9	0.0106	0.01	5.8
Bismuth	µg/L	0.01	0.01	0.01	0.0	0.01	0.01	0.0	0.01	0.01	0.0	0.0141	0.01	34.0	<		

Appendix A2

Surface Water Quality Data

Table A2.1 Sources of water quality guidelines used in this report.

Notation in Water Quality Tables	Description/Explanation
1	Alberta Environment Guidelines for the Protection of Freshwater Aquatic Life (1999), unless otherwise specified.
a	at pH ≥ 6.5 ; Hardness $\geq 4\text{mg/L}$; DOC $\geq 2\text{mg/L}$ (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 $10^{(0.86 \cdot \text{LOG}(\text{Hardness}) - 3.2)}$ (CCME 2007).
f	Set to US Environmental Protection Agency continuous 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). Most stringent guideline (0.001 mg/L) is used.
h	BC working water quality guidelines (BC MOE 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 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 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.
o	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."
p	BC approved water quality guideline (BC MOE 2006).
q	BC Acute guideline is hardness-dependent: 0.8mg/L at hardness= 0 to 25mg/L; 1.1mg/L at hardness= 25 to 50mg/L;1.6mg/L at hardness= 50 to 100mg/L;2.2mg/L at hardness= 100 to 150mg/L;3.8mg/L at hardness= 150 to 300mg/L (BC MOE 2006).
r	Guideline is for chronic total (organic and inorganic) phosphorus (AENV 1999).
s	US Environmental Protection Agency continuous concentration guideline (as H ₂ S). (USEPA 1999).
t	AENV (1999) acute and chronic guideline for suspended solids states: "Not to be increased by more than 10 mg/L over background value."
u	US Environmental Protection Agency continuous concentration guideline. (USEPA 1999).

Table A2.2 Water quality data for lakes by season.

Water Quality Variable	Units	Guideline ¹	Conversion	Detection Limit	Fall 2006				Winter 2007				Spring 2007					Summer 2007					Fall 2007	
					C01	C02	C03	C05	C02	C03	C04	C05	C01	C02	C03	C04	C05	C01	C02	C03	C04	C05	C01	
					Sep-06	Sep-06	Sep-06	Sep-06	Feb-07	Feb-07	Feb-07	Feb-07	May-07	May-07	May-07	May-07	May-07	Jul-07	Jul-07	Jul-07	Jul-07	Jul-07	Aug-07	
Alkalinity, Total (as CaCO ₃)	mg/L	20 ^a	1000000	5	10	11	10	24	26	17	16	35	<5	11	8	6	16	<5	16	9	12	22	<5	
Ammonia-N	mg/L	1.37 ^b	1.37	0.05	<0.05	<0.05	<0.05	<0.05	0.32	0.33	0.4	0.12	0.05	<0.05	<0.05	<0.05	0.06	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	
Bicarbonate (HCO ₃)	mg/L	-	1000000	5	13	14	13	30	31	21	19	43	<5	13	10	8	20	<5	20	11	15	27	<5	
Biochemical Oxygen Demand	mg/L	-	1000000	2	<2	<2	<2	<2	<2	<2	2	<2	2	<2	3	<2	<2	3	<2	4	<2	<2	2	
Calcium (Ca)	mg/L	-	1000000	0.5	5.8	5	5.2	7.1	7.7	7.4	7.6	11.2	2.5	3.9	3.2	3.6	5.1	1.8	4	3.8	3.7	5.5	3.1	
Carbonate (CO ₃)	mg/L	-	1000000	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 ^d	230	1	2	1	2	1	2	2	2	1	2	1	2	2	2	2	<1	<1	2	1	2	
Chlorophyll a	ug/L	-	1000000	1	7	5	11	5										18	2	29	3	2		
Color, True	T.C.U.	-	1000000	2.5	150	50	125	70	130	290	310	150	200	87	150	150	100	220	70	150	190	80	250	
Conductivity (EC)	µS/cm	-	1000000	0.2	36	35.2	31.1	51.5	60.9	52	52.9	78.6	17.9	30.1	24.5	24	38.5	22	33.3	27.5	28.3	45.1	20.8	
Dissolved Organic Carbon	mg/L	-	1000000	1	32	19	17	16	27	32	39	29	24	16	19	22	20	23	17	18	24	17	28	
Dissolved oxygen (in situ)	mg/L	5 ⁱ	5		10.33	11	8.4	8.4	6.55	5.9	0.69	6.59	9.8	8.4	9.6	8.8	9.11	6.2	6.3	7.1	7.01	7.2	7.5	
Hardness (as CaCO ₃)	mg/L	-	1000000		22	21	20	30	30	28	28	44	8	15	13	14	20	4	14	14	11	20	11	
Hydrocarbons, Recoverable (I.R.)	mg/L	-	1000000	1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	
Hydroxide (OH)	mg/L	-	1000000	5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	
Magnesium (Mg)	mg/L	-	1000000	0.1	1.8	2	1.6	2.9	2.6	2.2	2.2	4	0.5	1.3	1.2	1.2	1.8	<0.1	0.9	1.2	0.5	1.5	0.8	
Naphthenic Acids	mg/L	-	1000000	1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	
Nitrate+Nitrite-N	mg/L	ⁿ	13.06	0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.1	0.7	1	<0.1	<0.1	<0.1	<0.1	<0.1	0.2	<0.1	<0.1	<0.1	0.3	<0.1	
pH	pH	6.5-9.0 ^o	1000000	0.1	6.9	7.2	7	7.7	7	6.8	6	7.1	5.9	7.1	6.9	6.7	7.2	6.4	7.1	6.8	6.9	7.5	5.9	
Phenols (4AAP)	mg/L	0.05 ^c	0.05	0.001	<0.001	<0.001	<0.001	<0.001	0.021	0.026	0.037	0.021	<0.001	<0.001	0.012	<0.001	<0.001	0.011	0.01	0.01	0.018	0.01	0.021	
Phosphorus, Total	mg/L	0.05 ^e	0.05	0.001	0.023	0.013	0.044	0.015	0.018	0.051	0.081	0.025	0.033	0.012	0.027	0.014	0.018	0.055	0.018	0.046	0.024	0.017	0.096	
Potassium (K)	mg/L	-	-	-	<0.5	1	1	0.8	0.9	<0.5	<0.5	0.9	0.8	0.7	0.8	0.7	0.8	1	1.5	0.9	0.8	0.9	0.9	
Sodium (Na)	mg/L	-	1000000	1	<1	1	1	1	2	1	2	1	<1	<1	<1	<1	<1	<1	<1	<1	<1	1	<1	
Sulfate (SO ₄)	mg/L	100 ^p	100	0.5	1.5	2.1	2	1	1.5	1	1.7	1.9	1.1	<0.5	1.2	<0.5	<0.5	2.4	5.7	1.3	1.9	2.7	1.3	
Sulphide	mg/L	0.014 ^s	0.014	0.003	0.003	0.004	0.008	0.004	0.008	0.007	0.023	0.011	0.004	<0.003	<0.003	<0.003	<0.003	0.01	<0.003	0.005	0.009	0.01	0.01	
Temperature (in situ)	°C	-	1000000		8.17	8.8	7.86	8	1.15	1.03	1.04	2.5	16.81	15.73	18.3	16.24	14.43	22.3	22.8	23.1	23.2	23.6	12.8	
Total Dissolved Solids	mg/L	-	1000000	10	70	60	40	40	70	80	90	80	65	45	50	62	57	23	25	28	62	36	61	
Total Kjeldahl Nitrogen	mg/L	1	1.0	0.2	0.8	0.6	0.7	0.7	1.2	1.2	1.2	1	1.1	0.5	0.8	0.8	0.5	0.9	0.6	1.2	0.6	0.6	0.9	
Total Organic Carbon	mg/L	-	1000000	1	33	19	21	17	28	32	40	29	26	20	20	23	18	23	17	18	25	19	27	
Total Suspended Solids	mg/L	+10 mg/L ^t	1000	3	<3	<3	<3	<3	<3	<3	<3	<3	9	<3	3	3	3	3	<3	7	3	<3	4	
Turbidity (in situ)	NTU	-	1000000										2.44	1.32	3.56	1.05	1.11			1.06	1.4			
Total Metals																								
Aluminum	mg/L	0.1 ^a	0.1	0.002	0.131	0.0649	0.0714	0.0344	0.0839	0.136	0.149	0.0725	0.16	0.0906	0.088	0.111	0.048	0.148	0.0615	0.102	0.103	0.0311	0.161	
Antimony	mg/L	0.02 ^h	1000000	0.000001	0.0000146	0.0000159	0.0000148	0.0000155	0.0000372	0.0000236	0.0000249	0.0000983	0.0000152	0.000017	0.0000133	0.0000108	0.0000137	0.0000272	0.0000187	0.000016	0.0000146	0.0000139	0.000013	
Arsenic	mg/L	0.005 ^c	0.005	0.00004	0.000535	0.000357	0.000556	0.00085	0.000516	0.000839	0.000707	0.00101	0.000338	0.000286	0.000367	0.000324	0.000541	0.000464	0.000359	0.000511	0.000426	0.000581	0.000446	
Barium	mg/L	5 ^h	5	0.0001	0.0123	0.0156	0.0124	0.0117	0.0299	0.0203	0.0165	0.0219	0.0077	0.0122	0.00879	0.00635	0.00807	0.0085	0.0148	0.0108	0.00927	0.00926	0.00902	
Beryllium	mg/L	0.0053 ^h	0.0053	0.00001	0.00001	0.00001	0.00001	0.00001	0.00001	0.0000129	0.0000128	0.0000176	0.00001	0.00001	0.00001	0.0000184	0.00001	0.00001	0.00001	0.000011	0.00001	<0.00001	0.0000107	
Bismuth	mg/L	-	1000000	0.00001	0.00001	0.00001	0.00001	0.00001	0.00001	0.00001	0.0000148	0.00001	0.00001	0.00001	0.00001	0.00001	0.00001	0.00001	0.00001	0.00001	0.00001	<0.00001	0.0000107	
Boron	mg/L	1.2 ^d	1.2	0.0008	0.00487	0.0101	0.00723	0.0101	0.014	0.0105	0.00371	0.0126	0.00694	0.00677	0.00639	0.00567	0.00929	0.00888	0.00743	0.00835	0.00492	0.00839	0.00394	
Cadmium	mg/L	^e	0.000006		0.0000101	0.000006	0.000006	<0.000006	0.000006	0.0000067	0.0000211	0.0000349	<0.000006	<0.000006	<0.000006	0.0000062	<0.000006	0.0000197	0.000006	0.0000095	0.0000233	0.000006	0.0000202	
Calcium	mg/L	-	1000000	0.1	5.78	4.37	4.49	8.08	8.96	8.42	8.18	12.2	2.33	3.92	3.37	3.61	5.27	2.29	3.82	3.54	4.08	5.35	2.86	
Chlorine	mg/L	-	1000000	0.3	0.31	0.567	0.389	0.3	0.3	0.3	<0.3	<0.3	<0.3	0.94	<0.3	<0.3	<0.3	0.303	0.692	0.672	<0.3	<0.3	<0.3	
Chromium	mg/L	0.001 ^g	0.0	0.0003	0.0003	0.0003	0.000323	0.0003	0.0003	0.0003	0.000374	0.000328	0.0003	0.0003	0.000374	0.0003	0.0003	0.000304	0.0003	0.0003	0.0003	0.0003	0.0003	
Cobalt	mg/L	0.0009 ^g	0.0009	0.00001	0.000274	0.0000288	0.000213	0.0000942	0.0000975	0.000718	0.00108	0.000648	0.000178	0.0000383	0.000107	0.0000958	0.0000731	0.000235	0.0000414	0.000199	0.000221	0.000106	0.000206	
Copper	mg/L	ⁱ		0.0001	0.000141	0.00015	0.000184	0.0001	0.000187	0.000731	0.000275	0.000633	0.000185	0.000147	0.000115	0.0001	0.000103	0.000266	0.000143	0.000194	0.000205	0.000118	0.000228	
Iron	mg/L	0.3	0.3	0.04	0.693	0.107	0.609	0.334	0.603	1.64	2.32													

Table A2.3 Water quality data for streams by season.

Water Quality Variable	Units	Guideline ¹	Conversion	Detection Limit	Fall 2006				Winter 2007				Spring 2007												
					C06	C07	C08	C09	C07	C08	C10	C11	C06	C07	C09	C10	C12	C13	C15	C16	C17	C18	C20	C21	C22
					Sep-06	Sep-06	Sep-06	Sep-06	Feb-07	Feb-07	Feb-07	Feb-07	May-07	May-07	May-07	May-07	May-07	May-07	May-07	May-07	May-07	May-07	May-07	May-07	May-07
Alkalinity, Total (as CaCO ₃)	mg/L	20 ^a	1000000	5	8	12	9	8	22	29		83	9	7	9	22	7	21	44	37	37	6	25	32	103
Ammonia-N	mg/L	1.37 ^b	1.37	0.05	<0.05	<0.05	<0.05	<0.05	0.26	0.25		0.2	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	0.08	<0.05	<0.05	<0.05	<0.05	<0.05
Bicarbonate (HCO ₃)	mg/L	-	1000000	5	10	14	11	10	27	35		101	11	9	11	26	9	26	53	45	45	7	31	39	125
Biochemical Oxygen Demand	mg/L	-	1000000	2	<2	<2	<2	<2	<2	<2		<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	4	<2	
Calcium (Ca)	mg/L	-	1000000	0.5	4.4	6.6	6.6	6.1	7.5	9		23.6	3.9	4	4.6	7.7	3.9	7.4	13.8	11.8	11.4	3.9	7.7	10.6	28.8
Carbonate (CO ₃)	mg/L	-	1000000	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 ^d	230	1	2	3	3	3	2	2		1	<1	2	1	2	2	2	2	2	2	2	3	5	
Chlorophyll <i>a</i>	ug/L	-	1000000	1																					
Color, True	T.C.U.	-	1000000	2.5	120	175	200	200	290	280		170	120	190	170	160	230	160	230	230	140	190	140	210	88
Conductivity (EC)	µS/cm	-	1000000	0.2	30.2	37.1	37.1	32.5	53.7	63.9		163	27.1	25.4	27.4	47.4	26.2	47.7	85.2	72.3	73	24.7	50.9	68.6	209
Dissolved Organic Carbon	mg/L	-	1000000	1	23	32	46	35	33	31		23	21	28	23	26	24	29	25	25	21	24	24	31	17
Dissolved oxygen (in situ)	mg/L	5 ^f	5		5.6	6.2	4.4	6.8	0.7	3.98	1.92	6.17	6.12	6.8	8.6	6.11	4.5	5.96	7.44	7.58	7.81	6.4	6.4	7.2	7.2
Hardness (as CaCO ₃)	mg/L	200 ^r	1000000		18	25	24	23	28	35		87	15	15	14	29	14	28	48	41	39	14	29	37	104
Hydrocarbons, Recoverable (I.R.)	mg/L	-	1000000	1	<1		<1	<1	<1	<1		<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	
Hydroxide (OH)	mg/L	-	1000000	5	<5	<5	<5	<5	<5	<5		<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	
Magnesium (Mg)	mg/L	-	1000000	0.1	1.6	2.1	1.9	1.8	2.3	3		6.8	1.3	1.2	0.6	2.4	1.1	2.4	3.4	2.9	2.5	1.1	2.3	2.6	7.8
Naphthenic Acids	mg/L	-	1000000	1	<1	<1	<1	<1	<1	<1		<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	
Nitrate+Nitrite-N	mg/L	ⁿ	13.06	0.1	<0.1	<0.1	<0.1	<0.1	0.8	0.7		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	
pH	pH	6.5-9.0 ^o	1000000	0.1	6.8	6.7	6.2	6.4	6.4	6.5		7.4	6.6	6.5	6.8	7.2	6.3	7.5	7.5	7.3	6.3	7.3	7.2	8.1	
Phenols (4AAP)	mg/L	0.05 ^c	0.05	0.001	<0.001	<0.001	<0.001	<0.001	0.03	0.029		0.019	<0.001	<0.001	<0.001	0.008	0.013	0.011	<0.001	<0.001	<0.001	<0.001	0.007	0.012	0.006
Phosphorus, Total	mg/L	0.05 ^e	0.05	0.001	0.015	0.042	0.05	0.022	0.077	0.087		0.092	0.012	0.033	0.026	0.012	0.047	0.019	0.076	0.065	0.042	0.026	0.026	0.5	0.128
Potassium (K)	mg/L	-	-	-	0.7	0.7	<0.5	<0.5	0.6	<0.5		0.7	0.5	0.6	1.3	<0.5	0.6	<0.5	0.6	0.6	0.9	0.7	1	1.2	1.6
Sodium (Na)	mg/L	-	1000000	1	<1	1	<1	1	1	1		6	<1	<1	1	<1	<1	1	2	1	2	<1	1	1	7
Sulfate (SO ₄)	mg/L	100 ^p	100	0.5	0.7	1.6	1.2	0.9	1.1	0.9		1	<0.5	1.4	2.6	2.1	1	1.5	1.4	1.3	3.2	1.4	<0.5	<0.5	4.1
Sulphide	mg/L	0.014 ^s	0.014	0.003	0.003	0.014	0.017	0.011	0.016	0.014		0.017	<0.003	0.006	0.005	0.004	0.007	0.005	0.005	<0.003	0.003	0.011	0.01	0.012	<0.003
Temperature (in situ)	°C	-	1000000		7.4	8	6.5	8	1.7	0.58	0.28	0.51	13.92	11.86	14.86	13.15	15.51	8.17	16.72	15.47	14.03	15.54			16.4
Total Dissolved Solids	mg/L	-	1000000	10	62	80	110	80	90	90		120	42	68	67	81	57	89	101	99	92	61	82	101	150
Total Kjeldahl Nitrogen	mg/L	1	1.0	0.2	0.5	0.7	1.2	0.7	1.3	1.1		0.8	0.5	0.4	0.4	0.4	0.6	0.5	0.6	0.6	0.4	0.5	0.6	1.7	0.4
Total Organic Carbon	mg/L	-	1000000	1	23	33	46	36	35	32		24	17	23	24	27	26	27	25	25	29	25	24	35	17
Total Suspended Solids	mg/L	+10 mg/L ^l	1000	3	<3	5	<3	<3	<3	<3		<3	<3	<3	<3	<3	7	<3	7	5	<3	<3	<3	44	<3
Turbidity (in situ)	NTU	-	1000000										0.23	0.83	0.96	0.81	0.59	1.22	6.17	4.65	1.64	0.96			3.41
Total Metals																									
Aluminum	mg/L	0.1 ^a	0.1	0.002	0.0797	0.234	0.366	0.199	0.394	0.167		0.0725	0.0813	0.181	0.152	0.127	0.205	0.145	0.205	0.172	0.102	0.183	0.0727	0.51	0.0669
Antimony	mg/L	0.02 ^b	1000000	0.000001	0.0000105	0.0000169	0.0000229	0.0000139	0.0000213	0.0000194		0.0000204	0.0000105	0.0000177	0.000015	0.0000201	0.0000218	0.0000244	0.0000173	0.0000137	0.0000189	0.0000199	0.0000143	0.0000317	0.0000336
Arsenic	mg/L	0.005 ^c	0.005	0.00004	0.000361	0.000674	0.000632	0.000494	0.000769	0.00106		0.00101	0.000358	0.000474	0.000449	0.000397	0.000664	0.000387	0.000861	0.000728	0.000561	0.000409	0.000689	0.00469	0.0029
Barium	mg/L	5 ^b	5	0.0001	0.00762	0.0133	0.0135	0.0122	0.0187	0.0181		0.0285	0.00732	0.00937	0.00912	0.0157	0.0119	0.0134	0.0388	0.0324	0.0172	0.00878	0.0151	0.04	0.0327
Beryllium	mg/L	0.0053 ^b	0.0053	0.00001	0.00001	0.0000204	0.0000247	0.0000162	0.0000262	0.000012		0.00001	0.00001	0.0000181	0.0000138	0.0000105	0.00001	0.0000116	0.0000197	0.000015	0.0000137	0.00001	0.00001	0.0000423	0.00001
Bismuth	mg/L	-	1000000	0.00001	0.00001	0.00001	0.0000105	0.00001	0.0000107	0.00001		0.00001	0.00001	0.00001	0.0000139	0.00001	0.00001	0.00001	0.00001	0.00001	0.00001	0.00001	0.0000204	0.0000163	0.00001
Boron	mg/L	1.2 ^d	1.2	0.0008	0.00531	0.00402	0.00476	0.00438	0.0069	0.00515		0.0145	0.00523	0.00752	0.00701	0.00982	0.00656	0.0104	0.0159	0.0131	0.0152	0.00656	0.00805	0.0098	0.0376
Cadmium	mg/L	^e	0.000006	0.000006	0.000006	0.000014	0.0000123	0.0000148	0.0000531	0.0000136		0.0000111	<0.000006	0.000006	<0.000006	<0.000006	<0.000006	<0.000006	<0.000006	<0.000006	<0.000006	<0.000006	0.0000436	<0.000006	
Calcium	mg/L	-	1000000	0.1	4.77	5.79	6.2	5.61	8.25	9.51		23.9	3.75	3.73	3.88	7.52	4.09	7.29	13.3	11.7	10.2	3.52	7.95	11.5	28.1
Chlorine	mg/L	-	1000000	0.3	0.363	0.3	0.737	0.3	<0.3	<0.3		<0.3	5.98	0.53	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	2.29
Chromium	mg/L	0.001 ⁹	0.001	0.0003	0.0003	0.000403	0.000749	0.000425	0.000764	0.000346		0.0003	0.000349	0.00033	0.000314	0.0003	0.000346	0.0003	0.0003	0.000484	0.0003	0.000316	0.0003	0.000833	0.0003
Cobalt	mg/L	0.0009 ^b	0.0009	0.00001	0.000119	0.00048	0.00113	0.000233	0.0019	0.00333		0.00211	0.000156	0.000179	0.000154	0.000185	0.000349	0.0004	0.000276	0.000256	0.000169	0.000176	0.000709	0.	

Table A2.3 (Cont'd.)

[illegible]

Table A2.3 (Cont'd.)

Water Quality Variable	Units	Guideline ¹	Conversion	Detection Limit	Fall 2007					CC1						Spring 2008					CC4				Summer 2009					
					C17	C19	C20	C21	C22	100U	50U	HR	West	100-D	200-D	300-D	100U	50U	Crossing	100D	200D	100U	50U	Crossing	100D	100U	Crossing	100D	200D	300D
					Aug-07	Aug-07	Aug-07	Aug-07	Aug-07	May-08	May-08	May-08	May-08	May-08	May-08	May-08	May-08	May-08	May-08	May-08	May-08	May-08	May-08	May-08	May-08	Jun-09	Jun-09	Jun-09	Jun-09	Jun-09
Alkalinity, Total (as CaCO ₃)	mg/L	20 ^a	1000000	5	38		17	25	87																					
Ammonia-N	mg/L	1.37 ^b	1.37	0.05	<0.05		<0.05	<0.05	<0.05																					
Bicarbonate (HCO ₃)	mg/L	-	1000000	5	47		21	31	107																					
Biochemical Oxygen Demand	mg/L	-	1000000	2	<2		<2	<2	<2																					
Calcium (Ca)	mg/L	-	1000000	0.5	13.1		7.3	10.9	26.9																					
Carbonate (CO ₃)	mg/L	-	1000000	5	<5		<5	<5	<5																					
Chloride (Cl)	mg/L	230 ^j	230	1	1		1	2	6																					
Chlorophyll <i>a</i>	ug/L	-	1000000	1																										
Color, True	T.C.U.	-	1000000	2.5	180		150	280	140																					
Conductivity (EC)	µS/cm	-	1000000	0.2	82.8		47.6	57.8	193	30	29	46	19	27	33	23	23	32	26	27	30.7	11.5	48.5	64.2	67	53	55	55	55	
Dissolved Organic Carbon	mg/L	-	1000000	1	29		26	39	24																					
Dissolved oxygen (in situ)	mg/L	5 ^j	5		7.2	4.5	7.2	7.4	8.6	5.5	6.5	5.5	6	7	7	6	7	6	5.5	5.5	7	9	9	8	8.49	9.02	8.54	8.24	8.15	
Hardness (as CaCO ₃)	mg/L	200 ^r	1000000		49		28	40	96																					
Hydrocarbons, Recoverable (I.R.)	mg/L	-	1000000	1	<1		<1	<1	<1																					
Hydroxide (OH)	mg/L	-	1000000	5	<5		<5	<5	<5																					
Magnesium (Mg)	mg/L	-	1000000	0.1	4		2.3	3	7.1																					
Naphthenic Acids	mg/L	-	1000000	1	<1		<1	<1	<1																					
Nitrate+Nitrite-N	mg/L	ⁿ	13.06	0.1	<0.1		<0.1	<0.1	<0.1																					
pH		6.5-9.0 ^o	1000000	0.1	7.6		7.2	7.2	8	5.83	6	5.66	6.43	6.17	4.83	5.63	5.7	5.96	6.05	6.11	7	7.01	7.02	7.06	7.17	7.32	7.25	7.26	7.19	
Phenols (4AAP)	mg/L	0.05 ^c	0.05	0.001	0.015		0.012	<0.001	0.016																					
Phosphorus, Total	mg/L	0.05 ⁱ	0.05	0.001	0.088		0.023	0.172	0.286																					
Potassium (K)	mg/L	-	-	-	0.8		<0.5	0.9	1																					
Sodium (Na)	mg/L	-	1000000	1	2		1	<1	6																					
Sulfate (SO ₄)	mg/L	100 ^p	100	0.5	1		1.1	0.6	3																					
Sulphide	mg/L	0.014 ⁵	0.014	0.003	0.01		0.011	0.015	0.008																					
Temperature (in situ)	°C	-	1000000		10.28	5.8	10.1	8.85	13.2	5.3	4.9	3.5	3.1	2.6	8.2	5.1	5	4.3	2.8	3.3	7.5	7.1	6.9	10	14.64	13.58	15.27	15.61	15.95	
Total Dissolved Solids	mg/L	-	1000000	10	107		82	110	148																					
Total Kjeldahl Nitrogen	mg/L	1	1.0	0.2	0.7		0.5	0.8	0.7																					
Total Organic Carbon	mg/L	-	1000000	1	29		26	39	24																					
Total Suspended Solids	mg/L	+10 mg/L ^t	1000	3	<3		<3	9	<3																					
Turbidity (in situ)	NTU	-	1000000		3.31	1.5	3.17	137	3.26	0.75	0.56</																			

Appendix A3

Field Work Activities and Methodology – Aquatic Habitat

A3.1 FIELD WORK ACTIVITIES AND METHODOLOGY – AQUATIC HABITAT

Habitat surveys

Aquatic habitat surveys were undertaken at 21 watercourses and five lakes over seven different sampling seasons. Habitat survey procedures developed and used extensively by the British Columbia Ministry of Fisheries (Anon 1998a, 1998b) 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* (Alberta Environment 2000); (ii) *Code of Practice for Pipelines and Telecommunication Lines Crossing a Waterbody* (Alberta Environment 2000); and (iii) *Code of Practice for Watercourse Crossings* (Alberta Environment 2000); as well as their associated guidelines. Surveys documented dominant and sub-dominant vegetation cover types and sources of instream cover, channel morphology, and bank shape, texture and vegetation. Detailed habitat cards are provided in this [Appendix A3](#).

Bathymetric surveys


Two bathymetric transects were conducted on each of four lakes (C02, C03, C04, C05) in the study area ([Figure A4.1](#) to [A4.4](#)). One transect was along the long lake axis, and a second along the short lake axis using a Portable Eagle “Fish Easy” depth sounder. *In situ* water quality measurements were recorded at the approximate intersection of these transects. These variables were recorded at the surface and at progressive intervals to depth of the waterbody at approximately 10% intervals. Bathymetric survey locations and results of detailed habitat surveys on the lakes are provided in [Appendix A4](#).


Flyover surveys


Overflights of a number of significant watercourses in the study area were taken in fall 2006. Digital pictures and field notes were taken of significant watercourse features as well as reaches and sections that were representative of watercourse habitats. The survey procedure, adapted from the British Columbia Ministry of Fisheries, Fish and Fish Habitat Inventory: Standards and Procedures scheme (Anon 1998a, 1998b) evaluates specific habitat elements to provide an overall description of suitability for fish use. A UTM coordinate was recorded for each digital picture to link photographs and habitat descriptions to the mapping output. Locations of beaver dams and beaver lodges were also noted. Stream habitat conditions recorded during the flyover surveys are also provided in [Appendix A4](#).


A3.2 HABITAT CARDS

Referencing Information				
Watershed:	Christina River			
Map Location:	CO1			
Date Assessed :	Sept 2006	31 May 2007	30 Aug 2007	
Time Assessed:	1215	1057	1100	
UTM (NAD83, 12V):	452637E, 6218116N			
Access:	Helicopter & Boat			
Water Quality				
	Fall 2006	Spring 2007	Fall 2007	
Temperature (°C):	8.17	16.81	12.8	
Dissolved Oxygen (mg/L):	10.33	9.8	7.5	
pH:	7.91	5.57	5.85	
Turbidity (NTUs):	-	2.42	-	
Conductivity (µS/cm):	0.33	12	15.7	
Channel Characteristics				
	Fall 2006	Spring 2007	Fall 2007	
Channel Width (m):	-	-	NA	
Wetted Width (m):	-	-	NA	
Residual Pool Depth (m):	2.6	0.85	1.37	
Flow Velocity (m/s):	-	-	-	
Stage:	-	-	-	
Cover and Streambanks				
Crown Closure (%):	1-20			
Instream Cover:	Moderate			
Dominant Cover Type:	Overhanging vegetation			
Secondary Cover Type:	-			
<i>Sources of Instream Cover:</i>				
Small Woody Debris:	None			
Large Woody Debris:	None			
Boulders:	-			
Undercut Banks:	None			
Deep Pools:	-			
Overhanging Vegetation:	None			
Aquatic Vegetation:	Moderate			
Functional Large Woody Debris:	None			
Debris:				
Aquatic Vegetation:	Algae, Plantain			
	LDB		RDB	
Bank Shape:	Vertical		Vertical	
Bank Texture:	Fines, peat		Fines, peat	
Bank Riparian Vegetation:	Grasses		Grasses	
Vegetation Stage:	-		-	
Channel Morphology				
Dominant Bed Material:	Organic			
Sub-Dominant Bed Material:	Organic			
Morphology:	Lake			
Disturbance Indicators:	-			
Pattern:	-			
Islands:	-			
Bars:	-			
Coupling:	-			
Confinement:	-			
Comments				
Spring 2007:	Shallow lake. Treeline surrounding the lake (distances from shoreline vary from 10m to 100m) is established. Treeline consists of burnt trees and scattered patches of living Black Spruce and Tamarack trees. Most of the living trees are situated on the east side of the lake. Turbid water.			
Summer 2007:	Patches of pond lily and plantain are scattered throughout the lake.			












Referencing Information		
Watershed:	Christina River	
Map Location:	C02	
Date Assessed:	21 Sept 2006	30 May 2007
Time Assessed:	0901	1105
UTM (NAD83, 12V):	454144E, 6221610N	
Access:	Helicopter & Boat	
Water Quality		
	Fall 2006	Spring 2007
Temperature (°C):	8.80	15.73
Dissolved Oxygen (mg/L):	9.9	8.4
pH:	8.86	6.9
Turbidity (NTUs):	-	1.32
Conductivity (µS/cm):	0.091	20
Channel Characteristics		
	Fall 2006	Spring 2007
Channel Width (m):	-	147.6
Wetted Width (m):	-	-
Residual Pool Depth (m):	2.4	1.3
Flow Velocity (m/s):	-	-
Stage:	-	-
Cover and Streambanks		
Crown Closure (%):	-	
Instream Cover:	-	
Dominant Cover Type:	Organic	
Secondary Cover Type:	-	
<i>Sources of Instream Cover:</i>		
Small Woody Debris:	None	
Large Woody Debris:	None	
Boulders:	-	
Undercut Banks:	None	
Deep Pools:	-	
Overhanging Vegetation:	None	
Aquatic Vegetation:	Abundant	
Functional Large Woody Debris:	None	
Debris:		
Aquatic Vegetation:	Vascular	
	<i>LDB</i>	<i>RDB</i>
Bank Shape:	-	
Bank Texture:	-	
Bank Riparian Vegetation:	Coniferous forest	Coniferous forest
Vegetation Stage:	-	
Channel Morphology		
Dominant Bed Material:	Organic	
Sub-Dominant Material:	Bed	Silt
Morphology:	Lake	
Disturbance Indicators:	-	
Pattern:	-	
Islands:	-	
Bars:	-	
Coupling:	-	
Confinement:	-	
Comments		
Spring 2007: There is an established forest behind the riparian vegetation that is made up of regrowth after a fire. Boreal chorus frogs were calling.		



September 2006





May 2007




July 2007


Referencing Information		
Watershed:	Christina River	
Map Location:	CO3	
Date Assessed :	19 Sept 2006	1 June 2007
Time Assessed:	1520	0845
UTM (NAD83, 12V):	455179E, 6221480N	
Access:	Argo & Boat	
Water Quality		
	Fall 2006	Spring 2007
Temperature (°C):	7.86	18.3
Dissolved Oxygen (mg/L):	8.4	9.6
pH:	8.17	6.8
Turbidity (NTUs):	-	3.56
Conductivity (µS/cm):	0.029	17
Channel Characteristics		
	Fall 2006	Spring 2007
Channel Width (m):	-	-
Wetted Width (m):	-	-
Residual Pool Depth (m):	2	1.7
Flow Velocity (m/s):	-	-
Stage:	-	-
Cover and Streambanks		
Crown Closure (%):	-	
Instream Cover:	-	
Dominant Cover Type:	Organic	
Secondary Cover Type:	-	
<i>Sources of Instream Cover:</i>		
Small Woody Debris:	Trace	
Large Woody Debris:	None	
Boulders:	-	
Undercut Banks:	None	
Deep Pools:	-	
Overhanging Vegetation:	None	
Aquatic Vegetation:	Abundant	
Functional Large Woody Debris:	None	
Debris:		
Aquatic Vegetation:	Vascular	
	<i>LDB</i>	<i>RDB</i>
Bank Shape:	-	
Bank Texture:	Fines	Fines
Bank Riparian Vegetation:	Coniferous forest	Coniferous forest
Vegetation Stage:	-	
Channel Morphology		
Dominant Bed Material:	Organic	
Sub-Dominant Bed Material:	Organic	
Morphology:	Lake	
Disturbance Indicators:	-	
Pattern:	-	
Islands:	-	
Bars:	-	
Coupling:	-	
Confinement:	-	
Comments		
Fall 2006:	Observed two cow moose grazing.	








Referencing Information		
Watershed:	Christina River	
Map Location:	C04	
Date Assessed:	29 May 2007	
Time Assessed:	1250	
UTM (NAD83, 12V):	457634E, 6221997	
Access:	Truck, Helicopter & Boat	
Water Quality		
	Spring 2007	
Temperature (°C):	16.24	
Dissolved Oxygen (mg/L):	8.8	
pH:	6.83	
Turbidity (NTUs):	1.05	
Conductivity (µS/cm):	0.016	
Channel Characteristics		
	Spring 2007	
Channel Width (m):	-	
Wetted Width (m):	-	
Residual Pool Depth (m):	-	
Flow Velocity (m/s):	-	
Stage:	-	
Cover and Streambanks		
Crown Closure (%):	-	
Instream Cover:	-	
Dominant Cover Type:	Organic	
Secondary Cover Type:	-	
<i>Sources of Instream Cover:</i>		
Small Woody Debris:	None	
Large Woody Debris:	None	
Boulders:	-	
Undercut Banks:	None	
Deep Pools:	-	
Overhanging Vegetation:	None	
Aquatic Vegetation:	Abundant	
Functional Large Woody Debris:	None	
Debris:		
Aquatic Vegetation:	Vascular, Algae	
Bank Shape:	<i>LDB</i> Vertical	<i>RDB</i> Vertical
Bank Texture:	Peat	Peat
Bank Riparian Vegetation:	-	-
Vegetation Stage:	-	-
Channel Morphology		
Dominant Bed Material:	Organic	
Sub-Dominant Bed Material:	-	
Morphology:	Lake	
Disturbance Indicators:	-	
Pattern:	-	
Islands:	-	
Bars:	-	
Coupling:	-	
Confinement:	-	
Comments		
Spring 2007: Wood and Boreal chorus frogs calling and tadpoles spotted.		




May 2007




July 2007


Referencing Information		
Watershed:	Christina River	
Map Location:	C05	
Date Assessed :	26 Sept 2006	29 May 2007
Time Assessed:	1248	1115
UTM (NAD83, 12V):	458403E, 6219733E	
Access:	Helicopter & Boat	
Water Quality		
	Fall 2006	Spring 2007
Temperature (°C):	8	14.43
Dissolved Oxygen (mg/L):	8.4	7.4
pH:	7	8.3
Turbidity (NTUs):	-	1.11
Conductivity (µS/cm):	60	.031
Channel Characteristics		
	Fall 2006	Spring 2007
Channel Width (m):	-	-
Wetted Width (m):	-	-
Residual Pool Depth (m):	2.1	-
Flow Velocity (m/s):	-	-
Stage:	-	-
Cover and Streambanks		
Crown Closure (%):	-	
Instream Cover:	-	
Dominant Cover Type:	Organic	
Secondary Cover Type:	-	
<i>Sources of Instream Cover:</i>		
Small Woody Debris:	None	
Large Woody Debris:	None	
Boulders:	-	
Undercut Banks:	None	
Deep Pools:	-	
Overhanging Vegetation:	Moderate	
Aquatic Vegetation:	Abundant	
Functional Large Woody Debris:	None	
Debris:	-	
Aquatic Vegetation:	Vascular	
	LDB	RDB
Bank Shape:	-	
Bank Texture:	Peat	Peat
Bank Riparian Vegetation:	Grasses	Grasses
Vegetation Stage:	-	
Channel Morphology		
Dominant Bed Material:	Organic	
Sub-Dominant Bed Material:	-	
Morphology:	Lake	
Disturbance Indicators:	-	
Pattern:	-	
Islands:	-	
Bars:	-	
Coupling:	-	
Confinement:	-	
Comments		
Spring 2007:	Three loons spotted on the lake.	



September 2006




May 2007




July 2007


Referencing Information		
Watershed:	Christina River	
Map Location:	C06	
Date Assessed:	04 Oct 2006	30 May 2007
Time Assessed:	1155	1130
UTM (NAD83, 12V):	456548E, 6220526N	
Access:	Helicopter, Boat & Foot	
Water Quality		
	Fall 2006	Spring 2007
Temperature (°C):	7.4	13.92
Dissolved Oxygen (mg/L):	5.6	6.12
pH:	7.25	5.83
Turbidity (NTUs):	-	0.23
Conductivity (µS/cm):	278	28
Channel Characteristics		
	Fall 2006	Spring 2007
Channel Width (m):	-	51.8
Wetted Width (m):	-	Endless wetted area
Residual Pool Depth (m):	1.0	>2
Flow Velocity (m/s):	-	-
Stage:	-	-
Cover and Streambanks		
Crown Closure (%):	1-20	
Instream Cover:	Moderate	
Dominant Cover Type:	Small woody debris	
Secondary Cover Type:	Aquatic vegetation	
<i>Sources of Instream Cover:</i>		
Small Woody Debris:	Moderate	
Large Woody Debris:	Trace	
Boulders:	None	
Undercut Banks:	Moderate	
Deep Pools:	Moderate	
Overhanging Vegetation:	Moderate	
Aquatic Vegetation:	Moderate	
Functional Large Woody Debris:	Few	
Debris:		
Aquatic Vegetation:	Algae	
	LDB	RDB
Bank Shape:	Vertical	Vertical
Bank Texture:	Fines	Fines
Bank Riparian Vegetation:	Grasses, Shrub, Wetlands	Grasses, Shrub, Wetlands
Vegetation Stage:	Grass floating mat with Sphagnum	Grass floating mat with Sphagnum
Channel Morphology		
Dominant Bed Material:	Organic	
Sub-Dominant Bed Material:	Fines	
Morphology:	Run/pool	
Disturbance Indicators:	Beaver dam, Small and large woody debris, homogenous bed texture	
Pattern:	Irregular meandering	
Islands:	Occasional	
Bars:	Braided	
Coupling:	Decoupled	
Confinement:	Unconfined	
Comments		
Fall 2006:	Beaver pond.	
Spring 2007:	Beaver pond with river above.	



October 2006



May 2007





July 2007

Referencing Information			
Watershed:	Christina River		
Map Location:	C07		
Date Assessed:	21 Sept 2006	29 May 2007	29 Aug 2007
Time Assessed:	1030	1058	1459
UTM (NAD83, 12V):	460122E, 6219754N		
Access:	Helicopter & Boat		
Water Quality			
	Fall 2006	Spring 2007	Fall 2007
Temperature (°C):	8	11.86	12.0
Dissolved Oxygen (mg/L):	6.2	6.8	-
pH:	6	5.52	5.6
Turbidity (NTUs):	-	0.83	-
Conductivity (µS/cm):	40	19	29
Channel Characteristics			
	Fall 2006	Spring 2007	Fall 2007
Channel Width (m):	-	7.5	8.7
Wetted Width (m):	3-6	10.3	NA
Residual Pool Depth (m):	>1.25	>2	>2
Flow Velocity (m/s):	-	-	-
Stage:	-	Moderate	Moderate
Cover and Streambanks			
Crown Closure (%):	1-20		
Instream Cover:	Moderate		
Dominant Cover Type:	Deep pools, Instream vegetation		
Secondary Cover Type:	Overhanging vegetation		
<i>Sources of Instream Cover:</i>			
Small Woody Debris:	Trace		
Large Woody Debris:	Trace		
Boulders:	None		
Undercut Banks:	None		
Deep Pools:	Abundant		
Overhanging Vegetation:	Moderate		
Aquatic Vegetation:	Abundant		
Functional Large Woody Debris:	None		
Debris:	Vascular		
Aquatic Vegetation:	LDB RDB		
Bank Shape:	Sloping		
Bank Texture:	Fines, Gravel		
Bank Riparian Vegetation:	Grasses, Shrub		
Vegetation Stage:	Shrub		
Channel Morphology			
Dominant Bed Material:	Fines		
Sub-Dominant Bed Material:	Vegetation		
Morphology:	Run		
Disturbance Indicators:	Beaver dam, Small and large woody debris, homogenous bed texture		
Pattern:	Irregular meandering		
Islands:	None		
Bars:	None		
Coupling:	Decoupled		
Confinement:	Unconfined		
Comments			
Fall 2006: Site was downstream of beaver dam and not wadeable.			
Fall 2007: Old burn site			



Referencing Information		
Watershed:	Christina River	
Map Location:	C08	
Date Assessed :	21 Sept 2006	
Time Assessed:	1100	
UTM (NAD83, 12V):	458840E, 6220865N	
Access:	Helicopter & Foot	
Water Quality		
	Fall 2006	
Temperature (°C):	6.5	
Dissolved Oxygen (mg/L):	4.4	
pH:	5.5	
Turbidity (NTUs):	-	
Conductivity (µS/cm):	40	
Channel Characteristics		
	Fall 2006	
Channel Width (m):	2-5	
Wetted Width (m):	-	
Residual Pool Depth (m):	>1.25	
Flow Velocity (m/s):	0	
Stage:	-	
Cover and Streambanks		
Crown Closure (%):	-	
Instream Cover:	-	
Dominant Cover Type:	-	
Secondary Cover Type:	-	
<i>Sources of Instream Cover:</i>		
Small Woody Debris:	-	
Large Woody Debris:	-	
Boulders:	-	
Undercut Banks:	-	
Deep Pools:	-	
Overhanging Vegetation:	-	
Aquatic Vegetation:	-	
Functional Large Woody Debris:	-	
Debris:	-	
Aquatic Vegetation:	-	-
	<i>LDB</i>	<i>RDB</i>
Bank Shape:	-	-
Bank Texture:	-	-
Bank Riparian Vegetation:	-	-
Vegetation Stage:	-	-
Channel Morphology		
Dominant Bed Material:	Organic	
Sub-Dominant Bed Material:	Silt	
Morphology:	-	
Disturbance Indicators:	-	
Pattern:	-	
Islands:	-	
Bars:	-	
Coupling:	-	
Confinement:	-	
Comments		
Fall 2006:	Site is downstream of a beaver dam. There is no visible flow at site but there is flow upstream and downstream of site.	









Referencing Information		
Watershed:	Christina River	
Map Location:	C09	
Date Assessed:	21 Sept 2006	29 May 2007
Time Assessed:	1140	1531
UTM (NAD83, 12V):	458809E, 6221234N	
Access:	Helicopter & Foot	
Water Quality		
	Fall 2006	Spring 2007
Temperature (°C):	8	14.86
Dissolved Oxygen (mg/L):	6.8	8.6
pH:	5.75	5.89
Turbidity (NTUs):	-	0.96
Conductivity (µS/cm):	30	25
Channel Characteristics		
	Fall 2006	Spring 2007
Channel Width (m):	0.8-1	1.3
Wetted Width (m):	-	2.3
Residual Pool Depth (m):	0.15	0.5
Flow Velocity (m/s):	-	-
Stage:	-	Moderate
Cover and Streambanks		
Crown Closure (%):	1-20	
Instream Cover:	Moderate	
Dominant Cover Type:	Undercut banks, Overhanging vegetation	
Secondary Cover Type:	Deep pools, Instream vegetation	
<i>Sources of Instream Cover:</i>		
Small Woody Debris:	Trace	
Large Woody Debris:	Trace	
Boulders:	Moderate	
Undercut Banks:	Dominant	
Deep Pools:	Sub-dominant	
Overhanging Vegetation:	Dominant	
Aquatic Vegetation:	Sub-dominant	
Functional Large Woody Debris:	Few	
Debris:		
Aquatic Vegetation:	-	
	<i>LDB</i>	<i>RDB</i>
Bank Shape:	Vertical	Vertical
Bank Texture:	Fines, Gravel	Fines, Gravel
Bank Riparian Vegetation:	Grasses, Shrub	Grasses, Shrub
Vegetation Stage:	Shrub	Shrub
Channel Morphology		
Dominant Bed Material:	Fines	
Sub-Dominant Bed Material:	Vegetation	
Morphology:	Run	
Disturbance Indicators:	Small and large woody debris, homogenous bed texture	
Pattern:	Irregular meandering	
Islands:	None	
Bars:	None	
Coupling:	Decoupled	
Confinement:	Confined	
Comments		
Fall 2006:	Channel coming down from UL-1. Shallower and more visible flow than at other water quality sampling sites.	
Spring 2007:	Channel has fast flow. Old burn.	



Referencing Information		
Watershed:	Christina River	
Map Location:	C10	
Date Assessed:	01 June 2007	
Time Assessed:	0910	
UTM (NAD83, 12V):	458413E, 6213744N	
Access:	Helicopter & Foot	
Water Quality		
	Spring 2007	
Temperature (°C):	13.15	
Dissolved Oxygen (mg/L):	6.11	
pH:	6.58	
Turbidity (NTUs):	0.81	
Conductivity (µS/cm):	37	
Channel Characteristics		
	Spring 2007	
Channel Width (m):	4.3	
Wetted Width (m):	7.3	
Residual Pool Depth (m):	0.9	
Flow Velocity (m/s):	-	
Stage:	Moderate	
Cover and Streambanks		
Crown Closure (%):	1-20	
Instream Cover:	Moderate	
Dominant Cover Type:	-	
Secondary Cover Type:	Small and large woody debris, Undercut banks, Deep pools, Overhanging vegetation, Instream vegetation	
<i>Sources of Instream Cover:</i>		
Small Woody Debris:	Moderate	
Large Woody Debris:	Moderate	
Boulders:	None	
Undercut Banks:	Moderate	
Deep Pools:	Moderate	
Overhanging Vegetation:	Moderate	
Aquatic Vegetation:	Moderate	
Functional Large Woody Debris:	Abundant	
Aquatic Vegetation:	Vascular	
	<i>LDB</i>	<i>RDB</i>
Bank Shape:	Sloping	Sloping
Bank Texture:	Fines	Fines
Bank Riparian Vegetation:	Grasses, Shrub, Wetlands	Grasses, Shrub, Wetlands
Vegetation Stage:	Shrub	Shrub
Channel Morphology		
Dominant Bed Material:	Fines	
Sub-Dominant Bed Material:	Organics	
Morphology:	Run	
Disturbance Indicators:	Small and large woody debris, homogenous bed texture	
Pattern:	Irregular meandering	
Islands:	Occasional	
Bars:	None	
Coupling:	Decoupled	
Confinement:	Unconfined	
Comments		
Spring 2007:	Shine on mud along shore.	





June 2007



July 2007


Referencing Information		
Watershed:	Christina River	
Map Location:	C11	
Date Assessed:	29 Aug 2007	
Time Assessed:	1006	
UTM (NAD83, 12V):	460868E, 6215796N	
Access:	Helicopter & Boat	
Water Quality		
	Fall 2007	
Temperature (°C):	11.5	
Dissolved Oxygen (mg/L):	4.0	
pH:	6.8	
Turbidity (NTUs):	-	
Conductivity (µS/cm):	80	
Channel Characteristics		
	Fall 2007	
Channel Width (m):	4	
Wetted Width (m):	NA	
Residual Pool Depth (m):	1.4	
Flow Velocity (m/s):	-	
Stage:	NA	
Cover and Streambanks		
Crown Closure (%):	0	
Instream Cover:	-	
Dominant Cover Type:	-	
Secondary Cover Type:	-	
<i>Sources of Instream Cover:</i>		
Small Woody Debris:	None	
Large Woody Debris:	None	
Boulders:	None	
Undercut Banks:	None	
Deep Pools:	None	
Overhanging Vegetation:	Trace	
Aquatic Vegetation:	Trace	
Functional Large Woody Debris:	-	
Debris:		
Aquatic Vegetation:	Vascular	
	<i>LDB</i>	<i>RDB</i>
Bank Shape:	Vertical	Vertical
Bank Texture:	Organic	Organic
Bank Riparian Vegetation:	Grasses, Shrub, Wetlands	Grasses, Shrub, Wetlands
Vegetation Stage:	Shrub	Shrub
Channel Morphology		
Dominant Bed Material:	-	
Sub-Dominant Bed Material:	-	
Morphology:	-	
Disturbance Indicators:	-	
Pattern:	Irregular meandering	
Islands:	None	
Bars:	None	
Coupling:	Decoupled	
Confinement:	Unconfined	
Comments		
Summer: Site located in bog/wetland area. Open area, little cover.		










Referencing Information		
Watershed:	Christina River	
Map Location:	C12	
Date Assessed:	01 June 2007	
Time Assessed:	1237	
UTM (NAD83, 12V):	453248E, 6217794N	
Access:	Helicopter & Foot	
Water Quality		
	Spring 2007	
Temperature (°C):	15.51	
Dissolved Oxygen (mg/L):	4.5	
pH:	5.6	
Turbidity (NTUs):	0.59	
Conductivity (µS/cm):	27	
Channel Characteristics		
	Spring 2007	
Channel Width (m):	21	
Wetted Width (m):	5	
Residual Pool Depth (m):	0.5 (sides)	
Flow Velocity (m/s):	-	
Stage:	-	
Cover and Streambanks		
Crown Closure (%):	1-20	
Instream Cover:	Moderate	
Dominant Cover Type:	Overhanging vegetation	
Secondary Cover Type:	Small and large woody debris, undercut banks, deep pools, Instream vegetation	
<i>Sources of Instream Cover:</i>		
Small Woody Debris:	Moderate	
Large Woody Debris:	Moderate	
Boulders:	None	
Undercut Banks:	Moderate	
Deep Pools:	Moderate	
Overhanging Vegetation:	Abundant	
Aquatic Vegetation:	Moderate	
Functional Large Woody Debris:	Few	
Debris:		
Aquatic Vegetation:	Vascular	
	<i>LDB</i>	<i>RDB</i>
Bank Shape:	Sloping	Undercut banks
Bank Texture:	Fines	Fines
Bank Riparian Vegetation:	Grasses, Shrub, Mixed forest, Wetlands	Grasses, Shrub, Mixed forest, Wetlands
Vegetation Stage:	Shrub	Shrub
Channel Morphology		
Dominant Bed Material:	-	
Sub-Dominant Bed Material:	-	
Morphology:	Pool	
Disturbance Indicators:	Small and large woody debris, homogenous bed texture	
Pattern:	Irregular, wandering	
Islands:	Occasional	
Bars:	Side bar, Braided	
Coupling:	Decoupled	
Confinement:	Unconfined	
Comments		
Spring 2007:	Frogs observed.	






Referencing Information		
Watershed:	Christina River	
Map Location:	C13	
Date Assessed:	01 June 2007	
Time Assessed:	0910	
UTM (NAD83, 12V):	451704E, 6211504N	
Access:	Helicopter & Foot	
Water Quality		
	Spring 2007	
Temperature (°C):	8.17	
Dissolved Oxygen (mg/L):	5.96	
pH:	6.14	
Turbidity (NTUs):	1.22	
Conductivity (µS/cm):	47	
Channel Characteristics		
	Spring 2007	
Channel Width (m):	2	
Wetted Width (m):	Endless Flooding area	
Residual Pool Depth (m):	0.47	
Flow Velocity (m/s):	-	
Stage:	-	
Cover and Streambanks		
Crown Closure (%):	1-20	
Instream Cover:	Moderate	
Dominant Cover Type:	-	
Secondary Cover Type:	Overhanging vegetation	
<i>Sources of Instream Cover:</i>		
Small Woody Debris:	Trace	
Large Woody Debris:	Trace	
Boulders:	None	
Undercut Banks:	None	
Deep Pools:	Trace	
Overhanging Vegetation:	Moderate	
Aquatic Vegetation:	Trace	
Functional Large Woody Debris:	Few	
Debris:	-	
Aquatic Vegetation:	-	
Bank Shape:	<i>LDB</i> Sloping	<i>RDB</i> Sloping
Bank Texture:	Fines	Fines
Bank Riparian Vegetation:	Wetlands	Wetlands
Vegetation Stage:	Shrub	Shrub
Channel Morphology		
Dominant Bed Material:	Fines	
Sub-Dominant Bed Material:	Organics	
Morphology:	-	
Disturbance Indicators:	Small and large woody debris, homogenous bed texture	
Pattern:	Irregular meandering	
Islands:	None	
Bars:	None	
Coupling:	Decoupled	
Confinement:	unconfined	
Comments		
Spring 2007: Flooded area, small channel, no visible flow. Dead standing trees, floating mat.		










Referencing Information		
Watershed:	Christina River	
Map Location:	C14	
Date Assessed:	29 Aug 2007	
Time Assessed:	1330	
UTM (NAD83, 12V):	456364E, 6217213N	
Access:	Helicopter	
Water Quality		
	Fall 2007	
Temperature (°C):	12.2	
Dissolved Oxygen (mg/L):	5.2	
pH:	6.8	
Turbidity (NTUs):	2.6	
Conductivity (µS/cm):	85	
Channel Characteristics		
	Fall 2007	
Channel Width (m):	2.8	
Wetted Width (m):	2.8	
Residual Pool Depth (m):	0.5-1.3	
Flow Velocity (m/s):	-	
Stage:	Moderate	
Cover and Streambanks		
Crown Closure (%):	0	
Instream Cover:	Moderate	
Dominant Cover Type:	Overhanging Vegetation	
Secondary Cover Type:	Instream vegetation	
<i>Sources of Instream Cover:</i>		
Small Woody Debris:	-	
Large Woody Debris:	-	
Boulders:	-	
Undercut Banks:	-	
Deep Pools:	-	
Overhanging Vegetation:	Abundant	
Aquatic Vegetation:	Moderate	
Functional Large Woody Debris:	None	
Debris:		
Aquatic Vegetation:	Vascular	
	<i>LDB</i>	<i>RDB</i>
Bank Shape:	Vertical	Vertical
Bank Texture:	Gravel	Gravel
Bank Riparian Vegetation:	Grasses	Grasses
Vegetation Stage:	Shrub	Shrub
Channel Morphology		
Dominant Bed Material:	Fines	
Sub-Dominant Bed Material:	Gravel	
Morphology:	Run	
Disturbance Indicators:	-	
Pattern:	Irregular meandering	
Islands:	None	
Bars:	None	
Coupling:	Decoupled	
Confinement:	Unconfined	
Comments		
None		









Referencing Information		
Watershed:	Christina River	
Map Location:	C15	
Date Assessed:	31 May 2007	
Time Assessed:	1710	
UTM (NAD83, 12V):	464395E, 6212973N	
Access:	Helicopter & Boat	
Water Quality		
	Spring 2007	
Temperature (°C):	16.72	
Dissolved Oxygen (mg/L):	7.44	
pH:	7.12	
Turbidity (NTUs):	6.17	
Conductivity (µS/cm):	76	
Channel Characteristics		
	Spring 2007	
Channel Width (m):	10	
Wetted Width (m):	14.3	
Residual Pool Depth (m):	>2	
Flow Velocity (m/s):	-	
Stage:	Moderate	
Cover and Streambanks		
Crown Closure (%):	21-40	
Instream Cover:	Abundant	
Dominant Cover Type:	Undercut banks, Deep pools, Overhanging vegetation	
Secondary Cover Type:	Small woody debris, Instream vegetation	
<i>Sources of Instream Cover:</i>		
Small Woody Debris:	Moderate	
Large Woody Debris:	Trace	
Boulders:	Trace	
Undercut Banks:	Abundant	
Deep Pools:	Abundant	
Overhanging Vegetation:	Abundant	
Aquatic Vegetation:	Moderate	
Functional Large Woody Debris:	Few	
Aquatic Vegetation:	-	
	<i>LDB</i>	<i>RDB</i>
Bank Shape:	Undercut	Undercut
Bank Texture:	Fines, Gravels	Fines, Gravels
Bank Riparian Vegetation:	Grasses, Shrub, Wetland	Grasses, Shrub, Wetland
Vegetation Stage:	Shrub, Pole/sapling	Shrub, Pole/sapling
Channel Morphology		
Dominant Bed Material:	Fines	
Sub-Dominant Bed Material:	Gravel	
Morphology:	Run	
Disturbance Indicators:	Small and large woody debris, homogenous bed texture	
Pattern:	Tortuous meanders	
Islands:	None	
Bars:	Side, Diagonal	
Coupling:	Decoupled	
Confinement:	Unconfined	
Comments		
Spring 2007: Old burned trees, shrubs, undercut banks, soft mud.		

Referencing Information	
Watershed:	Christina River
Map Location:	C16
Date Assessed:	31 May 2007
Time Assessed:	1336
UTM (NAD83, 12U):	466237E, 6213828N
Access:	Helicopter & Boat
Water Quality	
	Spring 2007
Temperature (°C):	15.47
Dissolved Oxygen (mg/L):	7.58
pH:	6.96
Turbidity (NTUs):	4.65
Conductivity (µS/cm):	77
Channel Characteristics	
	Spring 2007
Channel Width (m):	11
Wetted Width (m):	13.7
Residual Pool Depth (m):	>2
Flow Velocity (m/s):	-
Stage:	Moderate
Cover and Streambanks	
Crown Closure (%):	1-20
Instream Cover:	Abundant
Dominant Cover Type:	Aquatic vegetation
Secondary Cover Type:	None
<i>Sources of Instream Cover:</i>	
Small Woody Debris:	Abundant
Large Woody Debris:	Moderate
Boulders:	Moderate
Undercut Banks:	Moderate
Deep Pools:	Moderate
Overhanging Vegetation:	Abundant
Aquatic Vegetation:	Moderate
Functional Large Woody Debris:	Abundant
Debris:	
Aquatic Vegetation:	Vascular plants
	<i>LDB</i> <i>RDB</i>
Bank Shape:	Undercut Undercut
Bank Texture:	Fines, Gravels Fines, Gravels
Bank Riparian Vegetation:	Grasses, Shrub, Deciduous forest Grasses, Shrub
Vegetation Stage:	Shrub Shrub
Channel Morphology	
Dominant Bed Material:	Fines
Sub-Dominant Bed Material:	Rocks
Morphology:	Riffle/run
Disturbance Indicators:	Small and large woody debris, homogenous bed texture
Pattern:	Tortuous meanders
Islands:	None
Bars:	Side, Diagonal
Coupling:	Decoupled
Confinement:	Occasionally confined
Comments	
Spring 2007:	Fast moving flow in narrow parts of river. Large rocks occasionally. Ripples, riffles, and rocky bottom in areas.




May 2007




July 2007

Referencing Information	
Watershed:	Christina River
Map Location:	C17
Date Assessed:	29 May 2007
Time Assessed:	1745
UTM (NAD83, 12V):	462694E, 6214992N
Access:	Helicopter & Foot
Water Quality	
	Spring 2007
Temperature (°C):	14.03
Dissolved Oxygen (mg/L):	7.81
pH:	6.99
Turbidity (NTUs):	1.64
Conductivity (µS/cm):	58
Channel Characteristics	
	Spring 2007
Channel Width (m):	5.5
Wetted Width (m):	6.75
Residual Pool Depth (m):	>2
Flow Velocity (m/s):	-
Stage:	Moderate
Cover and Streambanks	
Crown Closure (%):	1-20
Instream Cover:	Abundant
Dominant Cover Type:	Undercut banks, Deep pools
Secondary Cover Type:	Small and large woody debris, Overhanging vegetation, Instream vegetation
<i>Sources of Instream Cover:</i>	
Small Woody Debris:	Moderate
Large Woody Debris:	Moderate
Boulders:	Trace
Undercut Banks:	Abundant
Deep Pools:	Abundant
Overhanging Vegetation:	Moderate
Aquatic Vegetation:	Moderate
Functional Large Woody Debris:	Few
Aquatic Vegetation:	Algae
	<i>LDB</i> <i>RDB</i>
Bank Shape:	Undercut banks, overhanging Undercut banks, overhanging
Bank Texture:	Fines Fines
Bank Riparian Vegetation:	Grasses, Shrub Grasses, Shrub
Vegetation Stage:	Shrub Shrub
Channel Morphology	
Dominant Bed Material:	Organic
Sub-Dominant Bed Material:	Clay/sand
Morphology:	Run
Disturbance Indicators:	Beaver dam, Small and large woody debris, homogenous bed texture
Pattern:	Irregular meandering
Islands:	Occasional
Bars:	Side
Coupling:	Decoupled
Confinement:	Confined
Comments	
Spring 2007: Beaver dam further upstream.	




May 2007




July 2007


Referencing Information		
Watershed:	Christina River	
Map Location:	C18	
Date Assessed:	05 Oct 2006	29 May 2007
Time Assessed:	0930	1405
UTM (NAD83, 12V):	458309E, 6221658N	
Access:	Helicopter & Foot	
Water Quality		
	Fall 2006	Spring 2007
Temperature (°C):	6.5	15.54
Dissolved Oxygen (mg/L):	5.5	6.4
pH:	6.4	5.64
Turbidity (NTUs):	0.45	0.96
Conductivity (µS/cm):	-	22
Channel Characteristics		
	Fall 2006	Spring 2007
Channel Width (m):	1.5	1.7
Wetted Width (m):	1.5	5.7
Residual Pool Depth (m):	-	0.4
Flow Velocity (m/s):	-	-
Stage:	-	Moderate
Cover and Streambanks		
Crown Closure (%):	1-20	
Instream Cover:	Abundant	
Dominant Cover Type:	Undercut banks	
Secondary Cover Type:	Small woody debris, Deep pools, Overhanging vegetation, Instream vegetation	
<i>Sources of Instream Cover:</i>		
Small Woody Debris:	Sub-dominant	
Large Woody Debris:	Trace	
Boulders:	None	
Undercut Banks:	Dominant	
Deep Pools:	Sub-dominant	
Overhanging Vegetation:	Sub-dominant	
Aquatic Vegetation:	Sub-dominant	
Functional Large Woody Debris:	Few	
Debris:		
Aquatic Vegetation:	Vascular	
	LDB	RDB
Bank Shape:	Undercut	Undercut
Bank Texture:	Fines, Gravel	Fines, Gravel
Bank Riparian Vegetation:	Grasses, Shrub	Grasses, Shrub
Vegetation Stage:	Shrub	Shrub
Channel Morphology		
Dominant Bed Material:	Fines	
Sub-Dominant Bed Material:	Organic	
Morphology:	Run	
Disturbance Indicators:	Small and large woody debris, homogenous bed texture	
Pattern:	Irregular meandering	
Islands:	Occasional	
Bars:	None	
Coupling:	Decoupled	
Confinement:	Unconfined	
Comments		
Fall 2006:	Burnt forest on both sides, scattered tamarack.	
Spring 2007:	Channel has gravel dispersed in sections. Old burn. Lots of large willows, grass, mucky bottom. Flowing water upstream of beaver dam.	



October 2006





May 2007



July 2007


Referencing Information		
Watershed:	Horse River	
Map Location:	C20	
Date Assessed:	19 Sept 2006	05 June 2007
Time Assessed:	1320	1015
UTM (NAD83, 12V):	452934E, 6222307N	
Access:	Truck & Foot	
Water Quality		
	Fall 2006	Spring 2007
Temperature (°C):	9	-
Dissolved Oxygen (mg/L):	3	-
pH:	6	-
Turbidity (NTUs):	-	-
Conductivity (µS/cm):	80	-
Channel Characteristics		
	Fall 2006	Spring 2007
Channel Width (m):	-	1-2
Wetted Width (m):	0.2-1	-
Residual Pool Depth (m):	0.1-0.6	0.1-0.3
Flow Velocity (m/s):	-	-
Stage:	-	-
Cover and Streambanks		
Crown Closure (%):	-	
Instream Cover:	-	
Dominant Cover Type:	Overhanging and instream vegetation	
Secondary Cover Type:	-	
Sources of Instream Cover:		
Small Woody Debris:	-	
Large Woody Debris:	Moderate	
Boulders:	-	
Undercut Banks:	-	
Deep Pools:	-	
Overhanging Vegetation:	Moderate	
Aquatic Vegetation:	Moderate	
Functional Large Woody Debris:	Few	
Debris:		
Aquatic Vegetation:	Vascular	
	LDB	RDB
Bank Shape:	-	-
Bank Texture:	-	-
Bank Riparian Vegetation:	Grasses, shrub	Grasses, shrub
Vegetation Stage:	Young forest	Young forest
Channel Morphology		
Dominant Bed Material:	Organic	
Sub-Dominant Bed Material:	Organic	
Morphology:	pool	
Disturbance Indicators:	Beaver dam	
Pattern:	-	
Islands:	-	
Bars:	Braided	
Coupling:	-	
Confinement:	Unconfined	
Comments		
Fall 2006:	Pond surrounded by burnt forest. Pockets of water that are fed from pond have oil sheen visible. Channel is undefined but continues to Highway 63, slow moving water and no beaver dams present.	
Spring 2007:	Could not locate channel upstream of beaver pond. Canadian toad and shrew/mouse were spotted. Site was upstream of clearing for new road or pipeline. Visible oil sheen by both culverts.	











Referencing Information			
Watershed:	Horse River		
Map Location:	C21		
Date Assessed:	05 June 2007		
Time Assessed:	1422		
UTM (NAD83, 12V):	449361E, 6218814N		
Access:	Truck & Foot		
Water Quality			
	Spring 2007		
Temperature (°C):	20.57		
Dissolved Oxygen (mg/L):	3.55		
pH:	6.87		
Turbidity (NTUs):	-		
Conductivity (µS/cm):	66		
Channel Characteristic			
	Spring 2007		
Channel Width (m):	0.5		
Wetted Width (m):	-		
Residual Pool Depth (m):	0.1-0.75		
Flow Velocity (m/s):	-		
Stage:	-		
Cover and Streambanks			
Crown Closure (%):	-		
Instream Cover:	Moderate		
Dominant Cover Type:	-		
Secondary Cover Type:	-		
<i>Sources of Instream Cover:</i>			
Small Woody Debris:	Moderate		
Large Woody Debris:	Moderate		
Boulders:	-		
Undercut Banks:	-		
Deep Pools:	-		
Overhanging Vegetation:	Moderate		
Aquatic Vegetation:	-		
Functional Large Woody Debris:	Moderate		
Debris:			
Aquatic Vegetation:	-		
	<i>LDB</i>	<i>RDB</i>	
Bank Shape:	-	-	
Bank Texture:	-	-	
Bank Riparian	-	-	
Vegetation:			
Vegetation Stage:	-	-	
Channel Morphology			
Dominant Bed Material:	-		
Sub-Dominant Bed Material:	-		
Morphology:	-		
Disturbance Indicators:	-		
Pattern:	-		
Islands:	-		
Bars:	-		
Coupling:	-		
Confinement:	-		
Comments			
Spring 2007:	Grasses, sedges make up most of the bank, however alder and salix also line the stream. Water is very turbid (brown with algae). Channel would disappear under some debris and then appear again. Depth of water varied from 0.10 to 0.75m. Substrate varied from soft mud to compact gravel. A mouse/shrew was spotted.		






Referencing Information		
Watershed:	Horse River	
Map Location:	C22	
Date Assessed:	01 June 2007	
Time Assessed:	1342	
UTM (NAD83, 12V):	447899E, 6221877N	
Access:	Helicopter & Foot	
Water Quality		
	Spring 2007	
Temperature (°C):	16.40	
Dissolved Oxygen (mg/L):	7.2	
pH:	7.73	
Turbidity (NTUs):	3.41	
Conductivity (µS/cm):	182	
Channel Characteristics		
	Spring 2007	
Channel Width (m):	9	
Wetted Width (m):	11	
Residual Pool Depth (m):	0.5 to 2	
Flow Velocity (m/s):	-	
Stage:	Moderate	
Cover and Streambanks		
Crown Closure (%):	71-90	
Instream Cover:	-	
Dominant Cover Type:	Small and Large woody debris, Overhanging vegetation	
Secondary Cover Type:	Boulders, Deep pools, Instream vegetation	
<i>Sources of Instream Cover:</i>		
Small Woody Debris:	Abundant	
Large Woody Debris:	Abundant	
Boulders:	Moderate	
Undercut Banks:	None	
Deep Pools:	Moderate	
Overhanging Vegetation:	Abundant	
Aquatic Vegetation:	Moderate	
Functional Large Woody Debris:	Abundant	
Aquatic Vegetation:	-	
	<i>LDB</i>	<i>RDB</i>
Bank Shape:	Sloping	Sloping
Bank Texture:	Fines, Cobbles, Boulders	Fines, Cobbles, Boulders
Bank Riparian Vegetation:	Grasses, Deciduous forest	Grasses, Deciduous forest
Vegetation Stage:	-	-
Channel Morphology		
Dominant Bed Material:	Cobble/boulder	
Sub-Dominant Bed Material:	Fines	
Morphology:	Run	
Disturbance Indicators:	Beaver dam, Small and large woody debris, Debris jam, homogenous bed texture	
Pattern:	Irregular meandering	
Islands:	Occasional	
Bars:	Side	
Coupling:	Partially coupled	
Confinement:	Occasionally confined	
Comments		
None		


Referencing Information				
Watershed:	Horse River			
Transect Code:	CC1-100U			
Date Assessed:	6 May 2008			
Time Assessed:	1030			
Location (NAD83, Z12):	448973E, 6218023N			
Access:	Truck, Argo, Foot			
Water Quality				
Temperature (°C):	5.3			
Dissolved Oxygen (mg/L):	5.5			
pH:	5.83			
Conductivity (µS/cm):	30			
Turbidity (NTUs):	0.75			
Channel and Bottom Characteristics				
Bankfull Width (m):	12			
Wetted Width (m):	4			
Bottom – % Fines:	100			
Bottom – % Gravel	0			
Bottom – % Cobble	0			
Bottom – % Boulder	0			
Water Depth and Velocity				
% Wetted Width, from RDB →	25%	50%	75%	
Water Depth (m):	0.40	0.46	0.48	
Flow Velocity (m/s):	0.02	0.09	0.20	
Stage:	High			
Banks				
	LDB	RDB		
Height (m):	0.59	0.54		
Slope (%):	100	100		
Stability:	Moderate	Moderate		
Composition – % Fines:	100	100		
Composition – % Gravel	0	0		
Composition – % Cobble	0	0		
Composition – % Boulder	0	0		
Composition – % Bedrock:	0	0		
Type of Riparian Vegetation:	Grasses	Grasses		
	Shrubs	Shrubs		
Stage of Riparian Vegetation:	Shrub	Shrub		
Cover				
Crown Closure:	1% to 20%			
Small Woody Debris:	Dominant			
Large Woody Debris:	Trace			
Boulders:	None			
Undercut Banks:	Trace			
Deep Pools	Trace			
Overhanging Vegetation:	Trace			
Instream Vegetation:	None			
Channel Morphology				
Morphology:	Run			
Pattern:	Irregular meandering			
Islands:	None			
Bars:	None			
Coupling:	Decoupled			
Fish Inventory				
Gear Type:	Minnow trap			
Fishing Effort (hr):	4.83			
Total No. Fish Captured	0			
Species, Ave. Length	N/A			
Comments				
Water is higher than banks, wide wetted width due to recent snowmelt. Several branches flow into main channel between this location and 50 m downstream.				




Cross stream facing LDB



Cross stream facing RDB







Upstream from LDB



Downstream from LDB

Referencing Information				
Watershed:	Horse River			
Transect Code:	CC1-50U			
Date Assessed:	6 May 2008			
Time Assessed:	1012			
Location (NAD83, Z12):	448945E, 6218066N			
Access:	Truck, Argo, Foot			
Water Quality				
Temperature (°C):	4.9			
Dissolved Oxygen (mg/L):	6.5			
pH:	6.00			
Conductivity (µS/cm):	29			
Turbidity (NTUs):	0.56			
Channel and Bottom Characteristics				
Bankfull Width (m):	15			
Wetted Width (m):	6			
Bottom – % Fines:	100			
Bottom – % Gravel	0			
Bottom – % Cobble	0			
Bottom – % Boulder	0			
Water Depth and Velocity				
% Wetted Width, from RDB →	25%	50%	75%	
Water Depth (m):	0.52	0.48	0.28	
Flow Velocity (m/s):	0.17	0.19	0.34	
Stage:	High			
Banks				
	LDB	RDB		
Height (m):	0.36	0.52		
Slope (%):	100	88		
Stability:	Moderate	Moderate		
Composition – % Fines:	100	100		
Composition – % Gravel	0	0		
Composition – % Cobble	0	0		
Composition – % Boulder	0	0		
Composition – % Bedrock:	0	0		
Type of Riparian Vegetation:	Grasses	Grasses		
	Shrubs	Shrubs		
Stage of Riparian Vegetation:	Shrub	Shrub		
Cover				
Crown Closure:	1% to 20%			
Small Woody Debris:	Dominant			
Large Woody Debris:	Trace			
Boulders:	None			
Undercut Banks:	Trace			
Deep Pools	Trace			
Overhanging Vegetation:	Trace			
Instream Vegetation:	None			
Channel Morphology				
Morphology:	Run			
Pattern:	Irregular meandering			
Islands:	None			
Bars:	None			
Coupling:	Decoupled			
Fish Inventory				
Gear Type:	Minnow Trap			
Fishing Effort (hr):	4.15			
Total No. Fish Captured	0			
Species, Ave. Length (mm)	N/A			
Comments				
Main channel splits between this location and 100 m upstream.				


Cross stream facing RDB

Cross stream facing LDB

Upstream from LDB

Downstream from LDB

Referencing Information	
Watershed:	Horse River
Transect Code:	CC1 (HR West-Crossing)
Date Assessed:	6 May 2008
Time Assessed:	0957
Location (NAD83, Z12):	448913E, 6218102N
Access:	Truck, Argo, Foot
Water Quality	
Temperature (°C):	3.5
Dissolved Oxygen (mg/L):	5.5
pH:	5.66
Conductivity (µS/cm):	46
Turbidity (NTUs):	0.67
Channel and Bottom Characteristics	
Bankfull Width (m):	24
Wetted Width (m):	17
Bottom – % Fines:	100
Bottom – % Gravel	0
Bottom – % Cobble	0
Bottom – % Boulder	0
Water Depth and Velocity	
% Wetted Width, from RDB →	25% 50% 75%
Water Depth (m):	0.68 0.58 0.58
Flow Velocity (m/s):	0.41 0.52 0.36
Stage:	High
Banks	
	LDB RDB
Height (m):	0.70 0.5
Slope (%):	55 100
Stability:	Moderate Moderate
Composition – % Fines:	100 100
Composition – % Gravel	0 0
Composition – % Cobble	0 0
Composition – % Boulder	0 0
Composition – % Bedrock:	0 0
Type of Riparian Vegetation:	Grasses Grasses
	Shrubs Shrubs
Stage of Riparian Vegetation:	Shrub Shrub
Cover	
Crown Closure:	1% to 20%
Small Woody Debris:	Dominant
Large Woody Debris:	Trace
Boulders:	None
Undercut Banks:	Trace
Deep Pools	Trace
Overhanging Vegetation:	Trace
Instream Vegetation:	None
Channel Morphology	
Morphology:	Run
Pattern:	Irregular meandering
Islands:	None
Bars:	None
Coupling:	Decoupled
Fish Inventory	
Gear Type:	Minnow trap
Fishing Effort (hr):	4.88
Total No. Fish Captured	0
Species, Ave. Length (mm)	N/A



Cross stream facing RDB



Cross stream facing LDB



Upstream from LDB



Downstream from LDB

Referencing Information	
Watershed:	Horse River
Transect Code:	CC1-100D
Date Assessed:	6 May 2008
Time Assessed:	1105
Location (NAD83, Z12):	448897E, 6218191N
Access:	Truck, Argo, Foot
Water Quality	
Temperature (°C):	3.1
Dissolved Oxygen (mg/L):	6.0
pH:	6.43
Conductivity (µS/cm):	19
Turbidity (NTUs):	0.48
Channel and Bottom Characteristics	
Bankfull Width (m):	17
Wetted Width (m):	15
Bottom – % Fines:	100
Bottom – % Gravel	0
Bottom – % Cobble	0
Bottom – % Boulder	0
Water Depth and Velocity	
% Wetted Width, from RDB →	25% 50% 75%
Water Depth (m):	0.64 0.64 0.56
Flow Velocity (m/s):	0.26 0.35 0.24
Stage:	High
Banks	
	LDB RDB
Height (m):	1.02 0.68
Slope (%):	100 80
Stability:	Moderate Moderate
Composition – % Fines:	100 100
Composition – % Gravel	0 0
Composition – % Cobble	0 0
Composition – % Boulder	0 0
Composition – % Bedrock:	0 0
Type of Riparian Vegetation:	Grasses Grasses
	Shrubs Shrubs
Stage of Riparian Vegetation:	Shrub Shrub
Cover	
Crown Closure:	1% to 20%
Small Woody Debris:	Dominant
Large Woody Debris:	None
Boulders:	None
Undercut Banks:	Trace
Deep Pools	Trace
Overhanging Vegetation:	Trace
Instream Vegetation:	None
Channel Morphology	
Morphology:	Run
Pattern:	Irregular meandering
Islands:	None
Bars:	None
Coupling:	Decoupled
Fish Inventory	
Gear Type:	Minnow trap
Fishing Effort (hr):	5.08
Total No. Fish Captured	0
Species, Ave. Length (mm)	N/A



Cross stream facing RDB



Upstream from LDB






Downstream from LDB




Riparian habitat


Referencing Information				
Watershed:	Horse River			
Transect Code:	CC1-200D			
Date Assessed:	6 May 2008			
Time Assessed:	1121			
Location (NAD83, Z12):	448982E, 6218248N			
Access:	Truck, Argo, Foot			
Water Quality				
Temperature (°C):	2.6			
Dissolved Oxygen (mg/L):	7.0			
pH:	6.17			
Conductivity (µS/cm):	27			
Turbidity (NTUs):	0.65			
Channel and Bottom Characteristics				
Bankfull Width (m):	19			
Wetted Width (m):	16			
Bottom – % Fines:	100			
Bottom – % Gravel	0			
Bottom – % Cobble	0			
Bottom – % Boulder	0			
Water Depth and Velocity				
% Wetted Width, from RDB →	25%	50%	75%	
Water Depth (m):	0.52	0.52	0.56	
Flow Velocity (m/s):	0.16	0.14	0.18	
Stage:	High			
Banks				
	LDB	RDB		
Height (m):	0.45	0.45		
Slope (%):	65	100		
Stability:	Moderate	Moderate		
Composition – % Fines:	100	100		
Composition – % Gravel	0	0		
Composition – % Cobble	0	0		
Composition – % Boulder	0	0		
Composition – % Bedrock:	0	0		
Type of Riparian Vegetation:	Grasses	Grasses		
	Shrubs	Shrubs		
Stage of Riparian Vegetation:	Shrub	Shrub		
Cover				
Crown Closure:	1% to 20%			
Small Woody Debris:	Sub-dominant			
Large Woody Debris:	None			
Boulders:	None			
Undercut Banks:	Trace			
Deep Pools	None			
Overhanging Vegetation:	Dominant			
Instream Vegetation:	None			
Channel Morphology				
Morphology:	Run			
Pattern:	Irregular meandering			
Islands:	None			
Bars:	None			
Coupling:	Decoupled			
Fish Inventory				
Gear Type:	Minnow Trap			
Fishing Effort (hr):	5.22			
Total No. Fish Captured	0			
Species, Ave. Length (mm)	N/A			
Comments				
No cross-channel photo facing the LDB because of difficult access in this flooded area.				


Cross stream facing RDB

Upstream from LDB

Downstream from LDB


Referencing Information				
Watershed:	Horse River			
Transect Code:	CC1-300D			
Date Assessed:	6 May 2008			
Time Assessed:	1132			
Location (NAD83, Z12):	449016E, 6218341N			
Access:	Truck, Argo, Foot			
Water Quality				
Temperature (°C):	8.2			
Dissolved Oxygen (mg/L):	7.0			
pH:	4.83			
Conductivity (µS/cm):	33			
Turbidity (NTUs):	2.40			
Channel and Bottom Characteristics				
Bankfull Width (m):	38			
Wetted Width (m):	36			
Bottom – % Fines:	100			
Bottom – % Gravel	0			
Bottom – % Cobble	0			
Bottom – % Boulder	0			
Water Depth and Velocity				
% Wetted Width, from RDB →	25%	50%	75%	
Water Depth (m):	N/A	N/A	N/A	
Flow Velocity (m/s):	N/A	N/A	N/A	
Stage:	High			
Banks				
	LDB	RDB		
Height (m):	0	N/A		
Slope (%):	10	N/A		
Stability:	Low	N/A		
Composition – % Fines:	100	N/A		
Composition – % Gravel	0	N/A		
Composition – % Cobble	0	N/A		
Composition – % Boulder	0	N/A		
Composition – % Bedrock:	0	N/A		
Type of Riparian Vegetation:	Grasses	Grasses		
	Shrubs	Shrubs		
Stage of Riparian Vegetation:	Shrub	Shrub		
Cover				
Crown Closure:	0%			
Small Woody Debris:	Trace			
Large Woody Debris:	None			
Boulders:	None			
Undercut Banks:	None			
Deep Pools	Trace			
Overhanging Vegetation:	None			
Instream Vegetation:	None			
Channel Morphology				
Morphology:	Beaver pond			
Pattern:	N/A			
Islands:	None			
Bars:	None			
Coupling:	Decoupled			
Fish Inventory				
Gear Type:	Minnow trap			
Fishing Effort (hr):	5.48			
Total No. Fish Captured	0			
Species, Ave. Length (mm)	N/A			
Comments				
Creek flows into a beaver pond beginning ~30 m upstream of this location. Minnow trap was set at the location 300 m downstream of the crossing. No data are available for the 25%, 50% and 75% wetted width locations due to deep water and the RDB was not assessed because it was on the far side of the beaver pond.				



Cross stream facing RDB (beaver pond)



Upstream from LDB (beaver pond)



Downstream from LDB (beaver pond)



Cross stream facing RDB (beaver pond)







Upstream from LDB (beaver pond)







Downstream from LDB (beaver pond)





Referencing Information				
Watershed:	Horse River			
Transect Code:	CC2-100U			
Date Assessed:	7 May 2008			
Time Assessed:	0930			
Location (NAD83, Z12):	449250E, 6218480N			
Access:	Truck, Argo, Foot			
Water Quality				
Temperature (°C):	5.1			
Dissolved Oxygen (mg/L):	6.0			
pH:	5.63			
Conductivity (µS/cm):	23			
Turbidity (NTUs):	0.88			
Channel and Bottom Characteristics				
Bankfull Width (m):	8			
Wetted Width (m):	1.70			
Bottom – % Fines:	100			
Bottom – % Gravel	0			
Bottom – % Cobble	0			
Bottom – % Boulder	0			
Water Depth and Velocity				
% Wetted Width, from RDB →	25%	50%	75%	
Water Depth (m):	0.24	0.60	0.22	
Flow Velocity (ft/s):	0.63	1.40	0.27	
Stage:		High		
Banks				
	LDB	RDB		
Height (m):	0.58	0.40		
Slope (%):	50	60		
Stability:	Low	Low		
Composition – % Fines:	100	100		
Composition – % Gravel	0	0		
Composition – % Cobble	0	0		
Composition – % Boulder	0	0		
Composition – % Bedrock:	0	0		
Type of Riparian Vegetation:	Grasses	Grasses		
	Shrubs	Shrubs		
Stage of Riparian Vegetation:	Shrub	Shrub		
Cover				
Crown Closure:	1% to 20%			
Small Woody Debris:	Dominant			
Large Woody Debris:	Trace			
Boulders:	None			
Undercut Banks:	Trace			
Deep Pools	None			
Overhanging Vegetation:	Trace			
Instream Vegetation:	None			
Channel Morphology				
Morphology:	Run			
Pattern:	Irregular Meandering			
Islands:	None			
Bars:	None			
Coupling:	Decoupled			
Fish Inventory				
Gear Type:	Minnow Trap			
Fishing Effort (hr):	5.02			
Total No. Fish Captured	0			
Species, Ave. Length (mm)	N/A			
Comments				
The cutline through black spruce is draining some water into creek that may not have occurred prior to cutline establishment.				


Cross stream facing LDB

Upstream from RDB

Downstream from RDB

Riparian habitat





Referencing Information				
Watershed:	Horse River			
Transect Code:	CC2-50U			
Date Assessed:	7 May 2008			
Time Assessed:	0918			
Location (NAD83, Z12):	449299E, 6218498N			
Access:	Truck, Argo, Foot			
Water Quality				
Temperature (°C):	5.0			
Dissolved Oxygen (mg/L):	7.0			
pH:	5.70			
Conductivity (µS/cm):	23			
Turbidity (NTUs):	1.1			
Channel and Bottom Characteristics				
Bankfull Width (m):	8			
Wetted Width (m):	1.30			
Bottom – % Fines:	100			
Bottom – % Gravel	0			
Bottom – % Cobble	0			
Bottom – % Boulder	0			
Water Depth and Velocity				
% Wetted Width, from RDB →	25%	50%	75%	
Water Depth (m):	0.72	0.90	0.82	
Flow Velocity (ft/s):	0.08	0.76	0.38	
Stage:	High			
Banks				
	LDB	RDB		
Height (m):	0.70	0.66		
Slope (%):	100	100		
Stability:	Low	Low		
Composition – % Fines:	100	100		
Composition – % Gravel	0	0		
Composition – % Cobble	0	0		
Composition – % Boulder	0	0		
Composition – % Bedrock:	0	0		
Type of Riparian Vegetation:	Grasses	Grasses		
	Shrubs	Shrubs		
Stage of Riparian Vegetation:	Shrub	Shrub		
Cover				
Crown Closure:	1% to 20%			
Small Woody Debris:	Dominant			
Large Woody Debris:	None			
Boulders:	None			
Undercut Banks:	Trace			
Deep Pools	None			
Overhanging Vegetation:	Trace			
Instream Vegetation:	None			
Channel Morphology				
Morphology:	Run			
Pattern:	Irregular Meandering			
Islands:	None			
Bars:	None			
Coupling:	Decoupled			
Fish Inventory				
Gear Type:	Minnow Trap			
Fishing Effort (hr):	4.93			
Total No. Fish Captured	0			
Species, Ave.Length (mm)	N/A			
Comments				
A lot of new willow growth at site.				


Cross stream facing LDB

Upstream from RDB

Downstream from RDB

Riparian habitat





Referencing Information				
Watershed:	Horse River			
Transect Code:	CC2-Crossing			
Date Assessed:	7 May 2008			
Time Assessed:	0859			
Location (NAD83, Z12):	449350E, 6218505N			
Access:	Truck, Argo, Foot			
Water Quality				
Temperature (°C):	4.3			
Dissolved Oxygen (mg/L):	6.0			
pH:	5.96			
Conductivity (µS/cm):	32			
Turbidity (NTUs):	3.60			
Channel and Bottom Characteristics				
Bankfull Width (m):	15			
Wetted Width (m):	1.87			
Bottom – % Fines:	100			
Bottom – % Gravel	0			
Bottom – % Cobble	0			
Bottom – % Boulder	0			
Water Depth and Velocity				
% Wetted Width, from RDB →	25%	50%	75%	
Water Depth (m):	0.28	0.46	0.44	
Flow Velocity (ft/s):	0.02	0.38	0.57	
Stage:	High			
Banks				
	LDB	RDB		
Height (m):	0.38	0.38		
Slope (%):	100	100		
Stability:	Low	Low		
Composition – % Fines:	100	100		
Composition – % Gravel	0	0		
Composition – % Cobble	0	0		
Composition – % Boulder	0	0		
Composition – % Bedrock:	0	0		
Type of Riparian Vegetation:	Grasses	Grasses		
	Shrubs	Shrubs		
Stage of Riparian Vegetation:	Shrub	Shrub		
Cover				
Crown Closure:	1% to 20%			
Small Woody Debris:	Trace			
Large Woody Debris:	None			
Boulders:	None			
Undercut Banks:	Trace			
Deep Pools	Trace			
Overhanging Vegetation:	Dominant			
Instream Vegetation:	None			
Channel Morphology				
Morphology:	Run			
Pattern:	Irregular Meandering			
Islands:	None			
Bars:	None			
Coupling:	Decoupled			
Fish Inventory				
Gear Type:	Minnow Trap			
Fishing Effort (hr):	6.63			
Total No. Fish Captured	0			
Species, Ave.Length (mm)	N/A			
Comments				
This location is very typical of the entire site, riparian vegetation dominated by grass and shrubs, cover provided by undercut banks, shrub cover and overhanging vegetation.				


Cross stream facing RDB

Upstream from LDB

Downstream from LDB

Minnow trap





Referencing Information				
Watershed:	Horse River			
Transect Code:	CC2-100D			
Date Assessed:	7 May 2008			
Time Assessed:	1003			
Location (NAD83, Z12):	449419E, 6218575N			
Access:	Truck, Argo, Foot			
Water Quality				
Temperature (°C):	2.8			
Dissolved Oxygen (mg/L):	5.5			
pH:	6.05			
Conductivity (µS/cm):	26			
Turbidity (NTUs):	0.86			
Channel and Bottom Characteristics				
Bankfull Width (m):	40			
Wetted Width (m):	1.0			
Bottom – % Fines:	100			
Bottom – % Gravel	0			
Bottom – % Cobble	0			
Bottom – % Boulder	0			
Water Depth and Velocity				
% Wetted Width, from RDB →	25%	50%	75%	
Water Depth (m):	0.32	0.38	0.40	
Flow Velocity (ft/s):	0.65	0.75	0.11	
Stage:		High		
Banks				
	LDB	RDB		
Height (m):	0.30	0.22		
Slope (%):	100	100		
Stability:	Low	Low		
Composition – % Fines:	100	100		
Composition – % Gravel	0	0		
Composition – % Cobble	0	0		
Composition – % Boulder	0	0		
Composition – % Bedrock:	0	0		
Type of Riparian Vegetation:	Grasses	Grasses		
	Shrubs	Shrubs		
Stage of Riparian Vegetation:	Shrub	Shrub		
Cover				
Crown Closure:	1% to 20%			
Small Woody Debris:	Trace			
Large Woody Debris:	None			
Boulders:	None			
Undercut Banks:	Trace			
Deep Pools	Trace			
Overhanging Vegetation:	Dominant			
Instream Vegetation:	None			
Channel Morphology				
Morphology:	Run			
Pattern:	Irregular Meandering			
Islands:	None			
Bars:	None			
Coupling:	Decoupled			
Fish Inventory				
Gear Type:	Minnow Trap			
Fishing Effort (hr):	5.40			
Total No. Fish Captured	0			
Species, Ave.Length (mm)	N/A			
Comments				
Several channels here and wetted width is very wide. Overall this location is very wet.				


Cross channel facing LDB

Cross channel facing RDB

Upstream from RDB

Downstream from RDB

Referencing Information				
Watershed:	Horse River			
Transect Code:	CC2-200D			
Date Assessed:	7 May 2008			
Time Assessed:	1112			
Location (NAD83, Z12):	449417E, 6218673N			
Access:	Truck, Argo, Foot			
Water Quality				
Temperature (°C):	3.3			
Dissolved Oxygen (mg/L):	5.5			
pH:	6.11			
Conductivity (µS/cm):	27			
Turbidity (NTUs):	1.0			
Channel and Bottom Characteristics				
Bankfull Width (m):	24			
Wetted Width (m):	3			
Bottom – % Fines:	100			
Bottom – % Gravel	0			
Bottom – % Cobble	0			
Bottom – % Boulder	0			
Water Depth and Velocity				
% Wetted Width, from RDB →	25%	50%	75%	
Water Depth (m):	0.44	0.54	0.38	
Flow Velocity (ft/s):	0.33	0.46	0.04	
Stage:		High		
Banks				
	LDB	RDB		
Height (m):	0.5	0.5		
Slope (%):	85	90		
Stability:	Low	Low		
Composition – % Fines:	100	100		
Composition – % Gravel	0	0		
Composition – % Cobble	0	0		
Composition – % Boulder	0	0		
Composition – % Bedrock:	0	0		
Type of Riparian Vegetation:	Grasses	Grasses		
	Shrubs	Shrubs		
Stage of Riparian Vegetation:	Shrub	Shrub		
Cover				
Crown Closure:	0%			
Small Woody Debris:	None			
Large Woody Debris:	Trace			
Boulders:	None			
Undercut Banks:	Trace			
Deep Pools	Trace			
Overhanging Vegetation:	Dominant			
Instream Vegetation:	None			
Channel Morphology				
Morphology:	Run			
Pattern:	Irregular Meandering			
Islands:	None			
Bars:	None			
Coupling:	Decoupled			
Fish Inventory				
Gear Type:	Minnow Trap			
Fishing Effort (hr):	4.07			
Total No. Fish Captured	0			
Species, Ave.Length (mm)	N/A			
Comments				
Water is wide and slow moving in this location because it enters a beaver pond just downstream. Water is about 1 m deep in most places across the wetted width.				


Cross stream facing LDB

Cross channel facing RDB

Downstream from LDB

Upstream from LDB

Referencing Information				
Watershed:	Horse River			
Transect Code:	CC4-100U			
Date Assessed:	27 May 2008			
Time Assessed:	1345			
Location (NAD83, Z12):	449620E, 6218465N			
Access:	Truck, Argo, Foot			
Water Quality				
Temperature (°C):	7.5			
Dissolved Oxygen (mg/L):	7.0			
pH:	7.0			
Conductivity (µS/cm):	30.7			
Turbidity (NTUs):	3.1			
Channel and Bottom Characteristics				
Bankfull Width (m):	15.0			
Wetted Width (m):	0.40			
Bottom – % Fines:	100			
Bottom – % Gravel	0			
Bottom – % Cobble	0			
Bottom – % Boulder	0			
Water Depth and Velocity				
% Wetted Width, from RDB →	25%	50%	75%	
Water Depth (m):	0.16	0.18	0.18	
Flow Velocity (ft/s):	0.20	0.24	0.26	
Stage:	Low			
Banks				
	LDB	RDB		
Height (m):	0.70	0.65		
Slope (%):	90	90		
Stability:	Moderate	Moderate		
Composition – % Fines:	100	100		
Composition – % Gravel	0	0		
Composition – % Cobble	0	0		
Composition – % Boulder	0	0		
Composition – % Bedrock:	0	0		
Type of Riparian Vegetation:	Grasses	Grasses		
	Shrubs	Shrubs		
Stage of Riparian Vegetation:	Shrub	Shrub		
Cover				
Crown Closure:	21-40%			
Small Woody Debris:	Trace			
Large Woody Debris:	None			
Boulders:	None			
Undercut Banks:	Moderate			
Deep Pools	None			
Overhanging Vegetation:	Abundant			
Instream Vegetation:	None			
Channel Morphology				
Morphology:	Riffle Pool			
Pattern:	Regular Meandering			
Islands:	None			
Bars:	None			
Coupling:	N/A- no hillslopes			
Fish Inventory				
Gear Type:	N/A			
Fishing Effort (hr):	0			
Total No. Fish Captured	0			
Species, Ave. Length (mm)	N/A			
Comments				
The grass overgrowth completely covered the channel, almost a 'hidden channel'. Flow is likely seasonal.				


RDB looking downstream

LDB looking upstream

LDB looking cross channel

RDB looking cross channel



RDB looking downstream



LDB looking upstream







LDB looking cross channel



RDB looking cross channel

Referencing Information				
Watershed:	Horse River			
Transect Code:	CC4-50U			
Date Assessed:	27 May 2008			
Time Assessed:	1135			
Location (NAD83, Z12):	449603E, 6218514N			
Access:	Truck, Argo, Foot			
Water Quality				
Temperature (°C):	7.1			
Dissolved Oxygen (mg/L):	9.0			
pH:	7.01			
Conductivity (µS/cm):	11.5			
Turbidity (NTUs):	1.5			
Channel and Bottom Characteristics				
Bankfull Width (m):	25.0			
Wetted Width (m):	0.6			
Bottom – % Fines:	90			
Bottom – % Gravel	10			
Bottom – % Cobble	0			
Bottom – % Boulder	0			
Water Depth and Velocity				
% Wetted Width, from RDB →	25%	50%	75%	
Water Depth (m):	0.10	0.12	0.8	
Flow Velocity (ft/s):	0.35	0.35	0.62	
Stage:	Low			
Banks				
	LDB	RDB		
Height (m):	0.50	0.50		
Slope (%):	90	90		
Stability:	High	High		
Composition – % Fines:	100	100		
Composition – % Gravel	0	0		
Composition – % Cobble	0	0		
Composition – % Boulder	0	0		
Composition – % Bedrock:	0	0		
Type of Riparian Vegetation:	Grasses	Grasses		
	Shrubs	Shrubs		
Stage of Riparian Vegetation:	Shrub	Shrub		
Cover				
Crown Closure:	1% to 20%			
Small Woody Debris:	Abundant			
Large Woody Debris:	None			
Boulders:	Trace			
Undercut Banks:	None			
Deep Pools	None			
Overhanging Vegetation:	Abundant			
Instream Vegetation:	None			
Channel Morphology				
Morphology:	Riffle Pool			
Pattern:	Regular Meandering			
Islands:	None			
Bars:	None			
Coupling:	N/A- no hillslopes			
Fish Inventory				
Gear Type:	Electrofishing			
Fishing Effort (s):	351 s			
Total No. Fish Captured	0			
Species, Ave.Length (mm)	N/A			
Comments				


LDB looking downstream

RDB looking upstream

LDB looking cross channel

RDB looking cross channel



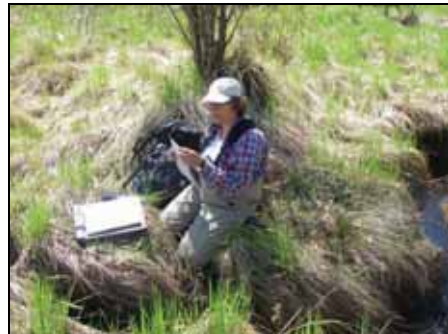
LDB looking downstream



RDB looking upstream







LDB looking cross channel



RDB looking cross channel

Referencing Information				
Watershed:	Horse River			
Transect Code:	CC4-Crossing			
Date Assessed:	27 May 2008			
Time Assessed:	1140			
Location (NAD83, Z12):	449577, 6218575N			
Access:	Truck, Argo, Foot			
Water Quality				
Temperature (°C):	6.9			
Dissolved Oxygen (mg/L):	9.0			
pH:	7.02			
Conductivity (µS/cm):	48.5			
Turbidity (NTUs):	1.6			
Channel and Bottom Characteristics				
Bankfull Width (m):	2.20			
Wetted Width (m):	0.60			
Bottom – % Fines:	70			
Bottom – % Gravel	25			
Bottom – % Cobble	5			
Bottom – % Boulder	0			
Water Depth and Velocity				
% Wetted Width, from RDB →	25%	50%	75%	
Water Depth (m):	0.22	0.12	0.04	
Flow Velocity (ft/s):	0.46	0.21	0.17	
Stage:	Low			
Banks				
	LDB	RDB		
Height (m):	0.25	0.60		
Slope (%):	30	30		
Stability:	High	High		
Composition – % Fines:	75	75		
Composition – % Gravel	25	25		
Composition – % Cobble	0	0		
Composition – % Boulder	0	0		
Composition – % Bedrock:	0	0		
Type of Riparian Vegetation:	Grasses	Grasses		
	Shrubs	Shrubs		
Stage of Riparian Vegetation:	Shrub	Shrub		
Cover				
Crown Closure:	71-90%			
Small Woody Debris:	Moderate			
Large Woody Debris:	Moderate			
Boulders:	None			
Undercut Banks:	Trace			
Deep Pools	None			
Overhanging Vegetation:	Dominant			
Instream Vegetation:	None			
Channel Morphology				
Morphology:	Riffle Pool			
Pattern:	Regular Meandering			
Islands:	None			
Bars:	None			
Coupling:	N/A- no hillslopes			
Fish Inventory				
Gear Type:	Minnow Trap/ Electrofishing			
Fishing Effort:	5.55 hr / 624 s			
Total No. Fish Captured	0			
Species, Ave.Length (mm)	N/A			
Comments				
Plenty of habitat during the spring, cobbles, gravel, undercut bands and overhanging vegetation.				


RDB looking downstream

RDB looking upstream

LDB looking cross channel

RDB looking cross channel



RDB looking downstream



RDB looking upstream







LDB looking cross channel



RDB looking cross channel

Referencing Information				
Watershed:	Horse River			
Transect Code:	CC4-100D			
Date Assessed:	27 May 2008			
Time Assessed:	1205			
Location (NAD83, Z12):	449444E, 6218699N			
Access:	Truck, Argo, Foot			
Water Quality				
Temperature (°C):	10.0			
Dissolved Oxygen (mg/L):	8.0			
pH:	7.06			
Conductivity (µS/cm):	64.2			
Turbidity (NTUs):	1.6			
Channel and Bottom Characteristics				
Bankfull Width (m):	20			
Wetted Width (m):	0.40			
Bottom – % Fines:	90			
Bottom – % Gravel	10			
Bottom – % Cobble	0			
Bottom – % Boulder	0			
Water Depth and Velocity				
% Wetted Width, from RDB →	25%	50%	75%	
Water Depth (m):	0.22	0.24	0.20	
Flow Velocity (ft/s):	0.20	0.26	0.18	
Stage:	Low			
Banks				
	LDB	RDB		
Height (m):	0.25	0.35		
Slope (%):	65	65		
Stability:	High	High		
Composition – % Fines:	100	100		
Composition – % Gravel	0	0		
Composition – % Cobble	0	0		
Composition – % Boulder	0	0		
Composition – % Bedrock:	0	0		
Type of Riparian Vegetation:	Grasses	Grasses		
	Shrubs	Shrubs		
Stage of Riparian Vegetation:	Shrub	Shrub		
Cover				
Crown Closure:	21-40%			
Small Woody Debris:	Abundant			
Large Woody Debris:	Abundant			
Boulders:	None			
Undercut Banks:	None			
Deep Pools	Trace			
Overhanging Vegetation:	Dominant			
Instream Vegetation:	None			
Channel Morphology				
Morphology:	Pool			
Pattern:	Regular Meandering			
Islands:	None			
Bars:	None			
Coupling:	N/A- no hillslopes			
Fish Inventory				
Gear Type:	Minnow Trap/ Electrofishing			
Fishing Effort:	3.45 hr / 624 s			
Total No. Fish Captured	0			
Species, Ave.Length (mm)	N/A			
Comments				
Good fish habitat with lots of woody debris for cover.				


LDB looking downstream

RDB looking upstream

LDB facing cross channel

RDB facing cross channel



LDB looking downstream



RDB looking upstream



LDB facing cross channel



RDB facing cross channel

Referencing Information	
Watershed:	Christina River
Transect Code:	CR-100U
Date Assessed:	24 June 2009
Time Assessed:	1235
Location (NAD83, 12V):	456838E, 6216985N
Access:	Helicopter and Foot
Water Quality	
Temperature (°C):	14.64
Dissolved Oxygen (mg/L):	8.49
pH:	7.17
Conductivity (µS/cm):	67
Turbidity (NTUs):	1.9
Channel and Bottom Characteristics	
Channel Width (m):	3.5
Wetted Width (m):	2.5
Bottom – % Fines:	10
Bottom – % Gravel	0
Bottom – % Cobble	85
Bottom – % Boulder	5
Water Depth and Velocity	
% Wetted Width, from RDB →	25% 50% 75%
Water Depth (m):	0.15 0.23 0.12
Flow Velocity (m/s):	0.01 0.02 0.03
Stage:	Moderate
Banks	
	LDB RDB
Height (m):	1.0 0.9
Slope (%):	85 85
Stability:	Moderate Moderate
Composition – % Fines:	100 100
Composition – % Gravel	0 0
Composition – % Cobble	0 0
Composition – % Boulder	0 0
Composition – % Bedrock:	0 0
Type of Riparian Vegetation:	Grasses Grasses
	Shrubs Shrubs
Stage of Riparian Vegetation:	Shrub Shrub
Overhead Cover	
Overhead cover:	30%
Overhead litter (<150mm):	5%
Overhead litter (>150mm):	0%
Overhead Undercut banks:	30%
Overhanging trees:	0%
Overhanging grasses:	30%
Overhanging shrubs:	35%
Channel Morphology	
Morphology:	Riffle
Pattern:	Irregular meandering
Islands:	None
Bars:	None
Meander frequency:	5m
Landscape	
Riparian zone (25m buffer):	Coniferous forest, shrubs
Landscape zone (beyond 25m):	Coniferous forest, grasses, re-growth forest, cutlines, shrubs, hills
Visible disturbances:	None
Barriers to fish passage:	None



Upstream from LDB



Downstream from LDB




Cross stream from LDB




In stream substrate


Referencing Information				
Watershed:	Christina River			
Transect Code:	CR-Crossing			
Date Assessed:	24 June 2009			
Time Assessed:	1055			
Location (NAD83, 12V):	445884E, 6217055N			
Access:	Helicopter and Foot			
Water Quality				
Temperature (°C):	13.58			
Dissolved Oxygen (mg/L):	9.02			
pH:	7.32			
Conductivity (µS/cm):	53			
Turbidity (NTUs):	1.83			
Channel and Bottom Characteristics				
Channel Width (m):	2.69			
Wetted Width (m):	2.68			
Bottom – % Fines:	100			
Bottom – % Gravel	0			
Bottom – % Cobble	0			
Bottom – % Boulder	0			
Water Depth and Velocity				
% Wetted Width, from RDB →	25%	50%	75%	
Water Depth (m):	0.55	0.47	0.41	
Flow Velocity (m/s):	1.30	1.30	1.30	
Stage:	Moderate			
Banks				
	LDB	RDB		
Height (m):	0.93	0.90		
Slope (%):	85	85		
Stability:	Moderate	Moderate		
Composition – % Fines:	100	100		
Composition – % Gravel	0	0		
Composition – % Cobble	0	0		
Composition – % Boulder	0	0		
Composition – % Bedrock:	0	0		
Type of Riparian Vegetation:	Grasses	Grasses		
	Shrubs	Shrubs		
Stage of Riparian Vegetation:	Shrub	Shrub		
Cover				
Overhead cover:	15%			
Overhead litter (<150mm):	0%			
Overhead litter (>150mm):	0%			
Overhead Undercut banks:	0%			
Overhanging trees:	0%			
Overhanging grasses:	23%			
Overhanging shrubs:	77%			
Channel Morphology				
Morphology:	Run			
Pattern:	Irregular meandering			
Islands:	None			
Bars:	1 (0.6m by 0.35m)			
Meander frequency:	5			
Landscape				
Riparian zone (25m buffer):	Coniferous forest, mixed forest, grasses, shrubs, sedges			
Landscape zone (beyond 25m):	Coniferous forest, grasses, re-growth forest, cutlines, shrubs, hills			
Visible disturbances:	None			




Upstream from LDB



Downstream from LDB



Cross stream from LDB



Cross stream from RDB

Referencing Information	
Watershed:	Christina River
Transect Code:	CR-100D
Date Assessed:	24 June 2009
Time Assessed:	1430
Location (NAD83, 12V):	456953E, 6217138N
Access:	Helicopter and Foot
Water Quality	
Temperature (°C):	15.27
Dissolved Oxygen (mg/L):	8.54
pH:	7.25
Conductivity (µS/cm):	55
Turbidity (NTUs):	3.03
Channel and Bottom Characteristics	
Channel Width (m):	3.16
Wetted Width (m):	1.15
Bottom – % Fines:	95
Bottom – % Gravel	5
Bottom – % Cobble	0
Bottom – % Boulder	0
Water Depth and Velocity	
% Wetted Width, from RDB →	25% 50% 75%
Water Depth (m):	0.49 0.48 0.53
Flow Velocity (m/s):	0.45 0.50 0.30
Stage:	Moderate
Banks	
	LDB RDB
Height (m):	1.05 1.10
Slope (%):	85 85
Stability:	Moderate Moderate
Composition – % Fines:	100 100
Composition – % Gravel	0 0
Composition – % Cobble	0 0
Composition – % Boulder	0 0
Composition – % Bedrock:	0 0
Type of Riparian Vegetation:	Grasses Grasses
	Shrubs Shrubs
Stage of Riparian Vegetation:	Shrub Shrub
Cover	
Overhead cover:	30%
Overhead litter (<150mm):	30%
Overhead litter (>150mm):	0%
Overhead Undercut banks:	0%
Overhanging trees:	0%
Overhanging grasses:	40%
Overhanging shrubs:	30%
Channel Morphology	
Morphology:	Run/Pool
Pattern:	Irregular meandering
Islands:	
Bars:	
Meander frequency:	7.5
Landscape	
Riparian zone (25m buffer):	Coniferous forest, re-growth forest, cutlines, shrubs, sedges
Landscape zone (beyond 25m):	Coniferous forest, cutlines, shrubs, hills
Visible disturbances:	None



Upstream from LDB



Downstream from LDB



Cross stream from LDB



Cross stream from RDB

Referencing Information	
Watershed:	Christina River
Transect Code:	CR-200D
Date Assessed:	24 June 2009
Time Assessed:	1500
Location (NAD83, 12V):	456994E, 6217075N
Access:	Helicopter and Foot
Water Quality	
Temperature (°C):	15.61
Dissolved Oxygen (mg/L):	8.24
pH:	7.26
Conductivity (µS/cm):	55
Turbidity (NTUs):	3.2
Channel and Bottom Characteristics	
Channel Width (m):	3.4
Wetted Width (m):	1.9
Bottom – % Fines:	100
Bottom – % Gravel	0
Bottom – % Cobble	0
Bottom – % Boulder	0
Water Depth and Velocity	
% Wetted Width, from RDB →	25% 50% 75%
Water Depth (m):	0.41 0.29 0.09
Flow Velocity (m/s):	0.68 0.68 0.39
Stage:	Moderate
Banks	
	LDB RDB
Height (m):	1.05 0.70
Slope (%):	90 90
Stability:	Moderate Moderate
Composition – % Fines:	100 100
Composition – % Gravel	0 0
Composition – % Cobble	0 0
Composition – % Boulder	0 0
Composition – % Bedrock:	0 0
Type of Riparian Vegetation:	Grasses Grasses
	Shrubs Shrubs
Stage of Riparian Vegetation:	Shrub Shrub
Cover	
Overhead cover:	30%
Overhead litter (<150mm):	0%
Overhead litter (>150mm):	0%
Overhead Undercut banks:	0%
Overhanging trees:	0%
Overhanging grasses:	70%
Overhanging shrubs:	30%
Channel Morphology	
Morphology:	Run
Pattern:	Irregular meandering
Islands:	
Bars:	
Meander frequency:	7.5
Landscape	
Riparian zone (25m buffer):	Coniferous forest, re-growth forest, grasses, shrubs, sedges
Landscape zone (beyond 25m):	Coniferous forest, cutlines, re-growth forest, shrubs, hills
Visible disturbances:	
Barriers to fish movement	None



Upstream from LDB



Downstream from LDB



Cross stream from LDB



Cross stream from RDB

Referencing Information	
Watershed:	Christina River
Transect Code:	CR-300D
Date Assessed:	24 June 2009
Time Assessed:	1550
Location (NAD83, 12V):	457053E, 6217153N
Access:	Helicopter and Foot
Water Quality	
Temperature (°C):	15.95
Dissolved Oxygen (mg/L):	8.15
pH:	7.19
Conductivity (µS/cm):	55
Turbidity (NTUs):	2.93
Channel and Bottom Characteristics	
Channel Width (m):	3.70
Wetted Width (m):	2.15
Bottom – % Fines:	25
Bottom – % Gravel	5
Bottom – % Cobble	60
Bottom – % Boulder	10
Water Depth and Velocity	
% Wetted Width, from RDB →	25% 50% 75%
Water Depth (m):	0.27 0.23 0.13
Flow Velocity (m/s):	0.60 0.92 0.56
Stage:	Moderate
Banks	
	LDB RDB
Height (m):	1.10 0.85
Slope (%):	90 90
Stability:	
Composition – % Fines:	100 100
Composition – % Gravel	0 0
Composition – % Cobble	0 0
Composition – % Boulder	0 0
Composition – % Bedrock:	0 0
Type of Riparian Vegetation:	Grasses Grasses
	Shrubs Shrubs
Stage of Riparian Vegetation:	Shrub Shrub
Cover	
Overhead cover:	40%
Overhead litter (<150mm):	10%
Overhead litter (>150mm):	10%
Overhead Undercut banks:	0%
Overhanging trees:	0%
Overhanging grasses:	60%
Overhanging shrubs:	20%
Channel Morphology	
Morphology:	Run
Pattern:	Irregular meandering
Islands:	
Bars:	
Meander frequency:	7.5
Landscape	
Riparian zone (25m buffer):	Coniferous forest, re-growth forest, grasses, shrubs, sedges
Landscape zone (beyond 25m):	Coniferous forest, re-growth forest, shrubs
Visible disturbances:	
Barriers to fish movement	None



Upstream from LDB



Downstream from LDB



Cross stream from LDB



Cross stream from RDB

Appendix A4

Lake Habitat Survey and Bathymetry Data and Flyover Surveys

Figure A4.1 Results of habitat surveys for C02 (Unnamed Lake-2.)

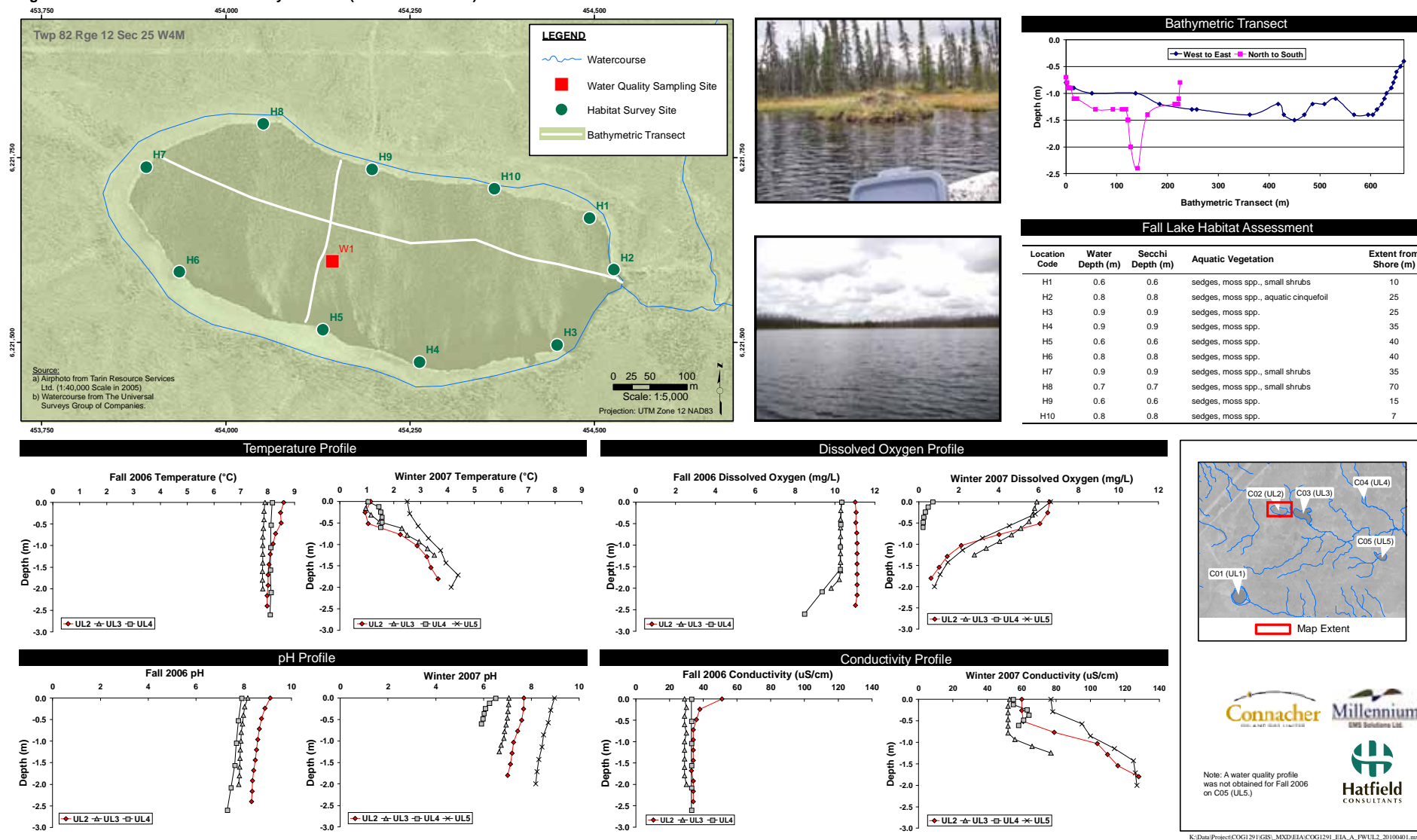
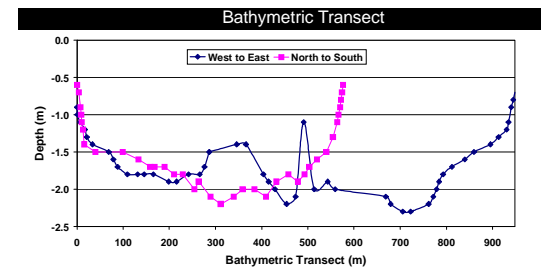
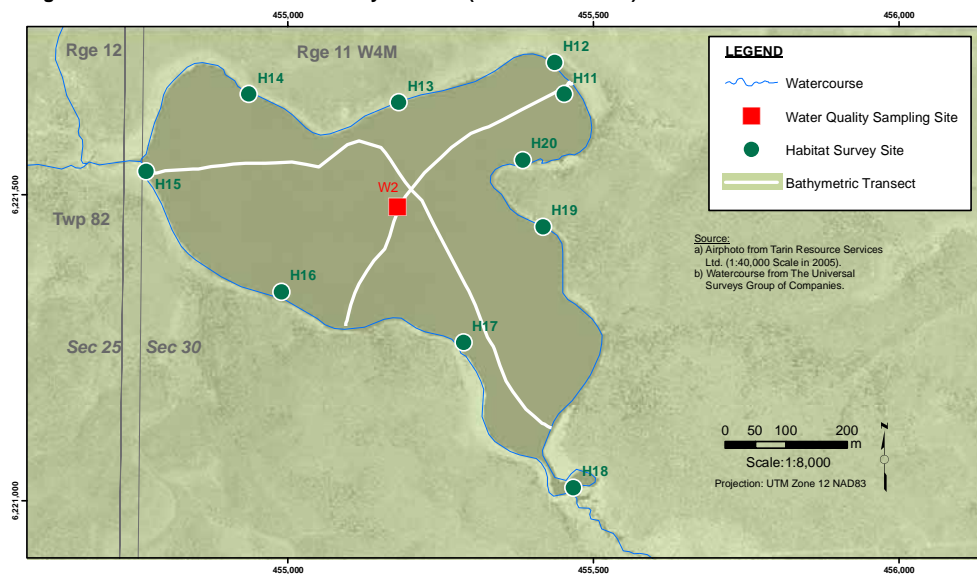


Figure A4.2 Results of habitat surveys for C03 (Unnamed Lake-3.)



Fall Lake Habitat Assessment

Location Code	Water Depth (m)	Secchi Depth (m)	Aquatic Vegetation	Extent from Shore (m)
H11	1.0	n/a	sedges	10
H12	0.7	n/a	sedges	10
H13	0.8	n/a	sedges	5
H14	0.9	n/a	sedges	6
H15	0.8	n/a	sedges	15
H16	0.9	n/a	sedges	3
H17	0.7	n/a	sedges	
H18	1.5	n/a	sedges	25
H19	0.7	n/a	sedges	4
H20	0.8	n/a	sedges	4

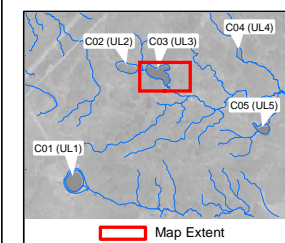
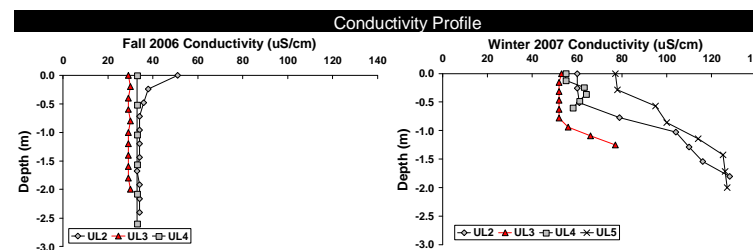
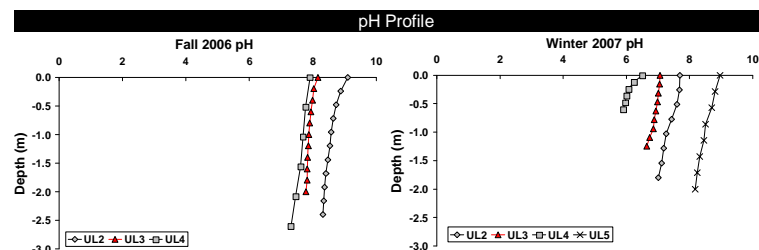
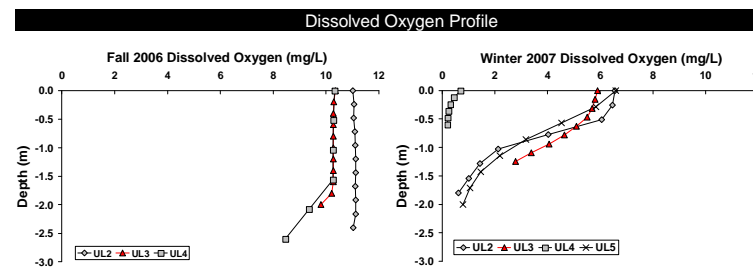
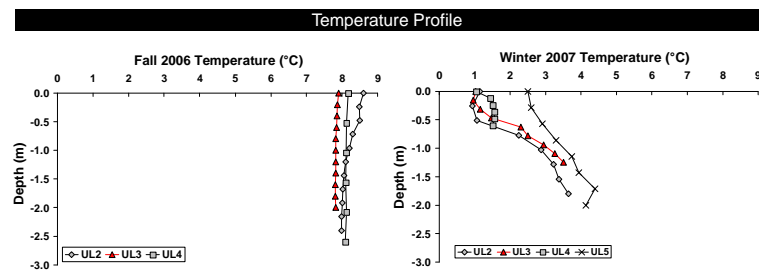
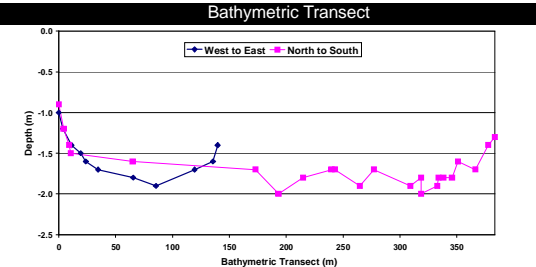
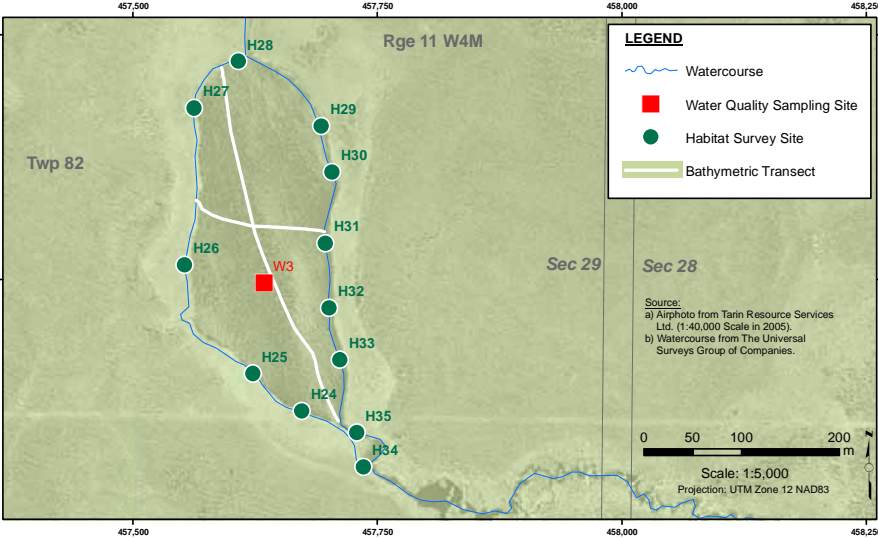
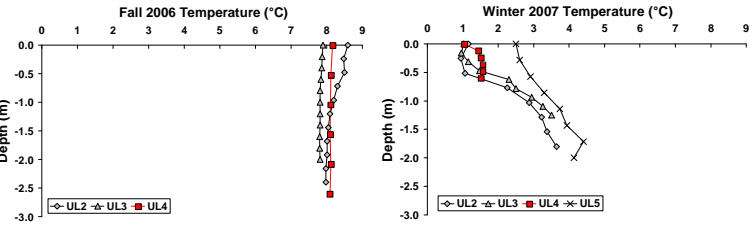


Figure A4.3 Results of habitat surveys for C04 (Unnamed Lake-4.)

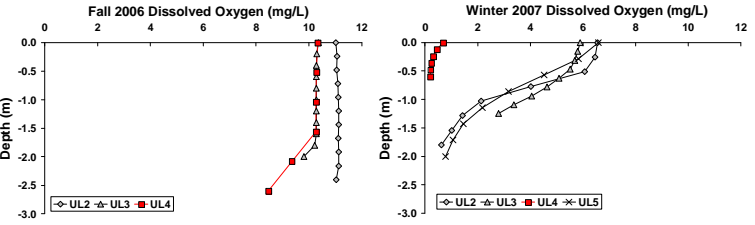


Fall Lake Habitat Assessment				
Location Code	Water Depth (m)	Secchi Depth (m)	Aquatic Vegetation	Extent from Shore (m)
H24	0.8	0.7	sedges, small willows to black spruce	35
H25	0.6	0.6	sedges, buck bean	32
H26	0.6	0.6	sedges, buck bean	42
H27	0.6	0.5	sedges, buck bean, aquatic cinquefoil	30
H28	0.7	0.5	sedges, buck bean, aquatic cinquefoil	140
H29	0.6	0.5	sedges, buck bean, aquatic cinquefoil	65
H30	1.5	0.6	sedges, buck bean, aquatic cinquefoil	35
H31	1.2	0.5	sedges, moss spp., small shrubs	30
H32	1.3	0.6	sedges, small willows to mature black spruce	25
H33	0.5	0.5	sedges, small willows to black spruce	40
H34	0.6	0.6	sedges, small willows to black spruce	5
H35	0.8	0.7	sedges, small willows to black spruce	n/a

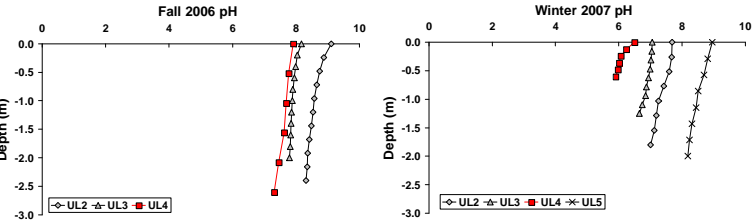
Temperature Profile



Dissolved Oxygen Profile



pH Profile



Conductivity Profile

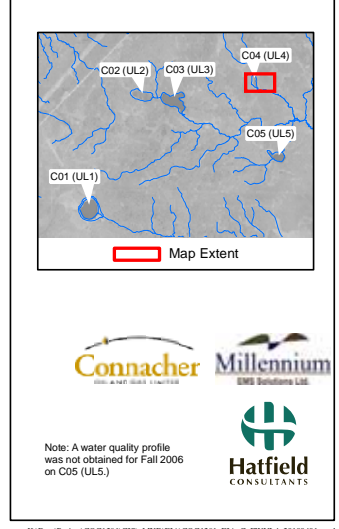
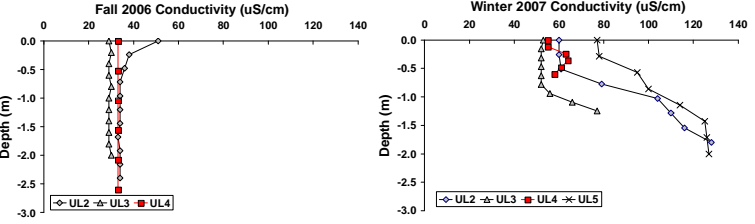


Figure A4.4 Results of habitat surveys for C06 (Unnamed Lake-5.)

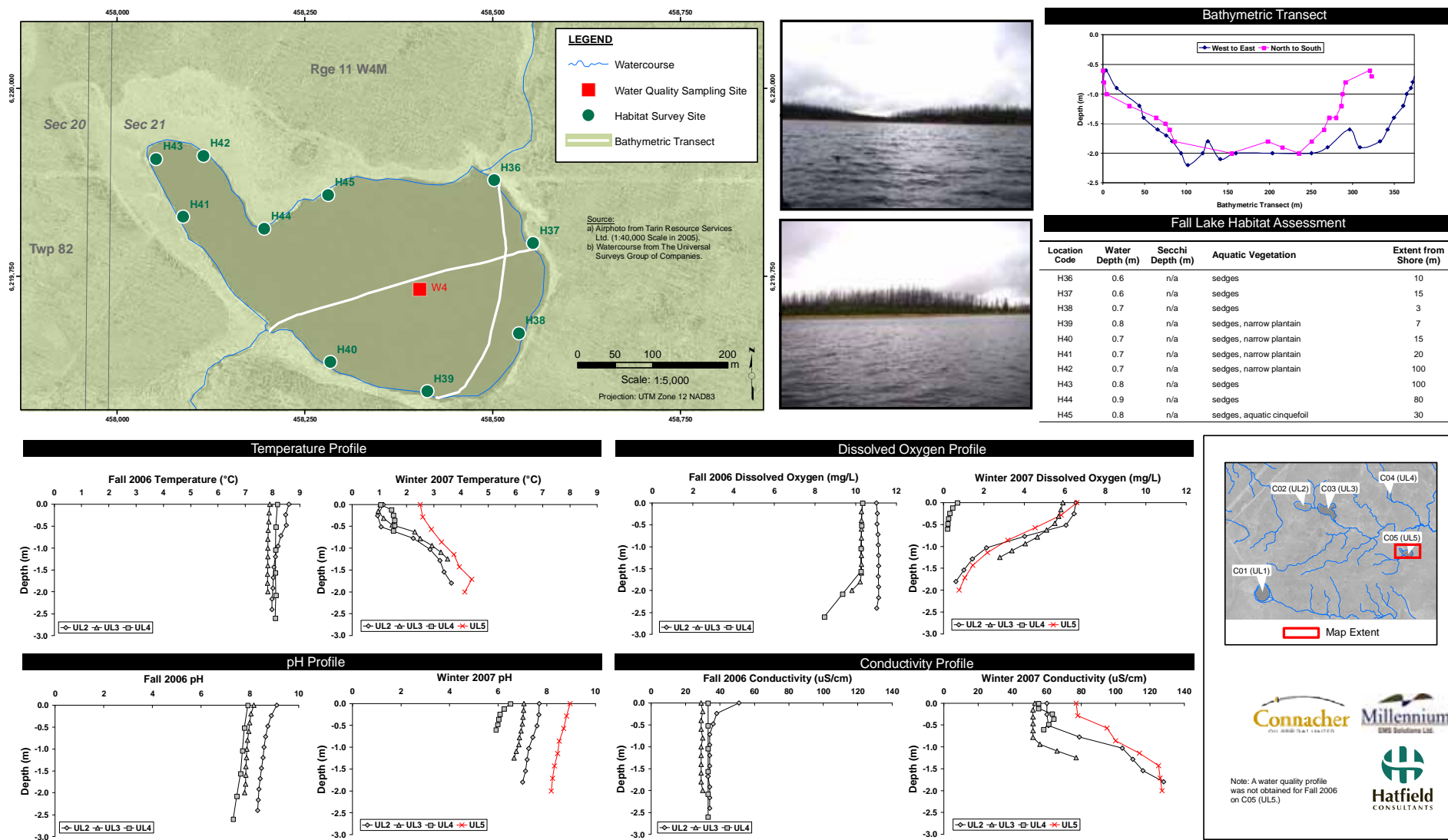


Figure A4.5 Fall 2006 stream habitat conditions: waypoints 17 to 32.

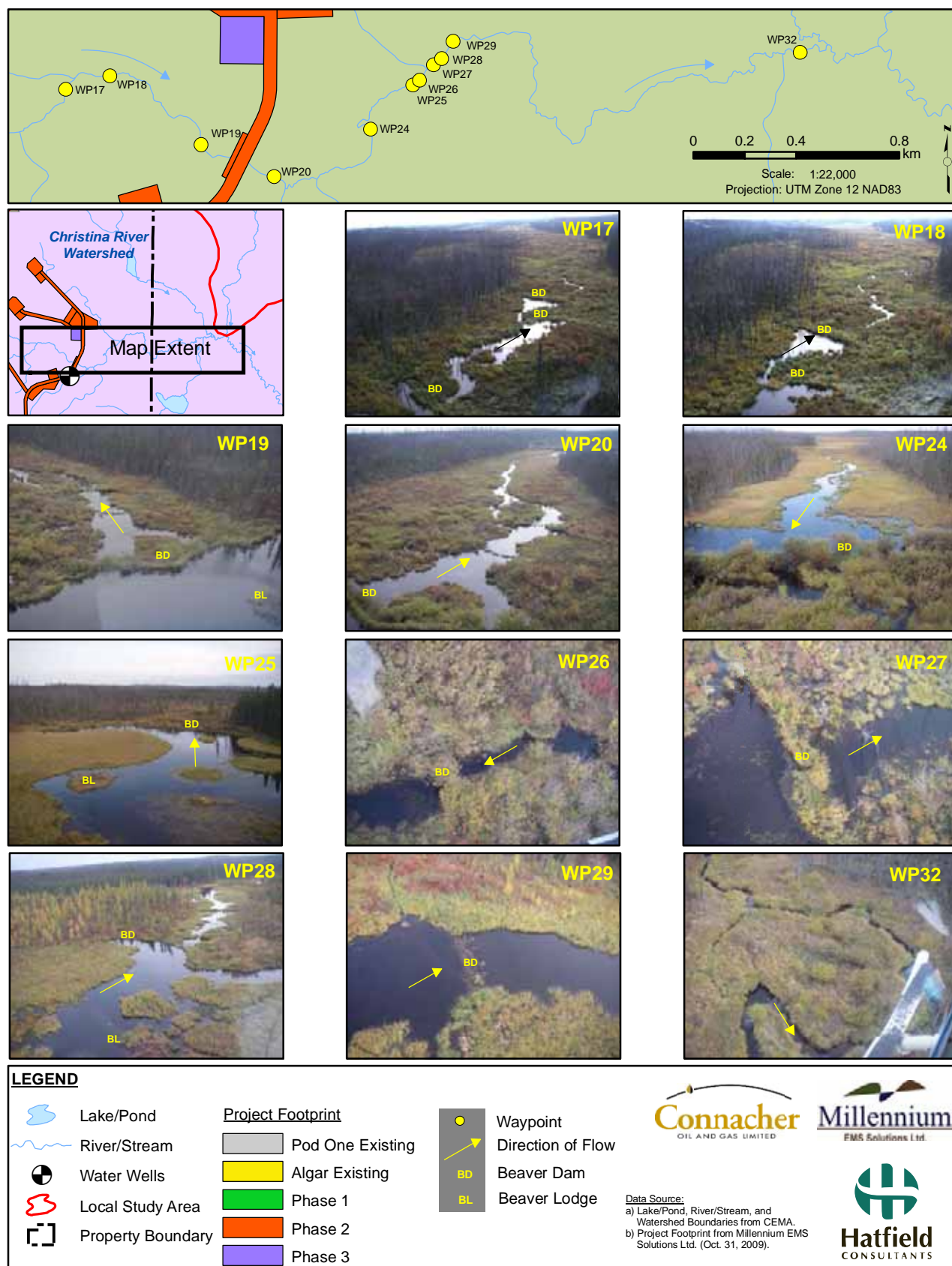


Figure A4.6 Fall 2006, stream habitat conditions: waypoints 40 to 54.

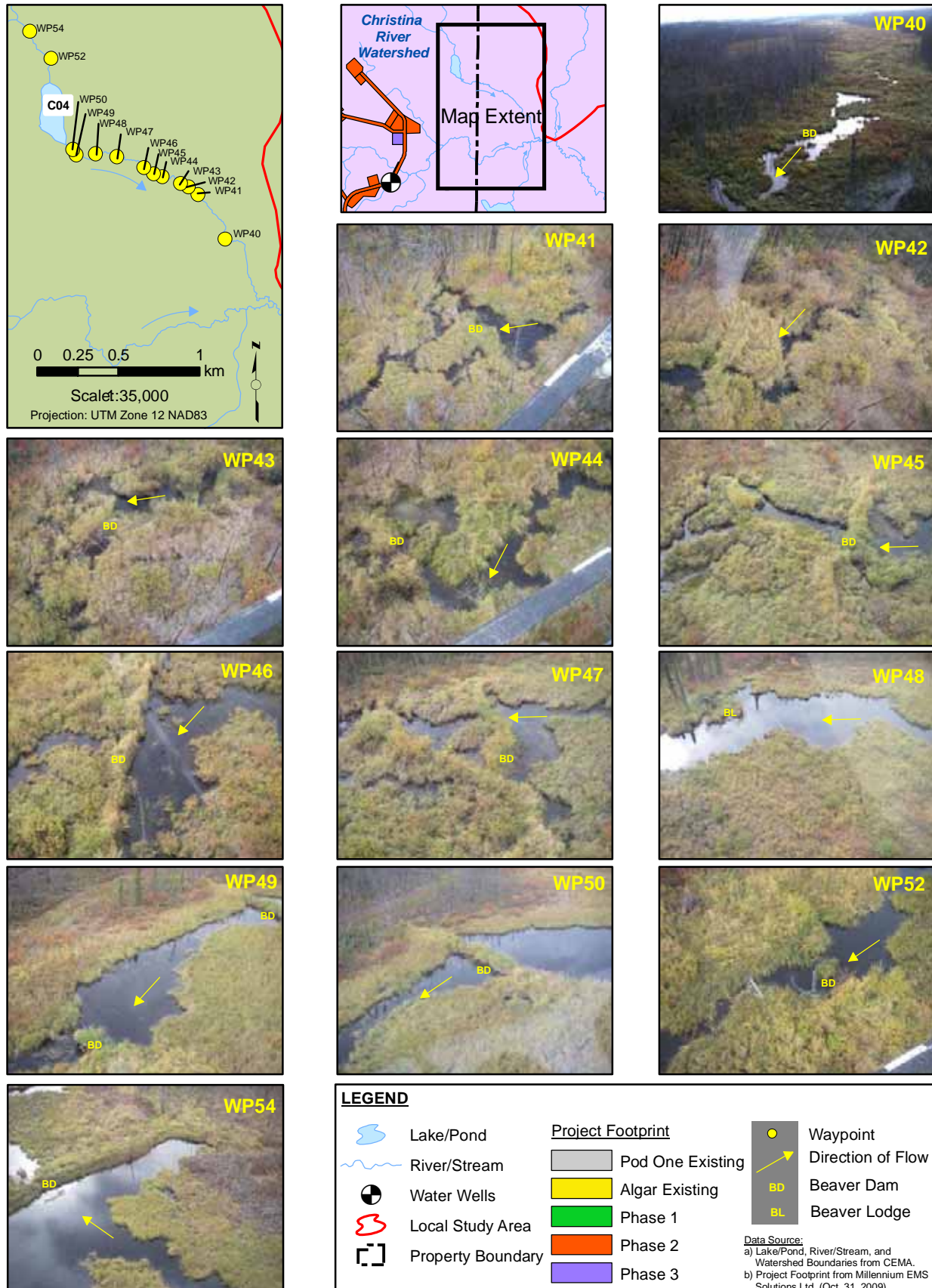
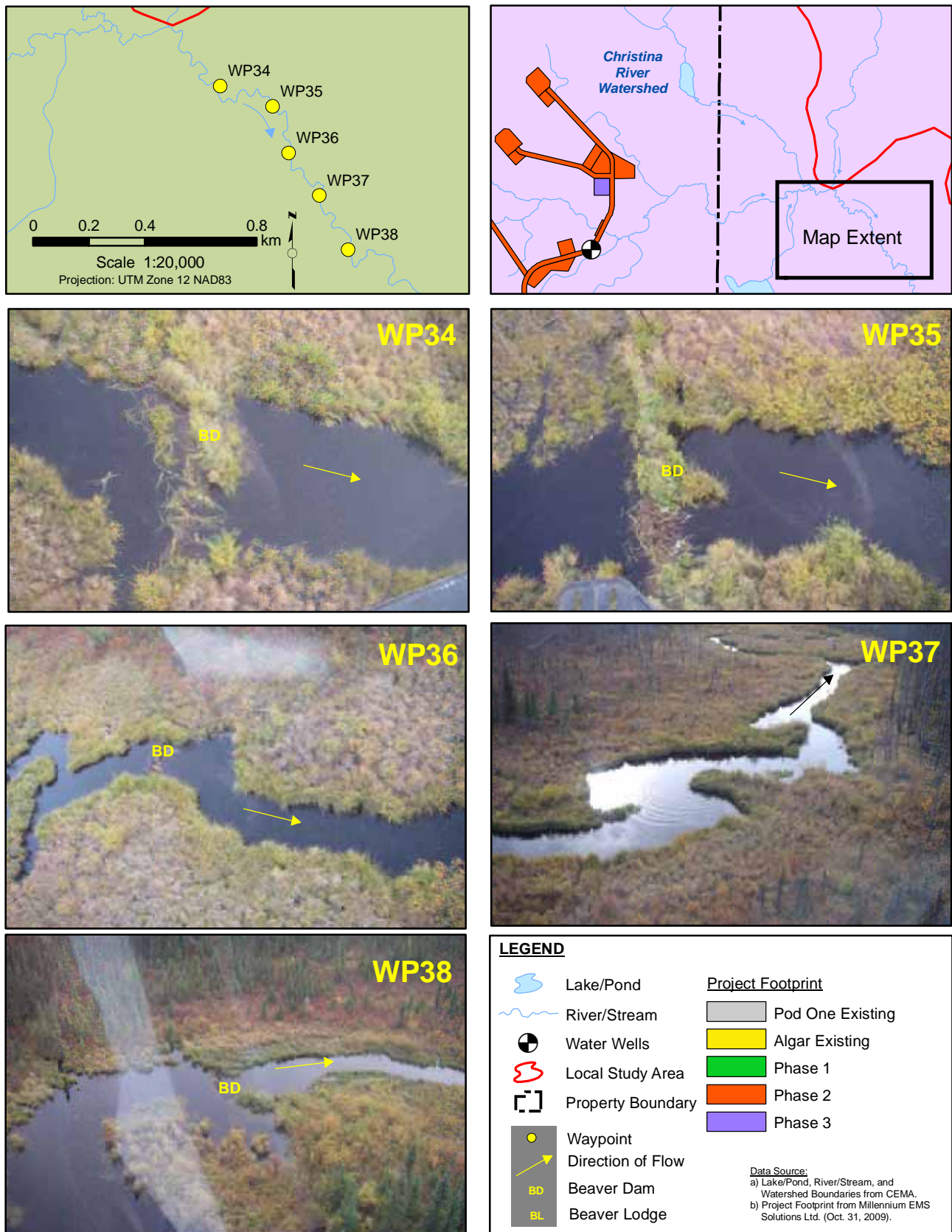


Figure A4.7 Fall 2006, stream habitat conditions: waypoints 34 to 38.



Appendix A5

Field Work Activities and Methodology – Sediment Quality

A5.1 FIELD WORK ACTIVITIES AND METHODOLOGY – SEDIMENT QUALITY

Sediment quality sampling was conducted at nine sites in fall 2007 ([Table A5.1](#)) following RAMP protocol (RAMP 2005). Three replicate samples were collected at each sampling site with a 6" x 6" Ekman dredge (0.023 m² opening). Samples were transferred into labeled, sterilized glass jars for chemical analyses. All samples were stored on ice prior to and during shipment to the analytical laboratory. All analyses were completed by Enviro-Test Laboratories Ltd. (ETL, Edmonton, Alberta). Sediment quality results are provided in [Table A5.1](#).

Table A5.1 Sediment Quality for sampled sites.

Analyte	Units	Guideline		C02	C03	C04	C06	C07	C10	C17	C19	C22
		ISQG ¹	PEL ²	Aug 07	Aug 07	Aug 07	Aug 07	Aug 07	Aug 07	Aug 07	Aug 07	Aug 07
% Clay	%			42	48	31	2	4	36	15	5	5
% Silt	%			32	38	46	32	37	30	24	12	15
% Sand	%			26	13	23	66	59	35	61	83	80
Texture	mg/kg			Clay	Clay	Clay	Sandy loam	Sandy loam	Clay loam	Sandy loam	Loamy sand	Loamy sand
% Moisture	%			91	92	95		81				
2-Bromobenzotrifluoride	%			74	72	39		103				
Aluminum (Al)	mg/kg								4400	2770		
Antimony (Sb)	mg/kg			<0.2	<0.2	<0.2	<0.2	<0.2			<0.2	<0.2
Arsenic (As)	mg/kg	5.9	17	2.5	3	2.7	1.1	0.7	7.6	1.6	1.2	9.9
Barium (Ba)	mg/kg			140	106	69	66	62	174	55.7	25	94
Benzene	mg/kg			<0.06	<0.07	<0.01		<0.03				
Beryllium (Be)	mg/kg			<1	<1	<1	<1	<1	0.2	<0.2	<1	<1
Bismuth (Bi)	mg/kg								<0.5	<0.5		
Boron (B)	mg/kg								6	3		
CaCO3 Equivalent	%			<0.7	0.9	1.5	5.4	0.7	1.8	<0.7	<0.7	<0.7
Cadmium (Cd)	mg/kg	0.6	3.5	0.7	1.1	1.1	<0.5	<0.5	0.7	0.2	<0.5	<0.5
Calcium (Ca)	mg/kg								8400	1900		
Chromatogram to baseline at nC50				NO	NO	NO		NO				
Chromium (Cr)	mg/kg	37.3	90	7.2	9.9	5.8	4.4	6.2	6.8	4.7	3.4	4.7
Cobalt (Co)	mg/kg			4	5	5	3	2	16.6	2	3	3
Copper (Cu)	mg/kg	35.7	197	7	10	7	6	3	7	2.8	3	4
Ethylbenzene	mg/kg			<0.1	<0.1	<0.2		<0.05				
F1-BTEX	mg/kg			<5	<5	<5		<5				
F1 (C6-C10)	mg/kg	30 ³		<5	<5	<5		<5				
F2 (C10-C16)	mg/kg	150 ³		<5	<5	<5		<5				
F3 (C16-C34)	mg/kg	400 ³		2400	490	240		1100				
F4 (C34-C50)	mg/kg	2800 ³		1900	170	81		610				
Hexatriacontane	%			100	48	69		143				
Inorganic Carbon	%			<0.1	<0.1	<0.1	0.6	<0.1	0.2	<0.1	<0.1	<0.1
Iron (Fe)	mg/kg								35700	6000		
Lead (Pb)	mg/kg	35	91.3	7	6	<5	<5	<5	4.4	3.2	<5	<5
Magnesium (Mg)	mg/kg								1060	680		
Manganese (Mn)	mg/kg								1160	155		
Mercury (Hg)	mg/kg	0.17	0.486	<0.05	<0.05	<0.05	<0.05	<0.05	0.08	<0.05	<0.05	<0.05
Molybdenum (Mo)	mg/kg			<1	<1	<1	<1	<1	1	0.3	<1	<1
Nickel (Ni)	mg/kg			11	17	12	4	4	8.6	3.1	5	5
Potassium (K)	mg/kg								500	300		
Selenium (Se)	mg/kg			0.8	1	0.7	0.4	0.4	1.1	0.2	0.2	0.3
Silver (Ag)	mg/kg			<1	<1	<1	<1	<1	<0.2	<0.2	<1	<1
Sodium (Na)	mg/kg								100	<100		
Strontium (Sr)	mg/kg								39	14		
Thallium (Tl)	mg/kg			<1	<1	<1	<1	<1	0.12	0.08	<1	<1
Tin (Sn)	mg/kg			<5	<5	<5	<5	<5	<2	<2	<5	<5
Titanium (Ti)	mg/kg								31	35		
Toluene	mg/kg			<0.1	<0.1	<0.2		<0.05				
Total Carbon by Combustion	%			23.8	23	26.2	10.1	9.7	16.7	4.7	1.3	2
Total Hydrocarbons (C6-C50)	mg/kg			4300	660	320		1700				
Total Organic Carbon	%			23.8	23	26.2	9.5	9.7	16.5	4.7	1.3	2
Uranium (U)	mg/kg			<2	<2	<2	<2	<2	1.39	0.55	<2	<2
Vanadium (V)	mg/kg			11	15	8	7	8	18.8	7.3	6	9
Xylenes	mg/kg			<0.2	<0.3	<0.5		<0.1				
Zinc (Zn)	mg/kg	123	315	90	130	100	40	20	56	28	20	20

¹ Freshwater sediment quality guidelines (CCME 2002).

² Freshwater sediment quality probable effects levels (CCME 2002).

³ Guideline is for residential/parkland coarse (median grain size > 75 µm) surface soils (CCME 2001).

Below Detection Limit

Exceeds relevant guideline

Appendix A6

Field Work Activities and Methodology – Benthic Invertebrate Communities

A6.1 FIELD WORK ACTIVITIES AND METHODOLOGY – BENTHIC INVERTEBRATE COMMUNITIES

Benthic invertebrate sampling occurred at the same at nine locations as sediment sampling in fall 2007 ([Table 6.1](#)) and followed the RAMP protocol (RAMP 2005). Specifically, three replicate samples were collected from each site using 6" x 6" Ekman dredge (0.023 m² opening) for each sample. Samples were analyzed by Dr. Jack Zloty in Summerland, British Columbia. Organisms were identified using published taxonomic keys (e.g., Edmunds et al. 1976; Pennak 1989; Clifford 1991; Stewart et al. 1993; Wiggins 1996; Epler 2001) to the lowest possible taxonomic level; immature organisms were typically identified to family. Hence, community estimates are based at the family taxonomic level. Benthic Invertebrate community results are provided in this [Appendix A6](#).

Table 6.1 Benthic Invertebrate Communities Analysis.

Major Taxon	Family	Subfamily/Tribe	C02			C03			C04			C06			C07			C10			C17			C19			C22			
			#1	#2	#3	#1	#2	#3	#1	#2	#3	#1	#2	#3	#1	#2	#3	#1	#2	#3	#1	#2	#3	#1	#2	#3	#1	#2	#3	
Nematoda	Lumbriculidae	—				9	16					104			8	16			1			8	1				8	16		
Oligochaeta	Naididae	—			1		16					8			72			1			1						88			
Hirudinea	Tubificidae	—				9		8				18		1	9	33	26	1		26	40	1		16		1	24	17		
	Erpobdellidae	<i>Erpobdella punctata</i>											1										1		1	2				
	Glossiphoniidae	<i>Glossiphonia complanata</i> <i>Helobdella stagnalis</i>				24		1	8						2						1									
Hydracarina	—	—						8	32	8		24	8	8	8			8		16						45	40	16		
Ostracoda	—	—				8								8	24			64		8			1			1488	2496	304		
Cladocera	Chydoridae	—										280	32	24				16								40		120		
	Macrothricidae	—					8						16									2								
Copepoda—Cyclopoida	—	—							40			48	8	24	8		8	48				1				56	184	24		
Copepoda— Harpacticoida	—	—										24		16	8		8									8		8		
Amphipoda	Talitridae	<i>Hyaella azteca</i>													8															
Gastropoda	Planorbidae (i/d)	—																												
	Valvatidae	<i>Valvata sincera</i>			1	9		4	16						8															
Pelecypoda	Sphaeriidae	<i>Pisidium</i>					16	1				16	1	1	10		2										1			
	Sphaeriidae	<i>Sphaerium</i>													1															
	Sphaeriidae (i/d)	—	16	8		16	16	48	24		8	40		8				24	8	24		8	3							
Ephemeroptera	Caenidae	<i>Caenis</i>																												
Trichoptera	Hydroptilidae	<i>Oxyethira</i>							8			8																		
	Molannidae	<i>Molanna</i>																												
	Phryganeidae	<i>Ptilostomis</i>			1										8															
Odonata –Anisoptera	Corduliidae	<i>Cordulia shurtleffi</i> <i>Somatochlora</i>												1										2						
Neuroptera	Sialidae	<i>Sialis</i>																									1			
Coleoptera	Chrysomelidae	<i>Donacia</i>																1									1			
	Dytiscidae	(i/d)																									1			
Diptera	Ceratopogonidae	<i>Bezzia</i> <i>Culicoides</i> <i>Probezzia</i> <i>Chaoborus</i> <i>Hemerodromia</i> <i>Pericoma</i> <i>Simulium</i> <i>Chrysops</i> <i>Hexatoma/Limnophila</i>							8					1							8		1					8		
	Chironomidae – pupa	(i/d)					8					8															2	32		
		<i>Ablabesmyia</i> <i>Clinotanytus</i> <i>Procladius</i> (i/d) <i>Chironomus</i> <i>Cladopelma</i> <i>Cryptochironomus</i> <i>Cryptotendipes</i> <i>Dicrotendipes</i> <i>Einfeldia</i> <i>Endochironomus</i> <i>Glyptotendipes</i> <i>Microtendipes</i> <i>Pagastiella</i> <i>Parachironomus</i> <i>Paratendipes</i> <i>Phaenopsectra</i> <i>Polypedilum</i> <i>Sergentia</i> <i>Stictochironomus</i> <i>Tribeles</i>				1	1	1	1	8	8	5	76	115	1	42	1	78	5	81		1		8		1	112	24		
		<i>Chironomus</i> <i>Cladopelma</i> <i>Cryptochironomus</i> <i>Cryptotendipes</i> <i>Dicrotendipes</i> <i>Einfeldia</i> <i>Endochironomus</i> <i>Glyptotendipes</i> <i>Microtendipes</i> <i>Pagastiella</i> <i>Parachironomus</i> <i>Paratendipes</i> <i>Phaenopsectra</i> <i>Polypedilum</i> <i>Sergentia</i> <i>Stictochironomus</i> <i>Tribeles</i>				6		1		8		15	35	5	9		8		61		8		1	8		99	107			
		<i>Chironomus</i> <i>Cladopelma</i> <i>Cryptochironomus</i> <i>Cryptotendipes</i> <i>Dicrotendipes</i> <i>Einfeldia</i> <i>Endochironomus</i> <i>Glyptotendipes</i> <i>Microtendipes</i> <i>Pagastiella</i> <i>Parachironomus</i> <i>Paratendipes</i> <i>Phaenopsectra</i> <i>Polypedilum</i> <i>Sergentia</i> <i>Stictochironomus</i> <i>Tribeles</i>							8		8		8	96	48	8	128	128	48	128		8				8	32	16		
		<i>Chironomus</i> <i>Cladopelma</i> <i>Cryptochironomus</i> <i>Cryptotendipes</i> <i>Dicrotendipes</i> <i>Einfeldia</i> <i>Endochironomus</i> <i>Glyptotendipes</i> <i>Microtendipes</i> <i>Pagastiella</i> <i>Parachironomus</i> <i>Paratendipes</i> <i>Phaenopsectra</i> <i>Polypedilum</i> <i>Sergentia</i> <i>Stictochironomus</i> <i>Tribeles</i>								8		8		8				8									8	8		
		<i>Chironomus</i> <i>Cladopelma</i> <i>Cryptochironomus</i> <i>Cryptotendipes</i> <i>Dicrotendipes</i> <i>Einfeldia</i> <i>Endochironomus</i> <i>Glyptotendipes</i> <i>Microtendipes</i> <i>Pagastiella</i> <i>Parachironomus</i> <i>Paratendipes</i> <i>Phaenopsectra</i> <i>Polypedilum</i> <i>Sergentia</i> <i>Stictochironomus</i> <i>Tribeles</i>				1							8	17	1	9			25											
		<i>Chironomus</i> <i>Cladopelma</i> <i>Cryptochironomus</i> <i>Cryptotendipes</i> <i>Dicrotendipes</i> <i>Einfeldia</i> <i>Endochironomus</i> <i>Glyptotendipes</i> <i>Microtendipes</i> <i>Pagastiella</i> <i>Parachironomus</i> <i>Paratendipes</i> <i>Phaenopsectra</i> <i>Polypedilum</i> <i>Sergentia</i> <i>Stictochironomus</i> <i>Tribeles</i>											8															1	21	
		<i>Chironomus</i> <i>Cladopelma</i> <i>Cryptochironomus</i> <i>Cryptotendipes</i> <i>Dicrotendipes</i> <i>Einfeldia</i> <i>Endochironomus</i> <i>Glyptotendipes</i> <i>Microtendipes</i> <i>Pagastiella</i> <i>Parachironomus</i> <i>Paratendipes</i> <i>Phaenopsectra</i> <i>Polypedilum</i> <i>Sergentia</i> <i>Stictochironomus</i> <i>Tribeles</i>																16		1										
		<i>Chironomus</i> <i>Cladopelma</i> <i>Cryptochironomus</i> <i>Cryptotendipes</i> <i>Dicrotendipes</i> <i>Einfeldia</i> <i>Endochironomus</i> <i>Glyptotendipes</i> <i>Microtendipes</i> <i>Pagastiella</i> <i>Parachironomus</i> <i>Paratendipes</i> <i>Phaenopsectra</i> <i>Polypedilum</i> <i>Sergentia</i> <i>Stictochironomus</i> <i>Tribeles</i>																	1											
		<i>Chironomus</i> <i>Cladopelma</i> <i>Cryptochironomus</i> <i>Cryptotendipes</i> <i>Dicrotendipes</i> <i>Einfeldia</i> <i>Endochironomus</i> <i>Glyptotendipes</i> <i>Microtendipes</i> <i>Pagastiella</i> <i>Parachironomus</i> <i>Paratendipes</i> <i>Phaenopsectra</i> <i>Polypedilum</i> <i>Sergentia</i> <i>Stictochironomus</i> <i>Tribeles</i>																												
	Pseudochironomini	<i>Pseudochironomus</i> (i/d) <i>Cladotanytarsus</i> <i>Paratanytarsus</i> <i>Tanytarsus</i>			1																							24	354	
	Tanytarsini	(i/d) <i>Cladotanytarsus</i> <i>Paratanytarsus</i> <i>Tanytarsus</i>	8			63	85	58	8	16		8	25	129	308	80	200	16			24	2	16	8		64	64	48		
	Orthoclaadiinae	(i/d) <i>Cricotopus / Orthoclaadius</i> <i>Psectrocladius</i> <i>Tvetenia</i>												8				24			2					8	8			
Terrestrial											8								8		8									
Total			33	10	19	187	330	230	57	208	57	558	459	424	54	682	277	547	23	384	73	65	322	42	26	1	2262	3354	619	

i/d – immature or damaged.

Appendix A7

Field Work Activities and Methodology – Fish Sampling

A7.1 FIELD WORK ACTIVITIES AND METHODOLOGY – FISH SAMPLING

Fish inventories were conducted on five lakes and at 29 different watercourse sampling locations during fall 2006, spring and fall 2007 and spring 2008. Fisheries Research Licenses (#06-0441 FRL, #07-0419 FRL, #08-0418 FRL) were obtained from Alberta Sustainable Resource Development (ASRD) prior to all fish inventory activities. Fishing gear consisted of:

- gillnets consisting of four 50-ft panels with mesh sizes of 25, 38, 63, 89 mm were set perpendicular from shore towards the middle of sampled lakes while for streams with large pond areas created by beaver dams, a two-panel gillnet (mesh sizes of 63 and 89 mm) was used. The geographic locations of the start and end of each gillnet set were recorded, as well as the start and end times of gillnet deployment.
- minnow traps deployed around the lake perimeters or along the stream bank. The geographic location and start and end time of deployment of each minnow trap was recorded; and
- electrofishing was conducted on some watercourses using a Smith-Root Model 12B backpack electrofisher.

All fish caught were enumerated and identified to the species level when possible. Total lengths and weights of all large-bodied fish were recorded, as well as the lengths and weights of at least ten randomly-selected individuals of each small-bodied fish species for each sampling site. 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:

$$Z = \left(\frac{y}{x^3} \right) \times 10^5$$

Where:

Z is condition, y is weight (g) and 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).

A7.2 SUMMARY OF HABITAT LIMITING FACTORS FOR MODELED SPECIES

Arctic Grayling - Habitat was considered average for the watercourses of the Christina and Horse River drainages, and unacceptable (no suitability) for the lakes. In both watersheds, most of the parameters measured above average or excellent with the following exceptions:

- Winter dissolved oxygen measured at average levels in the winter. Dissolved oxygen measurements were not taken in the Horse River watershed at this time, but were assumed to be equal to the Christina River watershed;
- Riffles were observed in the Christina River watershed, but not in the Horse River watershed. Lake substrates were dominated by organic debris, rather than the coarser material preferred by Arctic Grayling; and
- Summer temperatures (summer 2007) exceeded maximum allowable values.

Brook Stickleback - Habitat was considered below average for the watercourses of the Christina and Horse River drainages, and above average for the lakes:

- Nesting material is limiting in both watercourse systems but abundant in the lakes;
- Watercourses in both watersheds are dominated by runs, considered to have average habitat value for Brook Stickleback. Beaver dams are common in both watersheds, but were not sampled. Including these in the habitat assessments may increase habitat suitability; and
- Brook Stickleback prefer depths less than 2 m. None of the lakes sampled exceeded 2.6 m at any time during the year. As a conservative estimate, this parameter was calculated using 50% occurrence of depths ≤ 2 m and 50% occurrence of depths > 2 m.

Finescale Dace - Habitat suitability was average in both watercourse systems, and above average in the Christina River lakes:

- High proportion of run-type habitat in watercourses of both watersheds; Finescale Dace prefer pool-type habitat;
- Low percentage of instream vegetation decrease the suitability of these watersheds; and
- Finescale Dace prefer lake depths of ≤ 2 m. None of the lakes sampled exceeded 2.6 at any time during the year. As a conservative estimate, this parameter was calculated using 50% occurrence of depths ≤ 2 m and 50% occurrence of depths > 2 m but less than 5 m.

Lake Chub - Habitat suitability was found to be average in both the lakes and watercourses of the Christina River watershed, and above average in the Horse River watershed:

- Lake Chub prefer coarser substrate. Both watercourses and lakes within these watersheds are limited by the high proportion of fines and organic material present.

Longnose Sucker - Habitat suitability for Longnose Sucker was above average in the Horse River drainage and excellent in the Christina drainage watercourses, but below average in the Christina watershed lakes:

- Longnose Sucker prefer coarser substrate material. Both watercourse and lake habitats are limited by the high proportion of fines and organic material;
- Riffle habitat for spawning is rare within watercourses of both watersheds;
- Lake depth has no habitat value for Longnose Sucker, preferring depths greater than 10 m; and
- Spring lake temperatures in the five lakes exceeded acceptable high values. This parameter is used only in the assessment of habitat suitability for embryos, and results in suitability for Longnose Sucker of 0.00. Since spawning usually occurs in the tributary watercourses of large bodies of water (Edwards 1983) and habitat suitability in Christina watershed watercourses was found to be excellent, spawning is assumed to occur in these tributaries. Therefore the high temperatures in the lakes were considered to be non-limiting.

Northern Pike - Habitat suitability for Northern Pike is average in both watercourses and lakes of the Christina and Horse River watersheds. This habitat suitability index model takes into consideration the proportion of spawning substrate containing fines and organic materials, total vegetated cover, water depth, and water velocities.

- Instream vegetation values between approximately 25 to 75% are preferred by this species. Watercourses have below the ideal amount of vegetation, while lakes exceed the maximum preferred amount; and
- Average length of the frost-free season in the Fort McMurray area was estimated at 70 days based on data from the National Atlas of Canada. This is much lower than the preferred 120 to 180 frost-free days.

White Sucker - Watercourse habitat in both watersheds was found to have above average habitat suitability for White Sucker, while the lake habitat in the Christina River had no habitat suitability:

- Watercourses in both watersheds are dominated by runs, considered to have average habitat value for white sucker. Beaver dams are common in both watersheds, but were not sampled. Including these in the habitat assessments may increase habitat suitability; and
- Lakes were dominated by organic material and fines, which provides very little habitat value to White Sucker.

Table A7.1 Habitat suitability of streams in Christina River Watershed and Horse River Watershed for Brook Stickleback.

Habitat Requirement	Data Used and Assumptions (Christina River / Horse River)	Christina Watershed	Horse Watershed
		SI Value	SI Value
Substrate	Watersheds are similar: both are dominated by fines, organic material and gravels (95% / 72%), considered excellent habitat materials, with smaller fractions (5%, 28%) of sediments with average habitat value.	0.98	0.86
Nesting Materials	Good nesting material is limited in both sites. Instream vegetation is typically submerged and considered to have excellent habitat value (16% / 7%). More common, but poorer quality nesting materials that occur are overhanging vegetation (26% / 39%), included due to the high frequency of flooding in both watersheds, but considered to have average habitat value, and woody debris (18% / 47%) which has below average habitat value.	0.34	0.38
Channel Unit	Pools, designated as excellent habitat, occur infrequently in both watersheds (15% / 20%). Instead, runs dominate both watersheds (77% / 80%) with a small proportion of riffles (8%) occurring only in the Christina River watershed. Runs and riffles are considered to have average to below average habitat value.	0.56	0.60
% Instream Cover	Both watersheds have an average amount of instream cover (30% / 22%) comprised of small fractions of submergent grasses, sedges, and algae (highest habitat value), Overhanging vegetation (average habitat value), woody debris (below average habitat value) and other cover types.	0.50	0.50
Late Winter Dissolved Oxygen (mg/L)	DO concentration was measured in February 2007 at 3.19 mg/L in the Christina watershed, but not sampled in the Horse watershed. The assumption was made that both watersheds should have a similar late winter DO based on this parameter being approximately equal during other seasons. A late winter DO value above 1.0 mg/L is considered excellent.	1.0	1.0
pH	Median seasonal pH was calculated to determine suitability. Excellent (78% / 85%) and Average (22% / 15%) pH values occurred over the sampling period.	0.89	0.92
	HSI value For Brook Stickleback, the HSI is set to the lowest of the SI values for the variables included in the model.	0.34	0.38

Table A7.2 Habitat suitability of lakes in Christina River Watershed for Brook Stickleback.

Habitat Requirement	Data Used and Assumptions	Christina Watershed SI Value
Substrate	Observations of lake bed material suggest that all five lakes are exclusively organic material.	1.0
Nesting Materials	Submergent vegetation is abundant in all five lakes, typically comprised of lily and plantain species (94%). Additionally, lower quality vegetation is present in the form of overhanging vegetation (5%) and woody debris (1%).	0.97
Depth	Limited data was obtained during sampling, but lakes typically appeared as 50% excellent habitat depth (≤ 2 m) and 50% average habitat depth (> 2 m to 5 m).	0.75
% Littoral Zone Cover	% littoral zone cover measurements were not conducted. However, typically the lakes were surrounded by muskeg and treeline. As a conservative estimate, a value of 60% cover was applied to this variable. Values greater than 50% are considered excellent.	1.0
Late Winter Dissolved Oxygen (mg/L)	Winter dissolved oxygen (4.93 mg/L) was sampled in February, 2007. Values above 1.0 mg/L are considered excellent.	1.0
pH	Median seasonal pH was calculated to determine suitability. Excellent (84%) and Average (16%) pH values occurred over the sampling period.	0.92
HSI value	For Brook Stickleback, the HSI is set to the lowest of the SI values for the variables included in the model.	0.75

Table A7.3 Habitat suitability of streams in Christina River Watershed and Horse River Watershed for Lake Chub and Finescale Dace.

Habitat Requirement	Data Used and Assumptions (Christina River / Horse River)	Lake Chub		Finescale Dace	
		Christina Watershed	Horse Watershed	Christina Watershed	Horse Watershed
		SI Value	SI Value	SI Value	SI Value
Substrate	Sediments are dominated by fines (60% / 43%) and organic material (25% / 14%). Christina river has a small fraction of gravels (10%) and bedrock (5%), while the Horse watershed shows approximately equal proportions of gravels (15%), cobbles (14%) and boulders (14%). Habitat containing gravel and larger sediment types is considered excellent for lake chub while smaller sediment sizes are less preferred. Conversely, habitat with sediment fractions of gravel and smaller are preferred by Finescale Dace.	0.55	0.72	0.96	0.86
% Instream Cover	Instream cover is similar in both watersheds (30% / 22%) and considered Average quality for Finescale Dace, preferring 50% or greater cover, but Excellent quality for Lake Chub.	1.00	1.00	0.50	0.50
Late Winter Dissolved Oxygen (mg/L)	DO concentration was measured in February 2007 at 3.19 mg/L in the Christina watershed, but not sampled in the Horse watershed. The assumption was made that both watersheds should have a similar late winter DO based on this parameter being approximately equal during other seasons. A late winter DO value above 1.0 mg/L is considered excellent.	1.00	1.00	1.00	1.00
pH	Median seasonal pH was calculated to determine suitability. Excellent (78% / 85%) and Average (22% / 15%) pH values occurred over the sampling period.	0.89	0.92	0.89	0.92
	HSI value For both Lake Chub and Finescale Dace, the HSI is set to the lowest of the SI values for the variables included in the model.	0.55	0.72	0.50	0.50

Table A7.4 Habitat suitability of streams in Christina River Watershed and Horse River Watershed for Lake Chub and Finescale Dace.

Habitat Requirement	Data Used and Assumptions	Lake Chub	Finescale Dace
		SI Value	SI Value
Substrate	Observations of lake bed material suggest that all five lakes are exclusively organic material. Finescale Dace prefer habitats with fine sediment types, Lake Chub prefer coarser substrate material.	0.50	1.00
Nesting Materials	Submergent vegetation is abundant in all five lakes, typically comprised of lily and plantain species (94%). Additionally, lower quality vegetation is present in the form of overhanging vegetation (5%) and woody debris (1%).	1.00	0.99
Depth	Limited data was obtained during sampling, but lakes typically measured half as ≤ 2 m depth, and half as > 2 m to 5 m. Shallower depths are considered excellent habitat for both species of fish. Depths between 2 to 5 m range from Average to Above Average quality depending on species.	0.88	0.75
% Littoral Zone Cover	% littoral zone cover measurements were not conducted. However, most lakes were surrounded by muskeg and treeline. As a conservative estimate, a value of 60% cover was applied to this variable. Values greater than 50% are considered excellent.	1.00	1.00
Late Winter Dissolved Oxygen (mg/L)	Winter dissolved oxygen (4.93 mg/L) was sampled in February, 2007. Values above 1.0 mg/L are considered excellent.	1.00	1.00
pH	Median seasonal pH was calculated to determine suitability. Excellent (84%) and Average (16%) pH values occurred over the sampling period.	0.92	0.92
	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	0.75

Table A7.5 Habitat suitability of lakes and streams in Christina River and Horse River Watersheds for White Sucker.

Habitat Requirement	Data Used and Assumptions (Christina Streams / Horse Streams / Lakes)	Christina watershed	Horse watershed	Lakes
		SI Value	SI Value	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	1.00	1.00
Average pH	Average pH measures similar across both watersheds and waterbody types.	0.82	0.85	1.00
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	1.00	1.00
Average of mean weekly water temperature (°C)	This variable is divided into three different parameters:			
	▪ July and August (for adults and juveniles);	0.98	0.98	1.00
	▪ July and August (for fry); and	0.72	0.72	0.98
	▪ April through July (for spawning and incubation).	1.00	0.85	0.75
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 Christina River. The assumption was made that they were suitable for spawning. No riffles were encountered in the Horse River, therefore this watershed is given a suitability value of 0.5.	1.00	0.50	N/A
Average riffle depth (cm) during spawning and incubation	As above: Assumption was made that the Christina River had suitable areas for spawning, but the Horse River did not.	1.00	0.50	N/A
Percent instream and overhanging shoreline cover	Both watersheds have similar amounts of instream (16% / 7%) and overhanging (26% / 39%) vegetation. This parameter is non-limiting.	1.00	1.00	N/A
Percent pools during average summer flows	Watersheds are dominated by run-type habitat (77% / 80%) with smaller proportions of pool habitat (15% / 20%).	0.38	0.55	N/A
Littoral spawning substrate	Lakes only. All five lakes sampled contain substrates that are dominated by organic material. White Suckers prefer much coarser sediment material for habitat.	N/A	N/A	0.05
HSI value	For White Sucker, the HSI is calculated using an equation with the following inputs:			
	▪ Minimum of water quality component (C_{WQ});	0.82	0.85	1.00
	▪ Minimum of reproduction component (C_R); and	0.72	0.50	0.05
	▪ Streams only—Average of cover component (C_C).	0.69	0.78	N/A
	Streams: $HSI = (C_{WQ} * C_R * C_C)^{1/3}$.	0.74	0.69	-
	Lakes: $HSI = (C_{WQ} * C_R)^{1/2}$ (or, if either component is ≤ 0.4 , the HSI is the lowest of C_{WQ} , C_R , and the HSI rating).	-	-	0.05

Table A7.6 Habitat suitability of lakes and streams in Christina River and Horse River Watersheds for Northern Pike.

Habitat Requirement	Data Used and Assumptions (Christina Streams / Horse Streams / Lakes)	Christina watershed	Horse watershed	Lakes
		SI Value	SI Value	SI Value
Ratio of spawning habitat to summer habitat area	This variable considers the percent area of appropriate spawning substrate (fines, organic material), total vegetated cover, and the water depth. Northern Pike prefer calm, protected, slow moving waters. Visual observations show velocities to be slow in both watersheds so this parameter was assumed to be non-limiting.	0.45	0.48	0.90
Drop in water level during embryo and fry stages	Drop in water levels was not measured during embryo and fry stages, so is assumed to be non-limiting.	1.00	1.00	1.00
Percent of mid-summer area with instream aquatic vegetation	Instream vegetation is infrequent in both streams (16% / 7%), but the habitat suitability of this parameter increases quickly. In all five measured lakes, instream vegetation was very high (94%), but beyond 75% vegetation, habitat suitability falls rapidly.	0.78	0.40	0.40
Log10 of total dissolved solids concentration during mid-summer	Total dissolved solids measured much higher in the streams (90.64 mg/L / 127.0 mg/L) than in the lakes (34.8 mg/L). The log10 of these values (1.96 / 2.10 / 1.54) was within the range of Excellent habitat suitability.	1.00	1.00	0.82
Least suitable pH in spawning habitat during embryo and fry stages	The lowest average spring data was used for this parameter. Within the range of pH 6.5 to 7.2 Northern Pike embryo and fry have low mortality rates. Below pH of 6.0, mortality increases rapidly.	1.00	1.00	1.00
Length of frost-free season (days)	Fort McMurray has approximately 70 frost free-days annually. Energy, Mines and Resources Canada – The National Atlas of Canada 5th Edition.	0.42	0.40	0.40
Maximum weekly average temperature (°C)	Limited data available for this parameter. The annual maximum temperature was calculated from all available data.	0.93	0.95	1.00
Percent area of backwaters, pools or standing water during summer	Streams only: All sampled reaches were designated either pool or run. Velocities were not measured. Model suggests if insufficient data are available, consider this value non-limiting.	1.00	1.00	N/A
Stream gradient (m/km)	Slopes were not measured during sampling, but visual observations showed stream gradient to be low. This parameter was considered non-limiting.	1.00	1.00	N/A
Late winter dissolved oxygen	DO concentration was measured in February 2007 at 3.19 mg/L in the Christina watershed, but not sampled in the Horse watershed. The assumption was made that both watersheds should have a similar late winter DO based on this parameter being approximately equal during other seasons. Lake DO was measured at 4.93. A value over 2.0 is considered excellent.	1.00	1.00	1.00
HSI value	For Northern Pike, the HSI is set to the lowest of the SI values for the variables included in the model.	0.45	0.40	0.40

Table A7.7 Habitat suitability of lakes and streams in Christina River and Horse River Watersheds for Longnose Sucker.

Habitat Requirement	Data Used and Assumptions (Christina Streams / Horse Streams)	Christina watershed	Horse watershed	Lakes
		SI Value	SI Value	SI Value
Spawning habitat	If any riffle areas are present and contain coarser substrate suitable for spawning, this parameter is assigned a value of 1.0. Otherwise, it is assigned a value of 0.5. Riffle areas were encountered in the Christina River watershed, but not in the Horse River watershed. This parameter is divided into three sections:			
	▪ Spawning location;	1.00	0.50	0.5
	▪ Depth of riffle for spawning; and	1.00	0.50	0.5
	▪ Current velocity within spawning habitat.	1.00	0.50	0.5
Mean water temperature during spawning and incubation	Spawning peak occurs in June (spring). The Christina watershed (13.76 °C) showed average spring temperatures slightly elevated over the Horse watershed (11.69 °C), but neither temperature was limiting. In the lakes, however, average temperatures (16.3 °C) exceeded maximum allowable values, and resulted in suitability index of 0. Since spawning usually occurs in tributary streams and these streams had excellent suitability, this value was considered non-limiting.	1.00	1.00	1.00
Substrate type	This part of the model represents substrate in spawning areas. The majority of substrate in both watersheds is either fines (60% / 43%) or organic material (25% / 14%) and considered to have poor or no habitat suitability. However, in areas where this variable limits the HSI output value, but has potential use other than spawning, the model assigns a value of 0.50.	0.50	0.50	0.50
Percent cover May to June	Total cover (30% / 22%) is considered excellent in both watersheds.	1.00	1.00	1.00
Fluctuation in water level in mid-summer	Lakes only: Measurements of summer water depth were not taken. This variable is assumed to be non-limiting.	N/A	N/A	1.00
Maximum depth	Lakes only: Values below 3 m are considered poor habitat.	N/A	N/A	0.00
Average turbidity during spring /summer	Lakes only: Assumed in the model to be non-limiting. Assigned a value of 1.0.	N/A	N/A	1.00
pH range during the summer	pH values were only measured once during the summer. Values were similar across both watersheds (7.04 / 7.60), but this slight variation was enough to drop the Christina River into a lower habitat suitability class.	0.40	1.00	0.30
Dissolved oxygen during the summer	Dissolved oxygen was much lower in the Christina River watershed (3.39) than in the Horse River watershed (5.16). DO above 5.5 is preferred by Longnose Sucker.	0.00	0.50	1.00
Mean water temperature during the summer	Water temperature was non-limiting in streams of both watersheds (18.34 °C / 17.9 °C). Temperatures between 12 to 20 °C are considered excellent for Longnose Suckers.	1.00	1.00	0.63
Channel units	Both watersheds were dominated by pools and runs (92% / 100%), with only a small proportion of riffles occurring in the Christina River watershed (8%).	0.98	1.00	N/A
HSI value	Habitat suitability for Longnose Sucker is calculated using an equation with three components:			
	▪ Embryo habitat suitability (C _E);	0.89	0.63	0.50
	▪ Fry habitat suitability (C _F); and	1.00	1.00	1.00
	▪ Juvenile and adult habitat suitability (C _{J-A}).	0.68	0.90	0.59
	HSI = (C_E²*C_F*C_{J-A})^{1/4}	0.86	0.77	0.62

Table A7.8 Habitat suitability of streams in Christina River Watershed and Horse River watershed for Arctic Grayling.

Habitat Requirement	Data Used and Assumptions (Christina watershed / Horse watershed)	Christina watershed	Horse watershed
		SI Value	SI Value
Average maximum daily water temperatures	Stream water temperatures were similar in both watersheds (18.34°C / 18.49°C) and provide excellent habitat suitability.	0.90	0.89
Average minimum dissolved oxygen during late summer	Dissolved oxygen was measured once in the mid-summer, but never in late summer. Sampling in the fall takes place between September and October so measurements collected during this time were used. This parameter is divided into two parts:		
	▪ Spawning streams; and	1.00	1.00
	▪ Streams inhabited by adults.	1.00	0.85
Percent of the substrate composed predominantly of gravel	If any riffle areas are present, this parameter is assigned a value of 1.0. Otherwise, it is assigned a value of 0.5. Riffle areas were encountered in the Christina River watershed, but not in the Horse River watershed.	1.00	0.50
Spawning areas	Both watersheds are dominated by fines and organic materials (85% / 57%), and slow moving waters, but insufficient data is available to draw specific conclusions about the riffle spawning habitats in either watershed. This parameter is broken into three parts, all of which are assigned a value of 1.0 by the model to be conservative:		
	▪ Percent of fines (<3 mm diameter) in spawning areas and downstream riffle areas;	1.00	1.00
	▪ Average velocity over spawning areas during spawning and embryo development; and	1.00	1.00
	▪ Percent of spawning areas and nursery areas that consist of backwater and side channel areas with a current velocity < 0.15 m/s.	1.00	1.00
Access to tributaries	Insufficient data exists to draw specific conclusions about spawning and overwintering access. However, water levels measured were generally over 0.5 m depth (75%) in the early spring and over 1 m depth (77%) in the fall. The assumption was made that fish could gain access to spawning sites in early spring and overwintering sites in late fall. If insufficient data is available for this parameter, the model assumes access is non-limiting This parameter is divided into two parts:		
	▪ Annual frequency of early spring access to spawning streams; and	1.00	1.00
	▪ Occurrence of winter habitat or access to overwintering habitat.	1.00	1.00
Late winter dissolved oxygen	DO concentration was measured in February 2007 at 3.19 mg/L in the Christina watershed, but not sampled in the Horse watershed. The assumption was made that both watersheds should have a similar late winter DO based on this parameter being approximately equal during other seasons.	0.50	0.50
HSI value	For Arctic Grayling, the HSI is set to the lowest of the SI values for the variables included in the model.	0.50	0.50

Table A7.9 Habitat suitability of lakes in the Christina River watershed for Arctic Grayling.

Habitat Requirement	Data Used and Assumptions (Christina watershed / Horse watershed)	Lakes SI Value
Substrate	Arctic Grayling prefer habitats with coarser substrates such as gravel and cobble. Lakes measured were found to be dominated by organic debris which is considered to have average habitat suitability.	0.50
Depth (m)	Maximum depth of all five lakes is never deeper than 2.5 m based on bathymetric surveys conducted in fall 2006. Arctic Grayling prefer shallow depths (<4 m), finding lakes between 4 to 10 m depth to have only average suitability.	1.00
Access to spawning streams	Insufficient data exists to draw specific conclusions about spawning and overwintering access. However, water levels measured were over generally 1.0 m depth in the early spring (67%) and over 1.5 m depth (80%) in the fall. The assumption was made that fish could gain access to spawning sites in early spring and overwintering sites in late fall.	1.00
Average maximum water temperature during the warmest period of the year	Summer spawning temperatures were measured during only a single year's sampling (summer 2007) and were found to be quite high (21.1°C). This places the habitat suitability of these lakes to 0.00. Arctic Grayling prefer temperatures of 7 to 17°C, and find temperatures lower than this, or higher up to 20°C to be acceptable. More data may change the suitability.	0.00
Percent littoral zone cover	% littoral zone cover measurements were not conducted. However, most lakes were surrounded by muskeg and treeline. As a conservative estimate, a value of 60% cover was applied to this variable. Values greater than 30% are considered excellent.	1.00
Late summer average minimum dissolved oxygen	Dissolved oxygen was measured once in the mid-summer, but never in late summer. Sampling in the fall takes place between September and October so the minimum measurement collected during this time (7.78 mg/L) was used. Values DO values greater than 6 are considered excellent.	1.00
HSI value	For Arctic Grayling, the HSI is set to the lowest of the SI values for the variables included in the model.	0.00

A7.3 METHODOLOGY FOR FWMIS ANALYSIS AND ASSIGNING STREAM ORDERS

FWMIS data was reviewed to determine the presence of fish within the Christina and Horse watersheds. 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 Christina and Horse River watersheds, ArcGIS 9.2 was used to display the FWMIS data and the hydrological network on a 1:50000 scaled 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 A7.3 Location of FWMIS data points within the Local and Regional Study Areas.

