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Lindbergh SAGD Expansion Project: Aquatic Resources Baseline and Effects Assessment

December 2013

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LINDBERGH SAGD EXPANSION PROJECT: AQUATIC RESOURCES BASELINE AND EFFECTS ASSESSMENT

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LIST OF ACRONYMS

AENV	Alberta Environment
AEPEA	Alberta Environmental Protection and Enhancement Act
ANC	acid neutralizing capacity
ASRD	Alberta Sustainable Resource Development
BPD	barrels per day
CCME	Canadian Council of Ministers of the Environment
COSEWIC	Committee on the Status of Endangered Wildlife
CPFs	central processing facilities
EIA	environmental impact assessment
ESRD	Alberta Environment and Sustainable Resource Development
FWMIS	Fish and Wildlife Management Information System
LSA	local study area
MEMS	Millennium EMS Solutions Ltd.
PAI	potential acid input
RAMP	Regional Aquatics Monitoring Program
RSA	regional study area
SAGD	steam-assisted gravity drainage
TCUs	true colour units
TOR	terms of reference
VEC	valued environmental component

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 Pengrowth Energy Corporation (Pengrowth) Lindbergh Steam-Assisted Gravity Drainage (SAGD) Expansion Project (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 EIA report for the Project (ESRD 2013). The ToR outlines the format and contents for the entire regulatory application and EIA (i.e., all environmental disciplines). This report addresses specific components of the ToR that are relevant to surface water quality and aquatic ecology (Table 1).

This report is based on the Project design and activities described in the application (Pengrowth 2013), including the construction, operation, reclamation, and closure of the Project and related facilities.

Table 1 Terms of Reference sections applicable to this assessment.

Section in Final Terms of Reference for Project (ESRD 2013)		Report Section
3.4	**Surface Water Quality**	
3.4.1	**Baseline Information**	
	[A] Describe the baseline water quality of watercourses and waterbodies.	3.1.1
3.4.2	**Impact Assessment**	
	[A] Describe the potential impacts of the Project on surface water quality.	4.3
3.5	**Aquatic Ecology**	
3.5.1	**Baseline Information**	
	[A] Describe and map the fish, fish habitat and aquatic resources (e.g., aquatic and benthic invertebrates) of the lakes, rivers, ephemeral water bodies and other waters. Describe the species composition, distribution, relative abundance, movements and general life history parameters of fish resources. Also identify any species that are: a) Listed as "at Risk, May be at Risk and Sensitive" in the *General Status of Alberta Wild Species* (Alberta Environment and Sustainable Resource Development); b) Listed in Schedule 1 of the federal *Species at Risk Act*; c) Listed as "at risk" by COSEWIC; and d) Traditionally used species.	3.1
	[B] Describe and map existing critical or sensitive areas such as spawning, rearing, and over-wintering habitats, seasonal habitat use including migration and spawning routes.	3.1
	[C] Describe the current and potential use of the fish resources by Aboriginal, sport or commercial fisheries.	3.1

Table 1 (Cont'd.)

Section in Final Terms of Reference for Project ()		Report Section
3.5.2	**Impact Assessment**	
	[A] Describe and assess the potential impacts of the Project to fish, fish habitat, and other aquatic resources, considering:	
	a) Habitat loss and alteration;	4.1, 4.2
	b) Increased fishing pressures in the region that could arise from the increased human activity and improved access from the Project. Characterize the current use of local and regional fisheries resources to support the assessment of potential changes in angling pressure;	4.5
	c) Increased habitat fragmentation;	4.1
	d) Acidification;	4.6
	e) Groundwater-surface water interactions; and	4.4
	f) Entrapment and entrainment of fish at water intakes.	4.4
	[B] Identify the key aquatic indicators that the Proponent used to assess project impacts. Discuss the rationale for their selection.	2.3
	[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.	4.8

1.3 PROJECT LOCATION AND SCOPE

The Project will expand bitumen production of the Lindbergh SAGD Project (Phase 1) from 1,987 m^3/day (12,500 barrels per day (bpd)) to 4,770 m^3/day (30,000 bpd).

The Project is located approximately 24 km southeast of Bonnyville within St. Paul County No. 19 and the Municipal District of Bonnyville No. 87. All facilities will be located within Townships 58 and 59 and Ranges 4 and 5, West of the 4th Meridian.

Planned facilities include a number of well pads and well pairs, with associated infrastructure including roads, above-ground gathering and distribution pipeline systems. The Phase 2 expansion components for the central processing facility (CPF) will be built within the existing Phase 1 CPF footprint, which will not increase in physical size. The existing water source will be utilized for the Project.

Pengrowth has identified two development scenarios, the Initial Development footprint required to bring production up to the design capacity of 4,770 m^3/day (30,000 bpd) and the Future Development required to sustain production for the life of the Project. The Project is expected to produce approximately 43.7 million m^3 (275 million barrels) of bitumen over 25 years.

1.4 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); and
- Canadian Council of Ministers of the Environment (CCME) Canadian Water Quality Guidelines (CWQG) (CCME 2007) and CCME Freshwater Sediment Quality Guidelines (CCME 2002).

1.5 DATA SOURCES

Data sources used in the preparation of this report include specific field studies undertaken in support of the Project and a review of the Fisheries and Wildlife Management Information System (FWMIS) maintained by Alberta Environment and Sustainable Resources Development (ESRD 2013).

2.0 SCOPE OF ENVIRONMENTAL ASSESSMENT

2.1 STUDY AREAS

2.1.1 Local Study Area

The Local Study Area (LSA) includes the watershed of all watercourses that are potentially affected by the Project footprint (Figure 1). It is the same LSA as for the hydrology component of this Application (nhc 2013). The rationale for this is that the LSA for hydrology was chosen to encompass the watersheds of any drainages that may be affected by Project activities. This could include direct disturbance of watercourses through construction activities as well as any potential changes in flow regime as a result of the project. Both direct disturbance or changes in flow have the potential to affect fish community or fish habitat and it was therefore deemed appropriate to set the LSA for aquatic resources to match that of the LSA for hydrology.

2.1.2 Regional Study Area

The Regional Study Area (RSA) includes all watersheds within the LSA plus any other watersheds that contributed flow to the watersheds within the LSA but which are not directly affected by the Project footprint (Figure 1). The RSA was also set to match that of the RSA for hydrology as it represents the area in which there is potential for alterations in flow to affect fish habitat.

2.1.3 Study Area for the Effects of Acidifying Emissions

Potential effects of acidifying emissions on aquatic resources were assessed on the lakes for which water quality data is available and which are also located within the Air Quality Regional Study Area (Figure 2).

2.2 AQUATIC RESOURCES ISSUES CONSIDERED

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

- the scope and findings of environmental assessments and studies conducted 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.

Table 2 Aquatic resource issues considered in this report.

Issue/Description of Potential Effect	Related Project Activities
Changes in fish habitat	Construction, operation, reclamation and decommissioning Project activities giving rise to: ▪ surface disturbances and watercourse crossings; ▪ changes in surface water quality; ▪ physical changes in stream channel morphology or fragmentation of habitat; and ▪ changes in surface water flow rates which may affect habitat availability.
Changes in fish health and abundance	Construction, operation, reclamation and decommissioning Project activities giving rise to: ▪ changes in fish habitat which can affect abundance; and ▪ modified access to and increased recreational angling in fish-bearing watercourses and waterbodies.
Changes in surface water quality	Construction, operation, reclamation and decommissioning Project activities giving rise to: ▪ surface disturbances and increased sediment loading; ▪ accidental release or seepage of Project-affected water; ▪ accidental spills of chemicals and waste products; ▪ acidifying emissions from Project facilities and equipment; ▪ potential contamination of groundwater; and ▪ potential interactions between groundwater and surface water.

2.3 VALUED ENVIRONMENTAL COMPONENTS

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

2.3.1 Variables Used to Characterize Valued Environmental Components

2.3.1.1 Surface Water Quality

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

- requirements of the ToR for this EIA (ESRD 2013);
- water quality variables that have regulatory concern in the form of guidelines; and
- various water quality variables required for interpretation of effects on other aquatic components, particularly fish populations and human health.

Table 3 Variables used to characterize surface water quality.

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

2.3.1.2 Fish Resources

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

- fish species presence and abundance including the suitability of respective habitats as determined during the 2011 to 2013 field programs for the baseline studies and stream crossing assessments;
- 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 (ESRD 2013);
- importance of particular species as a traditional resource; and
- species designated as having a status of special concern (ASRD 2005) or a status of candidate wildlife species by a federal agency (COSEWIC 2010).

Table 4 Summary of key indicator fish species.

Fish Species	Scientific Name	Species Code	Recovered in FWMIS Database[1]	Historical Presence[2]	Captured in Baseline Field Studies[3]	Status of Special Concern[4]
Large-Bodied Species						
Burbot	*Lota lota*	BURB		✓		
Lake whitefish	*Coregonus clupeaformis*	LKWH		✓		
Longnose sucker	*Catostomus catostomus*	LNSC	✓		✓	
Northern pike	*Esox lucius*	NRPK	✓		✓	
Walleye	*Sander vitreus*	WALL		✓		
White sucker	*Catostomus commersoni*	WHSC		✓		
Yellow perch	*Perca flavescens*	YLPR	✓		✓	
Small-Bodied Species						
Brook stickleback	*Culaea inconstans*	BRST	✓		✓	
Fathead minnow	*Pimphales promelas*	FTMN	✓		✓	
Finescale dace	*Phoxinus neogaeus*	FNDC	✓			
Iowa darter	*Etheostoma exile*	IWDR	✓			
Lake chub	*Couesius plumbeus*	LKCH	✓		✓	
Longnose dace	*Rhinichthys cataractae*	LNDC			✓	
Log perch	*Percina caprodes*	LGPR		✓	✓	
Spottail Shiner	*Notropus hudsonius*	SPSH	✓	✓	✓	

[1] from ESRD (2013A)
[2] records older than 15 years from ESRD (2013A)
[3] this report
[4] from http://www.cosewic.gc.ca/eng/sct3/index_e.cfm assessment cases

2.4 ASSESSMENT CASES

2.4.1 Baseline Case

The Baseline Case consists of the existing and approved developments 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 existing projects on aquatic resources are already reflected in the data gathered to establish the baseline conditions; and (ii) existing projects will not cause any different effects on aquatic resources in the future.

2.4.2 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.

2.4.3 Planned Development Case

The Planned Development Case is an assessment of the incremental environmental effects of the combined Application and Baseline Cases with reasonably foreseeable or planned developments that have been publicly disclosed at least six months prior to submission of this report.

There are no additional planned projects located within the LSA and RSA. Therefore, the Planned Development Case is only assessed for possible effects on aquatic resources via changes in acidifying emissions within the Air Quality Local and Regional Study Areas.

3.0 AQUATIC RESOURCES BASELINE CASE

The aquatic resources baseline case first describes surface water quality, fish resources, and aquatic habitat for the watercourses and waterbodies within the LSA, followed by those within the RSA.

3.1 BASELINE CASE FOR LOCAL STUDY AREA

The location of sites for the baseline aquatic resources field program conducted in support of this EIA is provided in Table 5 and in Figure 3. Water quality collection, fish inventory and aquatic habitat assessment followed the requirements of the Standard Operating Procedures (SOPs) used in the Regional Aquatics Monitoring Program (RAMP)[1].

Baseline information was collected for different parts of the LSA in different years. Baseline field programs in 2011 and 2012 focused on Mooswa Creek and Garnier Creek and the lower reaches of their tributaries. There was a defined channel at most of the locations and water was present during the entire open water season. Numerous named lakes were also sampled, included Garnier Lakes, Michel Lake and Muriel Lake. Baseline studies conducted in 2013 focused on the upper reaches of tributaries to Garnier Creek and Muriel Lake, the main watercourses and waterbodies in a number of additional lease areas. These watercourses contained mostly poorly-defined and/or intermittent drainages with low potential for fish habitat. Beaver ponds were present along some of the drainages, but were generally not connected by defined channels. Lakes in this area were small, shallow and had poorly-defined shorelines.

[1] found at http://ramp-alberta.org/UserFiles/File/RAMP_Design_&_Rationale.pdf

Table 5 Summary of sampling conducted in the Local and Regional Study Area for aquatic resources.

Site Code	Stream Name	UTM (Zone 12 NAD 83)		Season						
		Easting	Northing	Summer 2011	Fall 2011	Winter 2012	Spring 2012	Winter 2013	Spring 2013	Summer 2013
Watercourses										
SC1-4	Unnamed	530061	5999690					dry	dry	dry
SC1-3	Unnamed	528848	5998851					dry	dry	dry
SG2-3	Unnamed	533159	5996415					Frozen	aifh	aif
TRL1-1	Unnamed	535260	5996788					Frozen	ndc	ndc
SC2-1	Unnamed	528198	6000186					Frozen	ndc	ndc
SC1-2	Unnamed	526863	5996781					Frozen	ndc	ndc
SG2-2	Unnamed	531346	5996858					Frozen	ndc	ndc
SG21-1	Unnamed	533178	5995218					Frozen	ndc	ndc
SG4-4	Unnamed	531470	5993295					Frozen	ndc	ndc
SG4-2	Unnamed	528583	5991829					Frozen	aifh	aif
SG4-3	Unnamed	530172	5990778					Frozen	ndc	ndc
SC1-1	Unnamed	527071	5997554					ai	aifh	ai
SG2-4	Unnamed	533984	5994680					Frozen	ndc	ndc
SG4-5	Unnamed	533759	5991597					Frozen	ndc	ndc
GAC-4	Unnamed	527765	5983546					ai	aifh	if
SG7-1	Unnamed	526144	5987246		^	^	ahi			
SM3b-1	Unnamed	522962	5984121	h	^	^	ahi			
SM3a-1	Unnamed	522890	5982449	afhi	afhi	ai	afhi			
MOC-1	Moosewa Creek	523299	5968948	fh	afhi	^	afhi			
SL1-1	Unnamed	524238	5994429	^	^	^	ahi			
GAC-1	Garnier Creek	525489	5994514	afhi	afhi	ai	afhi			
GAC-2	Garnier Creek	525979	5991218	fh	f		fh			
GAC-3	Garnier Creek	527104	5988482	fh	f	^	fh			
SG2-1	Unnamed	527405	5993827	afhi	afi	^	afhi			
SG4-1	Unnamed	527271	5990857	ahi	afi	^	afhi			
SG5-1	Unnamed	524818	5989857		^	^	afhi			
SG8-1	Unnamed	527576	5986577	^	^	^	ahi			
SG9-1	Unnamed	527585	5986312	^	^	^	ahi			
MOC-2	Moosewa Creek	521460	5982100	afhi	afhi	ai	afhi			
Lakes										
MUL-1	Muriel Lake	523573	5995546	ahi	ai	ai	ahi			
MIL-1	Michel Lake	520486	5989305	ai	ai	ai	afhi			
GAL-1	Garnier Lake	527432	5987357	afhi	afi	ai	afhi			
DIL-1	Dion Lake	525092	5981708	ai	afhi	ai	afhi			
LC11-1	Unnamed Lake	530502	5998571					ai	ai	
LC11-2	Unnamed Lake	532157	5997939					ai		ai
REL-1	Reita Lake	535404	5998348					Frozen	aifh	aif
LG2-2	Unnamed Lake	529087	5995125					ai	aifh	aif
LG2-1	Unnamed Lake	528562	5994485					Frozen	no access	i
GAL-2	Garnier Lake	529181	5982602					ai	ai	ai

a - analytical water quality, described in more detail in Section 3.1.1
f - fish inventory, described in more detail in Section 3.1.2
h - detailed aquatic habitat survey, described in more detail in Section 3.1.3
i - *in situ* water quality, described in more detail in Section 3.1.1
^ - simple aquatic habitat survey, described in more detail in Section 3.1.2
ndc - defined channel
dry - no water present

3.1.1 Water Quality - LSA

Appendix A1 contains quality assurance/quality control (QA/QC) analyses of surface water quality data obtained.

Detailed water quality information is provided in Appendix A2. A summary of surface water quality variables is provided in Table 6 (2011 and 2012) and Table 7 (2013). The tables include the frequency with which guidelines for each water quality variable (if applicable) were exceeded.

The waterbodies within the LSA are neutral to slightly alkaline (pH between 6.96 and 8.45) with the exception of summertime pH in Reita Lake which was 9.89. This value was verified by repeat measurement in the lab and is consistent with the field pH measured of 10.49. This value exceeds the upper limit of the Alberta guideline for the protection of aquatic life of 9.0. The shoreline of the lake appears to be receding, so elements may be concentrating in the lake, leading to the high pH. Sulphide concentrations were high in many of the samples, with over 50% of samples exceeding the guidelines (Table 6, Table 7).

Concentrations of water quality variables varied widely among the sites sampled. Sampled concentrations of total dissolved solids range from 127 mg/L (Michel Lake) to 2,210 mg/L (Garnier Lake), and concentrations of total suspended solids range from below the detection limit (<3 mg/L) to 120 mg/L. Water quality in the larger, named lakes (Muriel, Reita, Dion, Michel and Garnier Lakes) was indicative of eutrophic ecosystems with high total nitrogen (ranging from 1.6 to 3.7 mg/L) and total phosphorus (0.05 to 0.14 mg/L) The lakes are classified as eutrophic based on their summer phosphorus and nitrogen concentrations (Dodds et al. 1998).

Concentrations of phenols, total phosphorous, and total Kjeldhal nitrogen exceeded water quality guidelines for the protection of aquatic life at the majority of watercourse sites that were sampled over all four seasons (Table 6). Concentrations of sulphides were also above guideline values, particularly in the spring and at site SM3a-1 in all seasons. Concentrations of a number of metals were in exceedance of guidelines, including total iron, total aluminum, and total arsenic.

The concentration of dissolved oxygen was below the acute dissolved oxygen guidelines of Alberta for protection of aquatic life (5.0 mg/L) in most of the watercourses during the summer, and several of the sites in the fall (Table 4). The concentration of dissolved oxygen was generally above this guideline in the spring.

In the lakes, concentration of total Kjeldahl nitrogen was in exceedance of water quality guidelines at all sites during all seasons of sampling. Concentrations of phenols, sulfates, sulphides, and total phosphorous were also in exceedance at most sites during all seasons. Ammonia concentrations exceeded guidelines at site GAL-1 during the winter. Concentrations of a number of metals were in exceedance of guidelines, including total arsenic, total iron, and total aluminum. Dissolved oxygen concentrations were below acute concentrations (5.0 mg/L) at site DIL-1 during all season except spring, as well as at site MUL-1 during the winter.

Table 6 Summary of water quality variables collected in 2011 to 2012.*

Water Quality Variable	Units	Regulatory Guideline	Detection Limit	2011-2012 Data					
				n	Min	Med	Max	No. Exceeded	Freq %
Field Measurements									
Dissolved Oxygen	(mg/L)	5, 6.5[1]	-[2]	42	0	7	14.2	14	33
Conductivity	µS/cm	-	-[2]	39	76	467	2197		
pH	pH	6.5-9.0	-[2]	43	6.9	7.9	9.4	3	7
Temperature	°C	-	-[2]	43	0	8	21.2		
Conventional Variables									
Alkalinity, Total (as $CaCO_3$)	mg/L	-	5	43	76.9	285	1510		
Color, True	C.U.	-	2	43	5.5	38.5	339		
Conductivity (EC)	µS/cm	-	0.2	43	76	479	2197		
Dissolved Organic Carbon	mg/L	-	1	43	11	23	92.4		
Hardness (as $CaCO_3$)	mg/L	-		43	68.2	274	1120		
Total Dissolved Solids	mg/L	-	10	43	127	356	2210		
Total Organic Carbon	mg/L	-	1	43	11.1	23.7	91		
Total Suspended Solids	mg/L	+10mg/L [A]	3	43	3	5	120		
Turbidity	NTU	-	0.1	33	0.24	3.58	57		
General Organics									
Hydrocarbons, Recoverable (I.R.)	mg/L	-	1	43	1	1	3		
Naphthenic Acids	mg/L	-	1	42	1	1	1.4		
Phenols (4AAP)	mg/L	0.004	0.001	43	0.0035	0.0108	0.0501	41	95
Major Ions									
Bicarbonate (HCO_3)	mg/L	-	5	43	93.9	326	1850		
Calcium (Ca)	mg/L		0.5	43	9.21	51.8	133		
Carbonate (CO_3)	mg/L	-	5	43	5	5	193		
Chloride (Cl)	mg/L	640, 120[B]	0.5	43	0.75	2.52	53.5	0	0
Hydroxide (OH)	mg/L	-	5	43	5	5	5		
Magnesium (Mg)	mg/L	-	0.1	43	8.61	27.9	232		
Potassium (K)	mg/L	-	0.1	43	2.23	7.38	60		
Sodium (Na)	mg/L	-	1	43	1.4	11.1	337		
Sulfate (SO_4)	mg/L	-	0.5	43	0.5	4.89	393	11	26
Sulphide	mg/L	0.002[C]	0.002	43	0.002	0.0022	5.11	24	56

*See page 13 for General Notes.

Table 6 (Cont'd.)*

Water Quality Variable	Units	Regulatory Guideline	Detection Limit	2011-2012 Data					
				n	Min	Med	Max	No. Exceeded	Freq %
Nutrients and BOD									
Ammonia-N	mg/L	Variable[D]	0.05	43	0.05	0.05	2.04	2	5
Biochemical Oxygen Demand	mg/L	-	2	41	2	2	18.2		
Nitrate (as N)	mg/L	13	0.05	43	0.05	0.05	0.106	0	0
Nitrate and Nitrite as N	mg/L		0.071	43	0.071	0.071	0.106	0	0
Nitrite (as N)	mg/L	0.06	0.05	43	0.05	0.05	0.05	0	0
Phosphorus, Total	mg/L	0.05	0.01	43	0.001	0.0798	2.59	34	79
Phosphorus, Total Dissolved	mg/L	-	0.01	43	0.001	0.0226	1.12	9	21
Total Kjeldahl Nitrogen	mg/L	1	0.2	43	0.2	1.48	7.94	35	81
Dissolved Metals									
Aluminum (Al)	mg/L	0.1	0.001	39	0.001	0.0063	0.0209	0	0
Antimony (Sb)	mg/L	-	0.0001	39	0.0001	0.0001	0.0004	0	0
Arsenic (As)	mg/L	0.005	0.0001	39	0.0004	0.00094	0.00938	3	8
Barium (Ba)	mg/L	-	0.00005	39	0.000111	0.0454	0.125	0	0
Beryllium (Be)	mg/L	-	0.0005	39	0.0005	0.0005	0.0005	0	0
Bismuth (Bi)	mg/L	-	0.00005	39	0.00005	0.00005	0.00005		
Boron (B)	mg/L	29, 1.5[B]	0.002	39	0.0119	0.035	0.444	0	0
Cadmium (Cd)	mg/L	Variable[E]	0.00001	39	0.00001	0.00001	0.000143	0	0
Chromium (Cr)	mg/L	0.0089	0.0001	39	0.0001	0.00012	0.0004	0	0
Cobalt (Co)	mg/L	-	0.0001	39	0.0001	0.0001	0.00374	0	0
Copper (Cu)	mg/L	Variable[F]	0.0001	39	0.0001	0.0006	0.00187	0	0
Iron (Fe)	mg/L	0.3	0.01	39	0.01	0.027	2.39	2	5
Lead (Pb)	mg/L	Variable[G]	0.00005	39	0.00005	0.00005	0.0001	0	0
Lithium (Li)	mg/L	-	0.005	39	0.0047	0.0149	0.224	0	0
Manganese (Mn)	mg/L	-	0.002	39	0.00028	0.002	2.89	0	0
Molybdenum (Mo)	mg/L	0.073	0.00005	39	0.000062	0.000518	0.00279	0	0
Nickel (Ni)	mg/L	Variable[H]	0.0001	39	0.0001	0.00039	0.0043	0	0
Selenium (Se)	mg/L	0.001	0.0001	39	0.0001	0.00022	0.00063	0	0
Silver (Ag)	mg/L	0.0001	0.00001	38	0.00001	0.00001	0.0002	1	3
Strontium (Sr)	mg/L	-	0.0001	39	0.0121	0.122	0.596		
Thallium (Tl)	mg/L	0.0008	0.00005	39	0.00005	0.00005	0.00005	0	0
Tin (Sn)	mg/L	-	0.0001	39	0.0001	0.0001	0.0002		

* See page 13 for General Notes.

Table 6 (Cont'd.)*

Water Quality Variable	Units	Regulatory Guideline	Detection Limit	2011-2012 Data					
				n	Min	Med	Max	No. Exceeded	Freq %
Titanium (Ti)	mg/L	-	0.0003	39	0.0003	0.0003	0.0015	0	0
Uranium (U)	mg/L	0.033, 0.015[B]	0.00001	38	0.00001	0.000481	0.00882	0	0
Vanadium (V)	mg/L	-	0.0001	39	0.0001	0.00012	0.00072		
Zinc (Zn)	mg/L	0.03	0.001	39	0.001	0.0019	0.0074	0	0
Total Metals									
Aluminum (Al)	mg/L	0.1	0.003	43	0.003	0.02	0.634	7	16
Antimony (Sb)	mg/L	-	0.0001	43	0.0001	0.00018	0.0004	0	0
Arsenic (As)	mg/L	0.005	0.0001	43	0.00042	0.00115	0.0127	6	14
Barium (Ba)	mg/L	-	0.00005	43	0.0032	0.0487	0.208	0	0
Beryllium (Be)	mg/L	-	0.0005	43	0.0005	0.0005	0.001	0	0
Bismuth (Bi)	mg/L	-	0.00005	43	0.00005	0.00005	0.0002		
Boron (B)	mg/L	29, 1.5[B]	0.01	43	0.0134	0.037	0.421	0	0
Cadmium (Cd)	mg/L	Variable[E]	0.00001	43	0.00001	0.000121	0.0002	0	0
Chromium (Cr)	mg/L	0.0089	0.0001	43	0.0001	0.00049	0.0013	1	2
Cobalt (Co)	mg/L	-	0.0001	43	0.0001	0.0002	0.00402	0	0
Copper (Cu)	mg/L	Variable[F]	0.0001	43	0.00016	0.001	0.0023	0	0
Iron (Fe)	mg/L	0.3	0.01	43	0.01	0.431	9.44	23	53
Lead (Pb)	mg/L	Variable[G]	0.00005	43	0.00005	0.0001	0.000849	0	0
Lithium (Li)	mg/L	-	0.005	43	0.005	0.017	0.225	0	0
Manganese (Mn)	mg/L	-	0.002	43	0.00156	0.062	2.96	0	0
Mercury (Hg)-Trace	ug/L	5, 13[I]	0.0005	41	0.5	1.13	3.9	0	0
Molybdenum (Mo)	mg/L	0.073	0.00005	43	0.000078	0.0006	0.00296	0	0
Nickel (Ni)	mg/L	Variable[H]	0.0001	43	0.00015	0.00048	0.44	1	2
Selenium (Se)	mg/L	0.001	0.0001	43	0.0001	0.0004	0.00058	0	0
Silver (Ag)	mg/L	0.0001	0.00001	43	0.00001	0.000071	0.0004	1	2
Strontium (Sr)	mg/L	-	0.0001	43	0.0294	0.129	0.596		
Thallium (Tl)	mg/L	0.0008	0.00005	43	0.00005	0.00005	0.0001	0	0
Tin (Sn)	mg/L	-	0.0001	43	0.0001	0.0001	0.0004		
Titanium (Ti)	mg/L	-	0.0003	43	0.0003	0.005	0.0239	0	0
Uranium (U)	mg/L	0.033, 0.015[B]	0.00001	43	0.00001	0.0005	0.00838	0	0
Vanadium (V)	mg/L	-	0.0001	43	0.0001	0.0005	0.00227		
Zinc (Zn)	mg/L	0.03	0.003	43	0.003	0.004	0.0149	0	0

* See page 13 for General Notes.

Table 6 (Cont'd.)

General Notes:

Guidelines are CCME (2007), AENV (1999) unless otherwise noted

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

Detection limit exceeds guideline

* Detection limit used for winter and spring data

** Detection limit used for fall data only

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

[B] CCME short- and long-term guidelines respectively

[C] USEPA guideline for continuous concentration (USEPA 1999)

[D] CCME Guidelines for Ammonia – Total are based on temperature and pH as follows.

Temp (^{o}C)	pH								
	6	**6.5**	**7**	**7.5**	**8**	**8.5**	**9**	**9.5**	**10**
0	231	73	23.1	7.32	2.33	0.749	0.25	7.32	0.042
5	153	48.3	15.3	4.84	1.54	0.502	0.172	4.84	0.034
10	102	32.4	10.3	3.26	1.04	0.343	0.121	3.26	0.029

[E] CCME cadmium guideline is hardness dependent = $10^{\{0.86[\log(\text{hardness})]-3.2\}}$

[F] CCME copper guideline is hardness dependent = $0.2*e^{0.8545[\ln(\text{hardness})]-1.465}$

[G] CCME lead guideline is hardness dependent: $e^{1.273[\ln(\text{hardness})]-4.705}$

[H] CCME nickel guideline is hardness dependent: = $e^{0.76[\ln(\text{hardness})]+1.06}$

[I] Draft AENV guidelines for chronic (5) and acute (13) total mercury concentrations

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

[2] Field measurements were taken *in situ* and therefore there is no detection limit

Table 7 Summary of water quality variables collected in 2013.*

Water Quality Variable	Units	Regulatory Guideline	Detection Limit	2013 Data					
				n	Min	Med	Max	No. Exceeded	Freq %
Field Measurements									
Dissolved Oxygen	(mg/L)	5, 6.5[1]	-[2]	18	0	5.2	9	10	56
Conductivity	uS/cm	-	-[2]	20	216	452.5	1079		
pH	pH	6.5-9.0	-[2]	20	6.72	7.98	10.48	2	10
Temperature	°C	-	-[2]	20	0.1	20.2	22.2		
Conventional Variables									
Alkalinity, Total (as $CaCO_3$)	mg/L	-	5	22	130	253	607		
Color, True	C.U.	-	2	22	9.9	59.45	222		
Conductivity (EC)	uS/cm	-	0.2	22	233	450	1080		
Dissolved Organic Carbon	mg/L	-	1	20	18.6	25.6	64.6		
Hardness (as $CaCO_3$)	mg/L	-		22	116	233	541		
pH	pH	6.5-9.0	0.1	22	7.24	8.1	9.89	1	5
Total Dissolved Solids	mg/L	-	10	22	191	323.5	735		
Total Organic Carbon	mg/L	-	1	22	19.9	25.65	666		
Total Suspended Solids	mg/L	+10mg/L [A]	3	15	3	7	26	4	27
Turbidity	NTU	-	0.1	17	0.29	2.7	252		
General Organics									
Hydrocarbons, Recoverable (I.R.)	mg/L	-	1	22	<1.0	<1.0	<1.0		
Naphthenic Acids	mg/L	-	1	6	0.16	0.555	3.2		
Phenols (4AAP)	mg/L	0.004	0.001	22	0.0067	0.01095	0.362	22	100
Major Ions									
Bicarbonate (HCO_3)	mg/L	-	5	22	52.1	259	740		
Calcium (Ca)	mg/L		0.5	22	18	37.05	118		
Carbonate (CO_3)	mg/L	-	5	22	8	24.2	108		
Chloride (Cl)	mg/L	640, 120[B]	0.5	22	0.32	1.88	9.61	0	0
Hydroxide (OH)	mg/L	-	5	22	<5.0	<5.0	<5.0		
Magnesium (Mg)	mg/L	-	0.1	22	15.8	27.75	84.5		
Potassium (K)	mg/L	-	0.1	22	3.2	7.645	32.9		
Sodium (Na)	mg/L	-	1	22	2.3	8.75	69.1		
Sulfate (SO_4)	mg/L	-	0.5	22	0.61	6.09	176		
Sulphide	mg/L	0.002[C]	0.002	22	0.0024	0.0057	3.67	17	77

* See page 17 for General Notes.

Table 7 (Cont'd.)*

Water Quality Variable	Units	Regulatory Guideline	Detection Limit	2013 Data					
				n	Min	Med	Max	No. Exceeded	Freq %
Nutrients and BOD									
Ammonia-N	mg/L	Variable[D]	0.05	22	0.062	0.531	5.39	3	14
Biochemical Oxygen Demand	mg/L	-	2	22	2.2	15.4	51.8		
Nitrate (as N)	mg/L	13	0.05	22	<0.071	<0.071	<0.071	0	0
Nitrate and Nitrite as N	mg/L		0.071	22	<0.050	<0.050	<0.050		
Nitrite (as N)	mg/L	0.06	0.05	22	<0.050	<0.050	<0.050	0	0
Phosphorus, Total	mg/L	0.05	0.01	22	0.0106	0.0941	2.1	14	64
Phosphorus, Total Dissolved	mg/L	-	0.01	20	0.0043	0.0647	1.96		
Total Kjeldahl Nitrogen	mg/L	1	0.2	22	1.06	1.655	7.43	22	100
Dissolved Metals									
Aluminum (Al)	mg/L	0.1	0.001	22	0.001	0.00255	0.0206	0	0
Antimony (Sb)	mg/L	-	0.0001	22	0.00017	0.000215	0.00026		
Arsenic (As)	mg/L	0.005	0.0001	22	0.00038	0.001045	0.023	1	5
Barium (Ba)	mg/L	-	0.00005	22	0.0209	0.04705	0.249		
Beryllium (Be)	mg/L	-	0.0005	22	<0.00050	<0.00050	<0.00050		
Bismuth (Bi)	mg/L	-	0.00005	15	0.013	0.013	0.013		
Boron (B)	mg/L	29, 1.5[B]	0.002	22	0.0094	0.0225	0.119	0	0
Cadmium (Cd)	mg/L	Variable[E]	0.00001	22	0.107	0.107	0.107	0	0
Chromium (Cr)	mg/L	0.0089	0.0001	22	0.00015	0.00016	0.00041	0	0
Cobalt (Co)	mg/L	-	0.0001	22	0.00013	0.00022	0.007		
Copper (Cu)	mg/L	Variable[F]	0.0001	22	0.00011	0.0002	0.00058	0	0
Iron (Fe)	mg/L	0.3	0.01	19	0.011	0.062	57.8	5	26
Lead (Pb)	mg/L	Variable[G]	0.00005	22	0	<0.000050	0	0	0
Lithium (Li)	mg/L	-	0.005	22	0.0055	0.01245	0.0614		
Manganese (Mn)	mg/L	-	0.002	19	0.000233	0.3745	5.88		
Molybdenum (Mo)	mg/L	0.073	0.00005	19	0.000054	0.000224	0.00256	0	0
Nickel (Ni)	mg/L	Variable[H]	0.0001	17	0.00013	0.00061	0.00348	0	0
Selenium (Se)	mg/L	0.001	0.0001	5	0.00012	0.00019	0.00042	0	0
Silver (Ag)	mg/L	0.0001	0.00001	0	0	<0.000010	0	0	0
Strontium (Sr)	mg/L	-	0.0001	15	0.0724	0.127	0.355		
Thallium (Tl)	mg/L	0.0008	0.00005	0	0	<0.000050	0	0	0

* See page 17 for General Notes.

Table 7 (Cont'd.)*

Water Quality Variable	Units	Regulatory Guideline	Detection Limit	2013 Data					
				n	Min	Med	Max	No. Exceeded	Freq %
Tin (Sn)	mg/L	-	0.0001	3	0.00012	0.00018	0.00127		
Titanium (Ti)	mg/L	-	0.0003	5	0.00032	0.00045	0.00177		
Uranium (U)	mg/L	0.033, 0.015[B]	0.00001	19	0.000011	0.000256	0.00169	0	0
Vanadium (V)	mg/L	-	0.0001	13	0.00015	0.00026	0.00468		
Zinc (Zn)	mg/L	0.03	0.001	13	0.001	0.0016	0.0039	0	0
Total Metals									
Aluminum (Al)	mg/L	0.1	0.003	20	0.0031	0.01125	0.113	1	5
Antimony (Sb)	mg/L	-	0.0001	5	0.0001	0.00012	0.00027		
Arsenic (As)	mg/L	0.005	0.0001	22	0.00041	0.00121	0.0212	1	5
Barium (Ba)	mg/L	-	0.00005	22	0.0212	0.0589	0.228		
Beryllium (Be)	mg/L	-	0.0005	0	0	<0.00050	0		
Bismuth (Bi)	mg/L	-	0.00005	0	0	<0.000050	0		
Boron (B)	mg/L	29, 1.5[B]	0.01	21	0.012	0.023	0.145	0	0
Cadmium (Cd)	mg/L	Variable[E]	0.00001	0	<0.000010	<0.000010	<0.000010		
Chromium (Cr)	mg/L	0.0089	0.0001	13	0.00011	0.00022	0.00043	0	0
Cobalt (Co)	mg/L	-	0.0001	15	0.00011	0.00033	0.00705		
Copper (Cu)	mg/L	Variable[F]	0.0001	22	0.00012	0.000425	0.00106		
Iron (Fe)	mg/L	0.3	0.01	15	0.026	0.9175	56.8	9	60
Lead (Pb)	mg/L	Variable[G]	0.00005	22	0.000058	0.000089	0.000107		
Lithium (Li)	mg/L	-	0.005	20	0.0068	0.01555	0.0711		
Manganese (Mn)	mg/L	-	0.002	15	0.0049	0.354	7.23		
Mercury (Hg)-Trace	ug/L	5, 13[I]	0.0005	19	<0.0025	<0.0025	<0.0025	0	0
Molybdenum (Mo)	mg/L	0.073	0.00005	22	0.000063	0.000218	0.0026	0	0
Nickel (Ni)	mg/L	Variable[H]	0.0001	22	0.00011	0.00063	0.00345		
Selenium (Se)	mg/L	0.001	0.0001	22	0.0001	0.00012	0.00025	0	0
Silver (Ag)	mg/L	0.0001	0.00001	22	<0.000010	<0.000010	<0.000010	0	0
Strontium (Sr)	mg/L	-	0.0001	15	0.0725	0.126	0.353		
Thallium (Tl)	mg/L	0.0008	0.00005	22	<0.000050	<0.000050	<0.000050	0	0
Tin (Sn)	mg/L	-	0.0001	22	0.00018	0.00021	0.00024		
Titanium (Ti)	mg/L	-	0.0003	2	0.00038	0.00087	0.00475		

* See page 17 for General Notes.

Table 7 (Cont'd.)*

Water Quality Variable	Units	Regulatory Guideline	Detection Limit	2013 Data					
				n	Min	Med	Max	No. Exceeded	Freq %
Uranium (U)	mg/L	0.033, 0.015[B]	0.00001	22	0.000012	0.0002775	0.00157	0	0
Vanadium (V)	mg/L	-	0.0001	22	0.00014	0.00039	0.00489		
Zinc (Zn)	mg/L	0.03	0.003	22	0.0031	0.00625	0.0321	2	9

General Notes:

Guidelines are CCME (2007), AENV (1999) unless otherwise noted

Detection limit exceeds guideline

* Detection limit used for winter and spring data

** Detection limit used for fall data only

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

[B] CCME short- and long-term guidelines respectively

[C] USEPA guideline for continuous concentration (USEPA 1999)

[D] CCME Guidelines for Ammonia – Total are based on temperature and pH as follows.

Temp (°C)	pH								
	6	6.5	7	7.5	8	8.5	9	9.5	10
0	231	73	23.1	7.32	2.33	0.749	0.25	7.32	0.042
5	153	48.3	15.3	4.84	1.54	0.502	0.172	4.84	0.034
10	102	32.4	10.3	3.26	1.04	0.343	0.121	3.26	0.029

[E] CCME cadmium guideline is hardness dependent = $10^{\{0.86[\log(\text{hardness})]-3.2\}}$

[F] CCME copper guideline is hardness dependent = $0.2*e^{0.8545[\ln(\text{hardness})]-1.465}$

[G] CCME lead guideline is hardness dependent: $e^{1.273[\ln(\text{hardness})]-4.705}$

[H] CCME nickel guideline is hardness dependent: = $e^{0.76[\ln(\text{hardness})]+1.06}$

[I] Draft AENV guidelines for chronic (5) and acute (13) total mercury concentrations

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

[2] Field measurements were taken *in situ* and therefore there is no detection limit

3.1.2 Fish Resources – LSA

The Baseline Case for fish resources within the LSA was developed from a review of the area's fish resources as documented by the Fisheries and Wildlife Management Information System (FWMIS) database (ESRD 2013) in conjunction with fish inventory surveys conducted during the 2011-2012 and 2013 field programs in support of this EIA.

A review of the FWMIS database shows that brook stickleback, fathead minnow, lake chub, and finescale dace have been captured in the tributaries leading into Muriel Lake, with brook stickleback and fathead minnow being the most common. Records from the unnamed tributary leading into the North Saskatchewan River (Sites SM3b-1, SMB3a-1, and MOC-2) show that finescale dace, brook stickleback, longnose dace, and longnose sucker have been captured in these tributaries.

In Muriel Lake, recent surveys in the FWMIS database show that brook stickleback, fathead minnow, spottail shiner, yellow perch, Iowa darter, and longnose sucker have been captured in the past 15 years. Older records from the database indicate that lake whitefish, burbot, white sucker, walleye, and northern pike were once present in Muriel Lake, although they have not been captured in recent studies, including test netting conducted in September 2012 (ESRD 2013). Recent FWMIS records for Garnier Lake show that yellow perch, brook stickleback, northern pike, and logperch have been captured at the lake, while historic records show burbot as having also been captured in Garnier Lake. No FWMIS records are available for either Dion or Michel Lake. FWMIS information on Reita Lake is limited to surveys in 1977 and 1982 during which northern pike and white sucker were captured (ESRD 2013).

Sport fishing records are only available for Muriel Lake. The last reported creel survey was in 1986, which found a higher than provincial average catch of northern pike (Mitchell and Prepas 1990). More recent studies (AENV 2006) have found that the recreational fishery in Muriel Lake has been greatly affected by decreasing water levels and poor water quality.

Baseline fish inventories were conducted at fifteen locations in 2011 to 2012 (Table 8) and eight locations in 2013 (Table 9). A total of 1,564 fish were captured across all seasons, representing eleven different species: brook stickleback; finescale dace; yellow perch; fathead minnow; lake chub; northern pike; longnose dace; longnose sucker; pearl dace; log perch; and Iowa darter. Within the tributaries, brook stickleback was the most commonly-caught species (78%), followed by fathead minnow (12%) and finescale dace (7%). Within the lakes, fish were only caught at Garnier Lake, with yellow perch being the most commonly caught species (74%), followed by northern pike (16%). No fish were captured in the 2013 surveys.

Table 8 Summary of fish inventories conducted in 2011-2012 on watercourses and waterbodies within the Pengrowth LSA and RSA.

Site	Summer 2011				Fall 2011			Spring 2012			
	Gear Type	Sampling Effort	No. Fish Captured	Species	Gear Type	Sampling Effort	Species	Gear Type	Sampling Effort	No. Fish Captured	Species
SM3a-1	MT	1.25 h	0	-	MT	3 h	-	MT	1 h	0	-
MOC-1	EF	491 s	27	11 BRST, 14 FNDC, 2 LNDC	EF	212 s	2 LNDC, 2 LNSC	EF	570 s	14	BRST
MOC-1	MT	0.4 h	24		MT	4.6 h	BRST	MT	4.3 h	174	BRST
MIL-1	No fish inventory conducted, water quality only				No fish inventory conducted, water quality only			MT	1.3 h	19	1 BRST, 18 FTMN
GAC-1	MT	4.3 h	68	59 BRST, 9 FNDC	MT	19.4 h	7 LKCH, 4 BRST, 77 FTMN	MT	14.8 h	148	124 BRST, 24 FTMN
GAC-2	MT	1.75 h	0	-	MT	19.3 h	BRST	MT	4 h	1	BRST
								EF	1209 s	57	50 BRST, 7 FTMN
GAC-3	MT	0.3 h	0	-	MT	19.3 h	BRST	MT	1 h	0	-
SG2-1	MT	1 h	4	BRST	MT	1.25 h	BRST	MT	1.25 h	0	-
SG4-1	MT	n/a	-	-	MT	1.1 h	-	MT	2.7 h	0	-
SG5-1	No fish inventory conducted, dry channel				No fish inventory conducted, dry channel			EF	305 s	0	
GAL-1	GN	2.5 h	0	YLPR	GN	1.25 h	9 YLPR, 2 NRPK	GN	1.2 h	54	44 YLPR, 10 NRPK
GAL-1	MT	4 h	4	3 BRST, 1 LGPR	MT	2 h	-	MT	4.7 h	4	IWDR
MOC-2	MT	5.3 h	75	56 FNDC, 19 BRST	MT	3.4 h	8 BRST, 1 FNDC	MT	2.7 h	705	630 BRST, 46 FTMN, 29 PRDC
DIL-1	No fish inventory conducted, water quality only				MT	1.2 h		MT	1.7	0	-
Total		**20.9 h**	**202**	**5 species**		**75.9 h**	**8 species**		**44.2 h**	**1176**	**6 species**

Table 9 Summary of fish inventories conducted in 2013 on watercourses and waterbodies within the Pengrowth LSA and RSA.

	Spring 2013				Summer 2013			
Site	**Gear Type**	**Sampling Effort**	**No. Fish Captured**	**Species**	**Gear Type**	**Sampling Effort**	**No. Fish Captured**	**Species**
SC1-4	No defined channel				No defined channel			
SC1-3	No defined channel				No defined channel			
SG2-3	MT	64.5 h	0	-	MT	44 h	0	-
TRL1-1	Insufficient water for sampling				Insufficient water for sampling			
SC2-1	MT	63 h	0	-	No fish inventory		0	
SC1-2	No defined channel				No defined channel			
SG2-2	No defined channel				No defined channel			
SG21-1	Insufficient water for sampling				Insufficient water for sampling			
SG4-4	No defined channel				No defined channel			
SG4-2	MT	63 h	0	-	MT	36 h	0	-
SG4-3	No defined channel				No defined channel			
SC1-1	MT	66 h	0	-	No fish inventory		0	
SG2-4	No defined channel				No defined channel			
SG4-5	No defined channel				No defined channel			
GAC-4	No fish inventory				MT	36 h		-
LC11-1	No fish inventory				No fish inventory			
LC11-2	MT	66 h	0	-	No fish inventory		0	
REL-1	No fish inventory				MT	38 h		-
LG2-2	MT	66 h	0	-	MT	38 h	0	-
LG2-1	No fish inventory				No fish inventory			
GAL-2	No fish inventory				No fish inventory			
Total		**388.5 h**	**0**	**-**		**192 h**	**0**	**-**

3.1.3 Physical Aquatic Habitat - LSA

Physical habitat surveys were conducted for all aquatic sampling sites during at least one sampling season. Detailed habitat information is provided in Appendix A3.

Most of the watercourses within the LSA were small, unnamed tributaries draining into Moosewa Creek, Garnier Creek or Muriel Lake. The upper portions of the streams had no defined channel. The middle portion of the tributaries had poorly-defined channels with some beaver ponds that could possibly provide habitat for forage fish, although overwinter survival would likely be influenced by low winter dissolved oxygen levels. Water was present but generally not flowing at any time the baseline surveys were conducted. The lower portions of the unnamed tributaries close to the confluence with a given named waterbody had defined channels with some flow and habitat for forage fish that would be able to overwinter in the larger waterbody to which the tributary is connected. With the exception of a portion of Garnier Creek, all watercourses in the LSA are Class C with a restricted activity period of April 16 to June 30. The lower portion of Garnier Creek is a Class B habitat. This designation is due to use of this area for walleye spawning. Otherwise, no sensitive habitat is present in the study area.

In the watercourses that had defined channels and water present, the dominant substrate was organic material. Instream and overhead cover was generally abundant in all watercourses with values ranging from 20 to 100% coverage. Instream cover consisted mostly of instream vegetation and small woody debris, with lesser amounts of large woody debris, undercut banks, and deep pools providing cover. Overhead cover consisted mostly of overhanging grasses, shrubs, and debris. The riparian vegetation is comprised mostly of grasses, sedges, shrubs, and willow mixed forests.

3.2 BASELINE CASE FOR REGIONAL STUDY AREA

Moosewa Creek, a tributary to the North Saskatchewan River, was surveyed (site MOC-1) to collect surface aquatic resources information for the Baseline Case for the RSA (Figure 3). This site lies to the south and downstream of the Project, south of Highway 646. There was no flowing water at the site, or at the upstream culvert in the winter. Water quality at this location was sampled in spring, summer, and fall only. The Baseline Case for fish resources consists of FWMIS data for Moosewa Creek and the North Saskatchewan River, as well as data from the fish inventory conducted on Moosewa Creek during the baseline field studies.

3.2.1 Water Quality - RSA

Water quality at site MOC-1 (Appendix A2) on Moosewa Creek is similar to that in the watercourses of the LSA. Concentrations and levels of conventional variables such as conductivity, DOC, hardness, pH, and TDS measured for the RSA were similar to levels measured in the LSA, while colour measured within

the RSA were lower and TSS concentrations were higher than in the watercourses of the LSA. Water quality variables with concentrations that exceeded water quality guidelines in the RSA were similar to those in the LSA (Table 6, Table 7), with concentrations of phenols, total phosphorous, total nitrogen, sulphides, total aluminum, and total iron occurring at concentrations above water quality guidelines.

3.2.2 Fish Resources - RSA

Fish species captured at site MOC-1 during baseline surveys consisted of brook stickleback, longnose dace, finescale dace, and longnose sucker, with finescale dace being the most abundant species captures (54%) (Table 8). The FWMIS database indicates that Brook stickleback and fathead minnow have been recorded in Moosewa Creek (ESRD 2013). Brook stickleback are also recorded in Moosehills Creek, a tributary to the North Saskatchewan River similar to Moosewa Creek, while walleye, northern pike, sauger, and goldeye have been recorded in the North Saskatchewan River within 2 km of the outflow of Moosehill and Moosewa Creeks within the past ten years (ESRD 2013). While longnose sucker, shorthead redhorse, white sucker, and quillback have also been recorded at this location in the North Saskatchewan River, there are no records for these species since 1997 (ESRD 2013).

3.3 BASELINE CASE FOR ACID SENSITIVITY OF SURFACE AQUATIC RESOURCES

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

Acid-sensitive surface waters typically exhibit low pH (<6.5), low concentrations of all major ions (i.e., specific conductance is <25 µS/cm), low organic acid concentrations (i.e., DOC concentration is typically less than 3 to 5 mg/L), and low acid neutralizing capacity (i.e., ANC <200 µeq/L) (Sullivan 2000).

Chemical characteristics of the lakes within the AQLSA are shown in Table 10. Lakes in the AQLSA are all ranked as low sensitivity to acidifying emissions according to Saffron and Trew (1996). Using the alkalinity-based classification system developed by Saffran and Trew (1996), critical load of each of the lakes was calculated. Critical load is greater than the baseline PAI input in all lakes sampled in the AQLSA (Table 10).

The maximum predicted PAI in the Baseline Case for the entire AQRSA is 0.18 keq H+/ha/yr which occurs in the vicinity of an operator near Marie Lake to the north of the Project. Most of the AQRSA has a predicted PAI of less than

0.1 keq H+/ha/yr (MEMS 2013a). The maximum value of 0.18 keq H+/ha/yr is less than 0.22 keq H+/ha/yr, which is the target load for the most sensitive soils and aquatic systems as outlined by CASA (AENV 1999b).

Table 10 Acid-sensitivity of sampled lakes in the Air Quality Local Study Area.

Lake ID	pH (pH units)	Alkalinity (mg/L)	Conductivity (µS/cm)	TDS (mg/L)	DOC (mg/L)	Critical Load[1]	Baseline Case PAI[1]
DIL-1	7.48	246	318	335	36.88	1.99	0.04
GAL-1	8.74	625	771	953	30.05	1.60	0.04
MIL-1	8.52	155	287	182	12.13	0.77	0.03
MUL-1	9.31	1075	1688	1723	46.57	6.75	0.03
LC11-1	7.55	202	372	288	30.30	0.51	0.03
LC11-2	7.39	197	365	254	23.00	0.95	0.03
LG2-2	7.68	337	598	392	25.50	0.93	0.03
GAL-2	8.90	361	922	643	24.55	1.58	0.04
REL-1	9.52	269	486	397	39.65	0.91	0.03

[1] keq H^+/ha/ yr.

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 (2013a).

4.0 EFFECTS ASSESSMENT

4.1 EFFECTS ON AQUATIC HABITAT AND RESOURCES FROM SURFACE DISTURBANCE DURING CONSTRUCTION, OPERATION AND RECLAMATION ACTIVITIES

4.1.1 Description of Effects and Assessment of Validity of Impact Pathways

Surface disturbance and construction activities will take place within the LSA during the Project and may result in an increase in sediment loading in watercourses and waterbodies. These activities may have consequent effects on water quality, aquatic habitat and fish populations and include:

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

These Project disturbances will be located within tributary watersheds that are part of the Moosewa Creek and Muriel Lake watersheds (nhc 2013). Sediment from surface disturbances therefore has the potential to enter watercourses and the linkage between surface disturbance and construction activities and potential changes in sediment yield is assessed as valid.

4.1.2 Mitigation Measures to be Implemented

The Project will implement a number of widely-used best management practices that have been established to reduce erosion from exposed surfaces and prevent sediment from migrating from construction sites into watercourse (TAC 2005). These mitigation measures will effectively prevent, or reduce to acceptable levels, the effects from surface disturbance activities. A range of different measures will be implemented including:

- a sediment control plan will be developed;
- a 100 m setback will be applied to all waterbodies with fish habitat potential, while a 50 m setback will be applied at all defined channels with no fish habitat. Measures at stream crossings are described below. sediment control measures such as those described in the *Alberta Code of Practice for Watercourse Crossings* (AENV 2000) and associated guidelines will be implemented for earthworks which take place within or in close proximity to watercourses. These measures may include, as required: the use of cutoff trenches, silt fences, flow barriers, temporary and/or permanent sediment control ponds and/or traps, and ditches to minimize or eliminate sediment transport from exposed soil areas into receiving watercourses and waterbodies;
- whenever possible, surface disturbance activities in close proximity to watercourses will be carried out during periods of relatively low surface runoff in late fall, winter and early spring (from October to April);
- 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;

- 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 as soon as possible following earth works. 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.

4.1.3 Impact Analysis

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

- impacts from construction activities which have been identified as potentially adverse are mitigable using best management practices adopted by all levels of government to control sediment and erosion. This will include measures to reduce the potential for erosion at the source such as those described in Alberta Transportation (2011), preparation of site-specific sediment and erosion control plans and monitoring of the measures put in place to ensure they function as intended;

- 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;

- with the exception of crossings, a minimum 100 m buffer will be maintained from the edge of all fish bearing waterbodies and a minimum 50 m buffer will be maintained from the edge of the stream bank for all watercourses with defined channels;

- 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 direct water away from the road to undisturbed areas to minimize erosion. Culverts will be installed along the access roads to ensure that flows will be maintained across drainages and wetlands; and

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

4.1.4 Residual Effects Classification

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

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

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

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

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

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

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

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

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

Because the residual effects of the Project on surface aquatic resources through surface disturbance and construction activities are assessed as ***Low Impact*** in the LSA, these residual effects: these residual effects are also assessed as ***Low Impact*** for the RSA. The residual effects are also summarized in Table 12.

4.2 EFFECTS ON SURFACE AQUATIC RESOURCES THROUGH INSTREAM CONSTRUCTION ACTIVITIES

4.2.1 Description of Effects and Assessment of Validity on Impact Pathways

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

There are 19 potential watercourse crossings in the Project area (nhc 2013). Eighteen of the crossings are for access roads and all but one of the crossings is on a watercourse identified as having no fish habitat potential based on undefined or poorly defined channels and lack of flow. The one watercourse with fish habitat is Garnier Creek, which has a proposed clear span crossing downstream of Garnier Lakes (Figure 3). Garnier Creek provides habitat for sport fish, including northern pike, as well as forage fish habitat. The linkage between instream construction activities and effects on surface aquatic resources is therefore assessed as valid.

4.2.2 Mitigation Measures to be Implemented

Most of the crossings are on drainages with no defined channel and no fish habitat. For these a culvert would be sufficient to maintain drainage (NHC 2013) and there would be no impacts on fish habitat. For the crossing of Garnier Creek, a clear span bridge would be used to avoid instream works. Mitigation measures for road crossings of streams are documented in Alberta Transportation (2011). The measures that will be adopted for the Project include:

- instream construction activities at all watercourses with a defined channel and/or fish habitat will be carried out during periods of relatively low surface runoff whenever possible; and
- all watercourse crossings, including the crossing of Garnier Creek with a clear span bridge will be designed and constructed in compliance with the *Alberta Code of Practice for Watercourse Crossings* (AENV 2000), associated guidelines, the *Fish Habitat Manual* (Alberta Transportation 2001) and the *Measures to Avoid Causing Harm to Fish and Fish Habitat* (DFO 2013). For watercourse crossings these requirements include: aquatic and biological assessments; watercourse crossing design and construction; post-construction clean-up and reclamation; contingency measures; and watercourse crossing site monitoring. Implementation of appropriate mitigation measures means that all stream crossings constructed and operated for the Project will meet regulatory requirements for the protection of fish resources and aquatic habitat and will subsequently mitigate against effects on surface water quality.

4.2.3 Impact Analysis

Only one of the proposed crossings has the potential to affect fish habitat. The use of a clear span bridge for this one crossing will substantially reduce the amount of instream activity required and with the application of the mitigation measures summarized in Section 4.2.2, the potential impacts of instream construction activities are predicted to be low.

4.2.4 Residual Effects Classification

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

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

Because the residual effects of the Project on surface aquatic resources through in-stream construction activities are assessed as ***Low Impact*** in the LSA, these residual effects are also assessed as ***Low Impact*** for the RSA. The residual effects are also summarized in Table 12.

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

4.3.1 Description of Effects and Assessment of Validity Impact Pathways

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

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

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

4.3.2 Mitigation Measures to be Implemented

Discharge of Project-affected waters: Project water will be recycled as much as possible and the waste stream of concentrated brine from the evaporation-distillation process will be disposed of at one of Pengrowth's two approved and functional disposal wells or other disposal wells that may be developed or to a government approved disposal facility. No planned discharges of Project-affected waters will take place, hence impact to natural watercourses is considered low and no mitigation measures are proposed.

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

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 storm water runoff pond is not anticipated to contain any process related chemicals.

The storm water runoff pond will function as a sedimentation pond and will settle particulates to reduce levels of any sediment. To mitigate against potential adverse impacts, the runoff 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 storm water runoff pond, the release of runoff waters on nearby surface waters is predicted to have a negligible effect on water quality.

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

Management and disposal of drilling waste will be in accordance with all regulations and will be implemented under the Project's waste management plan. The oil content in the drilling fluids after drilling the bitumen sections is expected to be too high for onsite or offsite disposal. The rig will be equipped with centrifuges and linear motion shakers. The oil contaminated cuttings will be mixed with wood fibre and stored in steel containers on site, and then hauled to a certified Class II Landfill. The oil contaminated liquid mud will be hauled to certified Class II Salt Cavern for disposal or other approved facility.

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. Pengrowth will develop an Emergency Response Plan (ERP) for the Project construction and operation phases that will set out procedures to deal with emergency situations. The ERP will address unplanned releases to the environment. Collectively, the secondary containment and leak detection measures, along with management and response plans will minimize the risk of substance release into watercourses and waterbodies and resultant negative impacts to aquatic resources.

4.3.3 Impact Analysis

With strict implementation of the mitigation measures summarized in Section 4.3.2, potential impacts to aquatic resources through changes in surface water quality and discharge of Project-affected water into natural watercourses are predicted to be low for the following reasons:

- no planned discharges of Project-affected waters will take place**;**
- occasional releases from the storm water runoff 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 (MEMS 2013b).

4.3.4 Residual Effects Classification

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

- **Magnitude –** magnitude of effects will be ***Low to Moderate.*** There may be changes in surface water quality as a result of accidental releases, but the nature of most of the watercourses in the LSA means that the effect on the aquatic environment would be limited. With the effective application of well-accepted and regulated mitigation measures and contingency plans, these changes are expected to be generally within established protective standards and to cause no detectable change in surface water quality beyond occasional, local effects. However, under upset conditions, it is predicted that some disturbances may cause short-term detectable changes in background ecological parameters;
- **Geographic Extent –** effects will be ***Local,*** within the LSA;
- **Duration of Impact –** effects will be ***Long,*** occurring over the life of the Project from development and ongoing reclamation through to decommissioning;

- **Frequency** – effects will be ***Occasional to accidental,*** occurring intermittently and sporadically or rarely over assessment period;
- **Ability for Recovery –** effects will be ***reversible in the short-term*** and will diminish upon cessation of activities;
- **Project Contribution** – ***Negative***, there will be some localized, occasional negative effects on surface water quality from Project activities;
- **Confidence Rating** – ***High,*** the management practices and mitigation measures to be applied are well-accepted and there is good evidence from previous studies that the effective application of these measures will mitigate any effects of Project activities on surface water quality. The level of confidence in the groundwater assessment is dependent of the reliability and robustness of the hydrogeological analyses of Project effects as described in MEMS (2013b); and
- **Probability of Occurrence –** ***Medium,*** possible - based on experience from previous similar projects.

Because the residual effects of the Project on surface aquatic resources through changes in surface water quality are assessed as ***Low Impact*** in the LSA, these residual effects are also assessed as ***Low Impact*** for the RSA. The residual effects are also summarized in Table 12.

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

4.4.1 Description of Effects and Assessment of Validity Impact Pathways

Changes in stream flow can affect:

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

Changes to surface water flow rates could result from:

- surface disturbance activities altering natural run-off and drainage patterns;
- surface water withdrawal activities required to meet water requirements for the Project;
- release of Project-affected waters to natural waterbodies; and
- changes in the amount of shallow groundwater reporting to surface water.

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

4.4.2 Mitigation Measures to be Implemented

Changes to natural run-off and drainage patterns due to surface disturbance activities: Mitigation measures to minimize potential impacts include diverting runoff from disturbed areas into the natural environment, away from the existing stream networks. During construction and operation surface drainage will be maintained with the use of drainage structures (i.e., ditches, culverts, bridges). Reclamation activities will be phased such that they commence before the entire Project is developed restoring drainage patterns.

Changes to surface water flow rates due to release of Project-affected water: The full CPF has already been constructed for the Phase 1 Project along with the storm water runoff pond. No additional surface runoff will report to the storm water runoff pond. No planned discharges of Project-affected waters will take place. Occasional releases may take place from the storm water runoff 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: No Project activities have been identified (e.g., excavation works) that are expected to impact on shallow groundwater/surface water interactions. The Project will not use any groundwater is the stream generation process. Therefore no impact to the amount of shallow groundwater reporting to surface water is expected.

4.4.3 Impact Analysis

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

- only small increases in surface water runoff volumes are predicted as a result of surface disturbances. The Hydrology assessment (nhc 2013) predicts maximum changes in average runoff volume of between 1.2% and 6.1% above Baseline Case conditions in the unnamed watercourses in the LSA. Minor changes in peak annual flows and low flow rates are anticipated in streams in the LSA;

- no planned discharges of Project-affected waters will take place and therefore no consequent changes to surface water flow rates are expected;

- occasional releases from the storm water runoff pond may take place, but water will be released at a controlled rate in accordance with the terms and conditions of the operating approvals; and

- shallow groundwater levels are not expected to be affected by Project activities and therefore no resulting changes to surface water flow rates are expected.

4.4.4 Residual Effects Classification

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

- **Magnitude** – magnitude of effects will be ***Low.*** Changes are expected to be generally within established protective standards and to cause no detectable change to surface water flow rates beyond occasional, local effects;
- **Geographic Extent** – effects will be ***Local,*** within the LSA;
- **Duration of Impact** – effects will be ***Long,*** occurring over the life of the Project from development and ongoing reclamation through to decommissioning;
- **Frequency** – effects will be ***Occasional to Seasonal,*** occurring intermittently and sporadically over assessment period, and in the case of changes to water flows and levels due to surface disturbance;
- **Ability for Recovery –** effects to water flows and levels due to surface disturbance will be ***reversible in the long-term,*** all other effects will be ***reversible in the short-term*** and will diminish upon cessation of activities;
- **Project Contribution** – ***Negative***, there will be some localized, occasional, minor negative effects on surface water flow rates from Project activities;
- **Confidence Rating** – ***High,*** The level of confidence in this assessment is dependent of the reliability and robustness of the hydrological and hydrogeological analyses of Project effects as described in nhc (2013) and MEMS (2013b); and
- **Probability of Occurrence** – ***High***, based on experience from previous similar projects.

Because the residual effects of the Project on surface aquatic resources through changes in surface water flow rates are assessed as ***Low Impact*** in the LSA, these residual effects: are also assessed as ***Low Impact*** for the RSA. The residual effects are also summarized in Table 12.

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

4.5.1 Description of Effects and Assessment of Validity of Impact Pathways

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

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

4.5.2 Mitigation Measures to be Implemented

Pengrowth will work closely with ESRD to ensure the fisheries resources in the study area, particularly the lakes, do not become over-exploited as a result of increased sportfishing. Possible initiatives include:

- raising awareness among the Project workers of the existing ESRD 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 while at work.

4.5.3 Impact Analysis

There are limited angling opportunities with the LSA. The streams contain forage fish and juveniles of larger bodied species. Only the two larger lakes (Garnier and Muriel) are known to contain sport fish, but recent surveys on Muriel lake have concluded that the sport fish population has been extirpated, likely as a result of declining water levels and poor water quality (ESRD 2013b). The limited sport fishing opportunities mean that any increase in access to the lakes in the LSA will not impact the aquatic resources within the LSA and the effects of angling on LSA populations is expected to be low.

With no good, local fishing opportunities, it is possible that the additional personnel may look to the Cold Lake and Lac La Biche areas for fishing opportunities. Construction of the Project is expected to require 540 person years of labour over a two year period, or roughly 270 additional people per year. It is likely that this workforce will be drawn from the regional area and therefore fishing pressure would largely remain unchanged as those individuals that fish would do so regardless of their location within the region.

The Project is expected to result in a local population increase of approximately 60 people. This will likely result in an additional five anglers in the region which is a negligible change in fishing pressure.

4.5.4 Residual Effects Classification

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

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

Because the residual effects of the Project on surface aquatic resources through improved or altered access to fish-bearing watercourses are assessed as ***Low Impact*** in the LSA, these residual effects are also assessed as ***Low Impact*** for the RSA given the migratory patterns of sportfish in the watershed. The residual effects are also summarized in Table 12.

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

4.6.1 Description of Effects and Assessment of Validity of Impact Pathways

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

4.6.2 Mitigation Measures to be Implemented

Section 4.1.2, Section 4.2.2 and Section 4.3.2 outline mitigation measures to address potential contamination of surface waters; the mitigation measures that are also applicable to the issue of fish tainting are summarized below:

- No planned discharges of Project-affected waters will take place, hence impact to natural watercourses is considered low and no mitigation measures are proposed.
- Surface water run-off from the plant site will be directed to a storm water runoff pond constructed in accordance with relevant regulations and returned to the CPF for use as plant makeup water. The surface runoff collected in the storm water runoff pond may be released to the surrounding watershed if it meets the quality requirements outlined in the operating approval.
- 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 storm water runoff pond is not anticipated to contain any process related chemicals.
- The storm water runoff pond will function as a sedimentation pond and will settle particulates to reduce levels of any sediment. To mitigate against potential adverse impacts, the runoff 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 storm water runoff pond, the release of runoff waters on nearby surface waters is predicted to have a negligible effect on water quality.
- Management and disposal of drilling waste will be in accordance with all regulations and will be implemented under the Project's waste management plan.
- 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. Pengrowth will develop an Emergency Response Plan (ERP) for the Project construction and operation phases that will set out procedures to deal with emergency situations. The ERP will address unplanned releases to the environment. Collectively, the secondary containment and leak detection measures, along with management and response plans will minimize the risk of substance release into watercourses and waterbodies and resultant negative impacts to aquatic resources.

4.6.3 Impact Analysis

No ongoing release of water is anticipated and with implementation of the mitigation measures, the potential impacts to fish health through potential changes in water quality are predicted to be low.

4.6.4 Residual Effects Classification

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

- **Magnitude** – magnitude of effects will be ***Low.*** With the effective application of well-accepted and regulated mitigation measures, changes are expected to be well within established protective standards and to cause no detectable change in fish health;
- **Geographic Extent** – effects will be ***Regional*** given the migratory behavior of some fish species documented in the LSA;
- **Duration of Impact** – effects will be ***Long,*** occurring over the life of the Project from development and ongoing reclamation through to decommissioning;
- **Frequency** – effects will be ***Occasional to Accidental,*** occurring intermittently and sporadically or rarely over the assessment period;
- **Ability for Recovery –** effects will be ***Reversible in the short-term*** and will diminish upon cessation of activities;
- **Project Contribution** – *Negative,* as release of process-affected water could cause fish tainting;
- **Confidence Rating** – ***High,*** the mitigation measures to be applied are well-accepted and there is good evidence from previous studies that the effective application of these measures in accordance with operating procedures will mitigate effects of in-stream construction activities such that they are *Low Impact*; and
- **Probability of Occurrence** – ***Low***, given the mitigation measures to be put in place (Section 4.6.2).

Because the residual effects of the Project on surface aquatic resources on fish health are assessed as ***Low Impact*** in the LSA, these residual effects are also assessed as ***Low Impact*** for the RSA. The residual effects are also summarized in Table 12.

4.7 EFFECTS ON SURFACE AQUATIC RESOURCES FROM ACIDIFYING EMISSIONS

4.7.1 Description of Effects and Assessment of Validity of Impact Pathways

Activities associated with the Project will result in the release of acidifying emissions as described in the Air Quality Assessment (MEMS 2013a). Therefore, the potential for acidifying emissions from the Project to affect surface aquatic resources in the Air Quality RSA is considered a valid impact pathway.

4.7.2 Mitigation Measures

A series of mitigation measure are described in the Air Quality Assessment Report (MEMS 2013a) that will minimize acidifying emissions related to Project activities.

4.7.3 Impact Analysis

4.7.3.1 Application Case

The predicted PAI for the Baseline and Application cases (MEMS 2013a) for lakes in the AQLSA is presented in Table 11. Predicted PAI values at all lakes in the AQLSA for the Application Case are below Alberta's Clean Air Strategic Alliance (CASA) target load for sensitive grid cells of 0.22 keq H^+/ha/yr (AEP 1999b), and are also below the critical load for those lakes. The target load is a value set below the critical load of 0.25 keq H+/ha/yr in order to confer additional protection given the level of uncertainty currently associated with model predictions and the receptor sensitivity databases (AENV 199b). In addition, the predicted PAI in the Application Case for the entire AQRSA is also less than target load for sensitive grid cells of 0.22 keq H+/ha/yr (MEMS 2013a).

4.7.3.2 Planned Development Case

The predicted PAI for the Planned Development Case (MEMS 2013a) for lakes in the AQLSA is presented in Table 11. Predicted PAI values at all lakes for the Planned Development Case in the AQLSA are below the CASA target load for sensitive grid cells of 0.22 keq H^+/ha/yr (AEP 1999b), and are also below the critical load for those lakes. In addition, the predicted PAI in the Planned Development Case for the entire AQRSA is less the target load (as defined in Section 4.7.3.1) of 0.22 keq H+/ha/yr, (MEMS 2013a).

4.7.4 Residual Impact Classification

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

- **Magnitude** – magnitude of the effects of the Project will be ***Low,*** as there are predicted to be no lakes that exceed the critical load value in the Application Case but not the Baseline Case, as well as no lakes that

exceed the critical load value in the Planned Development Case but that do not exceed the critical load value in the Application Case and/or Baseline Cases;

- **Geographic Extent –** effects will be ***Regional***;
- **Duration of Impact** – effects will be ***Long,*** occurring over the life of the Project from development and during operation of the facility;
- **Frequency** – effects will be ***Continuous,*** occurring continually over assessment periods;
- **Ability for Recovery –** effects will be ***reversible in the long-term,*** they will remain after cessation of activities but will diminish with time;
- **Project Contribution** – ***Negative,*** there will be some net loss to the quality of aquatic resources;
- **Confidence Rating** – ***Moderate,*** predictions of impacts to aquatic resources resulting from Project related acidifying emissions are subject to uncertainty because of uncertainty in the estimation of critical loads. Uncertainty arises from an 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 and similar projects.

The Project's residual effects of changes in acidifying emissions on surface aquatic resources are assessed as ***Low Impact*** for both the Application and Planned Development Cases (Table 12).

Table 11 Comparison of estimated PAI inputs in baseline, application and planned development cases and critical load for AQLSA lakes.

Lake ID	Annual Average PAI (keq/ha/yr)			Critical Load
	Baseline Case	Application Case	Planned Development Case	
DIL-1	0.04	0.04	0.04	1.99
GAL-1	0.04	0.05	0.05	1.60
MIL-1	0.03	0.04	0.04	0.77
MUL-1	0.03	0.04	0.04	6.75
LC11-1	0.03	0.04	0.04	0.51
LC11-2	0.03	0.04	0.04	0.95
LG2-2	0.03	0.04	0.04	0.93
GAL-2	0.04	0.04	0.04	1.58
REL-1	0.03	0.04	0.04	0.91

Note: Critical loads calculated based on the relationship between ANC, base cation concentrations, and annual catchment runoff using Henriksen's steady state water chemistry model (RAMP 2011). PAI values from MEMS (2013a).

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

5.0 ENVIRONMENTAL ASSESSMENT SUMMARY

A summary of the environmental impact assessment is provided in Table 12. With mitigation, monitoring and adaptive management, described above, it is anticipated the Project will have a low impact on surface aquatic resources within the Local and Regional Study Areas.

5.1 SUMMARY OF MITIGATION MEASURES FOR AQUATIC RESOURCES

It is recommended that Pengrowth undertake the following mitigation measures to eliminate and/or reduce to acceptable levels, potential effects on surface aquatic resources:

- a sediment control plan will be developed;
- a 100 m setback will be applied to all waterbodies with fish habitat potential (Figure 4), while a 50 m setback will be applied at all defined channels with no fish habitat. These setbacks will not apply at stream crossings;
- sediment control measures such as those described in the *Alberta Code of Practice for Watercourse Crossings* (AENV 2000) and associated guidelines will be implemented for earthworks which take place within or in close proximity to watercourses. These measures may include, as required: the use of cutoff trenches, silt fences, flow barriers, temporary and/or permanent sediment control ponds and/or traps, and ditches to

minimize or eliminate sediment transport from exposed soil areas into receiving watercourses and waterbodies;

- whenever possible, surface disturbance activities in close proximity to watercourses will be carried out during periods of relatively low surface runoff in late fall, winter and early spring (from October to April);
- 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. Where possible, 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 as soon as possible following earth works. Soil erosion will be reduced by minimizing the time that reclaimed surfaces are left bare;
- where necessary, interim erosion/sediment control measures will be utilized until long-term protection can be effectively implemented;
- whenever possible, instream construction activities will be carried out during periods of relatively low surface runoff in late fall, winter and early spring (from October to April);
- all watercourse crossings including the crossing of Garnier Creek with a clear span bridge will be designed and constructed in compliance with the *Alberta Code of Practice for Watercourse Crossings* (AENV 2000) and associated guidelines. For watercourse crossings these requirements include: aquatic and biological assessments; watercourse crossing design and construction; post-construction clean-up and reclamation; contingency measures; and watercourse crossing site monitoring. Implementation of appropriate mitigation measures means that all stream crossings constructed and operated for the Project will meet regulatory requirements for the protection of fish resources and aquatic habitat and will subsequently mitigate against effects on surface water quality;

- surface water run-off from the plant site will be directed to a storm water runoff pond constructed in accordance with relevant regulations. All surface runoff will be collected in the storm water runoff pond and returned to the CPF for use as plant makeup water. It is anticipated that occasionally, depending upon site and operating conditions, the surface runoff collected in the storm water runoff pond may be released to the surrounding watershed if it meets the quality requirements outlined in the operating approval;

- 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 storm water runoff pond is not anticipated to contain any process related chemicals;

- the storm water runoff 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, runoff 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 storm water runoff pond, the release of runoff waters on nearby surface waters is predicted to have a negligible effect on water quality;

- the facilities or locations where potentially contaminating materials are handled, transferred or stored include the well pad during drilling of production wells and the CPF;

- management and disposal of all drilling waste will be in accordance with all regulations and will be implemented under the Project's waste management plan. The oil content in the drilling fluids after drilling the bitumen sections is expected to be too high for onsite or offsite disposal. The rig will be equipped with centrifuges and linear motion shakers. The oil contaminated cuttings will be mixed with wood fibre and stored in steel containers on site, and then hauled to a certified Class II Landfill. The oil contaminated liquid mud will be hauled to certified Class II Salt Cavern for disposal;

- 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;

- 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;

- water requirements for the Project will be met through an existing approved source on the North Saskatchewan River. There is a license to withdraw up to 8,000 m^3/day from the North Saskatchewan River, which is sufficient to meet demands for the Project at its full capacity;

- no planned discharges of Project-affected waters will take place from the Project. Occasional releases may take place from the storm water runoff 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;

- Pengrowth will work closely with ESRD to ensure the fisheries resources in the study area, particularly the lakes, do not become over-exploited as a result of increased sportfishing. Possible initiatives include:

    - raising awareness among the Project workers of the existing ESRD 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.

- A series of mitigation measure are described in the Air Quality Assessment Report (MEMS 2013a) that will minimize acidifying emissions related to Project activities.

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Table 12 Summary of impact rating on VECs for aquatic resources.

VEC	Nature of Potential Effect	Mitigation/ Protection Plan	Type of Effect	Geographical Extent of Effect[1]	Duration of Effect[2]	Frequency of Effect[3]	Ability for Recovery from Effect[4]	Magnitude of Effect[5]	Project Contribution[6]	Confidence Rating[7]	Probability of Effect Occurrence[8]	Significance[9]
NOTE: VEC 1: Water Quality; VEC 2: Fish Resources												
VEC 1 and VEC 2	Changes to aquatic habitat and resources from surface disturbance during construction, operation and reclamation activities	1) Implement sediment and erosion control plan and sediment control measures in line with the *Alberta Code of Practice for Watercourse Crossings*; 2) Observe timing windows and maintain appropriate buffers where possible; 3) Manage surface water runoff from disturbed areas; 4) Adopt slope stabilization techniques and progressive reclamation techniques where needed; and 5) Apart from watercourse crossings, avoid construction activities within 100 m of fish bearing streams.	Application and Planned Development	Local	Long	Occasional	Reversible in short term	Low	Negative	High	High	Low Impact
VEC 2	Changes to fish and fish habitat due to instream construction activities.	1) Watercourse crossings to comply with *Alberta Code of Practice for Watercourse Crossings*; 2) Comply with Alberta Transportation's Fish Habitat Manual; and 3) Observe restricted activity period.	Application and Planned Development	Local	Long	Occasional	Reversible in short term	Low	Negative	High	High	Low Impact
VEC 1	Changes to fish and fish habitat due to changes in surface water quality.	1) Surface water runoff from the plant site will returned to the CPF for use as plant makeup water. If site and operating conditions warrant, the surface runoff from the pond may be released to the surrounding watershed if it meets the quality requirements outlined in the operating approval; 2) Handle and dispose of drilling waste and chemicals in accordance. with management plans; and 3) Comply with integrated Environmental Health and Safety Management Plan and contingency plans for responses to accidental releases.	Application and Planned Development	Local	Long	Occasional to accidental	Reversible in short term	Low to Moderate	Negative	High	Medium	Low Impact

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

Table 12 (Cont'd.)

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

[1] Local, Regional, Provincial, National, Global.

[2] Short, Long, Extended, Residual.

[3] Continuous, Isolated, Periodic, Occasional, Accidental, Seasonal.

[4] Reversible in short term, Reversible in long term, Irreversible – Rare.

[5] Nil, Low, Moderate, High.

[6] Neutral, Positive, Negative.

[7] Low, Moderate, High.

[8] Low, Medium, High.

[9] No Impact, Low Impact, Moderate Impact, High Impact.

5.2 ENVIRONMENTAL MONITORING

5.2.1 Construction Monitoring

Contractors will be required to submit environmental management plans as part of construction agreements that will outline proposed 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) for all instream works occurring in flowing water.

5.2.2 Effects Monitoring

Pengrowth 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 Project implementation and to ensure environmental quality guidelines are being met. Monitoring requirements will be carried out in accordance with the terms and conditions of all approvals.

6.0 CLOSURE

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

HATFIELD CONSULTANTS:

Approved by:  December 11, 2013

Chris Briggs
Project Manager

Date

Approved by:  December 11, 2013

Peter McNamee
Project Director

Date

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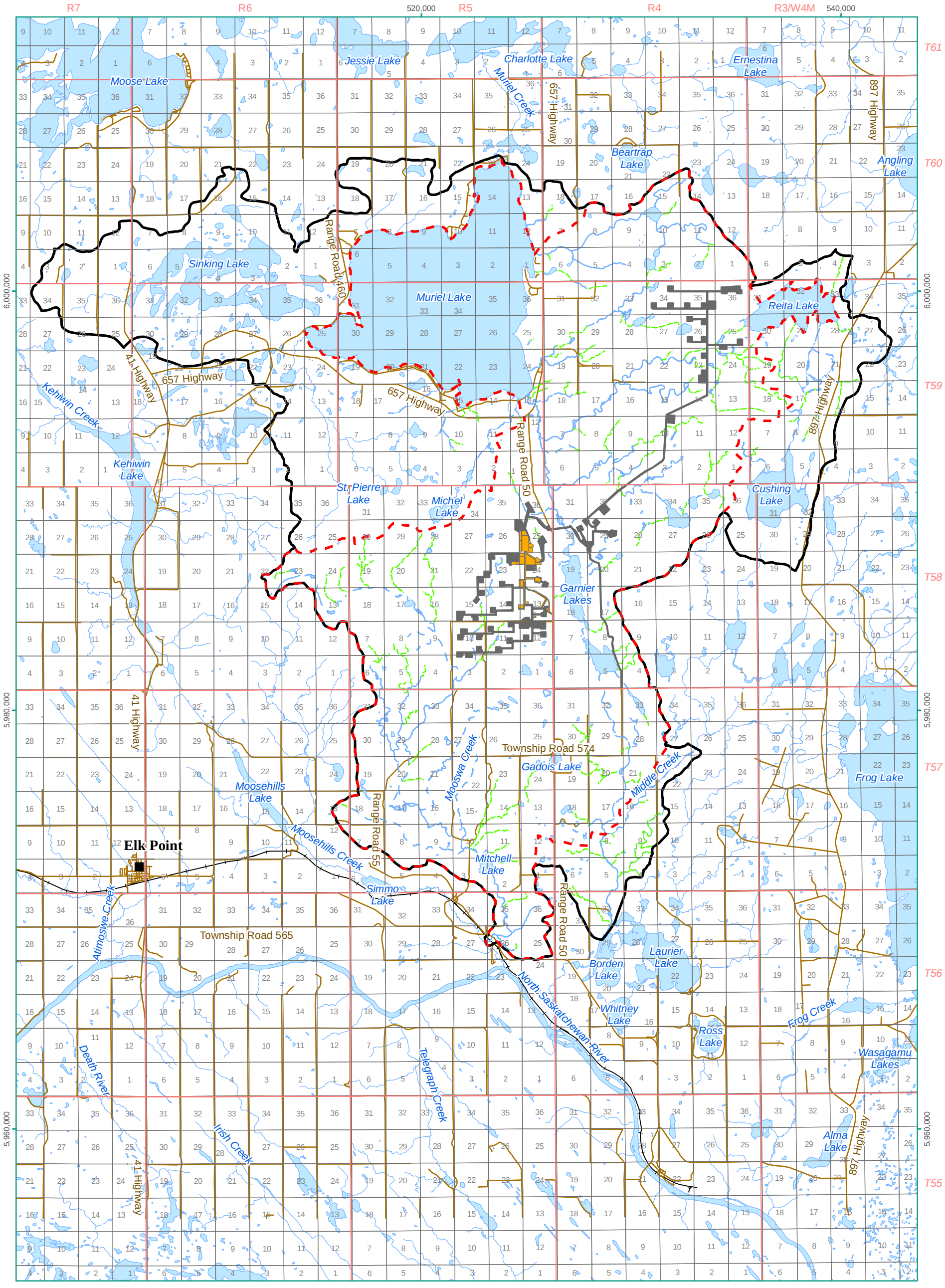
FIGURES

Figure 1 Pengrowth Lindberg SAGD Expansion Project aquatic resources study area.



Legend

- Lake/Pond
- River/Stream
- Streams (Permanent)
- Streams (Ephemeral)
- Drainages Without Defined Channels
- Major Road
- Railway
- Existing Pengrowth Development (Pilot + Phase 1)
- Project Footprint
- Local Study Area
- Regional Study Area

0 1 2 4 km

Scale: 1:180,000

Projection: NAD 1983 UTM Zone 12N

Data Sources:
a) Lake/Pond, Stream/Drainage within LSA from Northwest Hydraulics.
b) Lake/Pond outside of LSA from 1:50,000 National Topographic Data Base (NTDB).
c) Road Network from 1:50,000 National Topographic Data Base (NTDB).
d) Road Names from National Road Network, GeoBase, Canada.

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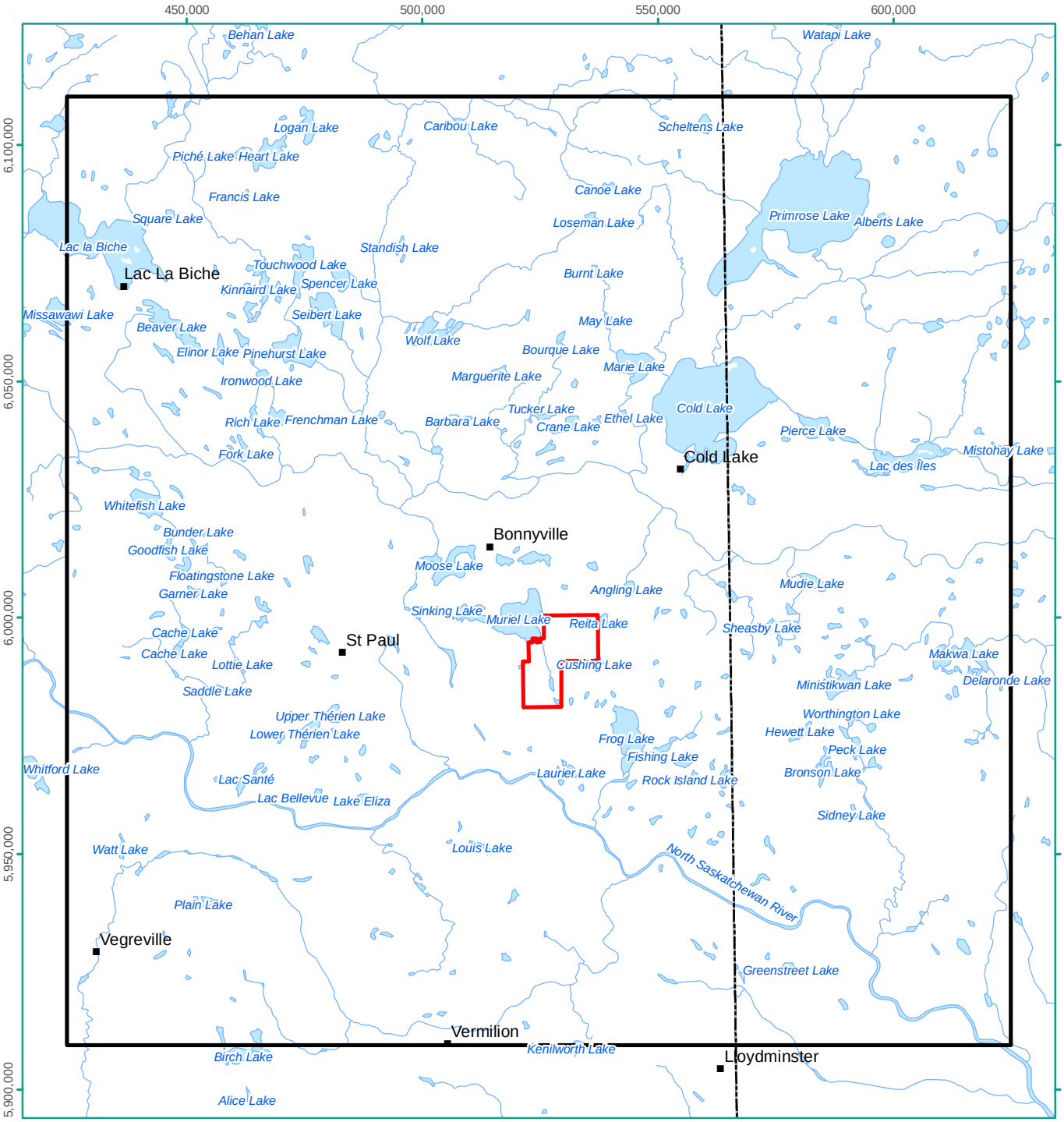
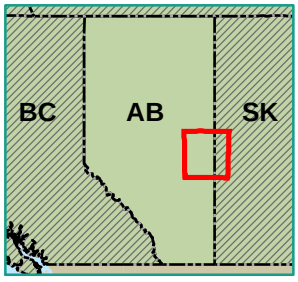
Figure 2 Air quality study areas for acid sensitive lake analysis.



Legend

- Lake/Pond
- River/Stream
- Project Area
- Study Are for the Effects of Acidifying Emissions



0 10 20 40 km

Scale: 1:1,250,000

Projection: NAD 1983 UTM Zone 12N

N

Data Sources:
Lake/Pond, River/Stream from the Atlas of Canada Framework Data.

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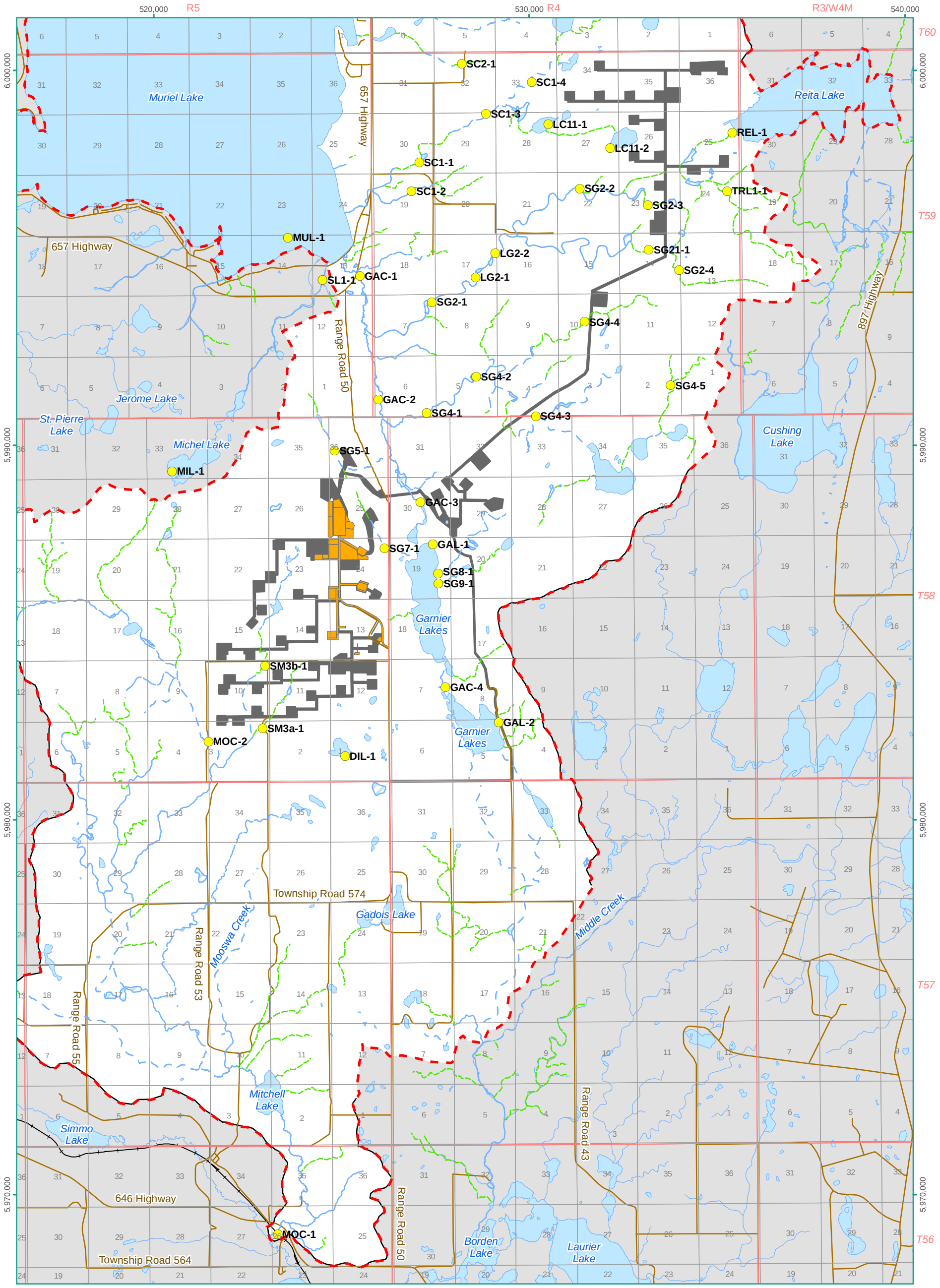
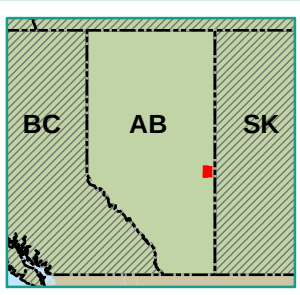
Figure 3 Project footprint and sampling locations for aquatic resources, 2011-2013.



Legend

- Lake/Pond
- Beaver Pond
- Streams (Permanent)
- Streams (Ephemeral)
- Drainages Without Defined Channels
- Major Road
- Railway
- Existing Pengrowth Development (Pilot + Phase 1)
- Project Footprint
- Local Study Area
- Regional Study Area



0 0.5 1 2 km

N

Scale: 1:100,000

Projection: NAD 1983 UTM Zone 12N

Data Sources:
a) Lake/Pond, Stream/Drainage within LSA from Northwest Hydraulics.
b) Lake/Pond outside of LSA from 1:50,000 National Topographic Data Base (NTDB).
c) Road Network from 1:50,000 National Topographic Data Base (NTDB).
d) Road Names from National Road Network, GeoBase, Canada.

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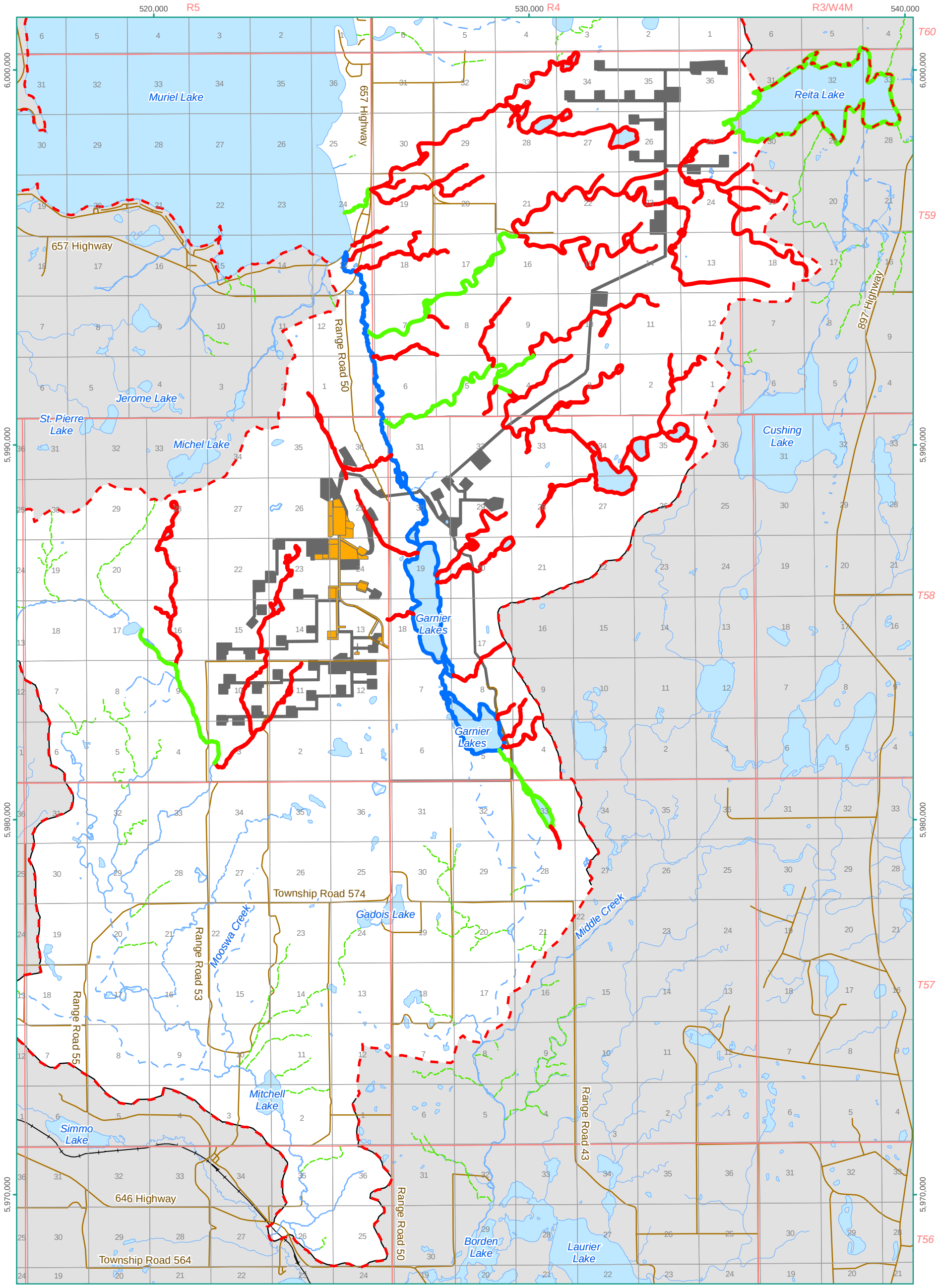
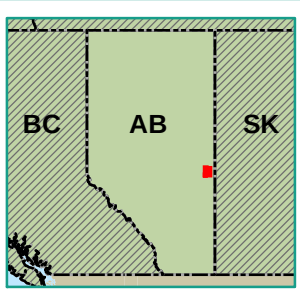
Figure 4 Fish habitat in the project area.



Legend

- Lake/Pond
- Beaver Pond
- Streams (Permanent)
- Streams (Ephemeral)
- Drainages Without Defined Channels
- Major Road
- Railway
- Existing Pengrowth Development (Pilot + Phase 1)
- Project Footprint
- Local Study Area
- Regional Study Area
- Sport Fish Habitat
- Forage Fish Habitat
- Not Fish Habitat



0 0.5 1 2 km

N

Scale: 1:100,000

Projection: NAD 1983 UTM Zone 12N

Data Sources:
a) Lake/Pond, Stream/Drainage within LSA from Northwest Hydraulics.
b) Lake/Pond outside of LSA from 1:50,000 National Topographic Data Base (NTDB).
c) Road Network from 1:50,000 National Topographic Data Base (NTDB).
d) Road Names from National Road Network, GeoBase, Canada.

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APPENDICES

Appendix A1

Field Work Activities and Methodology – Water Quality

A1.0 FIELD WORK ACTIVITIES AND METHODOLOGY – WATER QUALITY

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

In situ measurements of pH, dissolved oxygen, temperature and conductivity were collected using a Hanna multi pen. 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) Edmonton. A field blank, trip blank, and field duplicate were also collected for QA/QC purposes in each water quality sampling season. Due to the different years of collection, detection limits for some of the parameters were different. These are noted in the table where applicable.

QA/QC analyses for water quality are provided in Table A1.1 to Table A1.3 and are discussed in Section A1.2. Results of analytical and in situ water quality testing are provided in Appendix A2.

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

The quality assurance (QA) procedures that were used in the gathering and analysis of water samples followed the QA procedures used in the Regional Aquatics Monitoring Program (RAMP 2011).

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

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

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

A1.2 QUALITY CONTROL ANALYSIS RESULTS

A1.2.1 Field and Trip Blanks

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

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

- Concentrations of all physical variables, nutrients, ions, and organics/ hydrocarbons were less than five times the detection limits in field blanks in all sampling seasons except for total and dissolved tin in the Fall 2011 and Spring 2012 and total selenium in the Winter 2012. Neither tin, nor selenium were present in the samples in the same concentration as the field blanks indicating accidental contamination as the likely source.

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

Water Quality Variable	Unit	Detection Limit	Field Blank Summer 2011	Trip Blank Summer 2011	Field Blank Fall 2011	Trip Blank Fall 2011	Field Blank Winter 2012	Trip Blank Winter 2012	Field Blank Spring 2012	Trip Blank Spring 2012	Field Blank Winter 2013	Trip Blank Winter 2013	Field Blank Spring 2013	Trip Blank Spring 2013	Field Blank Summer 2013	Trip Blank Summer 2013
Conventional Variables																
Alkalinity, Total (as $CaCO_3$)	mg/L	5	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	-
Color, True	T.C.U.	2	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	13.1	<2.0	<5.0	<5.0	<2.0	-
Conductivity (EC)	µS/cm	0.2	0.87	0.52	0.3	<0.20	621	0.81	<0.20	<0.20	1.07	<0.20	<3.0	<3.0	0.64	-
Dissolved Organic Carbon	mg/L	1	<1.0	<1.0	<1.0	1	<1.0	<1.0	1.1	<1.0	1.2	1.1	<1.0	<1.0	<1.0	-
Hardness (as $CaCO_3$)	mg/L		<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	-
pH	pH	0.1	5.95	5.63	6.06	5.6					6.00	5.64	6.99	6.49	6.95	-
Total Dissolved Solids	mg/L	10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<20	<20	<10	-
Total Organic Carbon	mg/L	1	<1.0	<1.0	1.2	<1.0	<1.0	<1.0	1	1.1	1.0	<1.0	<1.0	<1.0	<1.0	-
Total Suspended Solids	mg/L	3	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<4.0	<4.0	<3.0	-
Turbidity	NTU	0.1	<0.10	<0.10	-	-	<0.10	<0.10	<0.10	<0.10	0.12	<0.10	<0.10	<0.10	<0.10	-
General Organics																
Hydrocarbons, Recoverable (I.R.)	mg/L	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	1.6	<1.0	<1.0	-
Naphthenic Acids	mg/L	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<0.10	<0.10	<1.0	-
Phenols (4AAP)	mg/L	0.001	<0.0010	<0.0010	0.0018	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.001	<0.001	<0.001	<0.001	<0.001	-
Major Ions																
Bicarbonate (HCO_3)	mg/L	5	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	-
Calcium (Ca)	mg/L	0.05	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.020	<0.020	<0.50	-
Carbonate (CO_3)	mg/L	5	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	-
Chloride (Cl)	mg/L	0.05	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.10	<0.10	<0.50	-
Hydroxide (OH)	mg/L	5	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	-
Magnesium (Mg)	mg/L	0.1	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	0.0057	<0.005	<0.10	-
Potassium (K)	mg/L	0.5	<0.10	<0.10	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.10	<0.10	<0.050	<0.05	<0.50	-
Sodium (Na)	mg/L	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	0.051	<0.05	<1.0	-
Sulfate (SO_4)	mg/L	0.5	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	-
Sulphide	mg/L	0.002	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.002	<0.002	<0.002	<0.002	<0.002	-
Nutrients and BOD																
Ammonia-N	mg/L	0.05	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.05	<0.05	<0.05	<0.05	<0.05	-
Biochemical Oxygen Demand	mg/L	2	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	2.7	<2.0	<2.0	<2.0	<2.0	-
Nitrate (as N)	mg/L	0.05	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.05	<0.05	<0.05	<0.05	<0.05	-
Nitrate and Nitrite as N	mg/L	0.071	<0.071	<0.071	<0.071	<0.071	<0.071	<0.071	<0.071	<0.071	<0.071	<0.071	<0.071	<0.071	<0.071	-
Nitrite (as N)	mg/L	0.05	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.05	<0.05	<0.05	<0.05	<0.05	-
Phosphorus, Total	mg/L	0.001	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.001	<0.001	<0.001	<0.001	<0.001	-
Phosphorus, Total Dissolved	mg/L	0.001	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.001	<0.001	<0.001	<0.001	<0.001	-
Total Kjeldahl Nitrogen	mg/L	0.2	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	-
Dissolved Metals																
Aluminum (Al)	mg/L	0.01, 0.001*	-	-	<0.010	<0.010	0.0035	<0.0010	<0.0010	<0.0010	<0.001	<0.001	<0.001	<0.001	<0.001	-
Antimony (Sb)	mg/L	0.0004, 0.0001*	-	-	<0.00040	<0.00040	<0.00010	<0.00010	<0.00010	<0.00010	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	-
Arsenic (As)	mg/L	0.0004, 0.0001*	-	-	<0.00040	<0.00040	<0.00010	<0.00010	<0.00010	<0.00010	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	-
Barium (Ba)	mg/L	0.0001, 0.00005*	-	-	0.00014	<0.00010	<0.000050	<0.000050	0.000082	<0.000050	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	-
Beryllium (Be)	mg/L	0.0005	-	-	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	-
Bismuth (Bi)	mg/L	0.00005	-	-	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.00005	<0.00005	-	-	<0.00005	-
Boron (B)	mg/L	0.002	-	-	0.0033	0.0033	<0.0020	0.0028	0.0024	<0.0020	0.0040	-	<0.010	<0.010	0.0027	-
Cadmium (Cd)	mg/L	0.0001, 0.00001*	-	-	<0.00010	<0.00010	<0.000010	<0.000010	<0.000010	<0.000010	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	-
Chromium (Cr)	mg/L	0.0004, 0.0001*	-	-	<0.00040	<0.00040	<0.00010	<0.00010	<0.00010	<0.00010	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	-

Table A1.1 (Cont'd.)

Water Quality Variable	Unit	Detection Limit	Field Blank Summer 2011	Trip Blank Summer 2011	Field Blank Fall 2011	Trip Blank Fall 2011	Field Blank Winter 2012	Trip Blank Winter 2012	Field Blank Spring 2012	Trip Blank Spring 2012	Field Blank Winter 2013	Trip Blank Winter 2013	Field Blank Spring 2013	Trip Blank Spring 2013	Field Blank Summer 2013	Trip Blank Summer 2013
Cobalt (Co)	mg/L	0.0001	-	-	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	-
Copper (Cu)	mg/L	0.0006, 0.0001*	-	-	<0.00060	<0.00060	0.00025	<0.00010	<0.00010	<0.00010	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	-
Iron (Fe)	mg/L	0.01	-	-	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	-
Lead (Pb)	mg/L	0.0001, 0.00005*	-	-	<0.00010	<0.00010	<0.000050	<0.000050	<0.000050	<0.000050	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	-
Lithium (Li)	mg/L	0.003, 0.005*	-	-	<0.0030	<0.0030	<0.0050	<0.0050	<0.0050	<0.0050	<0.005	<0.005	<0.005	<0.005	<0.005	-
Manganese (Mn)	mg/L	0.002, 0.00005*	-	-	<0.0020	<0.0020	0.000103	<0.000050	0.000087	<0.000050	<0.002	<0.002	<0.002	<0.002	<0.002	-
Molybdenum (Mo)	mg/L	0.0001, 0.00005*	-	-	<0.00010	<0.00010	<0.50	<0.000050	<0.000050	<0.000050	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	-
Nickel (Ni)	mg/L	0.0001	-	-	0.00034	0.00017	<0.000050	<0.00010	<0.00010	<0.00010	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	-
Selenium (Se)	mg/L	0.0004, 0.0001*	-	-	<0.00040	<0.00040	<0.00010	<0.00010	<0.00010	<0.00010	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	-
Silver (Ag)	mg/L	0.0002, 0.0001**, 0.00001*	-	-	<0.00010	<0.00010		<0.050	<0.000010	<0.000010	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	-
Strontium (Sr)	mg/L	0.0001	-	-	0.00038	<0.00010	<0.000010	<0.00010	<0.00010	<0.00010	<0.0001	<0.0001	-	-	<0.0001	-
Thallium (Tl)	mg/L	0.00005	-	-	<0.000050	<0.000050	<0.00010	<0.000050	<0.000050	<0.000050	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	-
Tin (Sn)	mg/L	0.0002, 0.0001*	-	-	**0.00116**	<0.00020	<0.000050	<0.00010	**0.00189**	<0.00010	<0.0001	-	<0.0001	<0.0001	<0.0001	-
Titanium (Ti)	mg/L	0.0003	-	-	<0.00030	<0.00030	0.00494	<0.00030	<0.00030	<0.00030	<0.0003	<0.0003	<0.0003	<0.0003	<0.0003	-
Uranium (U)	mg/L	0.0001, 0.00001*	-	-	<0.00010	<0.00010	<0.00030	<0.000010	<0.000010	<0.000010	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	-
Vanadium (V)	mg/L	0.0001	-	-	<0.00010	<0.00010	<0.000010	<0.00010	<0.00010	<0.00010	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	-
Zinc (Zn)	mg/L	0.001	-	-	<0.0010	<0.0010	<0.00010	<0.0010	<0.0010	<0.0010	<0.001	<0.001	<0.001	<0.001	<0.001	-
Total Metals																
Aluminum (Al)	mg/L	0.02, 0.003*	<0.020	<0.020	<0.020	<0.020	0.0036	<0.0030	<0.0030	<0.0030	<0.003	<0.003	<0.003	<0.003	<0.003	-
Antimony (Sb)	mg/L	0.0004, 0.0001*	<0.00040	<0.00040	<0.00040	<0.00040	<0.00010	<0.00010	<0.00010	<0.00010	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	-
Arsenic (As)	mg/L	0.0004, 0.0001*	<0.00040	<0.00040	<0.00040	<0.00040	<0.00010	<0.00010	<0.00010	<0.00010	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	-
Barium (Ba)	mg/L	0.0002, 0.00005*	<0.00020	<0.00020	<0.00020	<0.00020	<0.000050	<0.000050	<0.000050	<0.000050	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	-
Beryllium (Be)	mg/L	0.001, 0.0005*	<0.0010	<0.0010	<0.0010	<0.0010	<0.00050	<0.00050	<0.00050	<0.00050	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	-
Bismuth (Bi)	mg/L	0.0002, 0.00005*	<0.00020	<0.00020	<0.00020	<0.00020	<0.000050	<0.000050	<0.000050	<0.000050	<0.00005	<0.00005	-	-	<0.00005	-
Boron (B)	mg/L	0.02, 0.002*	<0.020	<0.020	<0.020	<0.020	0.0031	<0.0020	<0.0020	<0.0020	<0.010	<0.010	<0.010	<0.010	<0.010	-
Cadmium (Cd)	mg/L	0.0002, 0.00001*	<0.00020	<0.00020	<0.00020	<0.00020	<0.000010	<0.000010	<0.000010	<0.000010	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	-
Chromium (Cr)	mg/L	0.0008, 0.0001*	<0.00080	<0.00080	<0.00080	<0.00080	<0.00010	<0.00010	<0.00010	<0.00010	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	-
Cobalt (Co)	mg/L	0.0002, 0.0001*	<0.00020	<0.00020	<0.00020	<0.00020	<0.00010	<0.00010	<0.00010	<0.00010	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	-
Copper (Cu)	mg/L	0.001, 0.0001*	<0.0010	<0.0010	<0.0010	<0.0010	0.00021	<0.00010	0.00029	<0.00010	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	-
Iron (Fe)	mg/L	0.01	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	-	-	<0.010	-
Lead (Pb)	mg/L	0.0001, 0.00005*	<0.00010	<0.00010	<0.00010	<0.00010	<0.000050	<0.000050	<0.000050	<0.000050	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	-
Lithium (Li)	mg/L	0.006, 0.005*	<0.0060	<0.0060	<0.0060	<0.0060	<0.0050	<0.0050	<0.0050	<0.0050	<0.005	<0.005	<0.005	<0.005	<0.005	-
Manganese (Mn)	mg/L	0.002, 0.00005*	<0.0020	<0.0020	<0.0020	<0.0020	0.000097	<0.000050	0.000104	<0.000050	<0.002	<0.002	-	-	<0.002	-
Mercury (Hg)-Trace	ng/L	1	<1.0	<1.0	<1.0	<1.0	<0.050	<0.50		<0.50	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	-
Molybdenum (Mo)	mg/L	0.0001, 0.00005*	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.000050	<0.000050	<0.000050	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	-
Nickel (Ni)	mg/L	0.0002, 0.0001*	<0.00020	<0.00020	<0.00020	<0.00020	<0.00010	<0.00010	<0.00010	<0.00010	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	-
Selenium (Se)	mg/L	0.0004, 0.0001*	<0.00040	<0.00040	<0.00040	<0.00040	**0.281**	<0.00010	<0.00010	<0.00010	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	-
Silver (Ag)	mg/L	0.0004, 0.0001**, 0.00001*	<0.00040	<0.00040	<0.00010	<0.00010	<0.000010	<0.000010	<0.000010	<0.000010	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	-
Strontium (Sr)	mg/L	0.0002, 0.0001*	<0.00020	<0.00020	<0.00020	<0.00020	<0.00010	<0.00010	<0.00010	<0.00010	<0.0001	<0.0001	-	-	<0.0001	-
Thallium (Tl)	mg/L	0.0001, 0.00005*	<0.00010	<0.00010	<0.00010	<0.00010	<0.000050	<0.000050	<0.000050	<0.000050	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	-
Tin (Sn)	mg/L	0.0004, 0.0001*	0.00299	<0.00040	0.0014	<0.00040	**0.00458**	<0.00010	**0.00066**	<0.00010	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	-
Titanium (Ti)	mg/L	0.005, 0.0003*	<0.0050	<0.0050	<0.0050	<0.0050	<0.00030	<0.00030	<0.00030	<0.00030	<0.0003	<0.0003	<0.0003	<0.0003	<0.0003	-
Uranium (U)	mg/L	0.0001, 0.00001*	<0.00010	<0.00010	<0.00010	<0.00010	<0.000010	<0.000010	<0.000010	<0.000010	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	-
Vanadium (V)	mg/L	0.0005, 0.0001*	<0.00050	<0.00050	<0.00050	<0.00050	<0.00010	<0.00010	<0.00010	<0.00010	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	-
Zinc (Zn)	mg/L	0.004, 0.003*	<0.0040	<0.0040	<0.0040	<0.0040	<0.0010	<0.0030	<0.0030	<0.0030	<0.003	<0.003	<0.003	<0.003	0.0084	-

< = value is below detection limit

value is > 5 times the detection limit

A1.2.2 Field Duplicates

Concentrations of water quality variables in the field duplicates are shown in Table A1.2 and Table A1.3. The relative percent difference in concentrations was greater than 20% for several total and dissolved metals in all seasons; TSS and sulphide in most seasons, and many of the nutrients in spring 2012.

There were a eleven water quality variables with concentrations greater than five times the detection limit with a relative percent difference greater than 20%. Four of these occurred in winter 2012 and three occurred in Spring 2013. Other than that, there appeared to be no pattern to the differences.

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

Water Quality Variable	Units	Detection Limit	Summer 2011			Fall 2011			Winter 2012			Spring 2012		
			MUL-1	Duplicate	% Difference	GAC-1	Duplicate	% Difference	DIL-1	Duplicate	% Difference	DIL-1	Duplicate	% Difference
Conventional Variables														
Alkalinity, Total (as $CaCO_3$)	mg/L	5	995	991	0.40	499	496	0.60	460	464	0.87	144	141	2.11
Color, True	T.C.U.	2	13	14	7.41	30.8	30.7	0.33	186	219	16.30	76.8	79.3	3.20
Conductivity (EC)	µS/cm	0.2	2160	2160	0.00	837	834	0.36	350	350	0.00	276	275	0.36
Dissolved Organic Carbon	mg/L	1	41	39	5.00	16.7	17.2	2.95	68.2	65.8	3.58	21.6		
Hardness (as $CaCO_3$)	mg/L		779	769	1.29	403	426	5.55	416	422	1.43	124	127	2.39
pH	pH	0.1	9.16	9.15	0.11	8.35	8.36	0.12	7.88	7.88	0.00			
Total Dissolved Solids	mg/L	10	1630	1620	0.62	526	525	0.19	645	674	4.40	182	193	5.87
Total Organic Carbon	mg/L	1	45.4	44.3	2.45	16.7	16.7	0.00	68.4	71.5	4.43	22.6	22.2	1.79
Total Suspended Solids	mg/L	3	31	42	**30.14**	<3.0	4	**28.57**	120	31	**117.88**	5	3	**50.00**
Turbidity	NTU	0.1	16.6	18.2	9.20				20.6	11.5	**56.70**	2.08	2.1	0.96
General Organics														
Hydrocarbons, Recoverable (I.R.)	mg/L	1	<1.0	<1.0	0.00	<1.0	<1.0	0.00	<1.0	<1.0	0.00	<1.0	<1.0	0.00
Naphthenic Acids	mg/L	1	<1.0	<1.0	0.00	<1.0	<1.0	0.00	1.4	1.6	13.33	<1.0	<1.0	0.00
Phenols (4AAP)	mg/L	0.001	0.0112	0.0115	2.64	0.0048	0.0049	2.06	0.026	0.0259	0.39	0.0099	0.0247	**85.55**
Major Ions														
Bicarbonate (HCO_3)	mg/L	5	854	825	3.45	588	582	1.03	561	566	0.89	175	172	1.73
Calcium (Ca)	mg/L	0.05	15.3	15.6	1.94	90.2	95.3	5.50	78.4	79.1	0.89	23.2	24.1	3.81
Carbonate (CO_3)	mg/L	5	177	189	6.56	10	11.3	12.21	<5.0	<5.0	0.00	5	5	0.00
Chloride (Cl)	mg/L	0.05	37.3	37.1	0.54	2.96	2.97	0.34	7.18	7.14	0.56	5.22	3.68	**34.61**
Hydroxide (OH)	mg/L	5	<5.0	<5.0	0.00	<5.0	<5.0	0.00	<5.0	<5.0	0.00	<5.0	<5.0	0.00
Magnesium (Mg)	mg/L	0.1	154	158	2.56	43.1	45.7	5.86	53.6	54.6	1.85	16.2	16.7	3.04
Potassium (K)	mg/L	0.5	40.5	40.7	0.49	5.22	5.75	9.66	18.7	19.1	2.12	7.76	8.14	4.78
Sodium (Na)	mg/L	1	228	230	0.87	25.3	27.3	7.60	15.8	15.4	2.56	4.9	5.1	4.00
Sulfate (SO_4)	mg/L	0.5	347	347	0.00	6.27	6.32	0.79	<0.50	<0.50	0.00	1.65	0.86	**62.95**
Sulphide	mg/L	0.002	0.0059	<0.0020	**98.73**	<0.0020	<0.0020	0.00	0.0255	0.0164	**43.44**	0.005	<0.0053	5.83
Nutrients and BOD														
Ammonia-N	mg/L	0.05	0.213	0.223	4.59	<0.050	<0.050	0.00	1.25	1.28	2.37	0.05	0.05	0.00
Biochemical Oxygen Demand	mg/L	2	3.4	2.6	**26.67**	2	<2.0	0.00	18.1	17	6.27	4.5	4.1	9.30
Nitrate (as N)	mg/L	0.05	<0.050	<0.050	0.00	<0.050	<0.050	0.00	<0.050	<0.050	0.00	0.091	<0.050	**58.16**
Nitrate and Nitrite as N	mg/L	0.071	<0.071	<0.071	0.00	<0.071	<0.071	0.00	<0.071	<0.071	0.00	0.091	<0.071	**24.69**
Nitrite (as N)	mg/L	0.05	<0.050	<0.050	0.00	<0.050	<0.050	0.00	<0.050	<0.050	0.00	<0.050	<0.050	0.00
Phosphorus, Total	mg/L	0.001	0.0902	0.0941	4.23	0.0828	0.0826	0.24	0.419	0.384	8.72	0.0718	0.0765	6.34
Phosphorus, Total Dissolved	mg/L	0.001	0.0212	0.0227	6.83	0.0291	0.0281	3.50	0.0935	0.105	11.59	0.0226	0.0213	5.92
Total Kjeldahl Nitrogen	mg/L	0.2	3.38	2.91	14.94	1.35	1.28	5.32	7.94	6.12	**25.89**	1.54	1.43	7.41
Dissolved Metals														
Aluminum (Al)	mg/L	0.01, 0.001*	-	-	n/a	0.012	<0.010	18.18	0.0031	0.0025	**21.43**	0.0011	<0.001	9.52
Antimony (Sb)	mg/L	0.0004, 0.0001*	-	-	n/a	<0.00040	<0.00040	0.00	<0.00010	<0.00010	0.00	<0.00010	<0.00010	0.00
Arsenic (As)	mg/L	0.0004, 0.0001*	-	-	n/a	0.00448	0.00451	0.67	0.00166	0.00171	2.97	0.00054	0.00055	1.83
Barium (Ba)	mg/L	0.0001, 0.00005*	-	-	n/a	0.0663	0.066	0.45	0.118	0.122	3.33	0.0245	0.0235	4.17
Beryllium (Be)	mg/L	0.0005	-	-	n/a	<0.00050	<0.00050	0.00	<0.00050	<0.00050	0.00	<0.00050	<0.00050	0.00
Bismuth (Bi)	mg/L	0.00005	-	-	n/a	<0.000050	<0.000050	0.00	<0.000050	<0.000050	0.00	<0.000050	<0.000050	0.00
Boron (B)	mg/L	0.002	-	-	n/a	0.0957	0.0946	1.16	0.0479	0.0472	1.47	0.0231	0.0229	0.87
Cadmium (Cd)	mg/L	0.0001, 0.00001*	-	-	n/a	<0.00010	<0.00010	0.00	<0.000010	<0.000010	0.00	<0.00001	<0.00001	0.00
Chromium (Cr)	mg/L	0.0004, 0.0001*	-	-	n/a	<0.00040	<0.00040	0.00	<0.00010	<0.00010	0.00	<0.00010	<0.00010	0.00
Cobalt (Co)	mg/L	0.0001	-	-	n/a	<0.00010	<0.00010	0.00	0.00012	0.00013	8.00	<0.00010	<0.00010	0.00
Copper (Cu)	mg/L	0.0006, 0.0001*	-	-	n/a	<0.00060	<0.00060	0.00	<0.00010	<0.00010	0.00	<0.00010	<0.00010	0.00
Iron (Fe)	mg/L	0.01	-	-	n/a	0.015	0.017	12.50	1.05	1.23	15.79	0.048	0.034	**34.15**
Lead (Pb)	mg/L	0.0001, 0.00005*	-	-	n/a	<0.00010	<0.00010	0.00	<0.000050	<0.000050	0.00	<0.00005	<0.00005	0.00
Lithium (Li)	mg/L	0.003, 0.005*	-	-	n/a	0.0503	0.0495	1.60	0.0367	0.0363	1.10	0.0116	0.0114	1.74
Manganese (Mn)	mg/L	0.002, 0.00005*	-	-	n/a	0.0029	0.003	3.39	0.863	0.927	7.15	0.000872	0.000754	14.51
Molybdenum (Mo)	mg/L	0.0001, 0.00005*	-	-	n/a	0.00105	0.00108	2.82	0.00079	0.000779	1.40	0.000424	0.000418	1.43

Table A1.2 (Cont'd.)

Water Quality Variable	Units	Detection Limit	Summer 2011			Fall 2011			Winter 2012			Spring 2012		
			MUL-1	Duplicate	% Difference	GAC-1	Duplicate	% Difference	DIL-1	Duplicate	% Difference	DIL-1	Duplicate	% Difference
Nickel (Ni)	mg/L	0.0001	-	-	n/a	0.00052	0.00055	5.61	0.00025	0.00027	7.69	0.00012	0.00015	**22.22**
Selenium (Se)	mg/L	0.0004, 0.0001*	-	-	n/a	<0.00040	<0.00040	0.00	0.0001	0.00012	18.18	<0.00010	<0.00010	0.00
Silicon (Si)	mg/L	0.05							20.3	20.2	0.49	<3.60000	<3.55000	1.40
Silver (Ag)	mg/L	).0002, 0.0001**, 0.00001	-	-	n/a	<0.00010	<0.00010	0.00	<0.000010	<0.000010	0.00	<0.00001	<0.00001	0.00
Strontium (Sr)	mg/L	0.0001	-	-	n/a	0.415	0.417	0.48	0.326	0.321	1.55	<0.0924	<0.0906	1.97
Thallium (Tl)	mg/L	0.00005	-	-	n/a	<0.000050	<0.000050	0.00	<0.000050	<0.000050	0.00	<0.00005	<0.00005	0.00
Tin (Sn)	mg/L	0.0002, 0.0001*	-	-	n/a	<0.00020	<0.00020	0.00	<0.00010	<0.00010	0.00	<0.0001	<0.0001	0.00
Titanium (Ti)	mg/L	0.0003	-	-	n/a	<0.00030	<0.00030	0.00	<0.00030	<0.00030	0.00	<0.00030	<0.00030	0.00
Uranium (U)	mg/L	0.0001, 0.00001*	-	-	n/a	0.00058	0.00058	0.00	0.000057	0.000036	**45.16**	<0.0000	<0.0000	8.70
Vanadium (V)	mg/L	0.0001	-	-	n/a	0.00014	0.00013	7.41	0.00013	<0.00010	**26.09**	<0.00010	<0.00010	0.00
Zinc (Zn)	mg/L	0.001	-	-	n/a	0.0023	0.0018	**24.39**	0.0019	0.002	5.13	0.0014	0.002	**35.29**
Total Metals														
Aluminum (Al)	mg/L	0.02, 0.003*	0.028	0.022	**24.00**	<0.020	<0.020	0.00	0.183	0.0343	**136.86**	0.0193	0.0134	36.09
Antimony (Sb)	mg/L	0.0004, 0.0001*	<0.00040	<0.00040	0.00	<0.00040	<0.00040	0.00	<0.00010	<0.00010	0.00	<0.00010	<0.00010	0.00
Arsenic (As)	mg/L	0.0004, 0.0001*	0.00862	0.00862	0.00	0.00663	0.00661	0.30	0.00182	0.00167	8.60	0.00055	0.00054	1.83
Barium (Ba)	mg/L	0.0002, 0.00005*	0.00576	0.00568	1.40	0.0698	0.0682	2.32	0.145	0.138	4.95	0.0248	0.0245	1.22
Beryllium (Be)	mg/L	0.001, 0.0005*	<0.0010	<0.0010	0.00	<0.0010	<0.0010	0.00	<0.00050	<0.00050	0.00	<0.0005	<0.0005	0.00
Bismuth (Bi)	mg/L	0.0002, 0.00005*	<0.00020	<0.00020	0.00	<0.00020	<0.00020	0.00	<0.000050	<0.000050	0.00	<0.00005	<0.00005	0.00
Boron (B)	mg/L	0.02, 0.002*	0.34	0.341	0.29	0.095	0.097	2.08	0.046	0.0434	5.82	0.0221	0.0215	2.75
Cadmium (Cd)	mg/L	0.0002, 0.00001*	<0.00020	<0.00020	0.00	<0.00020	<0.00020	0.00	0.000027	<0.000010	**91.89**	<0.00001	<0.00001	0.00
Chromium (Cr)	mg/L	0.0008, 0.0001*	<0.00080	<0.00080	0.00	<0.00080	<0.00080	0.00	0.00038	0.00025	**41.27**	<0.00013	<0.00012	8.00
Cobalt (Co)	mg/L	0.0002, 0.0001*	<0.00020	<0.00020	0.00	<0.00020	<0.00020	0.00	0.00026	0.00016	**47.62**	<0.00010	<0.00010	0.00
Copper (Cu)	mg/L	0.001, 0.0001*	<0.0010	<0.0010	0.00	<0.0010	<0.0010	0.00	0.00083	0.00045	**59.38**	<0.0003	<0.0002	8.00
Iron (Fe)	mg/L	0.01	0.482	0.466	3.38	0.455	0.46	1.09	1.73	1.6	7.81	0.127	0.126	0.79
Lead (Pb)	mg/L	0.0001, 0.00005*	<0.00010	<0.00010	0.00	<0.00010	<0.00010	0.00	0.000279	0.00011	**86.89**	<0.00005	<0.00005	0.00
Lithium (Li)	mg/L	0.006, 0.005*	0.167	0.165	1.20	0.0488	0.0481	1.44	0.0364	0.0365	0.27	0.0122	0.0122	0.00
Manganese (Mn)	mg/L	0.002, 0.00005*	0.0288	0.0291	1.04	0.0686	0.069	0.58	0.949	0.944	0.53	0.0646	0.0646	0.00
Mercury (Hg)-Trace	ng/L	1	1.7	1.6	6.06	<1.0	<1.0	0.00	<0.50	<0.50	0.00	0.88		200.00
Molybdenum (Mo)	mg/L	0.0001, 0.00005*	0.0015	0.00148	1.34	0.00115	0.00113	1.75	0.000897	0.000803	11.06	0.000465	0.000464	0.22
Nickel (Ni)	mg/L	0.0002, 0.0001*	0.00031	0.00029	6.67	0.00055	0.00047	15.69	0.00061	0.00041	39.22	0.00016	0.00014	13.33
Selenium (Se)	mg/L	0.0004, 0.0001*	<0.00040	<0.00040	0.00	<0.00040	<0.00040	0.00	0.00018	0.00012	40.00	<0.00010	<0.00010	0.00
Silicon (Si)	mg/L	0.05							20.4	19.9	2.48	<4.06000	<4.11000	1.22
Silver (Ag)	mg/L	).0004, 0.0001**, 0.00001	<0.00040	<0.00040	0.00	<0.00010	<0.00010	0.00	<0.000010	<0.000010	0.00	<0.00001	<0.00001	0.00
Strontium (Sr)	mg/L	0.0002, 0.0001*	0.0426	0.0422	0.94	0.421	0.419	0.48	0.327	0.322	1.54	0.0912	0.0913	0.11
Thallium (Tl)	mg/L	0.0001, 0.00005*	<0.00010	<0.00010	0.00	<0.00010	<0.00010	0.00	<0.000050	<0.000050	0.00	<0.00005	<0.00005	0.00
Tin (Sn)	mg/L	0.0004, 0.0001*	<0.00040	<0.00040	0.00	<0.00040	<0.00040	0.00	<0.00010	<0.00010	0.00	<0.00010	<0.00010	0.00
Titanium (Ti)	mg/L	0.005, 0.0003*	<0.0050	<0.0050	0.00	<0.0050	<0.0050	0.00	0.00511	0.00107	**130.74**	<0.0003	<0.0003	0.00
Uranium (U)	mg/L	0.0001, 0.00001*	0.00135	0.00133	1.49	0.00059	0.00058	1.71	0.0001	0.000046	**73.97**	0.000013	0.000012	8.00
Vanadium (V)	mg/L	0.0005, 0.0001*	0.00053	0.00054	1.87	<0.00050	<0.00050	0.00	0.00051	0.00015	**109.09**	0.0001	0.0001	0.00
Zinc (Zn)	mg/L	0.004, 0.003*	<0.0040	<0.0040	0.00	0.0058	<0.0040	**36.73**	0.0133	0.0066	**67.34**	<0.0055	<0.0049	11.54

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

Analytes differ by >20% between sample and both concentrations are >5 times the detection limit

Table A1.3 Water quality QA/QC results: field duplicates 2013.

Water Quality Variable	Units	Detection Limit	Winter 2013			Spring 2013			Summer 2013		
			LG2-2	Duplicate	% Difference	SG4-2	Duplicate	% Difference	SG4-2	Duplicate	% Difference
Conventional Variables											
Alkalinity, Total (as $CaCO_3$)	mg/L	5	450	450	0.00	186	186	0.00	218	219	0.46
Color, True	T.C.U.	2	62.1	64.3	3.48	56.8	56.8	0.00	52.9	53.3	0.75
Conductivity (EC)	µS/cm	0.2	813	814	0.12	332	332	0.00	383	377	1.58
Dissolved Organic Carbon	mg/L	1	26.2	25.9	1.15	18.6	20.6	10.20	21.2	20.1	5.33
Hardness (as $CaCO_3$)	mg/L	-	409	401	1.98	192	188	2.11	208	212	1.90
pH	pH	0.1	7.64	7.69	0.65	8.15	8.17	0.25	7.38	7.39	0.14
Total Dissolved Solids	mg/L	10	499	502	0.60	238	241	1.25	278	272	2.18
Total Organic Carbon	mg/L	1	26.6	26.3	1.13	20.8	20.8	0.00	21.5	20.7	3.79
Total Suspended Solids	mg/L	3	17	18.0	5.71	7	<3.0	**80.00**	<4.0	<4.0	0.00
Turbidity	NTU	0.1	64.2	69.4	7.78	-	-	-	6.58	6.51	1.07
General Organics											
Hydrocarbons, Recoverable (I.R.)	mg/L	1	<1.0	<1.0	0.00	<1.0	<1.0	0.00	<1.0	1.5	**40.00**
Naphthenic Acids	mg/L	1	<1.0	<1.0	0.00	<1.0	<1.0	0.00	0.16	0.39	**83.64**
Phenols (4AAP)	mg/L	0.001	0.0078	0.0070	10.81	0.0094	0.0095	1.06	0.0104	0.0091	13.33
Major Ions											
Bicarbonate (HCO_3)	mg/L	5	548	549	0.18	227	226	0.44	266	267	0.38
Calcium (Ca)	mg/L	0.05	94.5	88.9	6.11	45.2	44.4	1.79	47.4	47.2	0.42
Carbonate (CO_3)	mg/L	5	<5.0	<5.0	0.00	<5.0	<5.0	0.00	<5.0	<5.0	0.00
Chloride (Cl)	mg/L	0.05	5.93	5.83	1.70	0.54	<0.5	7.69	0.63	0.57	10.00
Hydroxide (OH)	mg/L	5	<5.0	<5.0	0.00	<5.0	<5.0	0.00	<5.0	<5.0	0.00
Magnesium (Mg)	mg/L	0.1	42	39.0	7.41	19.2	18.8	2.11	22.8	22.5	1.32
Potassium (K)	mg/L	0.5	7.21	6.77	6.29	6.83	6.63	2.97	4.39	4.25	3.24
Sodium (Na)	mg/L	1	20.9	20.8	0.48	2.3	2.4	4.26	2.48	2.53	2.00
Sulfate (SO_4)	mg/L	0.5	2.26	2.24	0.89	<0.5	<0.5	0.00	<0.50	<0.50	0.00
Sulphide	mg/L	0.002	0.011	0.0088	**21.32**	0.002	0.004	**47.62**	<0.002	0.0025	**22.22**
Nutrients and BOD											
Ammonia-N	mg/L	0.05	1.44	1.44	0.00	<0.050	<0.050	0.00	<0.05	<0.05	0.00
Biochemical Oxygen Demand	mg/L	2	13.4	12.3	**8.56**	2	<2.0	0.00	<2.0	<2.0	0.00
Nitrate (as N)	mg/L	0.05	<0.05	<0.05	0.00	<0.050	<0.050	0.00	<0.050	<0.050	0.00
Nitrate and Nitrite as N	mg/L	0.071	<0.071	<0.071	0.00	<0.071	<0.071	0.00	<0.071	<0.071	0.00
Nitrite (as N)	mg/L	0.05	<0.05	<0.05	0.00	<0.050	<0.050	0.00	<0.050	<0.050	0.00
Phosphorus, Total	mg/L	0.001	0.511	0.593	14.86	0.0297	0.0409	**31.73**	0.117	0.123	5.00
Phosphorus, Total Dissolved	mg/L	0.001	0.582	0.520	11.25	0.144	0.14	2.82	0.0215	0.0211	1.88
Total Kjeldahl Nitrogen	mg/L	0.2	2.28	2.47	8.00	1.11	1.09	1.82	1.1	1.03	6.57
Dissolved Metals											
Aluminum (Al)	mg/L	0.001	0.004	0.0049	**22.73**	<0.001	<0.001	0.00	<0.001	0.0013	**26.09**
Antimony (Sb)	mg/L	0.0001	<0.00010	<0.00010	0.00	<0.00010	<0.00010	0.00	<0.00010	<0.00010	0.00
Arsenic (As)	mg/L	0.0001	0.001	0.00108	1.87	0.001	0.001	7.09	0.001	0.00096	4.08
Barium (Ba)	mg/L	0.00005	0.111	0.111	0.00	0.047	0.046	2.59	0.076	0.0742	2.53
Beryllium (Be)	mg/L	0.0005	<0.0005	<0.0005	0.00	<0.0005	<0.0005	0.00	<0.0005	<0.0005	0.00
Bismuth (Bi)	mg/L	0.00005	<0.00005	<0.00005	0.00	<0.00005	<0.00005	0.00	-	-	-
Boron (B)	mg/L	0.002	0.0355	0.0342	3.73	0.0225	0.0196	13.78	0.015	0.015	0.00

Table A1.3 (Cont'd.)

Water Quality Variable	Units	Detection Limit	Winter 2013			Spring 2013			Summer 2013		
			LG2-2	Duplicate	% Difference	SG4-2	Duplicate	% Difference	SG4-2	Duplicate	% Difference
Cadmium (Cd)	mg/L	0.00001	<0.00001	<0.00001	0.00	<0.00001	<0.00001	0.00	<0.00001	<0.00001	0.00
Chromium (Cr)	mg/L	0.0001	0.0002	0.00019	17.14	<0.0001	<0.0001	0.00	<0.00010	<0.00010	0.00
Cobalt (Co)	mg/L	0.0001	0.0004	0.00038	2.67	<0.0001	<0.0001	0.00	0.0003	0.00030	9.52
Copper (Cu)	mg/L	0.0001	<0.0001	<0.0001	0.00	<0.0001	<0.0001	0.00	<0.0001	<0.0001	0.00
Iron (Fe)	mg/L	0.01	6.4700	6.53	0.92	0.1100	0.0790	**32.80**	0.1850	0.187	1.08
Lead (Pb)	mg/L	0.00005	<0.00005	<0.00005	0.00	<0.00005	<0.00005	0.00	<0.00005	<0.00005	0.00
Lithium (Li)	mg/L	0.005	0.0128	0.0124	3.17	0.0057	0.0055	3.57	0.0056	0.0054	3.64
Manganese (Mn)	mg/L	0.002	1.2400	1.26	1.60	<0.002	<0.002	0.00	0.4540	0.404	11.66
Molybdenum (Mo)	mg/L	0.00005	0.00011	0.000108	0.93	0.0003	0.0003	0.77	0.0001	0.000079	5.19
Nickel (Ni)	mg/L	0.0001	0.0004	0.00041	4.76	0.0007	0.0007	4.51	0.0008	0.00087	4.71
Selenium (Se)	mg/L	0.0001	0.00012	0.00011	8.70	<0.00010	<0.00010	0.00	<0.0001	<0.0001	0.00
Silver (Ag)	mg/L	0.00001	<0.00001	<0.00001	0.00	<0.00001	<0.00001	0.00	<0.00001	<0.00001	0.00
Strontium (Sr)	mg/L	0.0001	0.263	0.263	0.00	0.0926	0.0928	0.22	-	-	-
Thallium (Tl)	mg/L	0.00005	<0.00005	<0.00005	0.00	<0.00005	<0.00005	0.00	<0.000050	<0.000050	0.00
Tin (Sn)	mg/L	0.0001	0.00012	<0.0001	18.18	<0.0001	<0.0001	0.00	<0.00010	<0.00010	0.00
Titanium (Ti)	mg/L	0.0003	0.00070	0.00047	**39.32**	<0.0003	<0.0003	0.00	<0.00030	<0.00030	0.00
Uranium (U)	mg/L	0.00001	0.00013	0.000126	0.79	0.000025	0.000024	4.08	0.000017	0.000019	11.11
Vanadium (V)	mg/L	0.0001	0.00043	0.00044	2.30	<0.0001	<0.0001	0.00	<0.0001	<0.00010	0.00
Zinc (Zn)	mg/L	0.001	<0.001	<0.001	0.00	<0.001	<0.001	0.00	0.0024	0.002	**46.15**
Total Metals											
Aluminum (Al)	mg/L	0.003	0.007	0.0072	1.38	0.042	0.005	**161.62**	0.0049	0.0041	17.78
Antimony (Sb)	mg/L	0.0001	<0.0001	<0.0001	0.00	<0.0001	<0.0001	0.00	<0.0001	<0.0001	0.00
Arsenic (As)	mg/L	0.0001	0.001	0.00121	0.82	0.00149	0.00120	**21.56**	0.00134	0.00138	2.94
Barium (Ba)	mg/L	0.00005	0.135	0.130	3.77	0.0782	0.0647	18.89	0.0809	0.0829	2.44
Beryllium (Be)	mg/L	0.0005	<0.0005	<0.0005	0.00	<0.0005	<0.0005	0.00	<0.0005	<0.0005	0.00
Bismuth (Bi)	mg/L	0.00005	<0.00005	<0.00005	0.00	<0.00005	<0.00005	0.00	-	-	-
Boron (B)	mg/L	0.01	0.037	0.035	5.56	0.019	0.019	0.00	0.020	0.019	5.13
Cadmium (Cd)	mg/L	0.00001	<0.00001	<0.00001	0.00	<0.00001	<0.00001	0.00	<0.00001	<0.00001	0.00
Chromium (Cr)	mg/L	0.0001	0.00026	0.00026	0.00	0.00042	0.00025	**50.75**	<0.0001	<0.0001	0.00
Cobalt (Co)	mg/L	0.0001	0.00040	0.00040	0.00	0.00078	0.00050	**43.75**	0.00072	0.00068	5.71
Copper (Cu)	mg/L	0.0001	0.00043	0.00030	**35.62**	0.00059	0.00047	**22.64**	0.00012	0.00016	**28.57**
Iron (Fe)	mg/L	0.01	7.78	7.67	1.42	2.80	1.74	**46.70**	-	-	-
Lead (Pb)	mg/L	0.00005	<0.00005	<0.00005	0.00	0.000073	<0.00005	**37.40**	<0.00005	<0.00005	0.00
Lithium (Li)	mg/L	0.005	0.0208	0.0196	5.94	<0.005	<0.005	0.00	0.0068	0.0057	17.60
Manganese (Mn)	mg/L	0.002	1.23	1.22	0.82	0.71	0.423	**50.66**	-	-	-
Mercury (Hg)-Trace	ng/L	0.0025	<0.001	<0.001	0.00	<0.0005	<0.0005	0.00	<0.0025	<0.0025	0.00
Molybdenum (Mo)	mg/L	0.00005	0.000	0.000127	2.33	0.00036	0.00031	15.84	0.000093	0.000098	5.24
Nickel (Ni)	mg/L	0.0001	0.000	0.00051	8.16	0.00099	0.00088	11.76	0.00090	0.00092	2.20
Selenium (Se)	mg/L	0.0001	0.000	0.00010	0.00	0.00010	<0.00010	0.00	0.00011	0.00010	9.52
Silver (Ag)	mg/L	0.00001	<0.00001	<0.00001	0.00	<0.00001	<0.00001	0.00	<0.00001	<0.00001	0.00
Strontium (Sr)	mg/L	0.0001	0.272	0.254	6.84	0.0915	0.0943	3.01	-	-	-
Thallium (Tl)	mg/L	0.00005	<0.00005	<0.00005	0.00	<0.00005	<0.00005	0.00	<0.00005	<0.00005	0.00
Tin (Sn)	mg/L	0.0001	<0.00010	<0.00010	0.00	<0.00010	<0.00010	0.00	0.00021	0.00022	4.65
Titanium (Ti)	mg/L	0.0003	0.001	0.00105	19.74	0.00189	0.00038	**133.04**	<0.0003	<0.0003	0.00
Uranium (U)	mg/L	0.00001	0.000	0.000142	0.70	0.00004	0.00003	11.43	0.000019	0.000018	5.41
Vanadium (V)	mg/L	0.0001	0.001	0.00079	9.64	0.00032	0.00017	**61.22**	0.00019	0.00022	14.63
Zinc (Zn)	mg/L	0.003	<0.0030	<0.0030	0.00	0.00910	0.00730	**21.95**	<0.005	<0.005	0.00

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

Analytes differ by >20% between sample and both concentrations are >5 times the detection limit

Appendix A2

Surface Water Quality Data

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

Water Quality Variable	Units	Regulatory Guideline	Detection Limit	Summer 2011										Fall 2011							
				SM3a-1	GAC-1	SG2-1	SG4-1	MOC-1	MOC-2	MUL-1	MIL-1	GAL-1	DIL-1	SM3a-1	GAC-1	SG2-1	SG4-1	MOC-1	MOC-2	MUL-1	MIL-1
Field Measurements																					
Dissolved Oxygen	(mg/L)	5, 6.5[1]	-[2]	**1.8**	**2.6**	**1.2**	**1.8**	5.7	-	6.8	7	6.6	4.7	**1.7**	7	**1.1**	**3.2**	6.8	6.9	9.2	7.5
Conductivity	uS/cm	-	-[2]	207	548	-	380	621	-	803	-	813	272	338	777	583	467	357	552	2065	257
pH	pH	6.5-9.0	-[2]	6.96	7.9	7.75	7.62	8.06	8.13	9.3	8.7	9	7.69	7.09	8.45	7.07	7.07	7.74	7.83	**9.4**	8.62
Temperature	°C	-	-[2]	16	18.2	16.9	16.8	17.1	17	21.2	19.6	20.4	18.9	3.8	7.4	4.7	5.9	5.8	7.9	10.8	10.6
Conventional Variables																					
Alkalinity, Total (as CaCO3)	mg/L	-	5	134	364	286	215	306	268	995	139	351	164	196	499	361	286	321	316	1030	147
Color, True	T.C.U.	-	2	11	75	77	96	68	51	13	10	10	100	110	30.8	36.4	33.9	45.1	21.1	8.3	7.5
Conductivity (EC)	uS/cm	-	0.2	257	639	494	389	621	410	2160	221	848	315	367	837	628	503	357	554	2065	257
Dissolved Organic Carbon	mg/L	-	1	28.3	23.1	26.9	25.4	23	17.1	41	11.6	23.5	26.3	37.8	16.7	21.6	21.7	24.6	13.9	44.5	11.4
Hardness (as CaCO3)	mg/L	-		121	338	242	187	279	237	779	122	349	136	181	403	309	266	281	278	744	121
Total Dissolved Solids	mg/L	-	10	211	436	356	282	441	317	1630	172	582	228	296	526	397	321	397	344	1660	166
Total Organic Carbon	mg/L	-	1	30.5	24	27	25.1	23.7	18	45.4	15	24.7	29.1	42.3	16.7	21.4	21.7	24.7	14.4	45.9	13.7
Total Suspended Solids	mg/L	+10mg/L [A]	3	7	3	5	<3.0	12	5	31	37	11	<3.0	<3.0	<3.0	65	<3.0	36	4	4	15
Turbidity	NTU	-	0.1	2.49	1.83	7.66	2.12	7.8	7.3	16.6	25.6	1.48	0.45	-	-	-	-	-	-	-	-
General Organics																					
Hydrocarbons, Recoverable (I.R.)	mg/L	-	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Naphthenic Acids	mg/L	-	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0		<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Phenols (4AAP)	mg/L	0.004	0.001	**0.0142**	**0.0098**	**0.0096**	**0.0141**	**0.0102**	**0.0058**	**0.0112**	0.0036	**0.0084**	**0.0139**	**0.0136**	**0.0048**	**0.0061**	**0.0046**	**0.0067**	0.0035	**0.0091**	**0.0042**
Major Ions																					
Bicarbonate (HCO3)	mg/L	-	5	163	444	349	262	351	326	854	154	318	201	239	588	441	349	388	386	868	176
Calcium (Ca)	mg/L		0.05	23.8	73.2	55.1	41.5	59.2	62.6	15.3	25.8	17	24.1	40.7	90.2	69.3	61.4	57.5	71.4	9.21	26.7
Carbonate (CO3)	mg/L	-	5	<5.0	<5.0	<5.0	<5.0	10.8	<5.0	177	7.6	54.2	<5.0	<5.0	10	<5.0	<5.0	<5.0	<5.0	193	<5.0
Chloride (Cl)	mg/L	640, 120[B]	0.05	1.49	1.57	1.06	0.93	9.71	0.85	37.3	2.47	8.27	2.52	1.14	2.96	1.32	0.75	10.4	1.65	39.7	0.98
Hydroxide (OH)	mg/L	-	5	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0
Magnesium (Mg)	mg/L	-	0.1	13.3	30.8	25	19.5	31.9	19.1	154	14	74.7	17.4	19.2	43.1	33	27.4	33.3	24.2	175	13.3
Potassium (K)	mg/L	-	0.5	4.4	3.46	4	5.8	5.59	2.23	40.5	10.8	15.4	9.01	7.38	5.22	5.48	7.85	5.51	3.03	46.9	10.1
Sodium (Na)	mg/L	-	1	5	15.6	10.5	2.4	28.7	6.5	228	3.9	43.3	5.2	4.5	25.3	15.9	3.1	23.7	9	268	3.5
Sulfate (SO4)	mg/L	-	0.5	<0.50	5.72	<0.50	<0.50	43.7	0.97	347	<0.50	137	<0.50	<0.50	6.27	<0.50	<0.50	24.5	2.43	361	<0.50
Sulphide	mg/L	0.002[C]	0.002	**0.0055**	<0.0020	0.0057	<0.0020	**0.0021**	<0.0020	**0.0059**	<0.0020	<0.0020	**0.0021**	**0.0063**	<0.0020	**0.0033**	<0.0020	**0.0059**	<0.0020	<0.0020	<0.0020
Nutrients and BOD																					
Ammonia-N	mg/L	Variable[D]	0.05	<0.050	<0.050	<0.050	0.065	0.057	<0.050	0.213	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	0.131	<0.050
Biochemical Oxygen Demand	mg/L	-	2	<2.0	2.6	<2.0	<2.0	3	2.6	3.4	5.1	<2.0	<2.0	<2.0	2	<2.0	<2.0	<2.0	<2.0	<2.0	4.5
Nitrate (as N)	mg/L	13	0.05	<0.050	<0.050	<0.050	0.106	<0.050	<0.050	<0.050	<0.050	<0.050	0.102	<0.050	<0.050	<0.050	<0.050	0.092	<0.050	<0.050	<0.050
Nitrate and Nitrite as N	mg/L		0.071	<0.071	<0.071	<0.071	0.106	<0.071	<0.071	<0.071	<0.071	<0.071	0.102	<0.071	<0.071	<0.071	<0.071	0.092	<0.071	<0.071	<0.071
Nitrite (as N)	mg/L	0.06	0.05	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050
Phosphorus, Total	mg/L	0.05	0.001	**0.143**	**0.107**	**0.21**	**0.282**	**0.113**	**0.0605**	**0.0902**	**0.132**	0.0147	**0.0509**	**0.0996**	**0.0828**	0.001	**0.0789**	**0.11**	**0.0555**	0.0434	**0.0968**
Phosphorus, Total Dissolved	mg/L	-	0.001	**0.113**	0.058	0.0409	0.18	0.0421	0.0172	0.0212	0.0079	0.0053	0.0242	0.0994	0.0291	0.001	0.0144	0.0219	0.0073	0.0235	0.0042
Total Kjeldahl Nitrogen	mg/L	1J	0.2	**1.54**	**1.18**	**1.2**	**1.54**	**1.49**	0.8	**3.38**	**1.48**	**1.48**	**1.61**	3.1	1.35	0.2	1.16	**2.31**	0.68	**3.17**	**1.73**
Dissolved Metals* **																					
Aluminum (Al)	mg/L	0.1	0.01, 0.001*	<0.010	-	<0.010	<0.010	-	-	-	<0.010	<0.010	<0.010	<0.010	0.012	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Antimony (Sb)	mg/L	-	0.0004, 0.0001*	<0.00040	-	<0.00040	<0.00040	-	-	-	<0.00040	<0.00040	<0.00040	<0.00040	<0.00040	<0.00040	<0.00040	<0.00040	<0.00040	<0.00040	<0.00040
Arsenic (As)	mg/L	0.005	0.0004, 0.0001*	0.00044	-	0.00252	0.00161	-	-	-	0.00059	0.00132	0.00061	0.00083	0.00448	0.00094	0.00081	0.00143	0.00059	**0.00798**	0.00058
Barium (Ba)	mg/L	-	0.0001, 0.00005*	0.0299	-	0.0778	0.0584	-	-	-	0.0149	0.0149	0.0476	0.0415	0.0663	0.0702	0.0453	0.0946	0.113	0.00073	0.0282
Beryllium (Be)	mg/L	-	0.0005	<0.00050	-	<0.00050	<0.00050	-	-	-	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050
Bismuth (Bi)	mg/L	-	0.00005	<0.000050	-	<0.000050	<0.000050	-	-	-	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050
Boron (B)	mg/L	29, 1.5[B]	0.002	0.0169	-	0.0405	0.0182	-	-	-	0.0277	0.0869	0.0398	0.0119	0.0957	0.033	0.021	0.0611	0.0265	0.404	0.0295
Cadmium (Cd)	mg/L	Variable[E]	0.0001, 0.00001*	<0.00010	-	<0.00010	<0.00010	-	-	-	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010
Chromium (Cr)	mg/L	0.0089	0.0004, 0.0001*	<0.00040	-	<0.00040	<0.00040	-	-	-	<0.00040	<0.00040	<0.00040	<0.00040	<0.00040	<0.00040	<0.00040	<0.00040	<0.00040	<0.00040	<0.00040
Cobalt (Co)	mg/L	-	0.0001	<0.00010	-	0.0002	0.00037	-	-	-	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	0.0001	0.00017	0.00011	<0.00010	<0.00010	<0.00010
Copper (Cu)	mg/L	Variable[F]	0.0006, 0.0001*	<0.00060	-	<0.00060	<0.00060	-	-	-	<0.00060	<0.00060	<0.00060	<0.00060	<0.00060	<0.00060	<0.00060	<0.00060	<0.00060	<0.00060	<0.00060
Iron (Fe)	mg/L	0.3	0.01	0.047	-	0.079	0.236	-	-	-	<0.010	<0.010	0.048	0.037	0.015	0.023	0.022	0.043	0.01	0.013	<0.010
Lead (Pb)	mg/L	Variable[G]	0.0001, 0.00005*	<0.00010	-	<0.00010	<0.00010	-	-	-	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010
Lithium (Li)	mg/L	-	0.003, 0.005*	0.0085	-	0.0146	0.0047	-	-	-	0.0057	0.0545	0.0129	0.0091	0.0503	0.0249	0.0075	0.0293	0.0129	0.196	0.0058

Table A2.1 (Cont'd.)

Water Quality Variable	Units	Regulatory Guideline	Detection Limit	Summer 2011										Fall 2011							
				SM3a-1	GAC-1	SG2-1	SG4-1	MOC-1	MOC-2	MUL-1	MIL-1	GAL-1	DIL-1	SM3a-1	GAC-1	SG2-1	SG4-1	MOC-1	MOC-2	MUL-1	MIL-1
Manganese (Mn)	mg/L	-	0.002, 0.00005*	<0.0020	-	0.398	0.308	-	-	-	<0.0020	0.0083	0.0047	0.0451	0.0029	0.267	0.098	<0.0020	0.158	0.0147	<0.0020
Molybdenum (Mo)	mg/L	0.073	0.0001, 0.00005*	<0.00010	-	0.00047	0.00078	-	-	-	<0.00010	0.00019	0.0009	<0.00010	0.00105	0.00011	0.00031	0.00091	0.00059	0.00189	<0.00010
Nickel (Ni)	mg/L	Variable[H]	0.0001	0.00027	-	0.00059	0.00123	-	-	-	0.0001	0.00011	0.00015	0.00031	0.00052	0.00039	0.00105	0.00153	0.00032	0.00014	<0.00010
Selenium (Se)	mg/L	0.001	0.0004, 0.0001*	<0.00040	-	<0.00040	<0.00040	-	-	-	<0.00040	<0.00040	<0.00040	<0.00040	<0.00040	<0.00040	<0.00040	<0.00040	<0.00040	<0.00040	<0.00040
Silicon (Si)	mg/L	-	0.05																		
Silver (Ag)	mg/L	0.0001	.0002, 0.0001**, 0.0000	<0.00020	-	<0.00020	<0.00020	-	-	-	<0.00020	<0.00020	<0.00020	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010
Strontium (Sr)	mg/L	-	0.0001	0.0832	-	0.189	0.0933	-	-	-	0.0692	0.0569	0.111	0.114	0.415	0.216	0.122	0.279	0.154	0.0121	0.0686
Thallium (Tl)	mg/L	0.0008	0.00005	<0.000050	-	<0.000050	<0.000050	-	-	-	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050
Tin (Sn)	mg/L	-	0.0002, 0.0001*	<0.00020	-	<0.00020	<0.00020	-	-	-	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020
Titanium (Ti)	mg/L	-	0.0003	<0.00030	-	<0.00030	<0.00030	-	-	-	<0.00030	<0.00030	<0.00030	<0.00030	<0.00030	<0.00030	0.00046	0.00039	<0.00030	0.00038	<0.00030
Uranium (U)	mg/L	0.033, 0.015[B]	0.0001, 0.00001*	<0.00010	-		0.00012	-	-	-	<0.00010	0.00071	<0.00010	<0.00010	0.00058	<0.00010	0.00015	0.00078	0.00035	0.00149	<0.00010
Vanadium (V)	mg/L	-	0.0001	<0.00010	-	<0.00010	0.00011	-	-	-	0.00012	0.00017	<0.00010	<0.00010	0.00014	<0.00010	<0.00010	0.0004	<0.00010	0.00045	0.00011
Zinc (Zn)	mg/L	0.03	0.001	0.0022	-	<0.0010	0.0043	-	-	-	<0.0010	0.001	<0.00150	0.0044	0.0023	<0.0010	0.0051	0.0045	0.0021	<0.0010	<0.0010
Total Metals																					
Aluminum (Al)	mg/L	0.1	0.02, 0.003*	0.04	<0.020	<0.020	0.021	0.067	<0.020	0.028	0.086	<0.020	<0.020	<0.020	<0.020	0.054	<0.020	**0.187**	<0.020	0.047	<0.020
Antimony (Sb)	mg/L	-	0.0004, 0.0001*	<0.00040	<0.00040	<0.00040	<0.00040	<0.00040	<0.00040	<0.00040	<0.00040	<0.00040	<0.00040	<0.00040	<0.00040	<0.00040	<0.00040	<0.00040	<0.00040	<0.00040	<0.00040
Arsenic (As)	mg/L	0.005	0.0004, 0.0001*	0.00042	**0.0127**	0.00454	0.00182	0.00218	0.00121	**0.00862**	0.00064	0.00124	0.00064	0.00083	**0.00663**	0.00369	0.00103	0.00223	0.00102	**0.00828**	0.00058
Barium (Ba)	mg/L	-	0.0002, 0.00005*	0.029	0.0736	0.0898	0.0657	0.0977	0.12	0.00576	0.0301	0.015	0.0478	0.0419	0.0698	0.103	0.0487	0.106	0.121	0.00766	0.03
Beryllium (Be)	mg/L	-	0.001, 0.0005*	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010
Bismuth (Bi)	mg/L	-	0.0002, 0.00005*	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020
Boron (B)	mg/L	29, 1.5[B]	0.02, 0.002*	<0.020	0.098	0.038	<0.020	0.07	0.028	0.34	0.03	0.094	0.037	<0.020	0.095	0.032	<0.020	0.058	0.023	0.407	0.027
Cadmium (Cd)	mg/L	Variable[E]	0.0002, 0.00001*	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020
Chromium (Cr)	mg/L	0.0089	0.0008, 0.0001*	<0.00080	<0.00080	<0.00080	<0.00080	<0.00080	<0.00080	<0.00080	<0.00080	<0.00080	<0.00080	<0.00080	<0.00080	<0.00080	<0.00080	<0.00080	<0.00080	<0.00080	<0.00080
Cobalt (Co)	mg/L	-	0.0002, 0.0001*	<0.00020	<0.00020	0.00024	0.00069	0.00027	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	0.00021	0.00034	0.00049	<0.00020	<0.00020	<0.00020
Copper (Cu)	mg/L	Variable[F]	0.001, 0.0001*	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010
Iron (Fe)	mg/L	0.3	0.01	0.13	**0.539**	**2.14**	**0.719**	**0.431**	**1.39**	**0.482**	0.194	<0.010	0.067	0.044	**0.455**	**4.84**	**0.534**	**0.929**	**1.25**	**0.452**	<0.010
Lead (Pb)	mg/L	Variable[G]	0.0001, 0.00005*	<0.00010	<0.00010	<0.00010	<0.00010	0.00013	<0.00010	<0.00010	0.00011	<0.00010	<0.00010	<0.00010	<0.00010	0.00011	<0.00010	0.00037	<0.00010	<0.00010	<0.00010
Lithium (Li)	mg/L	-	0.006, 0.005*	0.0086	0.0276	0.0161	<0.0060	0.029	0.0095	0.167	<0.0060	0.0615	0.0144	0.0084	0.0488	0.0231	0.0065	0.0271	0.0114	0.182	<0.0060
Manganese (Mn)	mg/L	-	0.002, 0.00005*	0.161	0.0644	0.688	0.713	0.0624	0.144	0.0288	0.0333	0.0082	0.0221	0.0609	0.0686	0.605	0.273	0.112	0.249	0.0315	0.0104
Mercury (Hg)-Trace	ng/L	5, 13[I]	1, 0.5	2	1.3	1.7	2.3	2.3	1.3	1.7	1.2	1.6	1.7	1.1	<1.0	<1.0	<1.0	1.9	<1.0	<1.0	<1.0
Molybdenum (Mo)	mg/L	0.073	0.0001, 0.00005*	0.00011	0.00138	0.00048	0.00074	0.00092	0.00062	0.0015	<0.00010	0.00022	0.00096	<0.00010	0.00115	0.00011	0.00032	0.00089	0.00061	0.00187	<0.00010
Nickel (Ni)	mg/L	Variable[H]	0.0002, 0.0001*	0.00043	0.00056	0.00061	0.00139	0.00116	0.00036	0.00031	0.0003	<0.00020	<0.00020	0.00035	0.00055	0.00055	0.00111	0.00198	0.00029	0.00031	<0.00020
Selenium (Se)	mg/L	0.001	0.0004, 0.0001*	<0.00040	<0.00040	<0.00040	<0.00040	<0.00040	<0.00040	<0.00040	<0.00040	<0.00040	<0.00040	<0.00040	<0.00040	<0.00040	<0.00040	<0.00040	<0.00040	<0.00040	<0.00040
Silicon (Si)	mg/L	-	0.05																		
Silver (Ag)	mg/L	0.0001	.0004, 0.0001**, 0.0000	<0.00040	<0.00040	<0.00040	<0.00040	<0.00040	<0.00040	<0.00040	<0.00040	<0.00040	<0.00040	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010
Strontium (Sr)	mg/L	-	0.0002, 0.0001*	0.0805	0.339	0.198	0.0975	0.289	0.136	0.0426	0.0704	0.0604	0.115	0.118	0.421	0.228	0.121	0.285	0.155	0.0511	0.0681
Thallium (Tl)	mg/L	0.0008	0.0001, 0.00005*	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010
Tin (Sn)	mg/L	-	0.0004, 0.0001*	<0.00040	<0.00040	<0.00040	<0.00040	<0.00040	<0.00040	<0.00040	<0.00040	<0.00040	<0.00040	<0.00040	<0.00040	<0.00040	<0.00040	<0.00040	<0.00040	<0.00040	<0.00040
Titanium (Ti)	mg/L	-	0.005, 0.0003*	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	0.0055	<0.0050	<0.0050	<0.0050
Uranium (U)	mg/L	0.033, 0.015[B]	0.0001, 0.00001*	<0.00010	0.0005	<0.00010	0.00012	0.00088	0.00034	0.00135	<0.00010	0.00112	<0.00010	<0.00010	0.00059	<0.00010	0.00014	0.00081	0.00035	0.00143	<0.00010
Vanadium (V)	mg/L	-	0.0005, 0.0001*	<0.00050	<0.00050	<0.00050	<0.00050	0.00085	<0.00050	0.00053	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	0.00124	<0.00050	0.00071	<0.00050
Zinc (Zn)	mg/L	0.03	0.004, 0.003*	0.0047	<0.0040	<0.0040	0.0099	<0.0040	<0.0040	<0.0040	<0.0040	<0.0040	<0.0040	0.0041	0.0058	<0.0040	<0.0040	<0.0040	<0.0040	<0.0040	<0.0040

Table A2.1 (Cont'd.)

Water Quality Variable	Fall 2011 (Cont'd.)		Winter 2012							Spring 2012														
	GAL-1	DIL-1	SM3a-1	GAC-1	MOC-2	MUL-1	MIL-1	GAL-1	DIL-1	SG7-1	SM3b-1	SM3a-1	SL1-1	GAC-1	SG2-1	SG4-1	SG5-1	SG8-1	SG9-1	MOC-1	MOC-2	MUL-1	MIL-1	GAL-1	DIL-1
Field Measurements																									
Dissolved Oxygen	9	**4.5**	**0.0**	5.0	7.6	**0.0**	9.8	8.3	**0.8**	8.8	10.0	7	**3.2**	8.4	**2.2**	8	8.2	11	9.8	8.8	9.1	14.2	9.7	11.8	7.4
Conductivity	800	385	76	926	615	-	305	872	350	722	383	136	209	479	379	175	668	405	514	497	322	2197	300	598	263
pH	8.53	6.9	7.99	8.24	7.79	8.86	8.81	8.65	7.88	7.8	8.09	7.73	7.11	7.85	7.32	7.8	7.6	7.63	8.13	8.24	7.92	**9.23**	7.93	8.78	7.45
Temperature	8.9	7.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.3	10.0	10.3	7.3	7.5	4.6	9.5	4.5	11.3	4	8.6	6.8	8.6	11.8	8	9.9
Conventional Variables																									
Alkalinity, Total (as CaCO3)	361	214	638	591	365	394	175	1510	460	426	152	76.9	125	227	223	108	364	257	285	261	199	1200	159	278	144
Color, True	9	84	271	10.7	11	8.2	8.8	36.3	186	85.7	168	96.4	339	47.5	44.6	47.1	81.9	36.2	63.1	38.5	38	7	14.2	5.5	76.8
Conductivity (EC)	800	385	76	926	615	1010	305	872	350	722	383	136	209	479	379	175	668	405	300	497	322	2197	514	598	263
Dissolved Organic Carbon	22.3	31.4	92.4	11.5	11	26.3	14.2	55.4	68.2	30.3	45.5	20.2	60.9	17.2	18.3	14.5	23.6	13.1	25.2	19.9	15.5	54.2	11.3	19	21.6
Hardness (as CaCO3)	369	196	604	523	336	409	147	1120	416	419	195	68.2	127	216	194	95.7	377	274	295	244	178	871	133	290	124
Total Dissolved Solids	573	285	907	670	418	677	219	2210	645	537	356	127	261	304	256	129	533	281	394	348	227	1880	170	447	182
Total Organic Carbon	25.6	30.9	91	11.9	12	27.3	16.5	64.1	68.4	32.7	45.6	20.7	60	17.4	17.7	13.5	23.5	12.7	25.6	19.5	15.7	53.2	11.1	19.1	22.6
Total Suspended Solids	7	4	53	6.0	13	<3.0	8	83	120	<3.0	7	<3.0	<3.0	<3.0	8	<3.0	<3.0	<3.0	<3.0	5	5	4	<3.0	4	5
Turbidity	-	-	39.3	8.33	44.5	1.23	10.8	57	20.6	0.59	1.4	0.59	1.99	4.69	6.95	3.58	1.31	0.24	0.26	5.4	5	1.8	5.64	0.8	2.08
General Organics																									
Hydrocarbons, Recoverable (I.R.)	<1.0	<1.0	1.8	<1.0	3	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Naphthenic Acids	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	1.4	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Phenols (4AAP)	**0.0076**	**0.0128**	**0.0316**	**0.0046**	**0.02**	**0.008**	**0.0052**	**0.0108**	**0.026**	**0.0326**	**0.0373**	**0.0169**	**0.0377**	**0.0501**	**0.0198**	**0.0191**	**0.0067**	**0.0063**	**0.019**	**0.0382**	**0.0191**	**0.0109**	**0.0201**	**0.0077**	**0.0099**
Major Ions																									
Bicarbonate (HCO3)	361	261	779	721	445	417	213	1850	561	520	185	93.9	153	277	272	132	428	314	348	309	243	1090	193	303	175
Calcium (Ca)	19.7	36.3	133	127	85.4	24.3	32.5	77.1	78.4	97.1	56.6	17.3	31.3	53.9	51.8	25.1	104	63.7	74.4	57.9	49.3	12.9	30.3	18.8	23.2
Carbonate (CO3)	38.9	<5.0	<5.0	<5.0	<5.0	31.6	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	7.8	<5.0	<5.0	<5.0	<5.0	188	<5.0	18	<5.0
Chloride (Cl)	8.3	3.66	8.7	2.69	2.52	9.98	1.32	53.5	7.18	1.38	8.76	5.33	1.06	3.6	2.86	0.98	1.16	1.49	2.16	9.09	1.93	47.3	1.15	6.81	5.22
Hydroxide (OH)	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0
Magnesium (Mg)	77.7	25.7	66	50.1	29.8	84.5	16	226	53.6	51.1	19.2	8.61	17.1	25.5	23.4	11.4	47.2	27.9	36	28.5	16.4	232	14	63.1	16.2
Potassium (K)	17.8	8.49	16.2	5.4	3.47	19.2	12.5	53	18.7	5.3	8.97	12.1	13.4	5.41	6.6	5.43	5.77	5.12	7.3	6.86	4.29	60	10.5	13.2	7.76
Sodium (Na)	44.9	6.9	17.4	33.2	11.3	54.7	4.5	337	15.8	15.3	10.3	2.8	1.4	13	11.1	1.5	20.4	5.4	6.1	20.3	5.6	329	3.6	32.4	4.9
Sulfate (SO4)	136	0.63	<0.50	22.7	4.89	159	<0.50	346	<0.50	56.9	63.4	<0.50	1.56	34.5	7.7	<0.50	86.9	20.3	49.1	38.2	1.89	393	<0.50	112	1.65
Sulphide	<0.0020	**0.0036**	**0.0101**	<0.0020	<0.0020	<0.0020	<0.0020	**5.11**	**0.0255**	**0.0043**	**0.0295**	0.0038	**0.034**	**0.0041**	**0.0051**	0.002	**0.0073**	<0.0020	**0.0022**	**0.0058**	<0.0020	**0.0027**	<0.0020	**0.107**	**0.005**
Nutrients and BOD																									
Ammonia-N	<0.050	<0.050	2.04	0.703	0.485	0.269	0.542	**1.51**	1.25	<0.050	<0.050	<0.050	<0.050	<0.050	0.195	<0.050	0.058	<0.050	<0.050	<0.050	<0.050	<0.050	0.14	<0.050	<0.050
Biochemical Oxygen Demand	<2.0	<2.0	16.6	<2.0	<2.0	2.5	3.3	18.2	18.1	<2.0	8	<2.0	5.8	2.1	3.3	2.4	<2.0	<2.0	<2.0	<2.0	<2.0	2.9	3.4	<2.0	4.5
Nitrate (as N)	<0.050	<0.050	<0.050	0.054	<0.050	<0.050	0.074	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	0.097	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	0.091
Nitrate and Nitrite as N	<0.071	<0.071	<0.071	<0.071	<0.071	<0.071	0.074	<0.071	<0.071	<0.071	<0.071	<0.071	<0.071	<0.071	<0.071	<0.071	<0.071	0.097	<0.071	<0.071	<0.071	<0.071	<0.071	<0.071	0.091
Nitrite (as N)	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050
Phosphorus, Total	**0.0636**	0.029	**2.59**	**0.0738**	**0.102**	0.0253	**0.0956**	**0.3**	**0.419**	**0.0546**	**0.0798**	**0.233**	**0.493**	**0.0757**	**0.188**	**0.1**	**0.0706**	0.0351	0.0446	**0.0565**	**0.111**	0.0478	**0.0523**	0.0223	**0.0718**
Phosphorus, Total Dissolved	0.0066	0.0157	1.12	0.0426	<0.0010	0.0061	0.0058	0.0194	0.0935	0.0454	0.0561	0.204	0.452	0.0212	0.0276	0.0464	0.04	0.027	0.0399	0.012	0.0136	0.0204	0.0067	0.0067	0.0226
Total Kjeldahl Nitrogen	**1.93**	**2.28**	**5.37**	**1.22**	0.81	**1.94**	**1.88**	**6.09**	**7.94**	**1.47**	**2.41**	**1.08**	**2.96**	**1.13**	**1.4**	0.86	**1.17**	0.66	0.96	**1.11**	0.9	**3.46**	**1.2**	**1.23**	**1.54**
Dissolved Metals																									
Aluminum (Al)	<0.010	<0.010	0.0205	0.0014	<0.0010	0.0016	<0.0010	0.003	0.0031	0.0034	0.0028	0.0116	0.0209	<0.0010	<0.0010	<0.0010	0.0014	<0.0010	0.0019	<0.0010	<0.0010	0.0063	0.0012	0.0012	0.0011
Antimony (Sb)	<0.00040	<0.00040	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	0.00016	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	0.00022	<0.00010	<0.00010	<0.00010
Arsenic (As)	0.00129	0.00071	0.00233	0.00274	0.00059	0.00146	0.00068	**0.00841**	0.00166	0.00083	0.00102	0.0005	0.00097	0.00227	0.00096	0.00061	0.00079	0.0004	0.00054	0.00111	0.00054	**0.00938**	0.00058	0.00098	0.00054
Barium (Ba)	0.0173	0.0458	0.0834	0.0965	0.125	0.0179	0.000111	0.0276	0.118	0.0685	0.0454	0.0123	0.0257	0.0453	0.0536	0.0303	0.0541	0.0548	0.0592	0.0839	0.0783	0.00184	0.0124	0.0134	0.0245
Beryllium (Be)	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050
Bismuth (Bi)	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050
Boron (B)	0.102	0.0345	0.0175	0.131	0.0288	0.115	0.0347	0.444	0.0479	0.0691	0.0142	0.0163	0.035	0.0575	0.0455	0.0163	0.0593	0.0305	0.0423	0.0444	0.023	0.411	0.0258	0.0702	0.0231
Cadmium (Cd)	<0.00010	<0.00010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	0.000046	<0.000010	<0.000010	<0.000010	<0.000010	0.000143	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010
Chromium (Cr)	<0.00040	<0.00040	0.00023	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	0.00012	<0.00010	0.00036	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	0.00033	<0.00010	<0.00010	<0.00010
Cobalt (Co)	<0.00010	<0.00010	0.00374	0.00019	<0.00010	<0.00010	<0.00010	0.00016	0.00012	0.00018	0.00018	<0.00010	0.00013	<0.00010	<0.00010	<0.00010	0.0001	<0.00010	<0.00010	0.0001	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010
Copper (Cu)	<0.00060	<0.00060	0.00017	0.00011	<0.00010	0.00035	<0.00010	<0.00010	<0.00010	0.00038	0.00046	0.00077	0.00187	0.0001	<0.00010	0.00017	0.00023	0.00105	0.00109	0.00027	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010
Iron (Fe)	<0.010	0.031	**2.39**	0.015	0.017	<0.010	<0.010	0.09	**1.05**	0.09	0.144	0.029	0.026	0.071	0.087	0.233	0.111	<0.010	0.012	0.022	0.108	0.027	<0.010	<0.010	0.048
Lead (Pb)	<0.00010	<0.00010	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050
Lithium (Li)	0.063	0.018	0.0313	0.0684	0.0149	0.0725	0.006	0.224	0.0367	0.0398	0.0071	<0.0050	<0.0050	0.0171	0.0149	<0.0050	0.0306	0.0147	0.0191	0.0222	0.0071	0.208	<0.0050	0.0444	0.0116

Table A2.1 (Cont'd.)

Water Quality Variable	Fall 2011 (Cont'd.)		Winter 2012							Spring 2012														
	GAL-1	DIL-1	SM3a-1	GAC-1	MOC-2	MUL-1	MIL-1	GAL-1	DIL-1	SG7-1	SM3b-1	SM3a-1	SL1-1	GAC-1	SG2-1	SG4-1	SG5-1	SG8-1	SG9-1	MOC-1	MOC-2	MUL-1	MIL-1	GAL-1	DIL-1
Manganese (Mn)	<0.0020	<0.0020	2.89	0.655	0.523	0.00352	0.000952	0.182	0.863	0.00256	0.000475	0.00138	0.00336	0.000646	0.00124	0.0004	0.00175	0.00028	0.000432	0.000336	0.000449	0.00324	0.000297	0.000352	0.000872
Molybdenum (Mo)	0.0002	0.00052	0.000088	0.00279	0.000518	0.0002	0.000065	0.000486	0.00079	0.0018	0.00128	0.000093	0.000124	0.00197	0.00104	0.000429	0.00111	0.000566	0.00135	0.00108	0.000862	0.00216	0.000062	0.000153	0.000424
Nickel (Ni)	0.00013	0.00013	0.00336	0.00044	0.00026	0.00017	0.0001	0.00047	0.00025	0.00155	0.00096	0.0043	0.00164	0.00064	0.00053	0.00074	0.00101	0.0009	0.00164	0.00083	0.00033	0.00039	<0.00010	0.00012	0.00012
Selenium (Se)	<0.00040	<0.00040	0.00016	<0.00010	<0.00010	<0.00010	<0.00010	0.00011	0.0001	0.00022	0.00015	<0.00010	0.00027	<0.00010	<0.00010	<0.00010	0.00011	0.00063	0.00055	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010
Silicon (Si)			25.6	12.7	9.85	1.36	3.43	15.8	20.3	4.67	5.94	0.272	3.97	3.16	2.42	1.75	3.95	3.41	4.66	2.74	4.86	1.22	2.45	0.514	3.6
Silver (Ag)	<0.00010	<0.00010	<0.000010	<0.000010	**0.000019**	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010
Strontium (Sr)	0.0621	0.15	0.348	0.596	0.187	0.0736	0.0592	0.313	0.326	0.332	0.131	0.0378	0.0608	0.197	0.147	0.0444	0.286	0.151	0.187	0.227	0.0931	0.0258	0.0608	0.055	0.0924
Thallium (Tl)	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050
Tin (Sn)	<0.00020	<0.00020	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010
Titanium (Ti)	<0.00030	<0.00030	0.0015	<0.00030	<0.00030	<0.00030	<0.00030	<0.00030	<0.00030	<0.00030	0.00034	0.0003	0.00042	<0.00030	<0.00030	<0.00030	<0.00030	<0.00030	<0.00030	<0.00030	<0.00030	<0.00030	<0.00030	<0.00030	<0.00030
Uranium (U)	0.00099	<0.00010	0.00002	0.00161	0.000459	0.00127	0.000013	0.00139	0.000057	0.00826	0.00178	<0.000010	0.000037	0.00125	0.000893	0.000092	0.0032	0.00186	0.00882	0.00127	0.000503	0.00182	0.000022	0.000928	0.000012
Vanadium (V)	0.00024	<0.00010	0.00072	<0.00010	<0.00010	0.00016	<0.00010	0.00015	0.00013	0.00037	0.00036	<0.00010	0.00023	0.00014	<0.00010	0.00015	0.00015	0.0002	0.00032	0.00027	<0.00010	0.00039	<0.00010	0.00012	<0.00010
Zinc (Zn)	<0.0010	0.0054	0.0043	0.0056	0.0026	0.0074	0.0016	<0.0010	0.0019	0.0024	0.0048	0.0027	0.006	<0.0010	<0.0010	0.0014	0.0019	0.0038	0.0016	0.0019	<0.0010	0.0016	<0.0010	0.0016	0.0014
Total Metals																									
Aluminum (Al)	0.031	<0.020	**0.634**	0.0121	0.0071	0.0121	0.0233	**0.126**	**0.183**	0.0134	0.0093	0.0165	0.0631	0.0269	**0.169**	0.029	0.0312	0.0127	<0.0030	**0.11**	0.0183	0.066	**0.18**	0.0104	0.0193
Antimony (Sb)	<0.00040	<0.00040	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	0.00018	<0.00010	0.0001	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	0.00021	<0.00010	<0.00010	<0.00010
Arsenic (As)	0.00126	0.00077	0.00269	0.00422	0.00112	0.00137	0.00064	**0.00922**	0.00182	0.00085	0.00102	0.00055	0.00098	0.00387	0.00235	0.00079	0.00115	0.00042	0.00055	0.00125	0.00098	**0.00859**	0.00057	0.00094	0.00055
Barium (Ba)	0.0164	0.0485	0.208	0.0997	0.161	0.0207	0.0356	0.0565	0.145	0.0691	0.0437	0.0125	0.0276	0.0468	0.0748	0.032	0.0595	0.0544	0.0595	0.0812	0.0837	0.0032	0.0225	0.0137	0.0248
Beryllium (Be)	<0.0010	<0.0010	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050
Bismuth (Bi)	<0.00020	<0.00020	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050
Boron (B)	0.094	0.033	0.0152	0.13	0.0275	0.109	0.0307	0.421	0.046	0.0723	0.0134	0.016	0.0321	0.0596	0.0468	0.016	0.065	0.0312	0.0413	0.0462	0.0238	0.384	0.0241	0.069	0.0221
Cadmium (Cd)	<0.00020	<0.00020	0.000012	<0.000010	0.00001	0.000012	<0.000010	0.000012	0.000027	<0.000010	<0.000010	<0.000010	**0.000148**	<0.000010	<0.000010	<0.000010	<0.000010	**0.000121**	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	0.000011	<0.000010
Chromium (Cr)	<0.00080	<0.00080	**0.0013**	0.00024	0.00013	<0.00010	0.00011	0.00038	0.00038	<0.00010	0.00013	<0.00010	0.00029	0.0002	0.00049	0.00015	0.00012	0.00013	<0.00010	0.00026	0.00021	0.00043	0.00031	0.00013	0.00013
Cobalt (Co)	<0.00020	<0.00020	0.00402	0.0002	0.0001	<0.00010	<0.00010	0.00033	0.00026	0.00028	0.00019	<0.00010	0.0008	0.00013	0.00026	0.00016	0.0004	<0.00010	<0.00010	0.00022	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010
Copper (Cu)	<0.0010	<0.0010	0.00125	0.00025	0.00016	0.00054	0.00033	0.00046	0.00083	0.00044	0.00056	0.00017	**0.0023**	0.00037	0.00048	0.00041	0.0003	0.00111	0.00104	0.00082	0.00022	0.00029	0.0004	0.0002	0.00026
Iron (Fe)	0.05	0.053	**9.44**	**0.961**	**4.69**	0.018	0.058	**0.548**	**1.73**	0.173	0.174	0.049	0.039	**0.776**	**2.4**	**0.99**	**0.663**	0.013	0.013	**0.37**	**1.85**	0.125	0.192	0.018	0.127
Lead (Pb)	<0.00010	<0.00010	0.000454	0.000849	<0.000050	0.000056	<0.000050	0.000171	0.000279	<0.000050	<0.000050	<0.000050	0.000102	0.000076	0.000134	0.000157	<0.000050	<0.000050	<0.000050	0.000113	<0.000050	0.00008	0.000054	<0.000050	<0.000050
Lithium (Li)	0.0567	0.017	0.0306	0.0635	0.0155	0.0659	0.0062	0.225	0.0364	0.0425	0.0076	<0.0050	<0.0050	0.0179	0.0161	<0.0050	0.0349	0.0163	0.0198	0.0244	0.0078	0.199	0.0052	0.0451	0.0122
Manganese (Mn)	0.0106	0.0209	2.96	0.645	0.576	0.0141	0.0129	0.208	0.949	0.042	0.00397	0.0346	0.383	0.062	0.235	0.0339	0.16	0.00544	0.00156	0.0391	0.106	0.0152	0.0268	0.00958	0.0646
Mercury (Hg)-Trace	<1.0	<1.0	<0.50	2.04	1.75	2.55	2.6	<0.50	<0.50	1.25	1.13	1.36	3.9	0.83	0.7	0.76	1.28		2.07	0.77	0.66	0.58		0.5	0.88
Molybdenum (Mo)	0.00019	0.0006	0.000109	0.00296	0.000529	0.000215	0.000078	0.000451	0.00061	0.002	0.0014	0.000118	0.000202	0.00207	0.0011	0.000445	0.0012	0.000597	0.00128	0.00112	0.000999	0.00197	0.000123	0.000167	0.000465
Nickel (Ni)	0.00021	<0.00020	0.00408	0.00048	0.00029	0.00024	0.00016	0.00087	0.44	0.00155	0.00101	0.00025	0.00155	0.00074	0.00085	0.00078	0.00102	0.00093	0.00155	0.00087	0.00041	0.00042	0.00029	0.00015	0.00016
Selenium (Se)	<0.00040	<0.00040	0.00018	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	0.00018	0.00021	0.00013	<0.00010	0.00028	<0.00010	<0.00010	<0.00010	0.00013	0.00058	0.00048	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010
Silicon (Si)			26.2	13.1	10.4	1.42	3.34	16.5	20.4	5.6	6.6	0.346	4.43	3.76	3.29	1.92	5.01	3.93	4.38	3.4	5.64	1.38	2.79	0.622	4.06
Silver (Ag)	<0.00010	<0.00010	0.000071	0.00001	**0.000111**	0.000037	<0.000010	0.000046	<0.000010	<0.000010	<0.000010	<0.000010	0.000012	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010
Strontium (Sr)	0.0597	0.158	0.348	0.596	0.196	0.0716	0.0828	0.376	0.327	0.347	0.129	0.0388	0.0623	0.199	0.154	0.0449	0.298	0.156	0.185	0.231	0.0995	0.0294	0.0688	0.0577	0.0912
Thallium (Tl)	<0.00010	<0.00010	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050
Tin (Sn)	<0.00040	<0.00040	<0.00010	<0.00010	0.0001	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010
Titanium (Ti)	<0.0050	<0.0050	0.0239	0.00079	0.00049	0.00037	0.00086	0.00799	0.00511	0.00058	0.00042	0.0007	0.00092	0.00094	0.00785	0.00045	0.00043	<0.00030	<0.00030	0.00282	0.00068	0.00067	0.00231	<0.00030	<0.00030
Uranium (U)	0.00094	<0.00010	0.000044	0.00159	0.000473	0.00116	0.000015	0.00129	0.0001	0.00838	0.00187	<0.000010	0.000041	0.00125	0.000928	0.000092	0.00343	0.0019	0.00827	0.00128	0.000554	0.00182	0.000093	0.000881	0.000013
Vanadium (V)	<0.00050	<0.00050	0.00227	0.00014	0.00029	0.00018	0.00011	0.00054	0.00051	0.00042	0.00039	<0.00010	0.00031	0.00036	0.00067	0.00032	0.00024	0.00024	0.00035	0.00067	0.00027	0.00037	0.00032	0.00014	<0.00010
Zinc (Zn)	<0.0040	<0.0040	0.0115	0.004	<0.0030	0.0083	<0.0030	0.0048	0.0133	<0.0030	0.0066	0.0078	0.0149	0.0127	0.0057	0.0082	<0.0030	0.0065	<0.0030	0.0046	0.0041	0.0047	0.0038	0.0032	0.0055

Table A2.1 (Cont'd.)

Water Quality Variable	Units	Regulatory Guideline	Detection Limit	Winter 2013						Spring 2013								
				LC11-1	LC11-2	SC1-1	LG2-2	GAC-4	GAL-2	GAL-2	LC11-1	SC1-1	GAC-4	LG2-2	REL-1	SG2-3	SG4-2	LC11-2
Field Measurements																		
Dissolved Oxygen	(mg/L)	5, 6.5[1]	-[2]	1.3	1.8	0	-	0	5.7	6.7	5.2	6.8	6.2	3.6	7.4	5.2	-	5.2
Conductivity	uS/cm	-	-[2]	634	383	1059	828	1079	989	472	216	311	446	423	481	270	-	216
pH	pH	6.5-9.0	-[2]	7.11	6.8	7.15	7.46	6.72	8.66	9.04	7.98	8.35	7.56	7.86	8.56	8.15	-	7.98
Temperature	°C	-	-[2]	0.3	0.3	0.4	0.5	0.1	0.2	17.3	21.9	20	17	21	21.1	21.4	-	21.9
Conventional Variables																		
Alkalinity, Total (as CaCO3)	mg/L	-	5	322	207	546	450	607	373	375	130	194	269	259	291	159	186	186
Color, True	C.U.	-	2	145	34.5	96.9	62.1	222	19.8	9.9	44.9	77.9	165	68.8	50.5	63.7	56.8	56.8
Conductivity (EC)	uS/cm	-	0.2	600	398	911	813	1080	1010	878	233	338	485	456	527	284	332	332
Dissolved Organic Carbon	mg/L	-	1	48.1	25.4	51.5	26.2	64.6	25.8	-	20.6	27	-	24.1	34.6	19.5	18.6	20.6
Hardness (as CaCO3)	mg/L	-		277	180	490	409	541	426	396	116	190	253	246	262	160	192	188
pH	pH	6.5-9.0	0.1	7.6	7.24	7.52	7.64	7.25	8.42	8.75	8.1	8.3	7.99	8.3	8.57	8.3	8.15	8.17
Total Dissolved Solids	mg/L	-	10	439	266	595	499	735	670	611	191	252	342	305	382	203	238	241
Total Organic Carbon	mg/L	-	1	49.5	25.6	666	26.6	68.9	25.7	23.3	20.9	26.6	29	23.8	34.5	19.9	20.8	20.8
Total Suspended Solids	mg/L	+10mg/L [A]	3	<3.0	8	<5.0	17	8	<3.0	4	26	18	18	5	<3.0	3	7	<3.0
Turbidity	NTU	-	0.1	2.76	2.92	252	64.2	6.69	0.29	0.95	0.96	8.51	2.35	-	-	-	-	-
General Organics																		
Hydrocarbons, Recoverable (I.R.)	mg/L	-	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Naphthenic Acids	mg/L	-	1	<1.0	<1.0	<1.0	<1.0	3.2	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Phenols (4AAP)	mg/L	0.004	0.001	**0.0143**	**0.0145**	**0.0184**	**0.0078**	**0.362**	**0.0067**	**0.0067**	**0.0079**	**0.01**	**0.017**	**0.0093**	**0.0131**	**0.0088**	**0.0094**	**0.0095**
Major Ions																		
Bicarbonate (HCO3)	mg/L	-	5	393	252	52.1	548	740	439	407	158	236	329	315	332	194	227	226
Calcium (Ca)	mg/L		0.5	35.7	48.9	111	94.5	118	31.1	30	20.3	38.4	54.1	54.2	28.4	34.7	45.2	44.4
Carbonate (CO3)	mg/L	-	5	<5.0	<5.0	108	<5.0	<5.0	8	25.1	<5.0	<5.0	<5.0	<5.0	11.3	<5.0	<5.0	<5.0
Chloride (Cl)	mg/L	640, 120[B]	0.5	3.29	1.88	1.41	5.93	5.96	9.61	8.12	<0.50	<0.50	<0.50	1.67	3.26	<0.50	0.54	<0.50
Hydroxide (OH)	mg/L	-	5	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0
Magnesium (Mg)	mg/L	-	0.1	22	37.6	51.7	42	59.9	84.5	78	15.8	22.8	28.7	26.8	46.4	17.7	19.2	18.8
Potassium (K)	mg/L	-	0.1	20.9	25.3	7.49	7.21	15	24.8	20.8	11.4	6.84	6.44	5.34	29.6	6.78	6.83	6.63
Sodium (Na)	mg/L	-	1	6.7	9.8	7.7	20.9	34.7	69.1	63.8	5.3	4.9	17.8	11.3	16.8	4.2	2.3	2.4
Sulfate (SO4)	mg/L	-	0.5	<0.50	<0.50	<0.50	2.26	6.09	176	152	<0.50	<0.50	0.61	<0.50	3.83	<0.50	<0.50	<0.50
Sulphide	mg/L	0.002[C]	0.002	<0.0020	<0.0020	0.003	0.011	3.670	<0.0020	0.006	0.005	0.007	0.227	0.010	0.010	0.004	0.002	0.004
Nutrients and BOD																		
Ammonia-N	mg/L	Variable[D]	0.05	1.55	0.531	1.09	1.44	5.39	0.266	<0.050	<0.050	0.102	0.062	<0.050	0.158	<0.050	<0.050	<0.050
Biochemical Oxygen Demand	mg/L	-	2	18.5	27.6	21.7	13.4	51.8	3.5	2.2	2.3	2.6	17.4	<2.0	<2.0	<2.0	<2.0	<2.0
Nitrate (as N)	mg/L	13	0.05	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050
Nitrate and Nitrite as N	mg/L		0.071	<0.071	<0.071	<0.071	<0.071	<0.071	<0.071	<0.071	<0.071	<0.071	<0.071	<0.071	<0.071	<0.071	<0.071	<0.071
Nitrite (as N)	mg/L	0.06	0.05	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050
Phosphorus, Total	mg/L	0.05	0.01	0.43	0.0312	2.1	0.511	0.879	0.0106	0.0172	0.0243	0.108	0.117	0.0591	0.118	0.0897	0.0297	0.0409
Phosphorus, Total Dissolved	mg/L	-	0.01	0.449	0.016	1.96	0.582	0.839	0.0092	-	0.008	0.0578	-	0.0271	0.103	0.0716	0.144	0.14
Total Kjeldahl Nitrogen	mg/L	1	0.2	3.19	1.45	3.33	2.28	7.43	1.82	1.68	1.37	1.94	2.02	1.32	3.17	1.06	1.11	1.09
Dissolved Metals																		
Aluminum (Al)	mg/L	0.1	0.001	0.001	<0.0010	0.021	0.004	0.012	<0.0010	<0.0010	0.001	0.003	0.003	<0.0010	0.005	0.001	<0.0010	<0.0010
Antimony (Sb)	mg/L	-	0.0001	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	0.000	<0.00010	<0.00010	<0.00010
Arsenic (As)	mg/L	0.005	0.0001	0.001	0.000	0.023	0.001	0.001	0.001	0.001	0.000	0.002	0.001	0.001	0.003	0.001	0.001	0.001
Barium (Ba)	mg/L	-	0.00005	0.103	0.067	0.249	0.111	0.130	0.026	0.021	0.028	0.050	0.061	0.060	0.046	0.036	0.047	0.046
Beryllium (Be)	mg/L	-	0.0005	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050
Bismuth (Bi)	mg/L	-	0.00005	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	0.013	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050
Boron (B)	mg/L	29, 1.5[B]	0.002	0.0136	0.0094	0.0158	0.0355	0.0319	0.105	<0.000010	<0.000050	0.0182	0.0183	0.0249	0.0893	0.0309	0.0225	0.0196
Cadmium (Cd)	mg/L	Variable[E]	0.00001	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	0.1070	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010
Chromium (Cr)	mg/L	0.0089	0.0001	<0.00010	<0.00010	0.0004	0.0002	0.0002	<0.00010	0.0002	<0.00010	<0.00010	0.0004	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010
Cobalt (Co)	mg/L	-	0.0001	<0.00010	<0.00010	0.0070	0.0004	0.0004	<0.00010	<0.00010	<0.00010	0.0002	0.0002	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010

Table A2.1 (Cont'd.)

Water Quality Variable	Units	Regulatory Guideline	Detection Limit	Winter 2013						Spring 2013								
				LC11-1	LC11-2	SC1-1	LG2-2	GAC-4	GAL-2	GAL-2	LC11-1	SC1-1	GAC-4	LG2-2	REL-1	SG2-3	SG4-2	LC11-2
Copper (Cu)	mg/L	Variable[F]	0.0001	<0.00010	0.0002	0.0002	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	0.0003	<0.00010	<0.00010	0.0002	0.0001	<0.00010	<0.00010
Iron (Fe)	mg/L	0.3	0.01	3.1600	0.0300	57.8000	6.4700	1.2100	<0.010	0.0110	0.0110	0.0590	0.4210	0.0270	0.0230	0.0140	0.1100	0.0790
Lead (Pb)	mg/L	Variable[G]	0.00005	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050
Lithium (Li)	mg/L	-	0.005	0.0103	0.0084	0.0095	0.0128	0.0209	0.0432	0.0538	0.0088	0.0104	0.0141	0.0148	0.0349	0.0124	0.0057	0.0055
Manganese (Mn)	mg/L	-	0.002	1.2400	0.4470	5.8800	1.2400	0.7580	<0.0020	<0.0020	<0.0020	<0.0020	0.3020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020
Molybdenum (Mo)	mg/L	0.073	0.00005	0.0001	<0.000050	0.0012	0.0001	<0.000050	0.0002	0.0002	0.0001	0.0007	<0.000050	0.0004	0.0020	0.0002	0.0003	0.0003
Nickel (Ni)	mg/L	Variable[H]	0.0001	<0.00010	<0.00010	0.0035	0.0004	0.0009	<0.00010	0.0002	<0.00010	0.0008	0.0004	0.0005	0.0004	0.0005	0.0007	0.0007
Selenium (Se)	mg/L	0.001	0.0001	<0.00010	<0.00010	0.0003	0.0001	0.0004	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	0.0001	<0.00010	<0.00010	<0.00010
Silver (Ag)	mg/L	0.0001	0.00001	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010
Strontium (Sr)	mg/L	-	0.0001	0.169	0.111	0.307	0.263	0.355	0.136	0.127	0.0724	0.113	0.169	0.152	0.125	0.103	0.0926	0.0928
Thallium (Tl)	mg/L	0.0008	0.00005	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050
Tin (Sn)	mg/L	-	0.0001	<0.00010	0.001	<0.00050	0.000	<0.00010	0.000	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010
Titanium (Ti)	mg/L	-	0.0003	<0.00030	<0.00030	0.002	0.001	0.000	<0.00030	<0.00030	<0.00030	<0.00030	<0.00030	<0.00030	0.000	<0.00030	<0.00030	<0.00030
Uranium (U)	mg/L	0.033, 0.015[B]	0.00001	<0.000010	<0.000010	0.000	0.000	0.000	0.001	0.001	<0.000010	0.001	0.000	0.000	0.001	0.000	0.000	0.000
Vanadium (V)	mg/L	-	0.0001	<0.00010	<0.00010	0.002	0.000	0.000	0.000	0.000	<0.00010	0.000	0.000	<0.00010	0.001	0.000	<0.00010	<0.00010
Zinc (Zn)	mg/L	0.03	0.001	0.002	0.003	0.002	<0.0010	<0.0010	<0.0010	<0.0010	0.001	0.001	0.002	<0.0010	0.001	0.001	<0.0010	<0.0010
Total Metals																		
Aluminum (Al)	mg/L	0.1	0.003	<0.0030	0.012	0.034	0.007	0.035	<0.0030	0.011	0.009	0.087	0.025	0.007	0.030	0.003	0.042	0.005
Antimony (Sb)	mg/L	-	0.0001	<0.00010	<0.00010	<0.00010	<0.00010	0.000	<0.00010	<0.00010	<0.00010	0.000	0.000	<0.00010	0.000	<0.00010	<0.00010	<0.00010
Arsenic (As)	mg/L	0.005	0.0001	0.001	0.000	0.021	0.001	0.001	0.001	0.001	0.000	0.003	0.001	0.001	0.003	0.001	0.001	0.001
Barium (Ba)	mg/L	-	0.00005	0.106	0.0734	0.228	0.135	0.134	0.0244	0.0235	0.0306	0.0545	0.0633	0.0697	0.052	0.0401	0.0782	0.0647
Beryllium (Be)	mg/L	-	0.0005	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050
Bismuth (Bi)	mg/L	-	0.00005	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050
Boron (B)	mg/L	29, 1.5[B]	0.01	0.015	0.012	0.018	0.037	0.031	0.130	0.145	0.014	0.016	0.015	0.023	0.089	0.026	0.019	0.019
Cadmium (Cd)	mg/L	Variable[E]	0.00001	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010
Chromium (Cr)	mg/L	0.0089	0.0001	<0.00010	0.000	0.000	0.000	0.000	<0.00010	<0.00010	0.000	0.000	0.000	<0.00010	0.000	<0.00010	0.000	0.000
Cobalt (Co)	mg/L	-	0.0001	<0.00010	<0.00010	0.007	0.000	0.001	<0.00010	<0.00010	<0.00010	0.000	0.000	0.000	0.000	0.000	0.001	0.001
Copper (Cu)	mg/L	Variable[F]	0.0001	0.001	0.000	0.001	0.000	0.000	0.001	0.000	0.001	0.001	0.000	0.000	0.000	0.000	0.001	0.000
Iron (Fe)	mg/L	0.3	0.01	3.25	0.073	56.8	7.78	1.36	<0.010	0.026	0.037	1.15	0.685	0.491	0.107	0.097	2.8	1.74
Lead (Pb)	mg/L	Variable[G]	0.00005	<0.000050	0.000089	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	0.000097	0.000058	<0.000050	0.000097	<0.000050	0.000073	<0.000050
Lithium (Li)	mg/L	-	0.005	0.0176	0.0106	0.0151	0.0208	0.0336	0.0639	0.0711	0.0101	0.0111	0.0185	0.0135	0.0358	0.0112	<0.0050	<0.0050
Manganese (Mn)	mg/L	-	0.002	1.25	0.452	7.23	1.23	0.772	0.0049	0.0136	0.0208	0.137	0.354	0.0669	0.0453	0.0444	0.71	0.423
Mercury (Hg)-Trace	ug/L	5, 13[I]	0.0005	<0.00050	<0.0010	<0.00050	<0.0010	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	-	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050
Molybdenum (Mo)	mg/L	0.073	0.00005	0.000	0.000	0.001	0.000	<0.000050	0.000	0.000	0.000	0.001	0.000	0.000	0.002	0.000	0.000	0.000
Nickel (Ni)	mg/L	Variable[H]	0.0001	0.000	0.000	0.003	0.000	0.001	<0.00010	0.000	0.000	0.001	0.001	0.001	0.000	0.001	0.001	0.001
Selenium (Se)	mg/L	0.001	0.0001	<0.00010	<0.00010	0.000	0.000	0.000	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	0.000	<0.00010	0.000	<0.00010
Silver (Ag)	mg/L	0.0001	0.00001	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010
Strontium (Sr)	mg/L	-	0.0001	0.172	0.101	0.302	0.272	0.353	0.126	0.135	0.0725	0.124	0.175	0.158	0.125	0.106	0.0915	0.0943
Thallium (Tl)	mg/L	0.0008	0.00005	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050
Tin (Sn)	mg/L	-	0.0001	<0.00010	0.000	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	0.000	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010
Titanium (Ti)	mg/L	-	0.0003	<0.00030	0.000	0.003	0.001	0.002	<0.00030	0.000	0.000	0.004	0.001	0.001	0.001	0.001	0.002	0.000
Uranium (U)	mg/L	0.033, 0.015[B]	0.00001	<0.000010	<0.000010	0.000	0.000	0.000	0.001	0.001	0.000	0.001	0.000	0.000	0.001	0.000	0.000	0.000
Vanadium (V)	mg/L	-	0.0001	0.001	0.000	0.002	0.001	0.001	0.000	0.000	0.000	0.001	0.000	0.000	0.002	0.000	0.000	0.000
Zinc (Zn)	mg/L	0.03	0.003	0.004	0.032	0.004	<0.0030	<0.0030	<0.0030	<0.0030	<0.0030	<0.0030	<0.0030	<0.0030	0.003	<0.0030	0.009	0.007

Table A2.1 (Cont'd.)

Water Quality Variable	Summer 2013							n	Min	Med	Max	# Exceeded	Freq %	Seasons Where Frequencies Were Observed
	SG4-2	LC11-1	SG2-3	REL-1	LG2-2	GAL-2	SC1-1							
Field Measurements														
Dissolved Oxygen	3.1	-	6.1	-	2.5	9	0.6	18	0	5.2	9	10	56	Wnter, Spring, Summer
Conductivity	459	-	310	415	612	1015	404	20	216	452.5	1079			
pH	7.27	-	8.3	10.48	7.73	9	8.52	20	6.72	7.98	10.48	2	10	Spring, Summer
Temperature	19.5	-	22.2	20.4	20.4	21.3	21.8	20	0.1	20.2	22.2			
Conventional Variables														
Alkalinity, Total (as CaCO3)	218	155	186	247	302	334	186	22	130	253	607			
Color, True	52.9	47.4	67.7	55.5	76	11.8	93.7	22	9.9	59.45	222			
Conductivity (EC)	383	282	331	444	525	878	335	22	233	450	1080			
Dissolved Organic Carbon	21.2	22.2	22.2	44.7	26.2	23.3	31.6	20	18.6	25.6	64.6			
Hardness (as CaCO3)	208	132	174	220	283	375	178	22	116	233	541			
pH	7.38	7.46	7.87	9.89	7.73	8.7	8.1	22	7.24	8.1	9.89	1	5	Summer
Total Dissolved Solids	278	234	260	412	372	648	274	22	191	323.5	735			
Total Organic Carbon	21.5	22.4	22.6	44.8	27.5	22.1	32.1	22	19.9	25.65	666			
Total Suspended Solids	<4.0	6	6	5	5	<4.0	8	15	3	7	26	4	27	Winter, Spring
Turbidity	6.58	0.87	2.66	2.7	2.52	0.69	4.25	17	0.29	2.7	252			
General Organics														
Hydrocarbons, Recoverable (I.R.)	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	22	<1.0	<1.0	<1.0			
Naphthenic Acids	0.16	<0.10	0.38	0.54	0.57	0.69	<0.10	6	0.16	0.555	3.2			
Phenols (4AAP)	**0.0104**	**0.0115**	**0.0115**	**0.0162**	**0.0144**	**0.0083**	**0.0125**	22	0.0067	0.01095	0.362	22	100	Wnter, Spring, Summer
Major Ions														
Bicarbonate (HCO3)	266	189	227	115	368	360	228	22	52.1	259	740			
Calcium (Ca)	47.4	22.6	34.4	18	62.7	26	30.4	22	18	37.05	118			
Carbonate (CO3)	<5.0	<5.0	<5.0	91.6	<5.0	23.3	<5.0	22	8	24.2	108			
Chloride (Cl)	0.63	1.49	0.32	2.59	0.9	8.8	0.56	22	0.32	1.88	9.61	0	0	
Hydroxide (OH)	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	22	<5.0	<5.0	<5.0			
Magnesium (Mg)	22.8	18.7	21	44.9	32.4	78	26.6	22	15.8	27.75	84.5			
Potassium (K)	4.39	12.6	7.38	32.9	3.2	20	7.8	22	3.2	7.645	32.9			
Sodium (Na)	2.48	6.32	4.86	19.5	12.5	64.8	6.41	22	2.3	8.75	69.1			
Sulfate (SO4)	<0.50	<0.50	<0.50	6.33	<0.50	160	1.99	22	0.61	6.09	176			
Sulphide	<0.0020	<0.0020	0.005	0.006	0.009	0.004	0.004	22	0.0024	0.0057	3.67	17	77	Wnter, Spring, Summer
Nutrients and BOD														
Ammonia-N	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	22	0.062	0.531	5.39	3	14	Winter, Spring
Biochemical Oxygen Demand	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	22	2.2	15.4	51.8			
Nitrate (as N)	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	22	<0.071	<0.071	<0.071	0	0	
Nitrate and Nitrite as N	<0.071	<0.071	<0.071	<0.071	<0.071	<0.071	<0.071	22	<0.050	<0.050	<0.050			
Nitrite (as N)	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	22	<0.050	<0.050	<0.050	0	0	
Phosphorus, Total	0.117	0.0256	0.144	0.0985	0.0749	0.0116	0.154	22	0.0106	0.0941	2.1	14	64	Wnter, Spring, Summer
Phosphorus, Total Dissolved	0.0215	0.0085	0.116	0.0386	0.0265	0.0043	0.0868	20	0.0043	0.0647	1.96			
Total Kjeldahl Nitrogen	1.1	1.3	1.5	4.28	1.63	1.49	2.15	22	1.06	1.655	7.43	22	100	Wnter, Spring, Summer
Dissolved Metals														
Aluminum (Al)	<0.0010	<0.0010	0.003	0.001	0.001	0.001	0.004	22	0.001	0.00255	0.0206	0	0	
Antimony (Sb)	<0.00010	<0.00010	<0.00010	0.000	<0.00010	<0.00010	<0.00010	22	0.00017	0.000215	0.00026			
Arsenic (As)	0.001	0.001	0.001	0.005	0.001	0.001	0.003	22	0.00038	0.001045	0.023	1	5	Winter
Barium (Ba)	0.076	0.045	0.043	0.047	0.081	0.022	0.036	22	0.0209	0.04705	0.249			
Beryllium (Be)	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	22	<0.00050	<0.00050	<0.00050			
Bismuth (Bi)	-	-	-	-	-	-	-	15	0.013	0.013	0.013			
Boron (B)	0.015	0.013	0.021	0.063	0.026	0.119	<0.010	22	0.0094	0.0225	0.119	0	0	
Cadmium (Cd)	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	22	0.107	0.107	0.107	0	0	
Chromium (Cr)	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	22	0.00015	0.00016	0.00041	0	0	
Cobalt (Co)	0.0003	<0.00010	0.0001	0.0002	<0.00010	<0.00010	0.0002	22	0.00013	0.00022	0.007			

Table A2.1 (Cont'd.)

Water Quality Variable	Summer 2013													Seasons Where Frequencies Were Observed
	SG4-2	LC11-1	SG2-3	REL-1	LG2-2	GAL-2	SC1-1	n	Min	Med	Max	# Exceeded	Freq %	
Copper (Cu)	<0.00010	<0.00010	<0.00010	0.0006	0.0001	<0.00010	0.0002	22	0.00011	0.0002	0.00058	0	0	
Iron (Fe)	0.1850	0.0250	0.0620	-	0.0530	<0.010	0.2160	19	0.011	0.062	57.8	5	26	Wnter, Spring, Summer
Lead (Pb)	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	22	0	<0.000050	0	0	0	
Lithium (Li)	0.0056	0.0110	0.0118	0.0391	0.0165	0.0614	0.0125	22	0.0055	0.01245	0.0614			
Manganese (Mn)	0.4540	0.0020	0.0451	-	0.0023	0.0002	0.0501	19	0.000233	0.3745	5.88			
Molybdenum (Mo)	0.0001	0.0001	0.0002	0.0026	0.0002	0.0001	0.0002	19	0.000054	0.000224	0.00256	0	0	
Nickel (Ni)	0.0008	<0.00010	0.0006	0.0006	0.0006	0.0001	0.0008	17	0.00013	0.00061	0.00348	0	0	
Selenium (Se)	<0.00010	<0.00010	<0.00010	0.0002	<0.00010	<0.00010	<0.00010	5	0.00012	0.00019	0.00042	0	0	
Silver (Ag)	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	0	0	<0.000010	0	0	0	
Strontium (Sr)	-	-	-	-	-	-	-	15	0.0724	0.127	0.355			
Thallium (Tl)	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	0	0	<0.000050	0	0	0	
Tin (Sn)	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	3	0.00012	0.00018	0.00127			
Titanium (Ti)	<0.00030	<0.00030	<0.00030	0.000	<0.00030	<0.00030	<0.00030	5	0.00032	0.00045	0.00177			
Uranium (U)	0.000	0.000	0.000	0.002	0.000	0.001	0.000	19	0.000011	0.000256	0.00169	0	0	
Vanadium (V)	<0.00010	<0.00010	0.000	0.005	<0.00010	0.000	0.000	13	0.00015	0.00026	0.00468			
Zinc (Zn)	0.002	0.001	0.002	<0.0050	0.002	<0.0010	0.004	13	0.001	0.0016	0.0039	0	0	
Total Metals														
Aluminum (Al)	0.005	0.010	0.021	0.018	0.006	0.003	0.113	20	0.0031	0.01125	0.113	1	5	Summer
Antimony (Sb)	<0.00010	<0.00010	<0.00010	0.000	<0.00010	<0.00010	<0.00010	5	0.0001	0.00012	0.00027			
Arsenic (As)	0.001	0.000	0.001	0.004	0.001	0.001	0.003	22	0.00041	0.00121	0.0212	1	5	Winter
Barium (Ba)	0.0809	0.0435	0.0473	0.0469	0.0951	0.0212	0.0424	22	0.0212	0.0589	0.228			
Beryllium (Be)	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	0	0	<0.00050	0			
Bismuth (Bi)	-	-	-	-	-	-	-	0	0	<0.000050	0			
Boron (B)	0.020	0.016	0.027	0.059	0.033	0.127	<0.010	21	0.012	0.023	0.145	0	0	
Cadmium (Cd)	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	0	<0.000010	<0.000010	<0.000010			
Chromium (Cr)	<0.00010	<0.00010	0.000	<0.00010	0.000	<0.00010	0.000	13	0.00011	0.00022	0.00043	0	0	
Cobalt (Co)	0.001	<0.00010	0.000	0.000	0.000	<0.00010	0.000	15	0.00011	0.00033	0.00705			
Copper (Cu)	0.000	0.000	0.000	0.001	0.000	0.000	0.001	22	0.00012	0.000425	0.00106			
Iron (Fe)	-	-	-	-	-	-	-	15	0.026	0.9175	56.8	9	60	Winter, Spring
Lead (Pb)	<0.000050	<0.000050	<0.000050	0.000089	<0.000050	<0.000050	0.000107	22	0.000058	0.000089	0.000107			
Lithium (Li)	0.0068	0.0117	0.0129	0.0325	0.016	0.0648	0.0129	20	0.0068	0.01555	0.0711			
Manganese (Mn)	-	-	-	-	-	-	-	15	0.0049	0.354	7.23			
Mercury (Hg)-Trace	<0.0025	<0.0025	<0.0025	<0.0025	<0.0025	<0.0025	<0.0025	19	<0.0025	<0.0025	<0.0025	0	0	
Molybdenum (Mo)	0.000	0.000	0.000	0.003	0.000	0.000	0.000	22	0.000063	0.000218	0.0026	0	0	
Nickel (Ni)	0.001	<0.00010	0.001	0.001	0.001	0.000	0.001	22	0.00011	0.00063	0.00345			
Selenium (Se)	0.000	<0.00010	<0.00010	0.000	0.000	<0.00010	<0.00010	22	0.0001	0.00012	0.00025	0	0	
Silver (Ag)	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	22	<0.000010	<0.000010	<0.000010	0	0	
Strontium (Sr)	-	-	-	-	-	-	-	15	0.0725	0.126	0.353			
Thallium (Tl)	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	22	<0.000050	<0.000050	<0.000050	0	0	
Tin (Sn)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	22	0.00018	0.00021	0.00024			
Titanium (Ti)	<0.00030	0.000	0.001	0.001	<0.00030	<0.00030	0.005	2	0.00038	0.00087	0.00475			
Uranium (U)	0.000	0.000	0.000	0.002	0.000	0.001	0.000	22	0.000012	0.0002775	0.00157	0	0	
Vanadium (V)	0.000	0.000	0.001	0.005	0.000	0.000	0.001	22	0.00014	0.00039	0.00489			
Zinc (Zn)	<0.0050	0.005	<0.0050	<0.0050	<0.0050	<0.0050	0.030	22	0.0031	0.00625	0.0321	2	9	Winter, Summer

General Notes:

Guidelines are CCME (2007), AENV (1999) unless otherwise noted

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

Detection limit exceeds guideline

* Detection limit used for winter and spring data

** Detection limit used for fall data only

*** Guidelines for dissolved metals are the guidelines for total metals.

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

B CCME short- and long-term guidelines respectively

C USEPA guideline for continuous concentration (USEPA 1999)

D CCME Guidelines for Ammonia – Total are based on temperature and pH as follows.

Temp (°C)	pH								
	6	6.5	7	7.5	8	8.5	9	8	10
0	231	73	23.1	7.32	2.33	0.749	0.25	7	0.042
5	153	48.3	15.3	4.84	1.54	0.502	0.172	5	0.034
10	102	32.4	10.3	3.26	1.04	0.343	0.121	3	0.029

E CCME cadmium guideline is hardness dependent = $10^{\{0.86[\log(\text{hardness})]-3.2\}}$

F CCME copper guideline is hardness dependent = $0.2*e^{0.8545[\ln(\text{hardness})]-1.465}$

G CCME lead guideline is hardness dependent: $e^{1.273[\ln(\text{hardness})]-4.705}$

H CCME nickel guideline is hardness dependent: = $e^{0.76[\ln(\text{hardness})]+1.06}$

I Draft AENV guidelines for chronic (5) and acute (13) total mercury concentrations.

J There is no guideline for TKN. The listed guideline is the guideline for total nitrogen applied to TKN.

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

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

Appendix A3

Aquatic Habitat Information

Referencing Information

Site Code:	**LC11-1**		
Date Assessed:	17 Jun 2013	8 Aug 2013	21 Mar 2013
Time Assessed:	16:45	15:40	14:55
UTM (NAD83, Zone 12):	530502E, 5998571N		
Access:	Truck/Argo		

Seasonal Information

	Spring	Summer	Fall	Winter
Temperature (°C):	21.9	-	-	0.3
Dissolved Oxygen (mg/L):	5.2	-	-	1.3
pH:	7.98	-	-	7.11
Conductivity (µS/cm):	216	-	-	634
Wetted Width (m):	-	-	-	-
Average Depth (m):	-	-	-	>1.5

Physical Description of Reach

Channel Width (m):	-	-	-	-
Channel Slope:	-	-	-	-
Stream Bank Slope	-	-	-	-
Stream Bank Slope	-	-	-	-
Substrate				
Composition - Organics:	√	-	-	-
Composition - Fines:	√	-	-	-
Composition - Sand:	-	-	-	-
Composition - Gravel:	-	-	-	-
Composition - Boulder:	-	-	-	-
Instream cover (presence/ absence)				
Small Woody Debris:	-	-	-	-
Large Woody Debris:	-	-	-	-
Detritus:	-	-	-	-
Substrate:	-	-	-	-
Undercut Banks:	-	-	-	-
Instream vegetation:	-	-	-	-
Overhead cover (presence/ absence)				
Undercut banks:	-	-	-	-
Overhanging trees:	-	-	-	-
Overhanging grasses:	-	-	-	-
Overhanging shrubs:	-	-	-	-
Overhead litter >150 mm:	-	-	-	-
Overhead litter <150 mm:	-	-	-	-
Riparian Vegetation:	Grasses, sedges shrubs/willows			

Channel Morphology 0 m US

Dominant Bed Material:	-
Sub-Dominant Bed Material:	-
Morphology:	-
Pattern:	-
Islands/Bars:	-

Notes

Lake is almost entirely emergent vegetation with a small area of open water. No defined inlet or outlet was observed.

LC11-1 open water, June 17, 2013

LC11-1, June 17, 2013

LC11-1, August 8, 2013

LC11-1, March 21, 2013

Referencing Information

Site Code:	**LC11-2**			
Date Assessed:	18 Jun 2013	7 Aug 2013	-	21 Mar 2013
Time Assessed:	16:15	12:20	-	12:30
UTM (NAD83, Zone 12):	532157E, 5997939N			
Access:	Truck/Argo			

Seasonal Information

	Spring	Summer	Fall	Winter
Temperature (°C):	-	19.7	-	0.3
Dissolved Oxygen (mg/L):	-	3.5	-	1.8
pH:	-	7.35	-	6.80
Conductivity (µS/cm):	-	264	-	383
Wetted Width (m):	-	-	-	-
Average Depth (m):	-	-	-	0.3

Physical Description of Reach

Channel Width (m):	-	-	-	-
Channel Slope:	-	-	-	-
Stream Bank Slope (LDB):	-	-	-	-
Stream Bank Slope (RDB):	-	-	-	-
Substrate				
Composition - Organics:	-	√	-	√
Composition - Fines:	-	-	-	-
Composition - Sand:	-	-	-	-
Composition - Gravel:	-	-	-	-
Composition - Boulder:	-	-	-	-
Instream cover (presence/ absence)				
Small Woody Debris:	-	-	-	-
Large Woody Debris:	-	-	-	-
Detritus:	-	-	-	-
Substrate:	-	-	-	-
Undercut Banks:	-	-	-	-
Instream vegetation:	-	-	-	-
Overhead cover (presence/ absence)				
Undercut banks:	-	-	-	-
Overhanging trees:	-	-	-	-
Overhanging grasses:	-	-	-	-
Overhanging shrubs:	-	-	-	-
Overhead litter >150 mm:	-	-	-	-
Overhead litter <150 mm:	-	-	-	-
Riparian Vegetation:	Shrubs, sedges, grasses, mixed forest			

Channel Morphology 0 m US

Dominant Bed Material:	-
Sub-Dominant Bed Material:	-
Morphology:	-
Pattern:	-
Islands:	-

Notes

Lake only has small area of open water within a wetland. Water depth prevented access for water sampling in June 2013.

LC11-2, June 18, 2013

LC11-2, August 7, 2013

LC11-2, August 7, 2013

LC11-2, March 21, 2013

Referencing Information

Site Code:	**REL-1**			
Date Assessed:	18 Jun 2013	7 Aug 2013	-	21 Mar 2013
Time Assessed:	12:10	16:20	-	11:15
UTM (NAD83, Zone 12):	535404E, 5998348N			
Access:	Truck/Argo			

Seasonal Information

	Spring	Summer	Fall	Winter
Temperature (°C):	21.1	20.4	-	-
Dissolved Oxygen (mg/L):	7.4	-	-	-
pH:	8.56	10.48	-	-
Conductivity (µS/cm):	481	415	-	-
Wetted Width (m):	-	-	-	-
Average Depth (m):	-	0.4	-	-

Physical Description of Reach

Channel Width (m):	-	-	-	-
Channel Slope:	-	-	-	-
Stream Bank Slope	-	-	-	-
Stream Bank Slope	-	-	-	-
Substrate				
Composition - Organics:	-	-	-	-
Composition - Fines:	√	√	-	-
Composition - Sand:	-	√	-	-
Composition - Gravel:	-	√	-	-
Composition - Boulder:	-	√	-	-
Instream cover (presence/ absence)				
Small Woody Debris:	-	-	-	-
Large Woody Debris:	-	-	-	-
Detritus:	-	-	-	-
Substrate:	-	-	-	-
Undercut Banks:	-	-	-	-
Instream vegetation:	-	-	-	-
Overhead cover (presence/ absence)				
Undercut banks:	-	-	-	-
Overhanging trees:	-	-	-	-
Overhanging grasses:	-	-	-	-
Overhanging shrubs:	-	-	-	-
Overhead litter >150 mm:	-	-	-	-
Overhead litter <150 mm:	-	-	-	-
Riparian Vegetation:	Grasses, sedges, shrubs/willows			

Channel Morphology 0 m US

Dominant Bed Material:	-
Sub-Dominant Bed Material:	-
Morphology:	-
Pattern:	-
Islands/Bars:	-

Notes

Shallow littoral zone with abundant macrophytes. Lake has receded in recent times and former lake bed is now grassland with cattle grazing. Creek flowing into lake had no defined channel.

Reita Lake/REL-1, June 18, 2013

Reita Lake/REL-1, August 7, 2013

Macrophyte cover on Reita Lake/ REL-1, August 7, 2013

Referencing Information

Site Code:	**SC1-4**			
Date Assessed:	17 Jun 2013	8 Aug 2013	-	21 Mar 2013
Time Assessed:	15:55	16:00	-	15:35
UTM (NAD83, Zone 12):	530061E, 5999690N			
Access:	Truck/Argo			

Seasonal Information

	Spring	Summer	Fall	Winter
Temperature (°C):	-	-	-	-
Dissolved Oxygen (mg/L):	-	-	-	-
pH:	-	-	-	-
Conductivity (µS/cm):	-	-	-	-
Wetted Width (m):	-	-	-	-
Average Depth (m):	-	-	-	-

Physical Description of Reach

Channel Width (m):	-	-	-	-
Channel Slope:	-	-	-	-
Stream Bank Slope (LDB):	-	-	-	-
Stream Bank Slope (RDB):	-	-	-	-
Substrate				
Composition - Organics:	-	-	-	-
Composition - Fines:	-	-	-	-
Composition - Sand:	-	-	-	-
Composition - Gravel:	-	-	-	-
Composition - Boulder:	-	-	-	-
Instream cover (presence/ absence)				
Small Woody Debris:	-	-	-	-
Large Woody Debris:	-	-	-	-
Detritus:	-	-	-	-
Substrate:	-	-	-	-
Undercut Banks:	-	-	-	-
Instream vegetation:	-	-	-	-
Overhead cover (presence/ absence)				
Undercut banks:	-	-	-	-
Overhanging trees:	-	-	-	-
Overhanging grasses:	-	-	-	-
Overhanging shrubs:	-	-	-	-
Overhead litter >150 mm:	-	-	-	-
Overhead litter <150 mm:	-	-	-	-
Riparian Vegetation:	-			

Channel Morphology 0 m US

Dominant Bed Material:	-
Sub-Dominant Bed Material:	-
Morphology:	-
Pattern:	-
Islands/Bars:	-

Notes

No water or defined channel at assessment location. Defined channel was found along other portions of the watercourse. Flow is intermittent along most of the watercourse.

SC1-4, June 17, 2013

SC1-4, August 8, 2013

SC1-4, March 21, 2013

Referencing Information

Site Code:	**SC1-3**			
Date Assessed:	17 Jun 2013	9 Aug 2013	-	21 Mar 2013
Time Assessed:	15:40	8:00	-	15:53
UTM (NAD83, Zone 12):	528848E, 5998851N			
Access:	Truck			

Seasonal Information

	Spring	Summer	Fall	Winter
Temperature (°C):	-	-	-	-
Dissolved Oxygen (mg/L):	-	-	-	-
pH:	-	-	-	-
Conductivity (µS/cm):	-	-	-	-
Wetted Width (m):	-	-	-	-
Average Depth (m):	-	-	-	-

Physical Description of Reach

Channel Width (m):	-	-	-	-
Channel Slope:	-	-	-	-
Stream Bank Slope (LDB):	-	-	-	-
Stream Bank Slope (RDB):	-	-	-	-
Substrate				
Composition - Organics:	-	-	-	-
Composition - Fines:	-	-	-	-
Composition - Sand:	-	-	-	-
Composition - Gravel:	-	-	-	-
Composition - Boulder:	-	-	-	-
Instream cover (presence/ absence)				
Small Woody Debris:	-	-	-	-
Large Woody Debris:	-	-	-	-
Detritus:	-	-	-	-
Substrate:	-	-	-	-
Undercut Banks:	-	-	-	-
Instream vegetation:	-	-	-	-
Overhead cover (presence/ absence)				
Undercut banks:	-	-	-	-
Overhanging trees:	-	-	-	-
Overhanging grasses:	-	-	-	-
Overhanging shrubs:	-	-	-	-
Overhead litter >150 mm:	-	-	-	-
Overhead litter <150 mm:	-	-	-	-
Riparian Vegetation:			-	

Channel Morphology 0 m US

Dominant Bed Material:	-
Sub-Dominant Bed Material:	-
Morphology:	-
Pattern:	-
Islands/Bars:	-

Notes

No well defined channel. No flowing water during assessments.

SC1-3, June 17, 2013

SC1-3, August 9, 2013

SC1-3, March 21, 2013

Referencing Information

Site Code:	**SG2-3**			
Date Assessed:	18 Jun 2013	7 Aug 2013	-	21 Mar 2013
Time Assessed:	12:55	16:08	-	10:25
UTM (NAD83, Zone 12):	533159E, 5996415N			
Access:	Truck/Argo			

Seasonal Information

	Spring	Summer	Fall	Winter
Temperature (°C):	21.4	22.2	-	-
Dissolved Oxygen (mg/L):	5.2	6.1	-	-
pH:	8.15	8.30	-	-
Conductivity (µS/cm):	270	310	-	-
Wetted Width (m):	-	-	-	-
Average Depth (m):	-	-	-	-

Physical Description of Reach

Channel Width (m):	-	-	-	-
Channel Slope:	-	-	-	-
Stream Bank Slope (LDB):	-	-	-	-
Stream Bank Slope (RDB):	-	-	-	-
Substrate				
Composition - Organics:	√	√	-	√
Composition - Fines:	-	-	-	-
Composition - Sand:	√	-	-	-
Composition - Gravel:	√	-	-	-
Composition - Boulder:	-	-	-	-
Instream cover (presence/ absence)				
Small Woody Debris:	-	-	-	-
Large Woody Debris:	-	-	-	-
Detritus:	-	-	-	-
Substrate:	-	-	-	-
Undercut Banks:	-	-	-	-
Instream vegetation:	-	-	-	-
Overhead cover (presence/ absence)				
Undercut banks:	-	-	-	-
Overhanging trees:	-	-	-	-
Overhanging grasses:	-	-	-	-
Overhanging shrubs:	-	-	-	-
Overhead litter >150 mm:	-	-	-	-
Overhead litter <150 mm:	-	-	-	-
Riparian Vegetation:	Shrubs, sedges, grasses, mixed forest			

Channel Morphology 0 m US

Dominant Bed Material:	-
Sub-Dominant Bed Material:	-
Morphology:	-
Pattern:	-
Islands/Bars:	-

Notes

Site is beaver impoundment. No sufficient water flowing at outlet. Winter water depth not sufficient for sampling.

SG2-3, June 18, 2013

SG2-3, August 7, 2013

SG2-3, March 21, 2013

Referencing Information

Site Code:	**TRL1-1**			
Date Assessed:	18 Jun 2013	7 Aug 2013	-	21 Mar 2013
Time Assessed:	12:35	15:20	-	10:50
UTM (NAD83, Zone 12):	535260E, 5996788N			
Access:	Truck/Argo			

Seasonal Information

	Spring	Summer	Fall	Winter
Temperature (°C):	21.4	-	-	-
Dissolved Oxygen (mg/L):	5.2	-	-	-
pH:	8.15	-	-	-
Conductivity (µS/cm):	270	-	-	-
Wetted Width (m):	-	-	-	-
Average Depth (m):	-	-	-	-

Physical Description of Reach

Channel Width (m):	-	-	-	-
Channel Slope:	-	-	-	-
Stream Bank Slope (LDB):	-	-	-	-
Stream Bank Slope (RDB):	-	-	-	-
Substrate				
Composition - Organics:	-	-	-	-
Composition - Fines:	-	-	-	-
Composition - Sand:	-	-	-	-
Composition - Gravel:	-	-	-	-
Composition - Boulder:	-	-	-	-
Instream cover (presence/ absence)				
Small Woody Debris:	-	-	-	-
Large Woody Debris:	-	-	-	-
Detritus:	-	-	-	-
Substrate:	-	-	-	-
Undercut Banks:	-	-	-	-
Instream vegetation:	-	-	-	-
Overhead cover (presence/ absence)				
Undercut banks:	-	-	-	-
Overhanging trees:	-	-	-	-
Overhanging grasses:	-	-	-	-
Overhanging shrubs:	-	-	-	-
Overhead litter >150 mm:	-	-	-	-
Overhead litter <150 mm:	-	-	-	-
Riparian Vegetation:	-			

Channel Morphology 0 m US

Dominant Bed Material:	-
Sub-Dominant Bed Material:	-
Morphology:	-
Pattern:	-
Islands/Bars:	-

Notes

No channel present, site is a wetland. No defined channel present. No water was found during winter sampling.

TRL1-1, June 18, 2013

TRL1-1, August 7, 2013

TRL1-1, March 21, 2013

Referencing Information

Site Code:	**LG2-2**			
Date Assessed:	18 Jun 2013	7 Aug 2013	-	20 Mar 2013
Time Assessed:	15:00	14:20	-	12:35
UTM (NAD83, Zone 12):	529087E, 5995125N			
Access:	Truck/Argo			

Seasonal Information

	Spring	Summer	Fall	Winter
Temperature (°C):	21.0	20.4	-	0.5
Dissolved Oxygen (mg/L):	3.6	2.5	-	-
pH:	7.86	7.73	-	7.46
Conductivity (µS/cm):	423	612	-	828
Wetted Width (m):	-	-	-	-
Average Depth (m):	-	>1.5	-	>1.5

Physical Description of Reach

Channel Width (m):	-	-	-	-
Channel Slope:	-	-	-	-
Stream Bank Slope (LDB):	-	-	-	-
Stream Bank Slope (RDB):	-	-	-	-
Substrate				
Composition - Organics:	√	√	-	√
Composition - Fines:	√	√	-	-
Composition - Sand:	-	-	-	-
Composition - Gravel:	-	-	-	-
Composition - Boulder:	-	-	-	-
Instream cover (presence/ absence)				
Small Woody Debris:	-	-	-	-
Large Woody Debris:	-	-	-	-
Detritus:	-	-	-	-
Substrate:	-	-	-	-
Undercut Banks:	-	-	-	-
Instream vegetation:	-	-	-	-
Overhead cover (presence/ absence)				
Undercut banks:	-	-	-	-
Overhanging trees:	-	-	-	-
Overhanging grasses:	-	-	-	-
Overhanging shrubs:	-	-	-	-
Overhead litter >150 mm:	-	-	-	-
Overhead litter <150 mm:	-	-	-	-
Riparian Vegetation:	Shrubs, sedges, grasses, mixed forest			

Channel Morphology 0 m US

Dominant Bed Material:	-
Sub-Dominant Bed Material:	-
Morphology:	-
Pattern:	-
Islands/Bars:	-

Notes

Beaver pond at assessment location. Defined channel upstream and downstream is meandering with no observable flow.

LG2-2-open water, June 18, 2013

LG2-2 open water, August 7, 2013

LG2-2, March 20, 2013

Referencing Information

Site Code:	**LG2-1**			
Date Assessed:	18 Jun 2013	8 Aug 2013	-	20 Mar 2013
Time Assessed:	-	11:45	-	11:03
UTM (NAD83, Zone 12):	528562E, 5994485N			
Access:	Truck/Argo			

Seasonal Information

	Spring	Summer	Fall	Winter
Temperature (°C):	-	20.0	-	0.4
Dissolved Oxygen (mg/L):	-	4.8	-	-
pH:	-	7.70	-	7.24
Conductivity (µS/cm):	-	478	-	2075
Wetted Width (m):	-	-	-	-
Average Depth (m):	-	-	-	-

Physical Description of Reach

Channel Width (m):	-	-	-	-
Channel Slope:	-	-	-	-
Stream Bank Slope (LDB):	-	-	-	-
Stream Bank Slope (RDB):	-	-	-	-
Substrate				
Composition - Organics:	-	-	-	-
Composition - Fines:	-	-	-	-
Composition - Sand:	-	-	-	-
Composition - Gravel:	-	-	-	-
Composition - Boulder:	-	-	-	-
Instream cover (presence/ absence)				
Small Woody Debris:	-	-	-	-
Large Woody Debris:	-	-	-	-
Detritus:	-	-	-	-
Substrate:	-	-	-	-
Undercut Banks:	-	-	-	-
Instream vegetation:	-	-	-	-
Overhead cover (presence/ absence)				
Undercut banks:	-	-	-	-
Overhanging trees:	-	-	-	-
Overhanging grasses:	-	-	-	-
Overhanging shrubs:	-	-	-	-
Overhead litter >150 mm:	-	-	-	-
Overhead litter <150 mm:	-	-	-	-
Riparian Vegetation:	Shrubs, sedges, grasses, mixed forest			

Channel Morphology 0 m US

Dominant Bed Material:	-
Sub-Dominant Bed Material:	-
Morphology:	-
Pattern:	-
Islands/Bars:	-

Notes

Series of beaver ponds with meandering channels, often poorly defined. No visible flow at the times of assessment.

LG2-1 wetland, August 8, 2013

LG2-1 wetland, August 8, 2013

Referencing Information

Site Code:	**SC2-1**			
Date Assessed:	17 Jun 2013	7 Aug 2013	-	18 Mar 2013
Time Assessed:	15:15	15:00	-	19:10
UTM (NAD83, Zone 12):	528198E, 6000186N			
Access:	Truck			

Seasonal Information

	Spring	Summer	Fall	Winter
Temperature (°C):	-	-	-	-
Dissolved Oxygen (mg/L):	-	-	-	-
pH:	-	-	-	-
Conductivity (µS/cm):	-	-	-	-
Wetted Width (m):	-	-	-	-
Average Depth (m):	-	-	-	-

Physical Description of Reach

Channel Width (m):	-	-	-	-
Channel Slope:	-	-	-	-
Stream Bank Slope (LDB):	-	-	-	-
Stream Bank Slope (RDB):	-	-	-	-
Substrate				
Composition - Organics:	-	-	-	-
Composition - Fines:	-	-	-	-
Composition - Sand:	-	-	-	-
Composition - Gravel:	-	-	-	-
Composition - Boulder:	-	-	-	-
Instream cover (presence/ absence)				
Small Woody Debris:	-	-	-	-
Large Woody Debris:	-	-	-	-
Detritus:	-	-	-	-
Substrate:	-	-	-	-
Undercut Banks:	-	-	-	-
Instream vegetation:	-	-	-	-
Overhead cover (presence/ absence)				
Undercut banks:	-	-	-	-
Overhanging trees:	-	-	-	-
Overhanging grasses:	-	-	-	-
Overhanging shrubs:	-	-	-	-
Overhead litter >150 mm:	-	-	-	-
Overhead litter <150 mm:	-	-	-	-
Riparian Vegetation:	-			

Channel Morphology 0 m US

Dominant Bed Material:	-
Sub-Dominant Bed Material:	-
Morphology:	-
Pattern:	-
Islands/Bars:	-

Notes

No defined channel or water present at site.

SC2-1, June 17, 2013

SC2-1, August 7, 2013

SC2-1, March 18, 2013

Referencing Information

Site Code:	**SC1-2**			
Date Assessed:	17 Jun 2013	7 Aug 2013	-	18 Mar 2013
Time Assessed:	14:20	15:30	-	18:30
UTM (NAD83, Zone 12):	526863E, 5996781N			
Access:	Truck/Argo			

Seasonal Information

	Spring	Summer	Fall	Winter
Temperature (°C):	-	-	-	-
Dissolved Oxygen (mg/L):	-	-	-	-
pH:	-	-	-	-
Conductivity (µS/cm):	-	-	-	-
Wetted Width (m):	-	-	-	-
Average Depth (m):	-	-	-	-

Physical Description of Reach

Channel Width (m):	-	-	-	-
Channel Slope:	-	-	-	-
Stream Bank Slope (LDB):	-	-	-	-
Stream Bank Slope (RDB):	-	-	-	-
Substrate				
Composition - Organics:	-	-	-	-
Composition - Fines:	-	-	-	-
Composition - Sand:	-	-	-	-
Composition - Gravel:	-	-	-	-
Composition - Boulder:	-	-	-	-
Instream cover (presence/absence)				
Small Woody Debris:	-	-	-	-
Large Woody Debris:	-	-	-	-
Detritus:	-	-	-	-
Substrate:	-	-	-	-
Undercut Banks:	-	-	-	-
Instream vegetation:	-	-	-	-
Overhead cover (presence/absence)				
Undercut banks:	-	-	-	-
Overhanging trees:	-	-	-	-
Overhanging grasses:	-	-	-	-
Overhanging shrubs:	-	-	-	-
Overhead litter >150 mm:	-	-	-	-
Overhead litter <150 mm:	-	-	-	-
Riparian Vegetation:	-			

Channel Morphology 0 m US

Dominant Bed Material:	-
Sub-Dominant Bed Material:	-
Morphology:	-
Pattern:	-
Islands/Bars:	-

Notes

Poorly defined channel. No water observed during any of the assessments.

SC2-1, June 17, 2013

SC2-1, August 7, 2013

SC2-1, March 18, 2013

Referencing Information

Site Code:	**SG2-2**			
Date Assessed:	19 Jun 2013	8 Aug 2013	-	19 Mar 2013
Time Assessed:	11:15	14:04	-	15:30
UTM (NAD83, Zone 12):	531346E, 5996858N			
Access:	Truck/Argo			

Seasonal Information

	Spring	Summer	Fall	Winter
Temperature (°C):	-	-	-	-
Dissolved Oxygen (mg/L):	-	-	-	-
pH:	-	-	-	-
Conductivity (µS/cm):	-	-	-	-
Wetted Width (m):	-	-	-	-
Average Depth (m):	-	-	-	-

Physical Description of Reach

Channel Width (m):	-	-	-	-
Channel Slope:	-	-	-	-
Stream Bank Slope (LDB):	-	-	-	-
Stream Bank Slope (RDB):	-	-	-	-
Substrate				
Composition - Organics:	-	-	-	-
Composition - Fines:	-	-	-	-
Composition - Sand:	-	-	-	-
Composition - Gravel:	-	-	-	-
Composition - Boulder:	-	-	-	-
Instream cover (presence/absence)				
Small Woody Debris:	-	-	-	-
Large Woody Debris:	-	-	-	-
Detritus:	-	-	-	-
Substrate:	-	-	-	-
Undercut Banks:	-	-	-	-
Instream vegetation:	-	-	-	-
Overhead cover (presence/absence)				
Undercut banks:	-	-	-	-
Overhanging trees:	-	-	-	-
Overhanging grasses:	-	-	-	-
Overhanging shrubs:	-	-	-	-
Overhead litter >150 mm:	-	-	-	-
Overhead litter <150 mm:	-	-	-	-
Riparian Vegetation:	-			

Channel Morphology 0 m US

Dominant Bed Material:	-
Sub-Dominant Bed Material:	-
Morphology:	-
Pattern:	-
Islands/Bars:	-

Notes

Poorly defined channel at assessment location. No water in winter. Only shallow, surface pools during open water season.

SG2-2, June 19, 2013

SG2-2, August 8, 2013

SG2-2, March 19, 2013

Referencing Information

Site Code:	**SG21-1**			
Date Assessed:	19 Jun 2013	8 Aug 2013	-	19 Mar 2013
Time Assessed:	11:26	13:22	-	13:43
UTM (NAD83, Zone 12):	533178E, 5995218N			
Access:	Truck/Argo			

Seasonal Information

	Spring	Summer	Fall	Winter
Temperature (°C):	-	-	-	-
Dissolved Oxygen (mg/L):	-	-	-	-
pH:	-	-	-	-
Conductivity (µS/cm):	-	-	-	-
Wetted Width (m):	-	-	-	-
Average Depth (m):	-	-	-	-

Physical Description of Reach

Channel Width (m):	-	-	-	-
Channel Slope:	-	-	-	-
Stream Bank Slope (LDB):	-	-	-	-
Stream Bank Slope (RDB):	-	-	-	-
Substrate				
Composition - Organics:	-	-	-	-
Composition - Fines:	-	-	-	-
Composition - Sand:	-	-	-	-
Composition - Gravel:	-	-	-	-
Composition - Boulder:	-	-	-	-
Instream cover (presence/absence)				
Small Woody Debris:	-	-	-	-
Large Woody Debris:	-	-	-	-
Detritus:	-	-	-	-
Substrate:	-	-	-	-
Undercut Banks:	-	-	-	-
Instream vegetation:	-	-	-	-
Overhead cover (presence/absence)				
Undercut banks:	-	-	-	-
Overhanging trees:	-	-	-	-
Overhanging grasses:	-	-	-	-
Overhanging shrubs:	-	-	-	-
Overhead litter >150 mm:	-	-	-	-
Overhead litter <150 mm:	-	-	-	-
Riparian Vegetation:			-	

Channel Morphology 0 m US

Dominant Bed Material:	-
Sub-Dominant Bed Material:	-
Morphology:	-
Pattern:	-
Islands/Bars:	-

Notes

No defined channel. Culvert under cutline has insufficient flow for sampling, leads to small pond with beaver dam downstream. Other surrounding area is marsh. No water was found in winter season.

SG21-1, June 19, 2013

Small beaver pond at SG21-1, August 8, 2013

Culvert under cutline at SG21-1, August 8, 2013

Culvert under cutline, SG21-1, August 8, 2013

Referencing Information

Site Code:	**SG4-4**			
Date Assessed:	19 Jun 2013	8 Aug 2013	-	19 Mar 2013
Time Assessed:	11:40	11:32	-	13:20
UTM (NAD83, Zone 12):	531470E, 5993295N			
Access:	Truck/Argo			

Seasonal Information

	Spring	Summer	Fall	Winter
Temperature (°C):	-	-	-	-
Dissolved Oxygen (mg/L):	-	-	-	-
pH:	-	-	-	-
Conductivity (µS/cm):	-	-	-	-
Wetted Width (m):	-	-	-	-
Average Depth (m):	-	-	-	-

Physical Description of Reach

Channel Width (m):	-	-	-	-
Channel Slope:	-	-	-	-
Stream Bank Slope (LDB):	-	-	-	-
Stream Bank Slope (RDB):	-	-	-	-
Substrate				
Composition - Organics:	-	-	-	-
Composition - Fines:	-	-	-	-
Composition - Sand:	-	-	-	-
Composition - Gravel:	-	-	-	-
Composition - Boulder:	-	-	-	-
Instream cover (presence/absence)				
Small Woody Debris:	-	-	-	-
Large Woody Debris:	-	-	-	-
Detritus:	-	-	-	-
Substrate:	-	-	-	-
Undercut Banks:	-	-	-	-
Instream vegetation:	-	-	-	-
Overhead cover (presence/absence)				
Undercut banks:	-	-	-	-
Overhanging trees:	-	-	-	-
Overhanging grasses:	-	-	-	-
Overhanging shrubs:	-	-	-	-
Overhead litter >150 mm:	-	-	-	-
Overhead litter <150 mm:	-	-	-	-
Riparian Vegetation:	-			

Channel Morphology 0 m US

Dominant Bed Material:	-
Sub-Dominant Bed Material:	-
Morphology:	-
Pattern:	-
Islands/Bars:	-

Notes

No defined channel or water present at site or culvert.

Culvert at SG4-4, June 19, 2013

Culvert at SG4-4, August 8, 2013

SG4-4, March 19, 2013

Referencing Information

Site Code:	**SG4-2**			
Date Assessed:	19 Jun 2013	8 Aug 2013	-	19 Mar 2013
Time Assessed:	12:15	9:10	-	12:25
UTM (NAD83, Zone 12):	528583E, 5991829N			
Access:	Truck/Argo			

Seasonal Information

	Spring	Summer	Fall	Winter
Temperature (°C):	19.0	19.5	-	-
Dissolved Oxygen (mg/L):	4.4	3.1	-	-
pH:	7.35	7.27	-	-
Conductivity (µS/cm):	306	459	-	-
Wetted Width (m):	-	-	-	-
Average Depth (m):	-	-	-	-

Physical Description of Reach

Channel Width (m):	-	-	-	-
Channel Slope:	-	-	-	-
Stream Bank Slope (LDB):	-	-	-	-
Stream Bank Slope (RDB):	-	-	-	-
Substrate				
Composition - Organics:	√	√	-	-
Composition - Fines:	-	-	-	-
Composition - Sand:	-	-	-	-
Composition - Gravel:	-	-	-	-
Composition - Boulder:	-	-	-	-
Instream cover (presence/absence)				
Small Woody Debris:	-	-	-	-
Large Woody Debris:	-	-	-	-
Detritus:	-	-	-	-
Substrate:	-	-	-	-
Undercut Banks:	-	-	-	-
Instream vegetation:	-	-	-	-
Overhead cover (presence/absence)				
Undercut banks:	-	-	-	-
Overhanging trees:	-	-	-	-
Overhanging grasses:	-	-	-	-
Overhanging shrubs:	-	-	-	-
Overhead litter >150 mm:	-	-	-	-
Overhead litter <150 mm:	-	-	-	-
Riparian Vegetation:	Aquatic plants, sedges, grasses.			

Channel Morphology 0 m US

Dominant Bed Material:	-
Sub-Dominant Bed Material:	-
Morphology:	-
Pattern:	-
Islands/Bars:	-

Notes

Slow moving channel with extensive macrophyte growth along margins. Ice thickness prevented winter sampling.

SG4-2, June 19, 2013

SG4-2, August 8, 2013

SG4-2, March 19, 2013

Referencing Information

Site Code:	**SG4-3**			
Date Assessed:	19 Jun 2013	8 Aug 2013	-	19 Mar 2013
Time Assessed:	13:45	11:53	-	12:00
UTM (NAD83, Zone 12):	530172E, 5990778N			
Access:	Truck/Argo			

Seasonal Information

	Spring	Summer	Fall	Winter
Temperature (°C):	-	-	-	-
Dissolved Oxygen (mg/L):	-	-	-	-
pH:	-	-	-	-
Conductivity (µS/cm):	-	-	-	-
Wetted Width (m):	-	-	-	-
Average Depth (m):	-	-	-	-

Physical Description of Reach

Channel Width (m):	-	-	-	-
Channel Slope:	-	-	-	-
Stream Bank Slope (LDB):	-	-	-	-
Stream Bank Slope (RDB):	-	-	-	-
Substrate				
Composition - Organics:	-	-	-	-
Composition - Fines:	-	-	-	-
Composition - Sand:	-	-	-	-
Composition - Gravel:	-	-	-	-
Composition - Boulder:	-	-	-	-
Instream cover (presence/absence)				
Small Woody Debris:	-	-	-	-
Large Woody Debris:	-	-	-	-
Detritus:	-	-	-	-
Substrate:	-	-	-	-
Undercut Banks:	-	-	-	-
Instream vegetation:	-	-	-	-
Overhead cover (presence/absence)				
Undercut banks:	-	-	-	-
Overhanging trees:	-	-	-	-
Overhanging grasses:	-	-	-	-
Overhanging shrubs:	-	-	-	-
Overhead litter >150 mm:	-	-	-	-
Overhead litter <150 mm:	-	-	-	-
Riparian Vegetation:	-			

Channel Morphology 0 m US

Dominant Bed Material:	-
Sub-Dominant Bed Material:	-
Morphology:	-
Pattern:	-
Islands/Bars:	-

Notes

Poorly defined channel with seasonal flow. Only shallow, isolated pools at time of assessments.

SG4-3, June 19, 2013

SG4-3, August 8, 2013

SG4-3, March 19, 2013

Referencing Information

Site Code:	**SC1-1**			
Date Assessed:	17 Jun 2013	7 Aug 2013	-	21 Mar 2013
Time Assessed:	14:40	16:00	-	8:25
UTM (NAD83, Zone 12):	527071E, 5997554N			
Access:	Truck/Argo			

Seasonal Information

	Spring	Summer	Fall	Winter
Temperature (°C):	20.0	21.8	-	0.4
Dissolved Oxygen (mg/L):	6.8	0.6	-	-
pH:	8.35	8.52	-	7.15
Conductivity (µS/cm):	311	404	-	1059
Wetted Width (m):	-	-	-	-
Average Depth (m):	-	-	-	-

Physical Description of Reach

Channel Width (m):	-	-	-	-
Channel Slope:	-	-	-	-
Stream Bank Slope (LDB):	-	-	-	-
Stream Bank Slope (RDB):	-	-	-	-
Substrate				
Composition - Organics:	√	√	-	√
Composition - Fines:	-	-	-	√
Composition - Sand:	-	-	-	-
Composition - Gravel:	-	-	-	-
Composition - Boulder:	-	-	-	-
Instream cover (presence/absence)				
Small Woody Debris:	-	-	-	-
Large Woody Debris:	-	-	-	-
Detritus:	-	-	-	-
Substrate:	-	-	-	-
Undercut Banks:	-	-	-	-
Instream vegetation:	-	-	-	-
Overhead cover (presence/absence)				
Undercut banks:	-	-	-	-
Overhanging trees:	-	-	-	-
Overhanging grasses:	-	-	-	-
Overhanging shrubs:	-	-	-	-
Overhead litter >150 mm:	-	-	-	-
Overhead litter <150 mm:	-	-	-	-
Riparian Vegetation:	Shrubs, sedges, grasses, mixed forest			

Channel Morphology 0 m US

Dominant Bed Material:	-
Sub-Dominant Bed Material:	-
Morphology:	-
Pattern:	-
Islands/Bars:	-

Notes

Site consists of beaver pond with markers indicating buried pipe. Site is in heavy use by cattle.

Pond site at SC1-1, June 17, 2013

Pond site at SC1-1, August 7, 2013

Pond site at SC1-1, August 7, 2013

SC1-1, March 21, 2013

Referencing Information

Site Code:	**SG2-4**			
Date Assessed:	20 Jun 2013	8 Aug 2013	-	19 Mar 2013
Time Assessed:	8:45	13:00	-	14:50
UTM (NAD83, Zone 12):	533984E, 5994680N			
Access:	Truck/Argo			

Seasonal Information

	Spring	Summer	Fall	Winter
Temperature (°C):	-	-	-	-
Dissolved Oxygen (mg/L):	-	-	-	-
pH:	-	-	-	-
Conductivity (µS/cm):	-	-	-	-
Wetted Width (m):	-	-	-	-
Average Depth (m):	-	-	-	-

Physical Description of Reach

Channel Width (m):	-	-	-	-
Channel Slope:	-	-	-	-
Stream Bank Slope (LDB):	-	-	-	-
Stream Bank Slope (RDB):	-	-	-	-
Substrate				
Composition - Organics:	-	-	-	-
Composition - Fines:	-	-	-	-
Composition - Sand:	-	-	-	-
Composition - Gravel:	-	-	-	-
Composition - Boulder:	-	-	-	-
Instream cover (presence/absence)				
Small Woody Debris:	-	-	-	-
Large Woody Debris:	-	-	-	-
Detritus:	-	-	-	-
Substrate:	-	-	-	-
Undercut Banks:	-	-	-	-
Instream vegetation:	-	-	-	-
Overhead cover (presence/absence)				
Undercut banks:	-	-	-	-
Overhanging trees:	-	-	-	-
Overhanging grasses:	-	-	-	-
Overhanging shrubs:	-	-	-	-
Overhead litter >150 mm:	-	-	-	-
Overhead litter <150 mm:	-	-	-	-
Riparian Vegetation:	-			

Channel Morphology 0m US

Dominant Bed Material:	-
Sub-Dominant Bed Material:	-
Morphology:	-
Pattern:	-
Islands/Bars:	-

Notes

No defined channel. Site is a wetland.

Wetland of SG2-4, June 20, 2013

Wetland of SG2-4, August 8, 2013

Wetland of SG2-4, August 8, 2013

SG2-4, March 19, 2013

Referencing Information

Site Code:	**SG4-5**			
Date Assessed:	20 Jun 2013	8 Aug 2013	-	20 Mar 2013
Time Assessed:	13:25	12:18	-	9:05
UTM (NAD83, Zone 12):	533759E, 5991597N			
Access:	Truck/Argo			

Seasonal Information

	Spring	Summer	Fall	Winter
Temperature (°C):	-	-	-	-
Dissolved Oxygen (mg/L):	-	-	-	-
pH:	-	-	-	-
Conductivity (µS/cm):	-	-	-	-
Wetted Width (m):	-	-	-	-
Average Depth (m):	-	-	-	-

Physical Description of Reach

Channel Width (m):	-	-	-	-
Channel Slope:	-	-	-	-
Stream Bank Slope (LDB):	-	-	-	-
Stream Bank Slope (RDB):	-	-	-	-
Substrate				
Composition - Organics:	-	-	-	-
Composition - Fines:	-	-	-	-
Composition - Sand:	-	-	-	-
Composition - Gravel:	-	-	-	-
Composition - Boulder:	-	-	-	-
Instream cover (presence/absence)				
Small Woody Debris:	-	-	-	-
Large Woody Debris:	-	-	-	-
Detritus:	-	-	-	-
Substrate:	-	-	-	-
Undercut Banks:	-	-	-	-
Instream vegetation:	-	-	-	-
Overhead cover (presence/absence)				
Undercut banks:	-	-	-	-
Overhanging trees:	-	-	-	-
Overhanging grasses:	-	-	-	-
Overhanging shrubs:	-	-	-	-
Overhead litter >150 mm:	-	-	-	-
Overhead litter <150 mm:	-	-	-	-
Riparian Vegetation:	-			

Channel Morphology 0 m US

Dominant Bed Material:	-
Sub-Dominant Bed Material:	-
Morphology:	-
Pattern:	-
Islands/Bars:	-

Notes

No defined channel, site is a wetland.

SG4-5, June 20, 2013

SG4-5, June 20, 2013

SG4-5, August 8, 2013

SG4-5, March 20, 2013

Referencing Information

Site Code:	**GAL-2**			
Date Assessed:	17 Jun 2013	7 Aug 2013	-	20 Mar 2013
Time Assessed:	11:00	11:30	-	16:15
UTM (NAD83, Zone 12):	529181E, 5982602N			
Access:	Truck/Argo			

Seasonal Information

	Spring	Summer	Fall	Winter
Temperature (°C):	17.3	21.3	-	0.2
Dissolved Oxygen (mg/L):	6.7	9.0	-	5.7
pH:	9.04	9.00	-	8.66
Conductivity (µS/cm):	472	1015	-	989
Wetted Width (m):	-	-	-	-
Average Depth (m):	-	-	-	>1.5

Physical Description of Reach

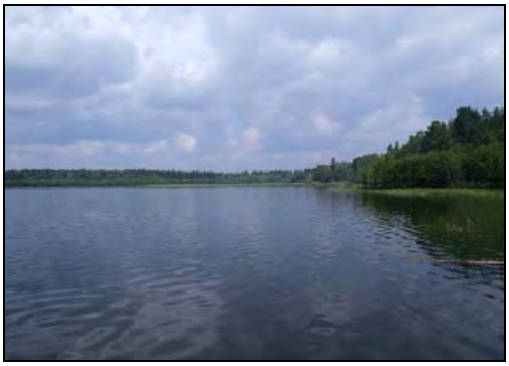
Channel Width (m):	-	-	-	-
Channel Slope:	-	-	-	-
Stream Bank Slope (LDB):	-	-	-	-
Stream Bank Slope (RDB):	-	-	-	-
Substrate				
Composition - Organics:	-	-	-	-
Composition - Fines:	√	√	-	√
Composition - Sand:	-	-	-	-
Composition - Gravel:	-	-	-	-
Composition - Boulder:	-	-	-	-
Instream cover (presence/absence)				
Small Woody Debris:	-	-	-	-
Large Woody Debris:	-	-	-	-
Detritus:	-	-	-	-
Substrate:	-	-	-	-
Undercut Banks:	-	-	-	-
Instream vegetation:	-	-	-	-
Overhead cover (presence/absence)				
Undercut banks:	-	-	-	-
Overhanging trees:	-	-	-	-
Overhanging grasses:	-	-	-	-
Overhanging shrubs:	-	-	-	-
Overhead litter >150 mm:	-	-	-	-
Overhead litter <150 mm:	-	-	-	-
Riparian Vegetation:			-	

Channel Morphology 0 m US

Dominant Bed Material:	-
Sub-Dominant Bed Material:	-
Morphology:	-
Pattern:	-
Islands/Bars:	-

Notes

Garnier Lake/GAL-2, June 17, 2013



Garnier Lake/GAL-2, June 17, 2013

Garnier Lake/GAL-2, August 7, 2013

Garnier Lake/GAL-2, March 20, 2013

Referencing Information

Site Code:	**GAC-4**			
Date Assessed:	17 Jun 2013	7 Aug 2013	-	20 Mar 2013
Time Assessed:	12:50	8:45	-	15:30
UTM (NAD83, Zone 12):	527765E, 5983546N			
Access:	Truck/Argo			

Seasonal Information

	Spring	Summer	Fall	Winter
Temperature (°C):	17.0	17.2	-	0.1
Dissolved Oxygen (mg/L):	6.2	0.5	-	-
pH:	7.56	7.40	-	6.72
Conductivity (µS/cm):	446	660	-	1079
Wetted Width (m):	-	-	-	-
Average Depth (m):	-	-	-	-

Physical Description of Reach

Channel Width (m):	-	-	-	-
Channel Slope:	-	-	-	-
Stream Bank Slope (LDB):	-	-	-	-
Stream Bank Slope (RDB):	-	-	-	-
Substrate				
Composition - Organics:	√	√	-	√
Composition - Fines:	-	√	-	-
Composition - Sand:	-	-	-	-
Composition - Gravel:	-	-	-	-
Composition - Boulder:	-	-	-	-
Instream cover (presence/absence)				
Small Woody Debris:	-	-	-	-
Large Woody Debris:	-	-	-	-
Detritus:	-	-	-	-
Substrate:	-	-	-	-
Undercut Banks:	-	-	-	-
Instream vegetation:	-	-	-	-
Overhead cover (presence/absence)				
Undercut banks:	-	-	-	-
Overhanging trees:	-	-	-	-
Overhanging grasses:	-	-	-	-
Overhanging shrubs:	-	-	-	-
Overhead litter >150 mm:	-	-	-	-
Overhead litter <150 mm:	-	-	-	-
Riparian Vegetation:	-			

Channel Morphology 0 m US

Dominant Bed Material:	-
Sub-Dominant Bed Material:	-
Morphology:	-
Disturbance:	-
Islands/Bars:	-

Notes

Site is large beaver pond with heavy growth of aquatic macrophytes (e.g., duckweed)

GAC-4, June 17, 2013

Duckweed cover, June 17, 2013

GAC-4, August 7, 2013

GAC-4, March 20, 2013

Referencing Information

Site Code:	**SG7-1**			
Date Assessed:	5 May 2012	-	15 Oct 2011	-
Time Assessed:	11:20	-	15:80	-
UTM (NAD83, Zone 12):	526144E 5987246N			
Access:	Truck, walk			

Seasonal Information

	Spring	Summer	Fall	Winter
Temperature (°C):	3.3	-	-	-
Dissolved Oxygen (mg/L):	8.8	-	-	-
pH:	7.80	-	-	-
Conductivity (µS/cm):	722	-	-	-
Wetted Width (m):	1.0	-	-	-
Average Depth (m):	0.5	-	-	-

Physical Description of Reach

Channel Width (m):	1.0	-	-	-
Channel Slope:	5	-	-	-
Stream Bank Slope (LDB):	None	-	-	-
Stream Bank Slope (RDB):	None	-	-	-
Substrate				
Composition - Organics:	√	-	-	-
Composition - Fines:	-	-	-	-
Composition - Sand:	-	-	-	-
Composition - Gravel:	-	-	-	-
Composition - Boulder:	-	-	-	-
Instream cover (%)				
Small woody debris:	90	-	-	-
Large woody debris:	-	-	-	-
Boulders:	-	-	-	-
Undercut banks:	10	-	-	-
Deep pools:	-	-	-	-
Instream vegetation:	-	-	-	-
Overhead cover (%)				
Overhanging grasses:	-	-	-	-
Overhanging trees:	40	-	-	-
Overhanging shrubs:	-	-	-	-
Overhanging debris >15 cm	20	-	-	-
Overhanging debris <15 cm	40	-	-	-
Riparian Vegetation:	-	-	-	-
Overhead cover (%)	Deciduous forest, shrubs			

Channel Morphology 0 m US

Dominant Bed Material:	Organic
Sub-Dominant Bed Material:	None
Morphology:	Run (60%), Pool (30%), Riffle (10%)
Disturbance:	Culvert, road
Islands/Bars:	None

Notes

A series of braided channels, fast flowing through the soil. Majority of them are covered in debris. Channels do not reach culvert, flow moves through grasses to left of new road access to highway ditch. Unsure if culvert was ever fully connected as it lies 50-60 m to the right of existing culverts that channels are currently flowing through.

SG7-1 upstream, October 15, 2011

SG7-1 downstream, October 15, 2011

SG7-1 culvert, October 15, 2011

New channels through grass to small culverts, May 5, 2012

Referencing Information

Site Code:	**SM3b-1**			
Date Assessed:	8 May 2012	July 13 2011	-	-
Time Assessed:	15:30	9:00	-	-
UTM (NAD83, Zone 12):	522962E 5984121N			
Access:	Truck, walk			

Seasonal Information

	Spring	Summer	Fall	Winter
Dissolved Oxygen (mg/L):	10.0	1.8	-	-
pH:	8.09	7.35	-	-
Conductivity (µS/cm):	383	321	-	-
Wetted Width (m):	12	-	-	-
Average Depth (m):	0.1	0.2	-	-

Physical Description of Reach

Channel Width (m):	7.5	-	-	-
Channel Slope:	-	-	-	-
Stream Bank Slope (LDB):	20°	-	-	-
Stream Bank Slope (RDB):	20°	-	-	-
Substrate				
Composition - Organics:	√	-	-	-
Composition - Fines:	-	-	-	-
Composition - Sand:	-	-	-	-
Composition - Gravel:	-	-	-	-
Composition - Boulder:	-	-	-	-
Instream cover (%)				
Small Woody Debris:	-	-	-	-
Large Woody Debris:	-	-	-	-
Boulders:	-	-	-	-
Undercut banks:	-	-	-	-
Deep Pools:	-	-	-	-
Instream vegetation:	100	-	-	-
Overhead cover (%)				
Overhanging grasses:	100	-	-	-
Overhanging trees:	-	-	-	-
Overhanging shrubs:	-	-	-	-
Overhanging debris >15 cm:	-	-	-	-
Overhanging debris <15 cm:	-	-	-	-
Riparian Vegetation:	-	-	-	-
Overhead cover (%)	Deciduous forest, shrubs			

Channel Morphology 0 m US

Dominant Bed Material:	Organic
Sub-Dominant Bed Material:	None
Morphology:	Pool
Pattern:	Roads
Islands/Bars:	None

Notes

No defined channel. Isolated pools near culverts. No flowing water during any assessment.

SM3b-1, July 13, 2011

SM3b-1, July 13, 2011

SM3b-1 center channel, May 8, 2012

SM3b-1, May 8, 2012

Referencing Information

Site Code:	**SM3a-1**			
Date Assessed:	8 May 2012	July 12 2011	Oct 14 2012	-
Time Assessed:	10:53	14:18	13:58	-
UTM (NAD83, Zone 12):	522890E 5982449N			
Access:	Truck/ATV			

Seasonal Information

	Spring	Summer	Fall	Winter
Temperature (°C):	10.3	16	3.8	
Dissolved Oxygen (mg/L):	7.0	1.8	1.7	-
pH:	7.73	6.96	7.09	-
Conductivity (µS/cm):	136	257	367	-
Wetted Width (m):	200	26	70	-
Average Depth (m):	0.6	0.8	0.6	-

Physical Description of Reach

	0 m US	100m DS	200m DS	300m DS
Channel Width (m):	36	95	160	118
Channel Slope:	>1°	-	>0.1°	>0.1°
Stream Bank Slope (LDB):	85°	85°	85°	85°
Stream Bank Slope (RDB):	85°	85°	85°	85°
Substrate Composition (%)				
Organics:	√	√	√	√
Fines:	-	-	-	-
Sand:	-	-	-	-
Gravel:	-	-	-	-
Cobble:	-	-	-	-
Boulder:	-	-	-	-
Instream cover (%)				
Small woody debris:	-	-	-	-
Large woody debris:	-	-	-	-
Boulders:	-	-	-	-
Undercut Banks:	-	-	-	-
Deep Pools:	-	-	-	-
Instream vegetation:	100	100	100	100
Overhead cover (%)				
Overhanging grasses:	80	80	80	80
Overhanging trees:	-	-	-	-
Overhanging shrubs:	20	20	20	20
Overhanging debris >15 cm:	-	-	-	-
Overhanging debris 150 cm:	-	-	-	-
Riparian Vegetation:	Grasses, sedges			

Channel Morphology 0 m US

Dominant Bed Material:	Organics
Sub-Dominant Bed Material:	Clay
Morphology:	Run/Pool
Pattern:	Beaver activity, culvert
Islands/Bars:	None

Notes

Defined channel for portions, but most water in a diffused, inundated marsh land. Some beaver activity near the road.

Right downstream bank looking upstream at SM3a-1, July 12, 2011

Left downstream bank looking downstream at SM3a-1, October 14, 2012

Upstream of culvert at SM3a-1, October 14, 2012

Beaver dam at SM3a-1, October 14, 2012

Referencing Information

Site Code:	**MOC-1**			
Date Assessed:	7 May 2012	July 11 2011	Oct 12 2011	-
Time Assessed:	10:05	11:00	9:30	-
UTM (NAD83, Zone 12):	523299E 5968948N			
Access:	Truck/walk			

Seasonal Information

	Spring	Summer	Fall	Winter
Temperature (°C):	8.6	17.1	5.8	
Dissolved Oxygen (mg/L):	8.8	5.7	6.8	-
pH:	8.24	8.06	7.74	-
Conductivity (µS/cm):	497	621	357	-
Wetted Width (m):	19.8	2.8	3.1	-
Average Depth (m):	1.5	0.9	0.8	-

Physical Description of Reach

	0m US	100m DS	200m DS	300m DS
Channel Width (m):	11.8	9.0	82	32
Channel Slope:	1°	1°	1°	1°
Stream Bank Slope (LDB):	90°	80°	-	3°
Stream Bank Slope (RDB):	20°	15°	-	5°
Substrate Composition (%)				
Organics:	√	√	√	√
Fines:	-	-	-	-
Sand:	-	√	-	-
Gravel:	-	√	-	-
Cobble:	-	√	-	-
Boulder:	-	-	-	-
Instream cover (%)				
Small woody debris:	10	10	10	15
Large woody debris:	10	20	10	5
Boulders:	-	-	-	-
Undercut Banks:	-	50	-	-
Deep Pools:	80	-	50	-
Instream vegetation:	-	20	30	80
Overhead cover (%)				
Overhanging grasses:	-	10	10	25
Overhanging trees:	-	-	-	-
Overhanging shrubs:	70	60	80	70
Overhanging debris >15 cm:	20	10	5	-
Overhanging debris 150 cm:	10	20	5	5
Riparian Vegetation:	Grasses, shrubs, mixed forest			

Channel Morphology 0m US

Dominant Bed Material:	Organics
Sub-Dominant Bed Material:	None
Morphology:	Run; riffle; pool; impoundment
Pattern:	Beaver dam, flooding
Islands/Bars:	None

Notes

Beaver dam cleared from culvert in July 2011, high water flow downstream of culvert. Multiple new beaver dams upstream and downstream of culvert in fall. Good rearing habitat for fish.

Upstream, MOC-1, July 11, 2011

Downstream, MOC-1, July 11, 2011

100 m upstream, MOC-1, Oct 12, 2011

200 m upstream, MOC-1, May 7, 2012

Referencing Information

Site Code:	**MUL-1**			
Date Assessed:	4 May 2012	July 11 2011	Oct 12 2011	Jan 24 2012
Time Assessed:	15:55	11:15	13:35	16:15
UTM (NAD83, Zone 12):	523573E 5995546N			
Access:	Truck/walk			

Seasonal Information

	Spring	Summer	Fall	Winter
Temperature (°C):	8.6	21.2	10.8	0.0
Dissolved Oxygen (mg/L):	14.2	6.8	9.2	0.0
pH:	9.23	9.3	9.40	8.86
Conductivity (µS/cm):	2197	2160	2065	1010
Wetted Width (m):	-	-	-	-
Average Depth (m):	-	-	-	-

Physical Description of Reach

Average Shore Depth (m):	0.27	-	-	-
Average Littoral Depth (m):	0.50	-	-	-
Average Littoral Length (m):	8.3	-	-	-
Substrate Composition (%)				
Organics:	-	-	-	-
Fines:	-	-	-	-
Sand:	√	-	-	-
Gravel:	√	-	-	-
Cobble:	-	-	-	-
Boulder:	-	-	-	-
Instream cover (%)				
Small woody debris:	-	-	-	-
Large woody debris:	-	-	-	-
Boulders:	-	-	-	-
Undercut Banks:	-	-	-	-
Deep Pools:	-	-	-	-
Instream vegetation:	-	-	-	-
Overhead cover (%)				
Overhanging grasses:	-	-	-	-
Overhanging trees:	-	-	-	-
Overhanging shrubs:	-	-	-	-
Overhanging debris >15 cm:	-	-	-	-
Overhanging debris 150 cm:	-	-	-	-
Riparian Vegetation:	Grasses, sedges			

Channel Morphology 0 m US

Dominant Bed Material:	Sand
Sub-Dominant Bed Material:	Gravel
Morphology:	Lake
Pattern:	n/a
Islands/Bars:	None

Notes

Access is through private residence.

MUL-1, July 11, 2011

MUL-1 shore, July 11, 2011

MUL-1, October 12, 2011

MUL-1, May 4, 2012

Referencing Information

Site Code:	**SL1-1**			
Date Assessed:	8 May 2012	July 11 2011	-	-
Time Assessed:	16:29	14:36	-	-
UTM (NAD83, Zone 12):	524238E 5994429N			
Access:	Truck			

Seasonal Information

	Spring	Summer	Fall	Winter
Temperature (°C):	7.3	-	-	-
Dissolved Oxygen (mg/L):	3.2	-	-	-
pH:	7.11	-	-	-
Conductivity (µS/cm):	209	-	-	-
Wetted Width (m):	7.0	-	-	-
Average Depth (m):	0.08	-	-	-

Physical Description of Reach

Channel Width (m):	-	-	-	-
Channel Slope:	-	-	-	-
Stream Bank Slope (LDB):	-	-	-	-
Stream Bank Slope (RDB):	-	-	-	-
Substrate Composition (%)				
Organics:	√	-	-	-
Fines:	-	-	-	-
Sand:	-	-	-	-
Gravel:	-	-	-	-
Cobble:	-	-	-	-
Boulder:	-	-	-	-
Instream cover (%)				
Small woody debris:	30	10	10	15
Large woody debris:	20	20	10	5
Boulders:	-	-	-	-
Undercut Banks:	-	50	-	-
Deep Pools:	-	-	50	-
Instream vegetation:	50	20	30	80
Overhead cover (%)				
Overhanging grasses:	20	10	10	25
Overhanging trees:	-	-	-	-
Overhanging shrubs:	-	60	80	70
Overhanging debris >15 cm:	40	10	5	-
Overhanging debris 150 cm:	50	20	5	5
Riparian Vegetation:	Deciduous forest, grasses, shrubs			

Channel Morphology 0 m US

Dominant Bed Material:	Organics
Sub-Dominant Bed Material:	n/a
Morphology:	Pool
Pattern:	Road, cutlines
Islands/Bars:	-

Notes

Site is flooded low-lying wetland area serving as headwaters, starting at access road and intercepted by cutlines. Site was dry in the summer, July 11, 2011.

SL1-1, May 8, 2012

Wetland of SL1-1, May 8, 2012

Wetland of SL1-1, May 8, 2012

Riparian community of SL1-1, May 8, 2012

Referencing Information

Site Code:	**MIL-1**			
Date Assessed:	6 May 2012	July 14 2011	Oct 12 2011	Jan 24 2012
Time Assessed:	11:45	10:58	13:55	14:30
UTM (NAD83, Zone 12):	520486E 5989305N			
Access:	Truck/ATV			

Seasonal Information

	Spring	Summer	Fall	Winter
Temperature (°C):	4.0	19.6	10.6	0.0
Dissolved Oxygen (mg/L):	9.8	7.0	7.5	9.8
pH:	8.13	8.7	8.62	8.81
Conductivity (µS/cm):	514	221	257	305
Wetted Width (m):	-	-	-	-
Average Depth (m):	-	-	-	-

Physical Description of Reach

Average Shore Depth (m):	0.44	-	-	-
Average Littoral Depth (m):	0.8	-	-	-
Average Littoral Length (m):	16	-	-	-
Substrate Composition (%)				
Organics:	√	-	-	-
Fines:	-	-	-	-
Sand:	-	-	-	-
Gravel:	-	-	-	-
Cobble:	-	-	-	-
Boulder:	-	-	-	-
Instream cover (%)				
Small woody debris:	-	-	-	-
Large woody debris:	-	-	-	-
Boulders:	-	-	-	-
Undercut Banks:	-	-	-	-
Deep Pools:	-	-	-	-
Instream vegetation:	-	-	-	-
Overhead cover (%)				
Overhanging grasses:	-	-	-	-
Overhanging trees:	-	-	-	-
Overhanging shrubs:	-	-	-	-
Overhanging debris >15 cm:	-	-	-	-
Overhanging debris 150 cm:	-	-	-	-
Riparian Vegetation:	Sedges, grasses			

Channel Morphology 0 m US

Dominant Bed Material:	Organic
Sub-Dominant Bed Material:	Organic
Morphology:	Lake
Pattern:	n/a
Islands/Bars:	None

Notes

Water quality was collected at south end of Michel Lake. Original sampling intended for channel at north end of lake, however channel was dry.

Michel Lake/MIL-1, July 14, 2011

Michel Lake/MIL-1, July 14, 2011

Michel Lake/MIL-1, January 24, 2012

Michel Lake/MIL-1 shoreline, May 6, 2012

Referencing Information

Site Code:	GAC-1			
Date Assessed:	6 May 2012	July 14 2011	Oct 14 2011	Jan 26 2012
Time Assessed:	18:16	15:00	15:10	10:15
UTM (NAD83, Zone 12):	525489E 5994514N			
Access:	Truck/walk			

Seasonal Information

	Spring	Summer	Fall	Winter
Temperature (°C):	7.5	18.2	7.4	-
Dissolved Oxygen (mg/L):	8.4	2.6	7.0	-
pH:	7.5	7.90	8.45	-
Conductivity (µS/cm):	479	548	777	-
Wetted Width (m):	33	7.3	6.0	-
Average Depth (m):	>1	>1	>2	-

Physical Description of Reach

	0m US	100m DS	200m DS	300m DS
Channel Width (m):	40	38	26	35
Channel Slope:	-	-	-	-
Stream Bank Slope (LDB):	70°	40°	45°	60°
Stream Bank Slope (RDB):	45°	20°	30°	60°
Substrate Composition (%)				
Organics:	√	√	√	√
Fines:	-	-	-	-
Sand:	-	-	-	-
Gravel:	-	-	-	-
Cobble:	-	-	-	-
Boulder:	-	-	-	-
Instream cover (%)				
Small woody debris:	-	100	-	-
Large woody debris:	-	-	-	-
Boulders:	-	-	-	-
Undercut Banks:	-	-	-	-
Deep Pools:	-	-	-	20
Instream vegetation:	100	-	100	80
Overhead cover (%)				
Overhanging grasses:	100	50	-	-
Overhanging trees:	-	-	-	10
Overhanging shrubs:	-	50	-	90
Overhanging debris >15 cm:	-	-	-	-
Overhanging debris 150 cm:	-	-	-	-
Riparian Vegetation:	Grasses, sedges, shrubs, mixed forest			

Channel Morphology 0 m US

Dominant Bed Material:	Organic
Sub-Dominant Bed Material:	None
Morphology:	Run/Impoundment
Pattern:	Road, culvert, beaver dam
Islands/Bars:	Beaver dam

Notes

Reach divided by culvert. Multiple intact and broken beaver dams upstream and downstream of culvert influencing channel flow.

Downstream end of GAC-1, July 14, 2011

Downstream end of GAC-1 culvert, July 14, 2011

Upstream end GAC-1 culvert, July 14, 2011

GAC-1, July 14, 2011

Referencing Information

Site Code:	**GAC-2**			
Date Assessed:	7 May 2012	July 14 2011	-	-
Time Assessed:	14:35	10:25	-	-
UTM (NAD83, Zone 12):	525979E 5991218N			
Access:	Truck/ATV			

Seasonal Information

	Spring	Summer	Fall	Winter
Temperature (°C):	13.5	17.6	-	-
Dissolved Oxygen (mg/L):	8.0	7.2	-	-
pH:	7.85	7.87	-	-
Conductivity (µS/cm):	518	587	-	-
Wetted Width (m):	12.8	18	-	-
Average Depth (m):	-	>1	-	-

Physical Description of Reach

	0m US	100m DS	200m DS	300m DS
Channel Width (m):	7	5	40	2
Channel Slope:	2°	1°	-	-
Stream Bank Slope (LDB):	35°	35°	-	40°
Stream Bank Slope (RDB):	80°	20°	-	30°
Substrate Composition (%)				
Organics:	√	-	√	√
Fines:	-	√	-	-
Sand:	√	√	-	-
Gravel:	√	√	-	-
Cobble:	-	-	-	√
Boulder:	-	-	-	√
Instream cover (%)				
Small woody debris:	70	60	-	5
Large woody debris:	10	20	-	-
Boulders:	-	-	-	-
Undercut Banks:	20	20	-	-
Deep Pools:	-	-	-	-
Instream vegetation:	-	-	100	95
Overhead cover (%)				
Overhanging grasses:	80	-	-	5
Overhanging trees:	-	-	-	10
Overhanging shrubs:	20	60	100	85
Overhanging debris >15 cm:	-	40	-	-
Overhanging debris 150 cm:	-	-	-	-
Riparian Vegetation:	Grasses, sedges, shrubs			

Channel Morphology 0 m US

Dominant Bed Material:	Organics
Sub-Dominant Bed Material:	None
Morphology:	Run, impoundment
Pattern:	Flooded, beaver dam
Islands/Bars:	Bars

Notes

Very heavy macrophyte cover. Multiple beaver dams across reach affecting channel flow, some sections dewatered, others flooded.

Downstream, GAC-2, July 14, 2011

GAC-2, July 14, 2011

GAC-2, July 14, 2011

100 m downstream of GAC-2, May 7, 2012

Referencing Information

Site Code:	GAC-3			
Date Assessed:	7 May 2012	July 12 2011	-	-
Time Assessed:	14:02	11:10	-	-
UTM (NAD83, Zone 12):	527104E 5988482N			
Access:	Truck/ATV			

Seasonal Information

	Spring	Summer	Fall	Winter
Temperature (°C):	15.1	18.6	-	-
Dissolved Oxygen (mg/L):	7.1	9.0	-	-
pH:	8.27	8.10	-	-
Conductivity (µS/cm):	336	434	-	-
Wetted Width (m):	58	76	-	-
Average Depth (m):	>1.5	0.7	-	-

Physical Description of Reach

	0m US	100m DS	200m DS	300m DS
Channel Width (m):	50	75	100	40
Channel Slope:	0°	0°	0°	0°
Stream Bank Slope (LDB):	-	-	-	-
Stream Bank Slope (RDB):	-	-	-	-
Substrate Composition (%)				
Organics:	√	√	√	√
Fines:	-	√	-	-
Sand:	√	√	-	-
Gravel:	√	√	-	-
Cobble:	-	-	-	√
Boulder:	-	-	-	√
Instream cover (%)				
Small woody debris:	-	-	-	-
Large woody debris:	-	-	-	-
Boulders:	-	-	-	-
Undercut Banks:	-	-	-	-
Deep Pools:	-	-	-	-
Instream vegetation:	100	100	100	100
Overhead cover (%)				
Overhanging grasses:	100	100	100	100
Overhanging trees:	-	-	-	-
Overhanging shrubs:	-	-	-	-
Overhanging debris >15 cm:	-	-	-	-
Overhanging debris 150 cm:	-	-	-	-
Riparian Vegetation:	Grasses, sedges			

Channel Morphology 0 m US

Dominant Bed Material:	Organic
Sub-Dominant Bed Material:	None
Morphology:	Pond
Pattern:	-
Islands/Bars:	Small islands

Notes

Large wetland with open water. No channel upstream, small outlet channel to north and series of smaller wetlands downstream. Thousands of frog eggs in the shallows in the spring.

Upstream, GAC-3, July 12, 2011

Downstream, GAC-2, July 12, 2011

Across wetland GAC-2, May 7, 2012

Riparian vegetation of GAC-3, May 7, 2012

Referencing Information

Site Code:	**SG2-1**			
Date Assessed:	7 May 2012	July 15 2011	Oct 12 2011	-
Time Assessed:	10:35	9:30	11:30	-
UTM (NAD83, Zone 12):	527405E 5993827N			
Access:	Truck/ATV			

Seasonal Information

	Spring	Summer	Fall	Winter
Temperature (°C):	4.6	16.9	4.7	-
Dissolved Oxygen (mg/L):	2.2	1.2	1.1	-
pH:	7.32	7.75	7.07	-
Conductivity (µS/cm):	379	494	583	-
Wetted Width (m):	20	39	-	-
Average Depth (m):	1.3	0.37	-	-

Physical Description of Reach

	0m US	100m DS	200m DS	300m DS
Channel Width (m):	1.5	20	20	20
Channel Slope:	-	-	-	-
Stream Bank Slope (LDB):	-	-	-	-
Stream Bank Slope (RDB):	-	-	-	-
Substrate Composition				
Organics:	√	√	√	√
Fines:	-	-	-	-
Sand:	-	-	-	-
Gravel:	-	-	-	-
Cobble:	-	-	-	-
Boulder:	-	-	-	-
Instream cover (%)				
Small woody debris:	-	-	10	-
Large woody debris:	-	-	-	-
Boulders:	-	-	-	-
Undercut Banks:	-	-	-	-
Deep Pools:	-	-	-	-
Instream vegetation:	100	100	90	100
Overhead cover (%)				
Overhanging grasses:	90	50	50	60
Overhanging trees:	-	-	-	-
Overhanging shrubs:	10	50	50	40
Overhanging debris >15cm:	-	-	-	-
Overhanging debris 150cm:	-	-	-	-
Riparian Vegetation:	Grasses, shrubs, sedges			

Channel Morphology 0m US

Dominant Bed Material:	Organics
Sub-Dominant Bed Material:	n/a
Morphology:	Impoundment/Run
Pattern:	Beaver dams, cutlines
Islands/Bars:	Beaver lodge, small islands

Notes

Flooded area downstream of beaver pond. Active and old beaver dams with braided channels downstream.

Upstream on SG2-1, July 15, 2011

Downstream on SG2-1, July 15, 2011

Cross-channel at beaver dam, SG2-1, July 15, 2011

200 m downstream of SG2-1, May 7, 2012

Referencing Information

Site Code:	**SG4-1**			
Date Assessed:	7 May 2012	July 13 2011	Oct 12 2011	-
Time Assessed:	12:55	9:35	13:19	-
UTM (NAD83, Zone 12):	527271E 5990857N			
Access:	Truck/ATV			

Seasonal Information

	Spring	Summer	Fall	Winter
Temperature (°C):	9.5	16.8	5.9	-
Dissolved Oxygen (mg/L):	8.0	1.8	3.2	-
pH:	7.8	7.62	7.07	-
Conductivity (µS/cm):	175	380	467	-
Wetted Width (m):	22	42		-
Average Depth (m):	1.5	>1	0.5	-

Physical Description of Reach

	0m US	100m DS	200m DS	300m DS
Channel Width (m):	30	4	7.5	35
Channel Slope:	-	-	-	-
Stream Bank Slope (LDB):	-	-	-	-
Stream Bank Slope (RDB):	-	-	-	-
Substrate Composition				
Organics:	√	√	√	√
Fines:	-	-	-	-
Sand:	-	-	-	-
Gravel:	-	-	-	-
Cobble:	-	-	-	-
Boulder:	-	-	-	-
Instream cover (%)				
Small woody debris:	2	50	-	-
Large woody debris:	-	-	-	-
Boulders:	-	-	-	-
Undercut Banks:	-	-	-	-
Deep Pools:	-	-	-	-
Instream vegetation:	98	50	100	100
Overhead cover (%)				
Overhanging grasses:	-	40	-	100
Overhanging trees:	-	-	-	-
Overhanging shrubs:	100	60	-	-
Overhanging debris >15 cm:	-	-	-	-
Overhanging debris 150 cm:	-	-	-	-
Riparian Vegetation:	Grasses, shrubs			

Channel Morphology 0 m US

Dominant Bed Material:	Organics
Sub-Dominant Bed Material:	None
Morphology:	Impoundment
Pattern:	Beaver dam, roads, cutlines
Islands/Bars:	Small island

Notes

Channel was dry in fall due to beaver dam recently built upstream. Fall samples collected from beaver pond. Flooded grassland area with defined channel in the spring; lots of frogs.

Upstream of SG4-1, July 13, 2011

Downstream of SG4-1, July 13, 2011

Riparian community of SG4-1, October 12, 2011

100 m upstream of SG4-1, May 7, 2012

Referencing Information

Site Code:	**SG5-1**			
Date Assessed:	6 May 2012	-	Oct 15 2011	-
Time Assessed:	12:33	-	9:50	-
UTM (NAD83, Zone 12):	524818E 598957N			
Access:	Truck/ATV			

Seasonal Information

	Spring	Summer	Fall	Winter
Temperature (°C):	4.5	-	-	-
Dissolved Oxygen (mg/L):	8.2	-	-	-
pH:	7.60	-	-	-
Conductivity (µS/cm):	668	-	-	-
Wetted Width (m):	0.8	-	-	-
Average Depth (m):	0.15	-	-	-

Physical Description of Reach

	0m US	100m DS	200m DS	300m DS
Channel Width (m):	1.1	1.3	0.80	0.95
Channel Slope:	1°	1°	1°	2°
Stream Bank Slope (LDB):	3°	5°	5°	2°
Stream Bank Slope (RDB):	3°	5°	5°	2°
Substrate Composition (%)				
Organics:	40	90	80	10
Fines:	60	-	10	30
Sand:	-	10	10	-
Gravel:	-	-	-	30
Cobble:	-	-	-	-
Boulder:	-	-	-	20
Instream cover (%)				
Small woody debris:	60	100	40	30
Large woody debris:	-	-	-	30
Boulders:	-	-	-	30
Undercut Banks:	10	-	60	10
Deep Pools:	-	-	-	-
Instream vegetation:	30	-	-	-
Overhead cover (%)				
Overhanging grasses:	20	30	10	30
Overhanging trees:	20	30	60	10
Overhanging shrubs:	20	20	20	40
Overhanging debris >15 cm:	-	20	10	10
Overhanging debris 150 cm:	40	-	-	10
Riparian Vegetation:	Grasses, shrubs, sedges, mixed forest			

Channel Morphology 0 m US

Dominant Bed Material:	Organics
Sub-Dominant Bed Material:	Fines
Morphology:	Run, pool
Pattern:	Cutline
Islands/Bars:	none

Notes

Site was not assessed during summer field program due to access restrictions. Water levels prevented sampling in fall season. Frozen to depth in winter. Small channel in spring, lots of fallen trees.

Upstream of SG5-1, October 15, 2011

Upstream end of SG5-1 culvert at highway, October 15, 2011

100 m upstream, cross-channel of SG5-1, May 6, 2012

Downstream of SG5-1, May 6, 2012

Referencing Information

Site Code:	**SG8-1**			
Date Assessed:	8 May 2012	July 12 2011	Oct 12 2011	Jan 25 2012
Time Assessed:	14:36	13:15	11:49	14:34
UTM (NAD83, Zone 12):	527576E 5986577N			
Access:	Truck/ATV			

Seasonal Information

	Spring	Summer	Fall	Winter
Temperature (°C):	11.3	-	-	-
Dissolved Oxygen (mg/L):	11.0	-	-	-
pH:	7.63	-	-	-
Conductivity (µS/cm):	405	-	-	-
Wetted Width (m):	0.65	-	-	-
Average Depth (m):	-	-	-	-

Physical Description of Reach

	0m US	100m DS	200m DS	300m DS
Channel Width (m):	0.8	-	-	-
Channel Slope:	2°	-	-	-
Stream Bank Slope (LDB):	40°	-	-	-
Stream Bank Slope (RDB):	60°	-	-	-
Substrate Composition (%)				
Organics:	100	-	-	-
Fines:	-	-	-	-
Sand:	-	-	-	-
Gravel:	-	-	-	-
Cobble:	-	-	-	-
Boulder:	-	-	-	-
Instream cover (%)				
Small woody debris:	70	-	-	-
Large woody debris:	20	-	-	-
Boulders:	-	-	-	-
Undercut Banks:	-	-	-	-
Deep Pools:	-	-	-	-
Instream vegetation:	10	-	-	-
Overhead cover (%)				
Overhanging grasses:	30	-	-	-
Overhanging trees:	-	-	-	-
Overhanging shrubs:	20	-	-	-
Overhanging debris >15 cm:	40	-	-	-
Overhanging debris 150 cm:	10	-	-	-
Riparian Vegetation:			-	

Channel Morphology 0 m US

Dominant Bed Material:	Organics
Sub-Dominant Bed Material:	n/a
Morphology:	Run, pool
Pattern:	n/a
Islands/Bars:	n/a

Notes

Seasonal channel, dry during all seasons of sampling except spring. In spring, small runs with numerous debris jams and step pools. No fish passage from lake unless much higher flow.

Stagnant water at outlet of SG8-1, July 12, 2011

Downstream of SG8-1, May 8, 2012

Upstream of SG8-1, May 8, 2012

Referencing Information

Site Code:	**SG9-1**			
Date Assessed:	8 May 2012	July 12 2011	Oct 12 2011	Jan 25 2012
Time Assessed:	15:00	13:15	11:49	14:38
UTM (NAD83, Zone 12):	527585E 5986312N			
Access:	Truck/ATV			

Seasonal Information

	Spring	Summer	Fall	Winter
Temperature (°C):	11.3	-	-	-
Dissolved Oxygen (mg/L):	11.0	-	-	-
pH:	7.63	-	-	-
Conductivity (µS/cm):	405	-	-	-
Wetted Width (m):	0.65	-	-	-
Average Depth (m):	-	-	-	-

Physical Description of Reach

	0m US	100m DS	200m DS	300m DS
Channel Width (m):	0.88	-	-	-
Channel Slope:	3°	-	-	-
Stream Bank Slope (LDB):	15°	-	-	-
Stream Bank Slope (RDB):	30°	-	-	-
Substrate Composition (%)				
Organics:	100	-	-	-
Fines:	-	-	-	-
Sand:	-	-	-	-
Gravel:	-	-	-	-
Cobble:	-	-	-	-
Boulder:	-	-	-	-
Instream cover (%)				
Small woody debris:	30	-	-	-
Large woody debris:	10	-	-	-
Boulders:	-	-	-	-
Undercut Banks:	50	-	-	-
Deep Pools:	-	-	-	-
Instream vegetation:	10	-	-	-
Overhead cover (%)				
Overhanging grasses:	-	-	-	-
Overhanging trees:	-	-	-	-
Overhanging shrubs:	10	-	-	-
Overhanging debris >15cm:	10	-	-	-
Overhanging debris 150cm:	80	-	-	-
Riparian Vegetation:		-		

Channel Morphology 0 m US

Dominant Bed Material:	Organics
Sub-Dominant Bed Material:	n/a
Morphology:	Run, pool
Pattern:	n/a
Islands/Bars:	n/a

Notes

Seasonal channel, dry during all other seasons of sampling. In spring, small runs with numerous debris jams and step pools. No fish passage from lake unless much higher flow.

Outlet of channel SG9-1 into Garnier Lake, dry upstream, July 12, 2011

Dry channel of SG9-1, October 12, 2011

Downstream at SG9-1, May 8, 2012

Upstream at SG9-1, May 8, 2012

Referencing Information

Site Code:	**MOC-2**			
Date Assessed:	8 May 2012	July 12 2011	Oct 14 2011	Jan 23 2012
Time Assessed:	10:35	10:00	12:45	16:20
UTM (NAD83, Zone 12):	521460E 5982100N			
Access:	Truck/Walk			

Seasonal Information

	Spring	Summer	Fall	Winter
Temperature (°C):	6.8	17.0	7.9	0
Dissolved Oxygen (mg/L):	9.1	-	6.9	7.6
pH:	7.92	8.13	7.83	7.79
Conductivity (µS/cm):	322	410	554	722
Wetted Width (m):	5.3	13	10.7	-
Average Depth (m):	0.47	1.4	>1.5	-

Physical Description of Reach

	0m US	100m DS	200m DS	300m DS
Channel Width (m):	7.7	flooded	6.5	1.75
Channel Slope:	1°	-	-	<1°
Stream Bank Slope (LDB):	90°	10°	90°	90°
Stream Bank Slope (RDB):	90°	20°	90°	25°
Substrate Composition (%)				
Organics:	100	100	60	10
Fines:	-	-	40	30
Sand:	-	-	-	10
Gravel:	-	-	-	10
Cobble:	-	-	-	30
Boulder:	-	-	-	10
Instream cover (%)				
Small woody debris:	10	40	5	-
Large woody debris:	-	-	-	-
Boulders:	-	-	-	-
Undercut Banks:	10	-	15	50
Deep Pools:	10	-	-	50
Instream vegetation:	70	60	80	-
Overhead cover (%)				
Overhanging grasses:	20	50	50	90
Overhanging trees:	-	-	-	-
Overhanging shrubs:	80	50	50	10
Overhanging debris >15 cm:	-	-	-	-
Overhanging debris 150 cm:	-	-	-	-
Riparian Vegetation:	Grasses, rushes, willows			

Channel Morphology 0 m US

Dominant Bed Material:	Organic
Sub-Dominant Bed Material:	Fines
Morphology:	Run/Impoundment
Pattern:	Beaver dam, bridge, road, collapsed
Islands/Bars:	Beaver dam

Notes

Site runs through a large culvert, beaver impoundment has flooded large area creating braided channels and wetlands – good rearing habitat for fish.

Upstream of MOC-2, July 12, 2011

Left Downstream Bank at MOC-2, July 12, 2011

Culvert at MOC-2, October 14, 2011

Downstream towards road at MOC-2, May 8, 2012

Referencing Information

Site Code:	**DIL-1**			
Date Assessed:	6 May 2012	July 13 2011	Oct 14 2011	Jan 24 2012
Time Assessed:	15:20	11:30	9:00	10:45
UTM (NAD83, Zone 12):	521460E 5982100N			
Access:	Truck/Walk			

Seasonal Information

	Spring	Summer	Fall	Winter
Temperature (°C):	9.9	18.9	7.9	0
Dissolved Oxygen (mg/L):	7.4	4.7	4.5	0.8
pH:	7.45	7.69	6.90	7.88
Conductivity (µS/cm):	263	272	385	350
Wetted Width (m):	-	-	-	-
Average Depth (m):	-	-	-	-

Physical Description of Reach

Average Shore Depth (m):	0.95	-	-	-
Average Littoral Depth (m):	1.38	-	-	-
Average Littoral Length (m):	43	-	-	-
Substrate Composition (%)				
Organics:	√	-	-	-
Fines:	-	-	-	-
Sand:	-	-	-	-
Gravel:	-	-	-	-
Cobble:	-	-	-	-
Boulder:	-	-	-	-
Instream cover (%)				
Small woody debris:	-	-	-	-
Large woody debris:	-	-	-	-
Boulders:	-	-	-	-
Undercut Banks:	-	-	-	-
Deep Pools:	-	-	-	-
Instream vegetation:	100	-	-	-
Overhead cover (%)				
Overhanging grasses:	-	-	-	-
Overhanging trees:	-	-	-	-
Overhanging shrubs:	-	-	-	-
Overhanging debris >15 cm:	-	-	-	-
Overhanging debris 150 cm:	-	-	-	-
Riparian Vegetation:	Sedges, aquatic macrophytes			

Channel Morphology

Dominant Bed Material:	Organic
Sub-Dominant Bed Material:	Organic
Morphology:	Lake
Pattern:	n/a
Islands/Bars:	None

Notes

Shore of DIL-1, July 13, 2011

Shore of DIL-1, May 6, 2012

Shore of DIL-1, May 6, 2012

DIL-1, May 6, 2012

Referencing Information

Site Code:	**GAL-1**			
Date Assessed:	8 May 2012	July 15 2011	Oct 12 2011	Jan 25 2012
Time Assessed:	10:56	11:15	10:25	14:10
UTM (NAD83, Zone 12):	527432E 5987357N			
Access:	Truck/Walk			

Seasonal Information

	Spring	Summer	Fall	Winter
Temperature (°C):	9.9	20.4	8.9	0
Dissolved Oxygen (mg/L):	7.4	6.6	9.0	8.3
pH:	7.45	9.00	8.53	8.65
Conductivity (µS/cm):	263	848	800	872
Wetted Width (m):	-	-	-	-
Average Depth (m):	-	-	-	-

Physical Description of Reach

Average Shore Depth (m):	0.15	-	-	-
Average Littoral Depth (m):	1.21	-	-	-
Average Littoral Length (m):	18.5	-	-	-
Substrate Composition (%)				
Organics:	√	-	-	-
Fines:	-	-	-	-
Sand:	√	-	-	-
Gravel:	-	-	-	-
Cobble:	-	-	-	-
Boulder:	-	-	-	-
Instream cover (%)				
Small woody debris:	10	-	-	-
Large woody debris:	-	-	-	-
Boulders:	30	-	-	-
Undercut Banks:	-	-	-	-
Deep Pools:	-	-	-	-
Instream vegetation:	60	-	-	-
Overhead cover (%)				
Overhanging grasses:	-	-	-	-
Overhanging trees:	-	-	-	-
Overhanging shrubs:	-	-	-	-
Overhanging debris >15 cm:	-	-	-	-
Overhanging debris 150 cm:	-	-	-	-
Riparian Vegetation:	Grasses, cattails, shrubs, mixed forests			

Channel Morphology

Dominant Bed Material:	Organic
Sub-Dominant Bed Material:	Organic
Morphology:	Lake
Pattern:	n/a
Islands/Bars:	None

Notes

Substrate changes from organic to sand within 2-5 m from shore. Strong sulphur smell from lake in the fall. Winter ice thickness = 61 cm

East shore, July 15, 2011

West shore, October 12, 2011

Cross-lake, GAL-1, May 8, 2012

Cross-lake, GAL-1, May 8, 2012