DOMINION
DIAMOND

SECTION 9

FISH AND FISH HABITAT

DOMINION DIAMOND

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Appendices

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Appendix 9B Conceptual Fish-Out Plan
Appendix 9C Conceptual Aquatic Effects Monitoring Plan

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Section 9 Abbreviations

Abbreviation	Definition
AEMP	Aquatic Effects Monitoring Program
BAF	bioaccumulation factor
BC	British Columbia
BHP Billiton	BHP Billiton Canada Inc. including subsidiary BHP Billiton Diamonds Inc.
BSA	baseline study area
$CaCO_3$	calcium carbonate
CCME	Canadian Council of Ministers of the Environment
COSEWIC	Committee on the Status of Endangered Wildlife in Canada
CPUE	catch-per-unit-effort
CWQG	Canadian Water Quality Guidelines
DAR	Developer's Assessment Report
DFO	Fisheries and Wildlife Canada
Diavik Mine	Diavik Diamond Mine
DDMI	Diavik Diamond Mines Inc.
Dominion Diamond	Dominion Diamond Ekati Corporation
EcoAnalysts	EcoAnalysts Inc.
e.g.	for example
Ekati Mine	Ekati Diamond Mine
EPT	Ephemeroptera, Plecoptera, and Trichoptera
ERM Rescan	ERM Rescan Environmental Services Ltd.
ESA	Effects Study Area
et al.	and more than one additional author
FPK	fine processed kimberlite
GIS	Geographic Information System
GPS	Global Positioning System
ICRP	Interim Closure and Reclamation Plan
i.e.	that is
KLOI	Key Line of Inquiry
LiDAR	light detection and ranging
LLCF	Long Lake Containment Facility
MVRB	Mackenzie Valley Review Board
NTU	nephelometric turbidity units
NWT	Northwest Territories
n	number of samples
NTS	National Topographic Service
PAG	potentially acid generating
PAI	potential acid input
PPV	peak particle velocity
Project	Jay Project
Rescan	Rescan Environmental Services Ltd.

Abbreviation	Definition
RFD	Reasonably Foreseeable Development
SD	standard deviation
SQGs	sediment quality guidelines
SRSi	soluble reactive silica
SSWC	Steady-State Water Chemistry
TDS	total dissolved solids
TN	total nitrogen
TOC	total organic carbon
TOR	Terms of Reference
TP	total phosphorous
TSI	Trophic State Index
TSS	total suspended solids
USA	United States
VC	valued component
var.	variety
WLWB	Wek'èezhìi Land and Water Board
WPKMP	Wastewater and Processed Kimberlite Management Plan
WRSA	waste rock storage area
YOY	young-of-the-year

DOMINION DIAMOND

Section 9 Units of Measure

Unit	Definition
%	%
±	plus or minus
<	less than
>	greater than
°C	degrees Celsius
µg/L	micrograms per litre
µm	micrometre
µS/cm	microSiemens per centimetre
cells/L	cells per litre
cm	centimetre
g	gram
ha	hectare
km	kilometre
km^2	square kilometre
m	metre
masl	metres above sea level
m/s	metres per second
m^2	square metre
m^3	cubic metre
m^3/s	cubic metres per second
mg/L	milligrams per litre
mg/m^3	milligrams per cubic metre
mg N/L	milligrams of nitrogen per litre
mg P/L	milligrams of phosphorus per litre
mm	millimetre
s	second

9 FISH AND FISH HABITAT

9.1 Introduction

9.1.1 Background

The existing Dominion Diamond Ekati Corporation (Dominion Diamond) Ekati Diamond Mine (Ekati Mine) and its surrounding claim block are located approximately 300 kilometres (km) northeast of Yellowknife in the Northwest Territories (NWT) (Map 9.1-1). Dominion Diamond proposes to develop the Jay Project (Project), which includes associated mining and transportation infrastructure to add 10 or more years of operating life to the Ekati Mine. The majority of the facilities required to support and process the kimberlite currently exist at the Ekati Mine, including:

- the Misery Pit mining infrastructure (e.g., fuel facility, explosives magazines);
- primary roads and transportation infrastructure (e.g., Ekati airstrip, Misery Road);
- the Ekati main camp and supporting infrastructure;
- the Ekati processing plant; and,
- fine processed kimberlite management facilities.

The Jay kimberlite pipe is located beneath Lac du Sauvage in the southeastern portion of the Ekati claim block, approximately 25 km from the main facilities and approximately 7 km to the northeast of the Misery Pit. A horseshoe-shaped dike will be constructed to isolate the portion of Lac du Sauvage overlying the Jay kimberlite pipe.

The isolated portion of Lac du Sauvage will be dewatered to allow for open-pit mining of the kimberlite pipe. The Project will also require an access road, pipelines, and power lines to the Jay Pit from the Misery Pit.

LEGEND

- JAY PROJECT
- EXISTING MINE OR PROJECT
- TERRITORIAL CAPITAL
- POPULATED PLACE
- HIGHWAY
- TERRITORIAL/PROVINCIAL BOUNDARY
- TREELINE
- WATERCOURSE
- WATERBODY

150 0 150

SCALE 1:6,000,000 KILOMETRES

REFERENCE

WATER OBTAINED FROM ATLAS OF CANADA
NATURAL RESOURCES CANADA, CENTRE FOR TOPOGRAPHIC INFORMATION, 2012
PROJECTION: CANADA LAMBERT CONFORMAL CONIC

DOCUMENT

DEVELOPER'S ASSESSMENT REPORT

PROJECT

DOMINION DIAMOND

JAY PROJECT
NORTHWEST TERRITORIES, CANADA

TITLE

LOCATION OF THE JAY PROJECT

Golder Associates

PROJECT	13-1328-0041	FILE No. DAR_Aqua_022_GIS	
DESIGN	JV	31/07/14	SCALE AS SHOWN	REV. 0
GIS	JE	20/10/14	
CHECK	CS	20/10/14	MAP 9.1-1
REVIEW	KM	20/10/14	

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9.1.2 Purpose and Scope

This section of the Developer's Assessment Report (DAR) for the Project consists solely of the Key Line of Inquiry (KLOI): Impacts to Fish and Fish Habitat from Project Components identified in the Terms of Reference (TOR) issued on July 17, 2014 by the Mackenzie Valley Review Board (MVRB). The TOR is included in Appendix 1A, and the Table of Concordance for the DAR is provided in Appendix 1D of Section 1.

Key Lines of Inquiry are areas of concern identified by the MVRB based on concerns expressed by various interested parties and the general public during the MVRB scoping exercise. The KLOIs require the most attention during the environmental impact review, and the most rigorous analysis and detail in the DAR.

The purpose of this KLOI is to assess the effects of the Project on fish and fish habitat and to meet the TOR issued by the MVRB. The KLOI: Fish and Fish Habitat includes a detailed and comprehensive assessment of potential effects from the Project on plankton, benthic invertebrates, fish habitat, and fish. Potential effects were considered by Project phase and key activities as follows:

- construction (e.g., development of the internal dike within Lac du Sauvage and dewatering of the isolated portion of the lake for pit development);
- operation (e.g., mining of the Jay Pit within the diked area and operational discharge to Lac du Sauvage);
- closure (e.g., back-flooding of the Misery and Jay pits and the dewatered area, breaching of the dike and reconnection with Lac du Sauvage); and,
- post-closure (e.g., natural flow paths in Lac du Sauvage, overflow from the Misery Pit to Lac de Gras).

The residual effects on water quantity (hydrology) and water quality from potential Project-related activities (Section 8) were incorporated as appropriate within this section.

9.1.3 Valued Components, Assessment Endpoints, and Measurement Indicators

Valued components (VCs) represent physical, biological, cultural, social, and economic properties of the environment that are considered important to society. The TOR for the Project (MVRB 2014) identified two valued components (VCs) to be used in the assessment of effects on fish and fish habitat from the Project:

- fish; and,
- aquatic life other than fish (i.e., plankton and benthic invertebrates).

As described in Section 6.2.1, VCs can be found at the beginning, middle, or end of pathways, or analogously, at the bottom, middle, or top trophic levels of food chains. For example, in aquatic ecosystems, plankton and benthic invertebrates are at the lower trophic level (i.e., towards the beginning of the pathway), while fish species, such as Lake Trout, can be the top predators in aquatic systems not fished by people (i.e., at the end of the pathway).

Fish species that are part of a fishery can be an important cultural, subsistence, and economic resource for people in the NWT and Nunavut, as well as species that support the fishery. The species-specific approach was considered for the selection of VCs for fish and fish habitat, which is consistent with previously completed environmental assessments, and assessments of other higher trophic level species in the terrestrial sections of the DAR (i.e., caribou and wildlife).

For each fish species, the sustainability of the population(s) depends on the quantity and quality of the habitats required for each life history stage, and on interactions with other species. While recognizing that populations can naturally fluctuate, sustainable or self-sustaining populations are defined as those with the inherent capacity to be productive when their habitats and environmental conditions permit (Randall et al. 2013); in other words, the population is not affected to the point where future recruitment is diminished. For the DAR, three fish species with different life history strategies were selected as VCs for assessing the effects of the Project on fish and fish habitat.

For fish and fish habitat, eleven species of fish were identified in the fish and fish habitat baseline study area (BSA) during baseline studies that could be considered as VCs (Annex XIV, Fish and Fish Habitat Baseline). None of these species were classified as federally listed species or species with a designated conservation status by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC; 2014). Arctic Grayling is classified as a sensitive species in NWT (NWT Infobase 2014), but does not have a conservation status in Canada under COSEWIC (2014). In NWT, the species is considered sensitive to warming climate trends and also to habitat degradation, such as siltation, corridor blockage, or removal of riparian vegetation (NWT Infobase 2014). Rare or protected fish species were not observed, and are not expected to occur in the BSA.

The criteria used to select VCs for the fish and fish habitat assessment were as follows:

- cultural, social, or economic importance to traditional and non-traditional users;
- relative abundance in Lac du Sauvage;
- trophic position; and,
- unique life history requirements.

Arctic Grayling, Lake Trout, and Lake Whitefish were identified as VCs (Table 9.1-1), in part, because they are species of economic and cultural importance to traditional users in the NWT and Nunavut. Domestic fishing is still an important part of the traditional way of life for local Aboriginal communities. Fish remains a large portion of the diet of many residents of the NWT and Nunavut, especially when caribou are scarce (Annex XVII, Traditional Land Use and Traditional Knowledge Baseline Report). Traditionally, fish were harvested for subsistence and to feed dogs.

The proposed Project is located on lands that have traditionally been used by Akaitcho, Métis, Dene, and Inuit people. The names of Lac de Gras and Lac du Sauvage originated from indigenous Métis. Several of the lakes in the BSA, such as Lac de Gras and Lac du Sauvage, continue to be fished today, and are often targeted for Lake Trout and Lake Whitefish. As Arctic Grayling, Lake Trout, and Lake Whitefish are fish species that can be part of a commercial, recreational, or Aboriginal fishery, the inclusion of these species as VCs in the environmental assessment of the Jay Project is consistent with Fisheries and Oceans Canada's (DFO's) legislation and policy (i.e., *Fisheries Act* [2012] and *Fisheries Protection Policy* [DFO 2013a]).

The three fish VC species also represent important ecosystems processes (e.g., they are relatively abundant and occupy various trophic positions in their respective food web). Furthermore, Arctic Grayling is classified as a sensitive species in NWT, and therefore, may require special attention in an environmental assessment (NWT Infobase 2014).

Lake Trout and Lake Whitefish typically rely on rocky shoals in lakes for spawning. Arctic Grayling typically rely on streams for spawning and rearing, and are considered an adfluvial species, as they will overwinter in lakes. All three species may move between lakes or rivers and streams for feeding or spawning movements (primarily Arctic Grayling). These life history traits may prevent a species from tolerating the loss of stream or lake habitat. For example, a barrier between the two habitat types may remove access to habitat, resulting in loss of habitat, and ultimately, effects to the stability of the self-sustaining population. Habitat loss through habitat fragmentation can be a major factor exacerbating population declines for species, such as Arctic Grayling (MacPherson et al. 2012).

Table 9.1-1 Rationale for Selection of Fish Valued Components

Fish Valued Component	Rationale
Arctic Grayling	• Fished for traditional/subsistence use, and popular sport fish in NWT • Abundant in Lac du Sauvage and Lac de Gras • Uses stream habitats for spawning and rearing, but overwinters in lakes; adfluvial life history suitable for assessing potential effects to stream habitats • Feeds primarily on aquatic and terrestrial insects, as well as plankton; suitable for assessing how potential changes to lower trophic levels may affect fish • Listed as "sensitive" in NWT
Lake Trout	• Fished for traditional/subsistence use, and popular sport fish in NWT • Abundant in Lac du Sauvage and Lac de Gras • Completes most of its life history in lakes, with occasional movements into streams, so suitable for assessing potential changes to lake habitats • Long-lived predatory species; primarily piscivorous • Top of food chain, so suitable for assessing potential effects of water quality changes (changes in lower trophic organisms or forage fish will ultimately affect lake trout), as well as for potential effects of metals or other substances that have the potential to bioaccumulate
Lake Whitefish	• Fished for traditional/subsistence use, and has been fished commercially in NWT at certain locations • Abundant in Lac du Sauvage and below the Lac du Sauvage-Lac de Gras Narrows • Completes most of its life history in lakes, with occasional movements into streams • Feeds primarily on benthic organisms; suitable for assessing how potential changes to sediment quality and benthic invertebrates may affect fish

Assessment endpoints are qualitative expressions used to assess the significance of effects on the fish and aquatic life VCs, and represent the key properties of these VCs that should be protected for future human generations (i.e., incorporate sustainability). Key properties of the VCs, such as ongoing fisheries productivity and self-sustaining and ecologically effective populations, are assessment endpoints that should be protected for their use by future generations (Table 9.1-2). The VCs and assessment endpoints were determined partially from the outcome of community and regulatory engagement process, which included local and traditional knowledge (Section 4). The maintenance of self-sustaining and ecologically effective fish populations are assessment endpoints for the fish VCs, which would maintain the ongoing productivity of fisheries important to the Aboriginal groups in NWT and Nunavut. In the human environment section of the DAR (Section 15), continued opportunity for the traditional and non-traditional use of fish is also an assessment endpoint for evaluating the significance of effects to the communities and people that value this resource as part of their culture and livelihood.

Table 9.1-2 Summary of Valued Components, Assessment Endpoints, and Measurement Indicators

Valued Component	Assessment Endpoint	Measurement Indicator
Arctic Grayling Lake Trout Lake Whitefish	• ongoing fisheries productivity • self-sustaining and ecologically effective fish populations	• habitat quantity (includes surface hydrology and water quality indicators) • habitat arrangement and connectivity (fragmentation) • habitat quality (includes surface hydrology and water quality indicators) • survival and reproduction • abundance and distribution of fish
Aquatic life other than fish	• ongoing support of fisheries productivity	• concentrations of chlorophyll *a*, nutrients • phytoplankton species composition, abundance, and biomass • zooplankton species composition, abundance, and biomass • benthic invertebrate species composition, richness, abundance, and biomass

For the assessment, measurement indicators were chosen to evaluate the assessment endpoints. Measurement indicators represent properties of the environment and VCs that, when changed, could result in, or contribute to, an effect on assessment endpoints. Measurement indicators are defined as quantifiable (i.e., measurable) expressions of change to assessment endpoints (e.g., changes to chemical concentration, lower trophic levels as a food source, habitat quantity, or habitat quality). Assessment endpoints include quality and quantity of habitat for various life history stages, which would include foraging habitat (i.e., areas that support forage fish species for fish feeding) and the status of lower trophic levels. Changes to measurement indicators (e.g., habitat area lost) are often assumed to have a direct proportional impact on assessment endpoints (DFO 2014a).

The fish species and other aquatic life VCs have both measurement indicators and assessment endpoints (Table 9.1-1). Results from other aquatic components are also used in determining the assessment endpoint for fish. Measurement indicators for water quantity and water quality represent linkages to the assessment endpoint for fish and other aquatic life. For example, water quantity has measurement endpoints (e.g., lake water levels). Changes to this measurement endpoint are assessed in Section 9, because changes in water levels could affect fish habitat and the maintenance of self-sustaining fish populations.

9.1.4 Spatial Boundaries

9.1.4.1 *Baseline Study Area*

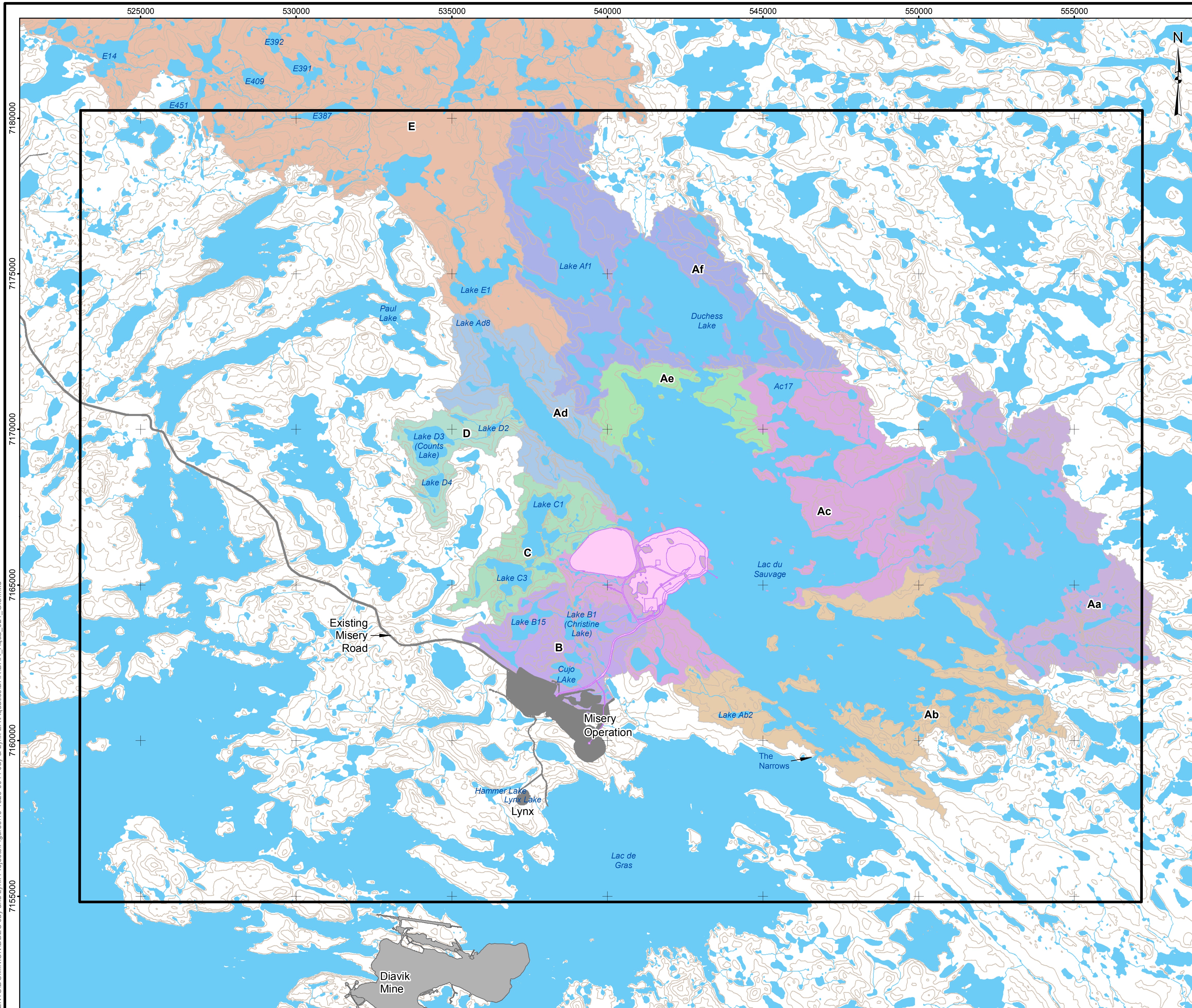
The fish and fish habitat BSA is located in the Lac de Gras sub-basin, which is in the headwaters of the Coppermine drainage, approximately 300 km northeast of Yellowknife, NWT, and 20 km northwest of the Diavik Diamond Mine (Map 9.1-2). The Coppermine River has a basin area of 50,800 square kilometres (km^2) and drops 416 metres (m) over a distance of approximately 850 km.

Lac de Gras is a large lake in the headwaters of the Coppermine River where the Lac de Gras sub-basin has an area of approximately 4,136 km^2. The Lac de Gras sub-basin, situated in the sub-arctic region of the Canadian Shield, has land features characteristic of glaciated terrain, including crag and lee drumlins, eskers, and kettle lakes. The maze of small lakes, wetlands, and creeks in the basin indicate poorly drained conditions. The upland areas are generally well drained and covered with sparse, mainly tundra vegetation. Lichens, mosses, heather, and dwarf shrub species dominate on the higher, well-drained areas, whereas sedges and grasses are predominant in the poorly drained areas, and along creeks and lakeshores.

The fish and fish habitat BSA is the area within which Project activities could potentially have direct or cumulative effects on fish and fish habitat. The BSA consists of sub-basins that flow directly into Lac du Sauvage (e.g., Ab, Ac, Ad, Af, B, C, D) and Lac de Gras (e.g., Paul, Lynx, Hammer, Koala). The surface elevations of the study lakes in the BSA range from approximately 415.9 metres above sea level (masl) at Lac de Gras (416.1 masl for Lac du Sauvage) to approximately 444.6 masl at Lake D4.

The lakes and streams within each sub-basin of Lac du Sauvage were named according to their position in the watershed. The naming convention starts at the mouth of the creek (e.g., at Lac du Sauvage) with the sub-basin letter and the number 1 (e.g., Stream C1), and increases sequentially upstream to the headwaters. Where applicable, lake and stream names incorporated the historical Ekati names consistent with the terminology in the 2006 Jay Pipe Aquatic Baseline (Rescan 2007), e.g., Lake B1 (Christine Lake), Lake B4 (Cujo Lake), and Lake D3 (Counts Lake).

The BSA includes Lac du Sauvage, Paul Lake, Duchess Lake, Lake E1, and smaller lakes and streams that connect these lakes or flow into them. The Paul Lake catchment flows in a southerly direction through Paul Creek into Lac de Gras. Adjacent to, and east of Paul Lake is the Lake E1 catchment, flowing in a southerly direction into Duchess Lake. Downstream of Duchess Lake is Lac du Sauvage, followed by Lac de Gras. The Koala watershed consists of a system of connected lakes extending from Vulture Lake and Grizzly Lake above the Panda and Koala pits in the northeast to Slipper Lake in the southwest where water drains into Lac de Gras. Leslie, Moose, Nema, and Slipper lakes are located downstream of the Long Lake Containment Facility (LLCF) at the Ekati Mine.



LEGEND

- EKATI MINE FOOTPRINT
- DIAVIK MINE FOOTPRINT
- PROPOSED JAY FOOTPRINT
- ELEVATION CONTOUR (10 m INTERVAL)
- WATERCOURSE
- WATERBODY
- BASELINE STUDY AREA

BASIN

- Aa
- Ab
- Ac
- Ad
- Ae
- Af
- B
- C
- D
- E

REFERENCE

CANVEC © NATURAL RESOURCES CANADA, 2012
NATURAL RESOURCES CANADA, CENTRE FOR TOPOGRAPHIC INFORMATION, 2012
DATUM: NAD83 PROJECTION: UTM ZONE 12N

DOCUMENT

DEVELOPER'S ASSESSMENT REPORT

3 0 3
SCALE 1:125,000 KILOMETRES

PROJECT
DOMINION DIAMOND
JAY PROJECT
NORTHWEST TERRITORIES, CANADA

TITLE

FISH AND FISH HABITAT BASELINE STUDY AREA, 2013

Golder Associates

PROJECT	13-1328-0041		FILE No. DAR_Aqua_024_GIS	
DESIGN	JV	31/0714	SCALE AS SHOWN	REV 0
GIS	JE	20/10/14	MAP 9.1-2	
CHECK	CS	20/10/14		
REVIEW	KM	20/10/14		

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Fish species expected to occur in the BSA and the codes used in this report are presented in Table 9.1-3. Eleven species of fish are expected to occur in the BSA, based on sampling conducted for the Project as well as previously completed studies.

Table 9.1-3 Common and Scientific Names of Fish Species Expected to Occur in the Baseline Study Area

Family	Common Name	Code[(a)]	Scientific Name
Salmonidae	Lake Trout	LKTR	*Salvelinus namaycush* (Walbaum)
	Arctic Grayling	ARGR	*Thymallus arcticus* (Pallas)
	Cisco	CISC	*Coregonus artedi* (Lesueur)
	Lake Whitefish	LKWH	*Coregonus clupeaformis* (Mitchill)
	Round Whitefish	RNWH	*Prosopium cylindraceum* (Pallas)
Esocidae	Northern Pike	NRPK	*Esox lucius* (Linnaeus)
Gadidae	Burbot	BURB	*Lota lota* (Linnaeus)
Catostomidae	Longnose Sucker	LNSC	*Catostomus catostomus* (Forster)
Gasterosteidae	Ninespine Stickleback	NNST	*Pungitius pungitius* (Linnaeus)
Cyprinidae	Lake Chub	LKCH	*Couesius plumbeus* (Agassiz)
Cottidae	Slimy Sculpin	SLSC	*Cottus cognatus* (Richardson)

a) According to Mackay et al. (1990).

9.1.4.2 *Effects Study Area*

As described in Section 6.3.1, the selection of the boundary for effects study areas was based on the physical and biological properties of VCs. Most relevant to a fish VC was the spatial scale of the population or fisheries unit under examination (Randall et al. 2013). Spatial scales of estimates of the effects, including cumulative effects, on assessment endpoints aligned to the scales of the changes in habitat relative to the full area contributing to the fishery (or self-sustaining population). By this design, effects assessment areas captured the maximum spatial extent of potential effects from the Project and other previous, existing, and reasonably foreseeable future developments.

The existing environmental setting of the assessment for fish and fish habitat occurs within the scale of the Lac de Gras sub-basin, which contains 1,770 km of streams and 6,336 lakes totalling 135,034 hectares (ha) in area. There are 106 lakes greater than 100 ha in size (Table 9.1-4). It is possible that all lakes and streams in the contributing watershed area of Lac de Gras and Lac du Sauvage have the potential to be a fishery (i.e., a resource unit) (Table 9.1-3). However, ecological, physical, social, and economic attributes of a fishery can be used to further delineate an area that is expected to react similarly to previous, existing, and reasonably foreseeable developments.

Table 9.1-4 Baseline Summary of Surface Water in Drainage Basins Potentially Affected by the Project

Sub-Basin	Total Sub-Basin Area (ha)	Total Stream Length (km)	Number of Lakes				Lake Area (ha)			
			<1 ha	1 to 10 ha	10 to 100 ha	>100 ha	<1 ha	1 to 10 ha	10 to 100 ha	>100 ha
Lac de Gras[a]	413,570	1,769.8	3,487	2,080	663	106	1,033	7,479	20,678	105,845
Koala [b]	18,573	89.8	187	116	29	5	65	370	998	852
Lac du Sauvage[b]	158,892	611.8	1,163	719	276	58	348	2,529	8,759	37,783
B[c]	1,459	8.6	19	6	5	0	8	15	193	0
C[c]	1,178	6.0	8	6	2	1	2	22	99	163
Ac4[c]	275	5.0	12	1	0	0	4	3	0	0
Ac35[c]	252	1.5	0	0	2	0	0	0	59	0

a) The Lac de Gras drainage basin is inclusive of all subsequent basins/sub-basins in the table.
b) In Lac de Gras sub-basin.
c) In Lac du Sauvage sub-basin.
ha = hectare; <= less than; >= greater than; km = kilometre.

Within the BSA, population and fishery units for the VCs were determined to operate on similar spatial scales beyond the area to be enclosed by the dike and dewatered in Lac du Sauvage (Map 9.1-3). Effects to Arctic Grayling, Lake Trout, and Lake Whitefish were examined at the spatial scale of the combined Lac du Sauvage and Lac de Gras waterbodies, because both lakes are relatively large and deep, are connected by a short outflow, and have similar species assemblages. Historical records also show traditional subsistence fishing of Lake Trout and Lake Whitefish in Lac de Gras and Lac du Sauvage.

In addition to the two lakes (combined area = 65,758 ha), the scale of the assessment [i.e., the Effects Study Area (ESA)] included tributaries that may be used for spawning, rearing, or feeding by VC species, and tributaries that may support forage fish for VC species in Lac du Sauvage and Lac de Gras (Map 9.1-3) (ESA-1; Table 9.1-5). The total length of tributaries identified in ESA-1 includes 43.3 km of stream in Lac de Gras and 11.6 km of stream in Lac du Sauvage. The tributaries included sections of small streams extending from Lac de Gras and Lac du Sauvage to the outlet of a first upstream lake of approximately 10 ha in area or larger. Tributary stream sections ranged in length from 23 m to 2,611 m (75 stream sections in total).

Table 9.1-5 Effects Study Areas for the Assessment of Effects to Fish

Valued Component	ESA Name	Geographic Extent Based on Population Unit
Arctic Grayling, Lake Trout, and Lake Whitefish[a]	ESA-1	Lac du Sauvage, Lac de Gras, and supporting tributaries
	ESA-B	Sub-basin B (includes Christine Lake)
	ESA-C	Sub-basin C
	ESA-Ac35	Sub-basin Ac35
	ESA-K	Koala watershed
Aquatic life (other than fish)	ESA-1	Lac du Sauvage, Lac de Gras, and supporting tributaries
	ESA-C	Sub-basin C
	ESA-K	Koala watershed

a) Lake Whitefish were not recorded in sub-basin B, C, and Koala watershed (Annex XIV; Section 9.3).

ESA = effects study area.

Potentially affected sub-basins of Lac du Sauvage and Lac de Gras include sub-basins B, C, Ac 4 and Ac35 of Lac du Sauvage, and the Koala watershed of Lac de Gras (Table 9.1-4) (Map 9.1-3). The occurrence of VCs was confirmed in the Koala watershed (18,573 ha), and sub-basin Ac35 (252 ha), sub-basin B (1,459 ha), and sub-basin C (1,178 ha). Each of these four fish-bearing sub-basins, and the surface waters within, was considered as an individual ESA. The populations of Arctic Grayling, Lake Trout, and Lake Whitefish in the affected basins may live out their life histories within these sub-basins rather than being part of the larger lake populations (Annex XIV, Fish and Fish Habitat Baseline), and thus, be separate populations than those of the Lac du Sauvage-Lac de Gras population.

Sub-basin Ac4 was initially considered as a potentially affected sub-basin, but was removed from the assessment because it is unlikely to support populations of VCs. Sub-basin Ac4 covers a relatively small area (less than 300 ha), there are no waterbodies over 10 ha in the sub-basin (Table 9.1-4), and previously completed surveys report low, dispersed flows (i.e., barriers to fish passage), and no defined bed or banks in Stream Ac4 (Rescan 2007). However, Stream Ac4 was included in the scale of ESA-1 for the assessment of Arctic Grayling, Lake Trout, and Lake Whitefish in Lac du Sauvage and Lac de Gras (Table 9.1-5).

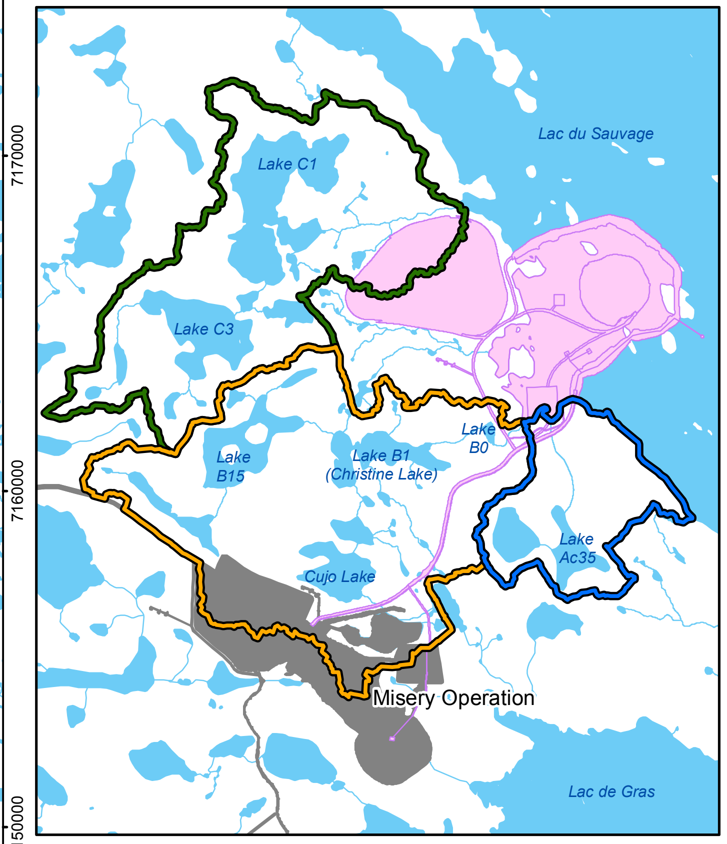
In summary, the assessment of effects to Fish and Fish Habitat VCs considered five Effects Study Areas (ESAs) to best evaluate effects, including cumulative effects, to ongoing fisheries productivity and self-sustaining and ecologically effective populations for the VCs (Map 9.1-3). The ESAs fall within the boundaries of the BSA and the Lac de Gras drainage basin (Table 9.1-5).

LEGEND

- EKATI MINE FOOTPRINT
- DIAVIK MINE FOOTPRINT
- PROPOSED JAY FOOTPRINT
- WATERCOURSE
- WATERBODY

EFFECTS STUDY AREA

- ESA-1 (LAC DE GRAS, LAC DU SAUVAGE AND SELECTED TRIBUTARIES)
- ESA-Ac35 (SUB-BASIN Ac35)
- ESA-B (SUB-BASIN B)
- ESA-C (SUB-BASIN C)
- ESA-K (KOALA WATERSHED)



REFERENCE

CANVEC © NATURAL RESOURCES CANADA, 2012
NATURAL RESOURCES CANADA, CENTRE FOR TOPOGRAPHIC INFORMATION, 2012
DATUM: NAD83 PROJECTION: UTM ZONE 12N

DOCUMENT

DEVELOPER'S ASSESSMENT REPORT

5 0 5
SCALE 1:225,000 KILOMETRES

PROJECT
DOMINION DIAMOND
JAY PROJECT
NORTHWEST TERRITORIES, CANADA

TITLE
EFFECTS STUDY AREA FOR VALUED COMPONENTS FOR FISH AND FISH HABITAT

Golder Associates

PROJECT	13-1328-0041	FILE No. DAR_Aqua_014_GIS	
DESIGN	JV	28/07/14	SCALE AS SHOWN REV 0
GIS	JE	20/10/14	
CHECK	CS	20/10/14	
REVIEW	KM	20/10/14	

MAP 9.1-3

9.2 Existing Environment

9.2.1 Surface Waters

A brief summary of hydrology, water and sediment quality characteristics of Lac du Sauvage and Lac de Gras is provided below to provide a general understanding of these components as they relate to fish and fish habitat. Additional information for water and sediment quality in Lac du Sauvage and additional waterbodies and watercourses is included in Section 8.2.5 and Annex XI (Water and Sediment Quality Baseline Report). Additional information on hydrology characteristics is included in Section 8.2.4 and Annex X, Hydrology Baseline Report).

9.2.1.1 *Lac du Sauvage*

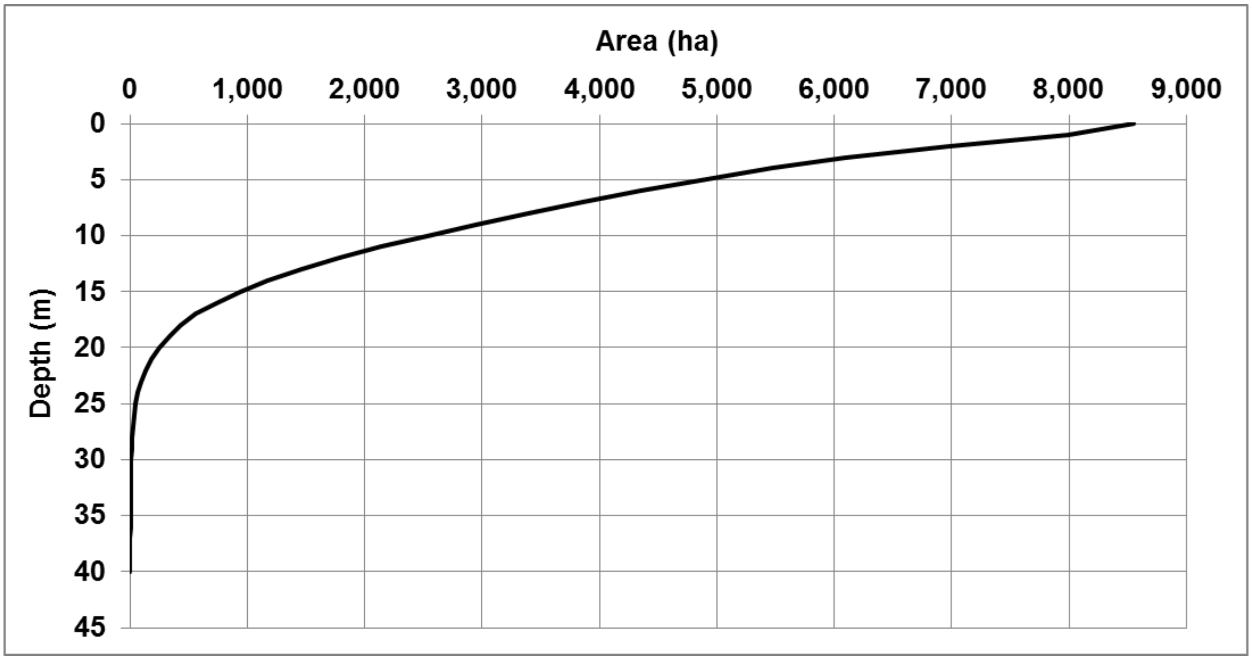
9.2.1.1.1 Hydrology Characteristics

Lac du Sauvage (all internal basins combined: Aa, Ab, Ac, Ad, and Ae) has a surface area of 8,651 ha based on 1:50,000 National Topographic Service (NTS) maps and a total volume of approximately 630,320,529 cubic metres (m^3). The shoreline of Lac du Sauvage, was also digitized using georeferenced orthophotos for use with habitat delineations, which resulted in a slightly different calculated surface area of 8,668 ha.

Lac du Sauvage has a mean depth of 6.8 m and a maximum depth of 40.4 m. Approximately 81 percent (%) of the surface area of Lac du Sauvage is deeper than 2 m, which is the maximum expected thickness of ice in winter; therefore, 19% of Lac du Sauvage may freeze to the bottom during winter (Figure 9.2-1). However, observed ice thickness data for Lac du Sauvage (2008 to 2012) indicates ice can be less than 2 m in thickness, ranging between 1.3 and 1.6 m (Annex X, Hydrology Baseline Report).

The Lac du Sauvage outlet is a relatively wide (minimum bankfull width of approximately 45 m) and short (210 m in length) stream that drains to Lac de Gras, which is locally known as "the Narrows". It has a low gradient (less than 0.1%). The highest flows occur in July and August. It is expected that year-round flows are maintained between Lac du Sauvage and Lac de Gras. The median flood peak discharge is 17.5 cubic metres per second (m^3/s). A detailed description of the Lac du Sauvage outlet is presented in Annex X.

Figure 9.2-1 Depth-Area Relationship for Lac du Sauvage



m = metre; ha = hectare.

9.2.1.1.2 Water and Sediment Quality

During the 2013 baseline studies (Annex XI, Water and Sediment Quality Baseline Report), water quality parameters in Lac du Sauvage were often similar among stations and sampling events, suggesting that the lake can be homogeneous throughout the open-water period. Water quality measures found in Lac du Sauvage were as follows:

- The range of values for total alkalinity (3.7 to 5.4 milligrams per litre [mg/L] as calcium carbonate [$CaCO_3$]) and total hardness (4.4 to 5.0 mg/L as $CaCO_3$) indicate the lake water is very soft and may be sensitive to acid deposition (McNeely et al. 1979; Saffran and Trew 1996).
- The lake was slightly acidic, with pH ranging from 6.1 to 6.8.
- Total dissolved solids (TDS) ranged from less than 10 mg/L to 25 mg/L.
- Concentrations of total suspended solids (TSS) were below the detection limit (less than 3.0 mg/L), with turbidity ranging from 0.30 to 0.86 nephelometric turbidity units (NTU).
- Specific conductivity was similar throughout the water column and generally ranged from 11 to 15 microSiemens per centimetre (µS/cm).
- In the fall, several deep stations had higher specific conductivity of 23 to 24 µS/cm.
- Major ions included bicarbonate, calcium, and sulphate.

- Metals were generally either below detection limits or Canadian Water Quality Guidelines (CWQG) (CCME 1999), with the exception of aluminum, cadmium, chromium, and lead, which exceeded CWQG for the protection of aquatic life.

Nutrient concentrations were low in Lac du Sauvage, consistent with its designation as an oligotrophic lake (CCME 2004; Annex XI). Measures of trophic status and primary production found in Lac du Sauvage were as follows:

- Concentrations of total phosphorus and total dissolved phosphorus ranged from 0.0026 to 0.014 milligrams of phosphorus per litre (mg P/L), and from less than 0.001 mg P/L to 0.004 mg P/L, respectively.
- Dissolved orthophosphate concentrations were less than 0.001 mg/L.
- Total Kjeldahl nitrogen concentrations ranged from less than 0.05 to 0.25 milligrams of nitrogen per litre (mg N/L).
- Nitrate and nitrite were below detection limits (less than 0.006 mg N/L and less than 0.002 mg N/L, respectively).
- Organic carbon occurred primarily in the dissolved form, with dissolved organic carbon concentrations ranging from 2.6 to 6.3 mg/L.
- Chlorophyll *a* concentrations ranged from 0.65 micrograms per litre (µg/L) during the summer to 3.24 µg/L during the fall, coinciding with peak phytoplankton biomass.
- Concentrations of soluble reactive silica (SRSi) were less than 0.1 mg/L, which suggests that silica may be limiting diatom growth.

Thermal stratification within the water column in Lac du Sauvage began in the late spring of 2013 and was evident at all deep water stations during the summer, persisting until the fall turnover (Annex XI). Dissolved oxygen profiles showed no evidence of oxic stratification. Dissolved oxygen concentrations were lower in the summer than in the late spring and fall, but the waters were well-oxygenated throughout the water column, ranging from 72% to 107% saturation during the open-water season.

For sediment quality, particle size distribution, total organic carbon (TOC), and metal concentrations were similar between shallow and deep water sites in Lac du Sauvage (Annex XI, Appendix A). Clays ranged from 7% to 22%, silt from 40% to 87%, fine sand from less than 1% to 27%, coarse sand from less than 0.1% to 22%, and gravel from less than 0.1% to 3%. Total organic carbon ranged from 0.8% to 1.8%, and metal concentrations were generally below Canadian Council of Ministers of the Environment (CCME) sediment quality guidelines (SQGs) (CCME 1999) with the exception of arsenic, chromium, and copper.

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9.2.1.2 Lac de Gras

9.2.1.2.1 Hydrological Characteristics

Lac de Gras is approximately 60.5 km long and up to 16.5 km wide, with a surface area of approximately 57,107 ha; the average depth is 12 m, with several areas up to approximately 56 m (BHP 1995a). Total volume of water is expected to be approximately 6,155,786,146 m^3, approximately ten times the volume of Lac du Sauvage. The median flood peak discharge for the Lac de Gras outlet (i.e., Coppermine River) is 28.1 m^3/s (Annex X). The highest flow month is September, and it is expected that the Lac de Gras outlet flows year-round.

9.2.1.2.2 Water and Sediment Quality

Baseline data for Lac de Gras are based on historic open-water information sourced from the 2010 to 2012 Diavik and Ekati mine AEMP monitoring programs (summarized in Annex XI and Section 8.2.5.2.2). Locations included the East Basin (FF2), Slipper Bay (S2 and S3), and the West Basin (FFA), which is one of the reference areas used by the Diavik Mine to represent baseline conditions. Ranges presented in this summary are for these three areas inclusive, unless stated otherwise. Water quality measures found in Lac de Gras were as follows:

- Total alkalinity (3.2 to 6.4 mg/L as $CaCO_3$) and total hardness (4.7 to 11 mg/L as $CaCO_3$) indicated Lac de Gras contained very soft water and may be sensitive to acid deposition (McNeely et al. 1979; Saffran and Trew 1996).
- The lake was circumneutral, with pH ranging from 6.7 to 7.6.
- Total dissolved solids ranged from less than 5 mg/L to 30 mg/L; total suspended solids ranged from less than 1.0 mg/L to 3.0 mg/L, with turbidity ranging from 0.12 to 0.47 NTU.
- Specific conductivity ranged from 15 to 20 µS/cm in the West Basin (FFA), and from 21 to 40 µS/cm in the East Basin (FF2) and Slipper Bay (S2 and S3) areas (Section 8.2.5.2.2); major ions included bicarbonate, calcium, and sodium.
- Metals were generally either below detection limits or CWQG (CCME 1999; Section 8.2.5.2.2).

Nutrient concentrations were low in Lac de Gras, falling within the range of ultra-oligotrophic to oligotrophic lakes (CCME 2004; Section 8.2.5.2.2). Measures of trophic status and primary production found in Lac de Gras were as follows:

- Concentrations of total phosphorus and total dissolved phosphorus ranged from 0.001 to 0.01 mg P/L and from less than 0.001 to 0.006 mg P/L, respectively; dissolved orthophosphate concentrations were less than 0.005 mg/L.
- Total Kjeldahl nitrogen concentrations ranged from less than 0.05 to 1.09 mg N/L, and nitrite was below detection limits (less than 0.002 mg N/L), with nitrate ranging from less than 0.002 to 0.03 mg N/L.
- Total organic carbon ranged from 1.5 to 5.0 mg/L.

- Chlorophyll *a* concentrations in Lac de Gras varied among areas, ranging from 0.31 µg/L (2012) and 0.67 µg/L (2009) in the FFA area, 0.79 µg/L (2005) to 1.55 µg/L (2007) in the FF2 area, and 0.20 (2006) to 1.59 (2007) in Slipper Bay (Section 8.2.5.2.2).

Temperature and oxygen profiles in Lac de Gras were vertically homogeneous at most stations during the 2013 AEMP, with oxygen concentrations exceeding 7 mg/L at each of the stations and depths sampled (DDMI 2014). Thermal stratification was observed in Lac de Gras during the 2012 AEMP for the Diavik Mine (DDMI 2014), indicating thermal stratification may not occur every year, or turnover occurs at approximately the same time as the AEMP sampling in late August.

For sediment quality in Lac de Gras, particle size distribution, TOC, and metal concentrations were similar between Slipper Bay (S2 and S3) and the East (FF2) and West (FFA) basins (Annex XI). Clays ranged from 2% to 40%, silt 22% to 90%, and sand from 2% to 76%. Total organic carbon ranged from 1.0% to 8.3%, and metal concentrations were generally below CCME SQGs with the exception of arsenic, cadmium, chromium, and copper.

9.2.2 Fish and Other Aquatic Life

The existing environment for fish and other aquatic life VCs is a summary of biological and environmental information collected across multiple years in the BSA. Summaries of plankton, benthic invertebrates and fish were provided to support the design engineers (in planning the layout of the mine), to meet regulatory requirements, and to provide baseline conditions against which to evaluate the potential effects of the Project.

A baseline sampling program was completed in 2013 to characterize plankton and benthic invertebrate communities in lakes within the BSA (Table 9.2-1; Maps 9.2.1 and 9.2-2, respectively). In addition, historical plankton and benthic invertebrate community data collected during previous studies for the Ekati and Diavik mines as part of their baseline or aquatic effects monitoring programs (AEMPs) were also reviewed. A summary of the results of the 2013 plankton and benthic invertebrate sampling programs and the historical data reviews are provided below; more details are included in Annexes XII (Plankton Baseline Report) and XIII (Benthic Invertebrate Baseline Report).

A fish and fish habitat baseline study was completed for the BSA from early August to mid-September 2013 to describe fish population characteristics and habitat in lakes and streams near the proposed Project (Table 9.2-1; Map 9.2-3). The 2013 baseline program focused on internal basins Ac, Ad, and Ae of Lac du Sauvage (i.e., the area near the Project), and their major tributaries and sub-catchments (i.e., sub-basins B and C). Historical fish and fish habitat information collected for the Ekati and Diavik mines as part of their baseline or AEMPs was also reviewed. A summary of the fish and fish habitat baseline information is provided below; more details are included in Annex XIV (Fish and Fish habitat Baseline Report).

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Table 9.2-1 Summary of Sampling Component by Waterbody during 2013 Baseline Sampling Programs

Lake or Stream	Sampling Component						
	Plankton	Benthic Invertebrates	Fish Habitat	Aerial Photos	Surface Water Quality	Vertical Profiles	Bathymetry
Lac du Sauvage	✓	✓	✓	✓	✓	✓	✓
Paul Lake	✓	✓	✓	✓	✓	✓	
Duchess Lake	✓	✓	✓	✓	✓	✓	
Lake Af1	✓	✓	✓	✓	✓		
Lake Ad8			✓	✓	✓	✓	✓
Lake Ab2			✓	✓	✓		
Lake Ac17			✓	✓	✓		✓
Lake B1 (Christine)			✓	✓	✓	✓	✓
Lake B4 (Cujo)			✓	✓	✓	✓	✓
Lake B15			✓	✓	✓	✓	✓
Lake C1		✓	✓	✓	✓	✓	✓
Lake C3			✓	✓	✓	✓	✓
Lake D2			✓	✓	✓	✓	✓
Lake D3 (Counts)			✓	✓	✓	✓	✓
Lake D4			✓	✓	✓	✓	✓
Lake E1	✓	✓	✓	✓	✓	✓	
Hammer Lake	✓		✓	✓	✓	✓	
Lynx Lake	✓		✓	✓	✓	✓	
Stream Ab1		✓					
Stream Ab2			✓	✓			
Stream Ac17			✓	✓			
Stream Ac20			✓	✓			
Stream Ad8			✓	✓			
Stream B1 (Christine Creek)			✓	✓	✓		
Stream B15			✓	✓	✓		
Stream C1			✓	✓	✓		
Stream C3			✓	✓	✓		
Stream D1			✓	✓	✓		
Stream E1				✓			
Stream E2		✓	✓	✓	✓		
Stream G1		✓					
Stream L1		✓		✓			
Lac du Sauvage Creek			✓	✓			
Paul Creek			✓	✓			
Duchess Creek				✓			
Hammer Creek				✓			
Lynx Creek				✓			

✓ = Included in 2013 surveys.

A sampling program in 2014 was also carried out in Lac du Sauvage, Lac de Gras, and several Lac du Sauvage area lakes and streams to collect additional baseline data on fish and fish habitat to support the analysis of mine-related effects, and to aid in developing a monitoring program in Lac du Sauvage for the proposed Jay Project. The results of these field programs will be reported in supplemental baseline reports to be issued in 2015.

Plankton and benthic invertebrate communities at stations in the FF2 and Slipper Bay (S2-S6) regions of Lac de Gras as well as all Lac du Sauvage stations, Duchess Lake, and lakes in the B (Christine Lake) and C (Lake C1) sub-basin regions of the Lac du Sauvage watershed were sampled during the 2014 open-water period.

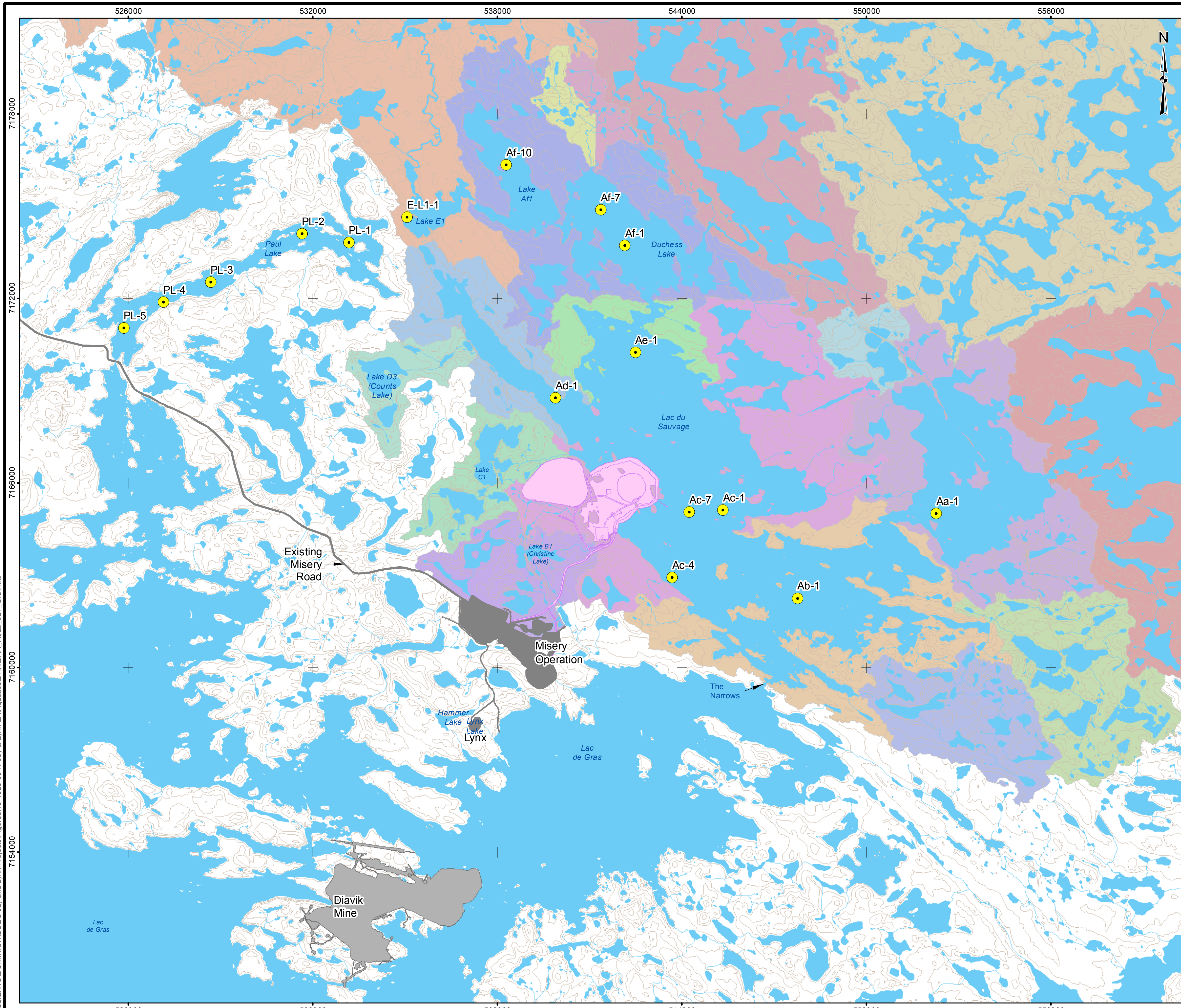
Fisheries inventories were performed in the Ac4, Ac35 and B sub-basins, and Ursula Lake and Lac du Sauvage. Two-way fyke net traps were installed on Stream B0 and B1 in June and August to monitor the abundance of fish in the stream and the direction of travel of fish using the stream. The timing of monitoring followed the expected breeding chronology of Arctic Grayling. Backpack electrofishing and habitat mapping were completed concurrently with trapping efforts for streams (Stream Ac4, Ac35, B1, B2, B3, B4, and B15). Electrofishing of representative sections of Lakes B0, B1, A4, and Ac35 and Lac du Sauvage provided abundance and life history data for small-bodied species in lakes. Gill netting in Lakes Ac35 and Ac36, Ursula Lake, and Lac du Sauvage provided information on species relative abundance and life history data for a diversity of species. Reconnaissance surveys of habitat potential for fish were performed for a subset of small lakes and streams at headwater locations of Sub-basin Ac4, B and C.

9.2.3 Methods

9.2.3.1 *Plankton*

The 2013 plankton baseline program was completed during the open-water period, from late July to mid-September 2013. Phytoplankton and zooplankton samples were collected during three open-water field programs in 2013:

- July 20 to 29 (late spring);
- August 8 to 17 (summer); and,
- September 5 to 19 (fall).

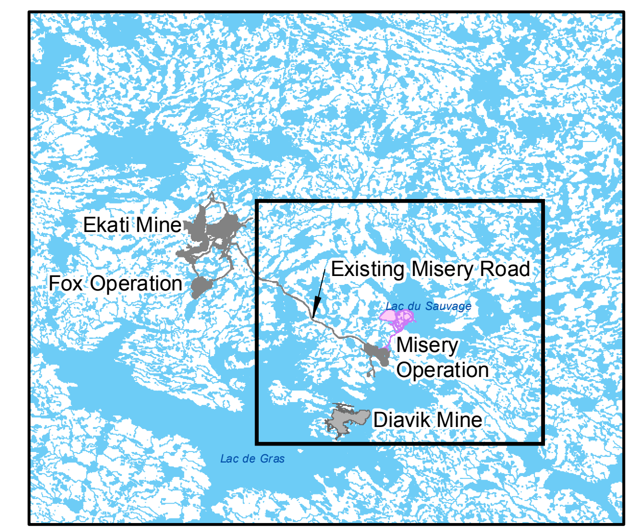


LEGEND

- EKATI MINE FOOTPRINT
- DIAVIK MINE FOOTPRINT
- PROPOSED JAY FOOTPRINT
- ELEVATION CONTOUR (10 m INTERVAL)
- WATERCOURSE
- WATERBODY
- PLANKTON STATION

BASIN

- Aa
- Ab
- Ac
- Ad
- Ae
- Af
- B
- C
- D
- E
- F
- F2
- G
- H
- I
- J
- K
- L



REFERENCE

CANVEC © NATURAL RESOURCES CANADA, 2012
NATURAL RESOURCES CANADA, CENTRE FOR TOPOGRAPHIC INFORMATION, 2012
DATUM: NAD83 PROJECTION: UTM ZONE 12N

DOCUMENT

DEVELOPER'S ASSESSMENT REPORT

2.5 0 2.5
SCALE 1:125,000 KILOMETRES

PROJECT

DOMINION DIAMOND

JAY PROJECT
NORTHWEST TERRITORIES, CANADA

TITLE

PLANKTON COMMUNITY SAMPLING LOCATIONS, 2013

Golder Associates

PROJECT		13-1328-0041	FILE No. DAR_Aqua_027_GIS
DESIGN	SE	27/08/14	SCALE AS SHOWN REV 0
GIS	JE	09/09/14	**MAP 9.2-1**
CHECK	SE	03/10/14	
REVIEW	ZK	06/10/14	

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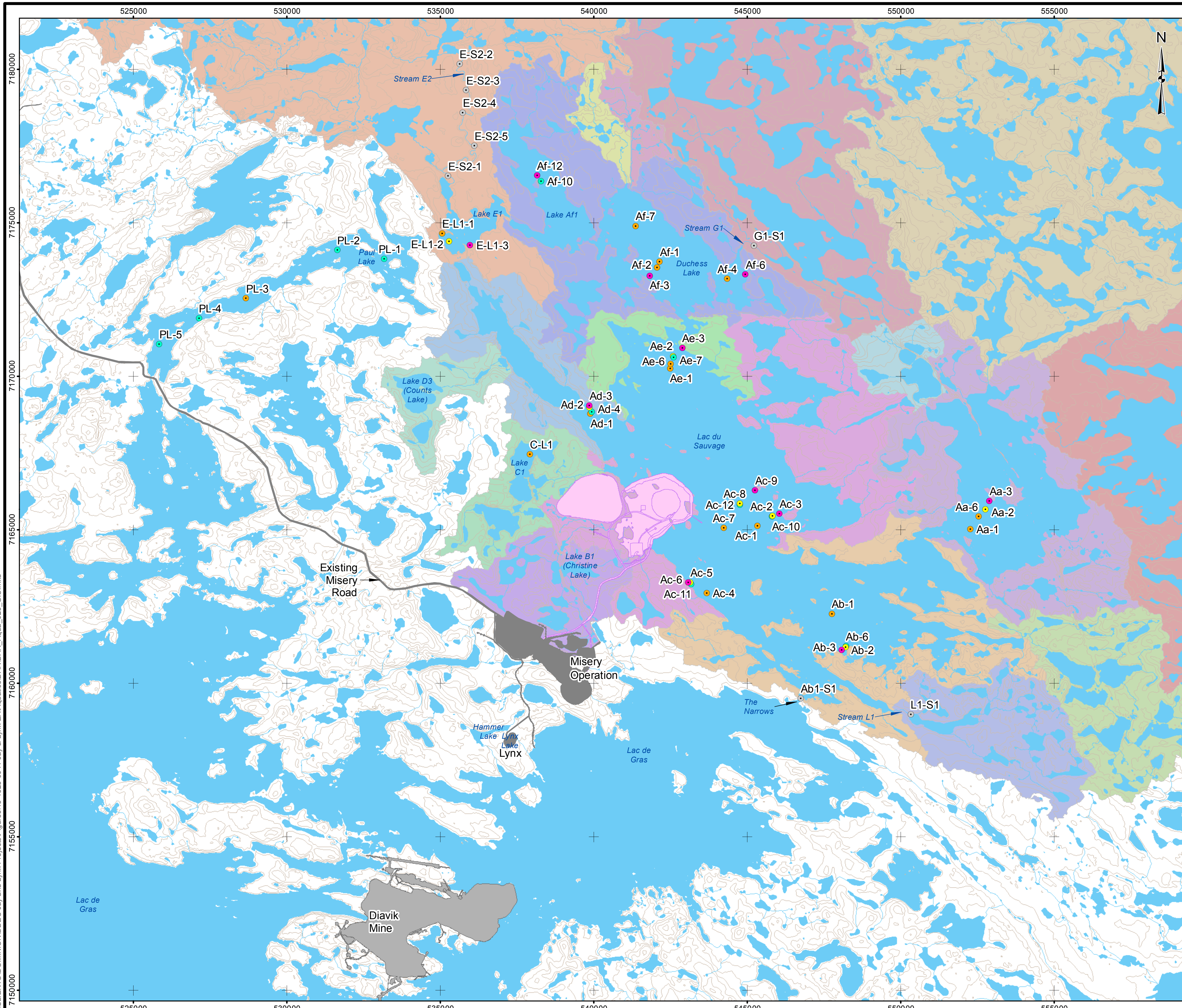


LEGEND

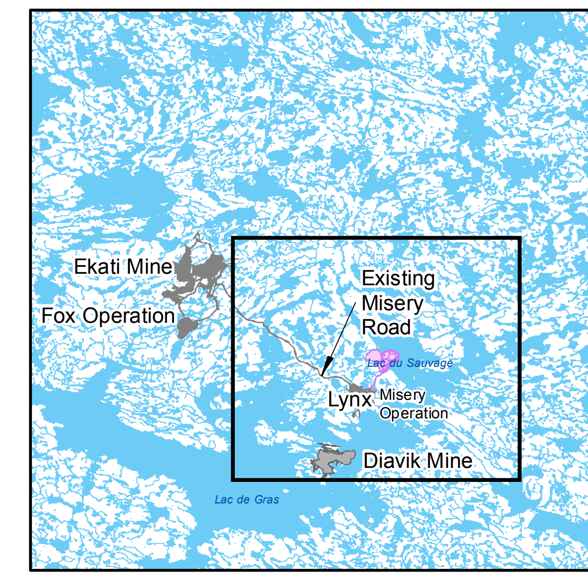
- EKATI MINE FOOTPRINT
- DIAVIK MINE FOOTPRINT
- PROPOSED JAY FOOTPRINT
- ELEVATION CONTOUR (10 m INTERVAL)
- WATERCOURSE
- WATERBODY

STATION DEPTH CATEGORIES

- LITTORAL STATION
- SHALLOW STATION
- MID-DEPTH STATION
- DEEP STATION
- STREAM STATION

BASIN

Aa, Ab, Ac, Ad, Ae, Af, B, C, D, E, F, F2, G, H, I, J, K, L



REFERENCE

CANVEC © NATURAL RESOURCES CANADA, 2012
NATURAL RESOURCES CANADA, CENTRE FOR TOPOGRAPHIC INFORMATION, 2012
DATUM: NAD83 PROJECTION: UTM ZONE 12N

DOCUMENT

DEVELOPER'S ASSESSMENT REPORT

2.5 0 2.5
SCALE 1:125,000 KILOMETRES

PROJECT

DOMINION DIAMOND

JAY PROJECT
NORTHWEST TERRITORIES, CANADA

TITLE

BENTHIC INVERTEBRATE COMMUNITY SAMPLING LOCATIONS, 2013

Golder Associates

PROJECT		13-1328-0041	FILE No. DAR_Aqua_025_GIS
DESIGN	SE	27/08/14	SCALE AS SHOWN REV 0
GIS	JE	09/09/14	MAP 9.2-2
CHECK	SE	06/10/14	
REVIEW	ZK	06/10/14	

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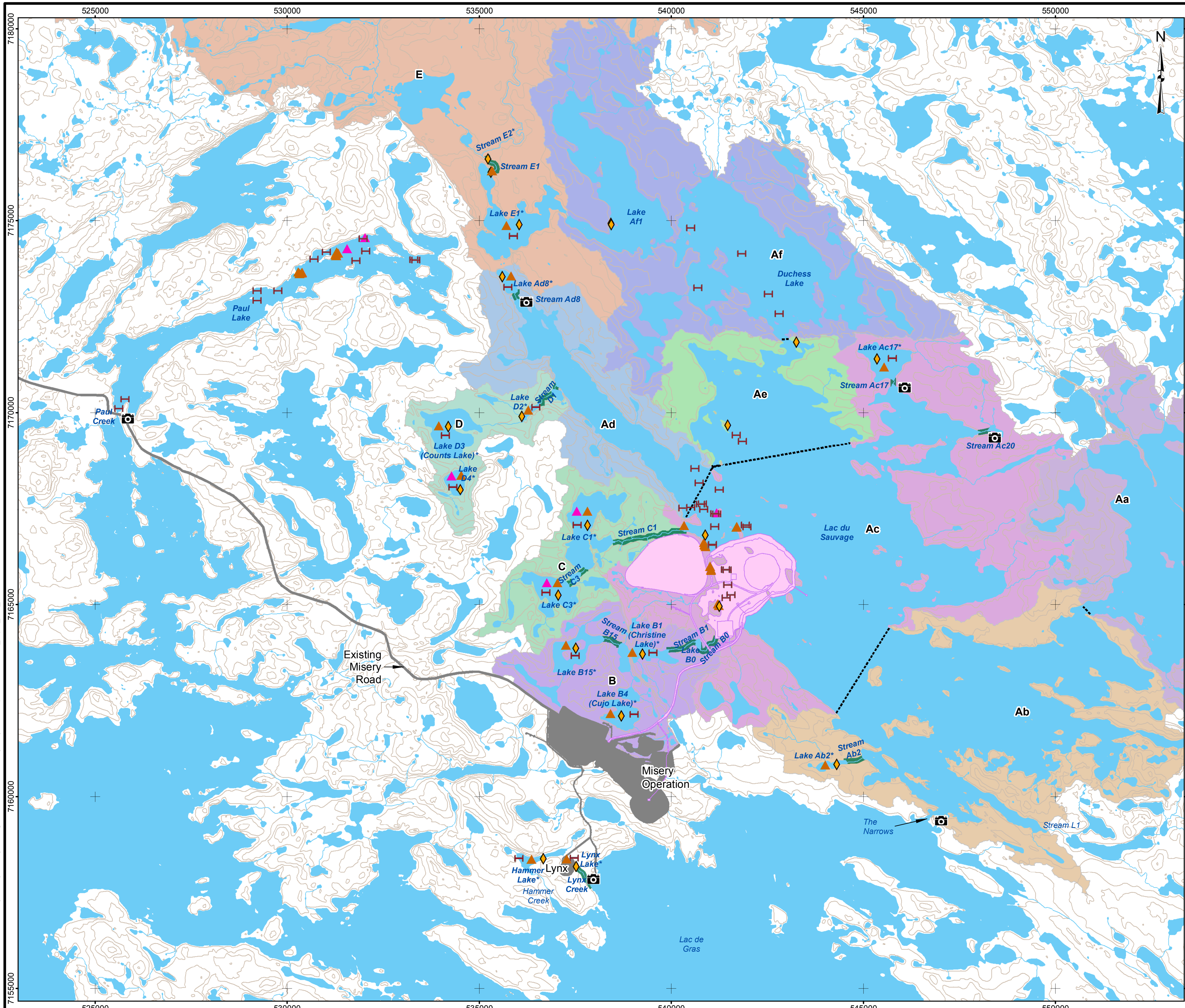

LEGEND

- EKATI MINE FOOTPRINT
- PROPOSED JAY FOOTPRINT
- ELEVATION CONTOUR (10 m INTERVAL)
- WATERCOURSE
- STREAM HABITAT ASSESSED
- WATERBODY
- ANGLING LOCATION, 2013
- ELECTROFISHING LOCATION, 2013
- GILL NET LOCATION, 2013
- MINNOW TRAP LOCATION, 2013
- SCOPING LEVEL HABITAT ASSESSMENT
- INTERNAL BASIN DIVIDE

BASIN

- Aa
- Ab
- Ac
- Ad
- Ae
- Af
- B
- C
- D
- E

NOTE

FISH SAMPLING LOCATIONS ARE A REPRESENTATION ONLY AND DO NOT INDICATE ACTUAL LOCATION FOR THE LAKES INDICATED WITH AN ASTERISK

REFERENCE

CANVEC © NATURAL RESOURCES CANADA, 2012
NATURAL RESOURCES CANADA, CENTRE FOR TOPOGRAPHIC INFORMATION, 2012
DATUM: NAD83 PROJECTION: UTM ZONE 12N

DOCUMENT

DEVELOPER'S ASSESSMENT REPORT

2 0 2

SCALE 1:100,000 KILOMETRES

PROJECT

DOMINION DIAMOND

JAY PROJECT
NORTHWEST TERRITORIES, CANADA

TITLE

SAMPLING LOCATIONS FOR FISH AND FISH HABITAT BASELINE STUDY AREA, 2013

Golder Associates

PROJECT		13-1328-0041	FILE No. DAR_Aqua_017_GIS
DESIGN	JV	31/07/14	SCALE AS SHOWN REV 0
GIS	JE	20/10/14	MAP 9.2-3
CHECK	CS	20/10/14	
REVIEW	KM	20/10/14	

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Chlorophyll *a* and depth-integrated nutrient (i.e., total phosphorus, total nitrogen, and soluble reactive silica) samples were collected as part of the plankton program; detailed nutrient results are presented in Annex XI (Plankton Baseline Report). Plankton sampling occurred in four lakes in the Lac du Sauvage basin (Lac du Sauvage, Duchess Lake, Lake Af1, and Lake E1), and one lake (Paul Lake) in the Lac de Gras basin (Map 9.2-1; Table 9.2-1). Phytoplankton were sampled using a Kemmerer sampler to collect discrete water samples at 2-m intervals within the euphotic zone (defined as two-times the Secchi depth). Two composite phytoplankton samples were submitted for analysis from each location. A 30-centimetre (cm) diameter, 80 µm mesh Turtox plankton tow net was used to collect zooplankton samples at each station. Each zooplankton sample consisted of a single vertical haul. Haul depths were recorded for each sample and were used to calculate the volume of water filtered through the net. Phytoplankton and zooplankton samples were analyzed for species composition at the lowest possible taxonomic level (typically species), and abundance and biomass by EcoAnalysts Inc. (EcoAnalysts) in Moscow, Idaho, United States (USA).

The trophic status of each major waterbody was evaluated by examining the nutrient data, chlorophyll *a*, and water transparency (Secchi depth) data. The trophic status was determined using: the Vollenweider (1970) trophic classification scheme for lakes (using total phosphorus [TP], total nitrogen [TN], chlorophyll *a*, and Secchi depth); the Canadian Council of Ministers of the Environment (CCME 2004) trophic classification scheme for Canadian lakes and streams (using TP); and the Trophic State Index (TSI) developed by Carlson (1977).

Additional details on field and laboratory methods and analyses for the 2013 data are presented in Annex XII.

Historical data were reviewed to provide regional context for plankton communities in key waterbodies within the Project area. The historical plankton data were obtained from the following sources:

- baseline and long-term AEMP data from 1995 to 2012 for the Ekati Mine (Rescan 2012a; ERM Rescan 2013);
- baseline data from the 2006 baseline program for the proposed development of the Jay pipe as part of the Ekati Mine (Rescan 2007); and,
- baseline and long-term AEMP data from 1997 to 2012 for the Diavik Mine (Golder 2011; DDMI 2012, 2013).

The historical data summary for plankton included the FF2 and Slipper Bay areas because these are areas currently showing changes as a result of mining activities. The FFA and FFB areas were also included because these are reference areas used by the Diavik Mine to represent baseline conditions. A qualitative overview of the Koala watershed is also provided using information presented in the Ekati 2013 AEMP (ERM Rescan 2014).

9.2.3.2 *Benthic Invertebrates*

Benthic invertebrate samples and supporting data were collected in fall 2013, between August 16 and September 14, from waterbodies identified in Table 9.2-2. Samples were collected at deep (greater than 10 m), mid-depth (5.1 to 10 m), and shallow (1 to 5 m) stations, and in littoral areas (near-shore and less than 1 m). Benthic invertebrate samples were also collected between August 5 and September 16, 2013, from four streams in the Lac du Sauvage basin. One station was sampled in each of Stream Ab1, Stream G1, and Stream L1; five stations were sampled in Stream E2 (Map 9.2-2)

Samples were collected from lake, littoral, and stream sampling stations according to standard sampling protocols based on relevant scientific literature (AENV 1990; Klemm et al. 1990; Environment Canada 1993; Rosenberg and Resh 1993). At each lake station, a standard Ekman grab was used from an anchored boat. Five individual Ekman grab samples were collected at each station. Each grab sample was sieved through a 250-µm mesh screen in the field. At each littoral station, a kick-net was used to sample at a water depth of less than 1 m. This kick-net method was repeated three times to collect a composite sample. At each stream station, a Surber sampler was used to collect invertebrates from cobble/gravel substrates. Supporting environmental information (weather conditions, habitat description, water depth, current velocity, water conductivity, and water temperature) was also recorded at each station. Benthic invertebrate samples were shipped to EcoAnalysts in Moscow, Idaho (USA) for taxonomic identification and enumeration of invertebrates.

Table 9.2-2 Benthic Invertebrate Lake and Littoral Sampling Stations in the Jay Project Baseline Study Area, August and September 2013

Waterbody	Sub-Basin	Location in Sub-Basin	Station	Date Sampled	Sample Depth Category	Sampling Depth (m)	Sampler Type	
							Kick-Net Samples	Ekman Grab Samples
Lac du Sauvage	Aa	—	Aa-1	27-Aug-13	deep	11.2	—	X
			Aa-6	27-Aug-13	mid-depth	8.0	—	X
			Aa-2	27-Aug-13	shallow	5.0	—	X
			Aa-3	27-Aug-13	littoral	0.4	X	—
	Ab	—	Ab-1	26-Aug-13	deep	12.4	—	X
			Ab-6	26-Aug-13	mid-depth	7.6	—	X
			Ab-2	26-Aug-13	shallow	5.0	—	X
			Ab-3	26-Aug-13	littoral	0.4	X	—
	Ac	Northeast	Ac-1	25-Aug-13	deep	12.8	—	X
			Ac-10	24-Aug-13	mid-depth	7.3	—	X
			Ac-2	25-Aug-13	shallow	5.0	—	X
			Ac-3	24-Aug-13	littoral	0.3	X	—
			Ac-7	24-Aug-13	deep	12.4	—	X
			Ac-12	24-Aug-13	mid-depth	6.5	—	X
			Ac-8	24-Aug-13	shallow	4.8	—	X
			Ac-9	24-Aug-13	littoral	0.4	X	—

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Table 9.2-2 Benthic Invertebrate Lake and Littoral Sampling Stations in the Jay Project Baseline Study Area, August and September 2013

Waterbody	Sub-Basin	Location in Sub-Basin	Station	Date Sampled	Sample Depth Category	Sampling Depth (m)	Sampler Type	
							Kick-Net Samples	Ekman Grab Samples
Lac du Sauvage Con't	Ac Con't	Southwest	Ac-4	19-Aug-13	deep	12.3	—	X
			Ac-11	19-Aug-13	mid-depth	8.2	—	X
			Ac-5	19-Aug-13	shallow	3.6	—	X
			Ac-6	19-Aug-13	littoral	0.4	X	—
	Ad	—	Ad-1	17-Aug-13	deep	12.6	—	X
			Ad-4	17-Aug-13	mid-depth	7.9	—	X
			Ad-2	17-Aug-13	shallow	4.2	—	X
			Ad-3	17-Aug-13	littoral	0.4	X	—
Lac du Sauvage	Ae	—	Ae-1	18-Aug-13	deep	12.4	—	X
			Ae-6	16-Aug-13	deep	12.2	—	X
			Ae-7	18-Aug-13	mid-depth	6.4	—	X
			Ae-2	16-Aug-13	shallow	5.0	—	X
			Ae-3	16-Aug-13	littoral	0.3	X	—
Duchess Lake	Af	—	Af-1	21-Aug-13	deep	13.5	—	X
			Af-2	21-Aug-13	shallow	4.3	—	X
			Af-3	20-Aug-13	littoral	0.3	X	—
			Af-4	20-Aug-13	shallow	3.0	—	X
			Af-6	15-Aug-13	littoral	0.4	X	—
			Af-7	20-Aug-13	deep	12.4	—	X
Lake Af1	—	—	Af-10	12-Sep-13	mid-depth	8.7	—	X
			Af-12	12-Sep-13	littoral	0.4	X	—
Lake C1	—	—	C-L1	15-Sep-13	deep	10.2	—	X
Lake E1	—	—	E-L1-1	23-Aug-13	deep	11.7	—	X
			E-L1-2	23-Aug-13	shallow	3.5	—	X
			E-L1-3	23-Aug-13	littoral	0.4	X	—
Paul Lake	—	—	PL-1	14-Sep-13	mid-depth	8.8	—	X
			PL-2	14-Sep-13	mid-depth	8.0	—	X
			PL-3	14-Sep-13	deep	13.0	—	X
			PL-4	14-Sep-13	mid-depth	8.0	—	X
			PL-5	14-Sep-13	mid-depth	8.0	—	X

m = metre; con't = continued.

Historical data were reviewed to provide regional context for benthic invertebrate communities in key waterbodies within the Project area. Historical benthic invertebrate data were obtained from the following sources:

- baseline and long-term AEMP data from 1996 to 2013 for the Diavik Mine, summarized by Diavik Diamond Mines Inc. (DDMI; 2001, 2002, 2010, 2011a, 2012) and Golder (1996, 2011);
- baseline and long-term AEMP data from 1994 to 2013 for the Ekati Mine, summarized by Rescan Environmental Services Ltd. (Rescan; 1995, 2002, 2011) and ERM Rescan Environmental Services Ltd. (ERM Rescan; 2013, 2014); and,
- baseline data from a 2006 baseline program for the proposed development of the Jay pipe as part of the Ekati Mine, summarized by Rescan (2007).

Direct comparisons of data among programs were limited by differences in mesh size and sampling depth. Due to these differences among programs, comparisons between historical and current results are largely qualitative.

Lakes and streams included in the historical review (Map 9.2-4) were:

- Lac du Sauvage basin: Lac du Sauvage in A sub-basin, Lake B1 (Christine Lake) in B sub-basin, Lake D3 (Counts Lake and its outflow) in D sub-basin, and Ursula Lake in E sub-basin; and,
- Lac de Gras basin: Lac de Gras, Nanuq Lake and its outflow, Vulture Lake, and the Vulture-Polar Outflow.

Similar to plankton, the historical data summary for benthic invertebrates included the FF2 and Slipper Bay areas because these areas are currently showing changes from mining activities, and the FFA and FFB areas as they are reference areas used by the Diavik Mine to represent baseline conditions.
A qualitative overview of the Koala watershed is also provided using information presented in the Ekati AEMP (ERM Rescan 2014).

LEGEND

- EKATI MINE FOOTPRINT
- DIAVIK MINE FOOTPRINT
- PROPOSED JAY FOOTPRINT
- ELEVATION CONTOUR (20 m INTERVAL)
- WATERCOURSE
- WATERBODY
- NOT INCLUDED HISTORICAL SITE
- INCLUDED HISTORICAL SITE
- QUALITATIVE DESCRIPTION IN DAR

NOTE

1. (a) STATION F16 WAS ONLY SAMPLED IN 1996; FOR THE HISTORICAL REVIEW THIS STATION WAS CLASSIFIED AS PART OF THE FF1 AREA FOR EASE OF REFERENCE.

REFERENCE

NATIONAL TOPOGRAPHIC BASE DATA (NTDB) 1:250,000
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NATURAL RESOURCES CANADA, CENTRE FOR TOPOGRAPHIC INFORMATION, 2012
DATUM: NAD83 PROJECTION: UTM ZONE 12N

DOCUMENT

DEVELOPER'S ASSESSMENT REPORT

5 0 5
SCALE 1:225,000 KILOMETRES

PROJECT
DOMINION DIAMOND
JAY PROJECT
NORTHWEST TERRITORIES, CANADA

TITLE
HISTORICAL BENTHIC INVERTEBRATE COMMUNITY SAMPLING LOCATIONS

Golder Associates

PROJECT		13-1328-0041	FILE No. DAR_Aqua_028_GIS	
DESIGN	SE	27/08/14	SCALE AS SHOWN	REV 0
GIS	JE/LR	09/09/14	MAP 9.2-4	
CHECK	SE	03/10/14		
REVIEW	ZK	03/10/14		

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DOMINION DIAMOND

9.2.3.3 *Fish and Fish Habitat*

Methods followed standard protocols for sampling lakes and streams for fish (Bonar et al. 2009), and included overnight and short-duration gill net sets, overnight index gill netting sets, minnow trapping, backpack electrofishing, angling, and visual observations (Table 9.2-3). Captured fish were identified to species and measured for length and weight, when possible. Life history data were used to describe the structure of the local population of fish, and to understand body condition of each species. Ageing structures (e.g., otoliths, fin rays, and scales) were collected to understand trends in growth.

Table 9.2-3 Summary of Fish and Fish Habitat Surveys and Sampling Methods Deployed per Waterbody and Watercourse, 2013

Lake or Stream	Survey Type						Fish Sampling Method			
	Fish Habitat	Aerial Photos	Surface Water Quality	Vertical Profiles	Bathymetry	Stream Discharge	Gill Net	Backpack Electro-Fisher	Minnow Trap	Angling
Lac du Sauvage	✓	✓	✓	✓	✓		✓	✓	✓	✓
Paul Lake	✓	✓	✓	✓			✓		✓	✓
Duchess Lake	✓	✓	✓	✓			✓	✓		
Lake Af1	✓	✓	✓					✓		
Lake Ad8	✓	✓	✓	✓	✓		✓	✓	✓	
Lake Ab2	✓	✓	✓					✓	✓	
Lake Ac17	✓	✓	✓		✓		✓	✓	✓	
Lake B1 (Christine)	✓	✓	✓	✓	✓		✓	✓	✓	
Lake B4 (Cujo)	✓	✓	✓	✓	✓		✓	✓	✓	
Lake B15	✓	✓	✓	✓	✓		✓	✓	✓	
Lake C1	✓	✓	✓	✓	✓		✓	✓	✓	✓
Lake C3	✓	✓	✓	✓	✓		✓		✓	✓
Lake D2	✓	✓	✓	✓	✓		✓	✓	✓	
Lake D3 (Counts)	✓	✓	✓	✓	✓		✓	✓	✓	
Lake D4	✓	✓	✓	✓	✓		✓	✓	✓	✓
Lake E1	✓	✓	✓	✓			✓	✓	✓	
Hammer Lake	✓	✓	✓	✓			✓	✓	✓	
Lynx Lake	✓	✓	✓	✓			✓	✓	✓	
Stream Ab2	✓	✓								
Stream Ac17	✓	✓								
Stream Ac20	✓	✓								
Stream Ad8	✓	✓								
Stream B1 (Christine Creek)	✓	✓	✓			✓		✓		
Stream B15	✓	✓	✓			✓		✓		
Stream C1	✓	✓	✓			✓		✓		
Stream C3	✓	✓	✓					✓		
Stream D1	✓	✓	✓					✓		
Stream E1		✓				✓				

Table 9.2-3 Summary of Fish and Fish Habitat Surveys and Sampling Methods Deployed per Waterbody and Watercourse, 2013

Lake or Stream	Survey Type						Fish Sampling Method			
	Fish Habitat	Aerial Photos	Surface Water Quality	Vertical Profiles	Bathymetry	Stream Discharge	Gill Net	Backpack Electro-Fisher	Minnow Trap	Angling
Stream E2	✓	✓	✓			✓		✓	✓	
Stream L1		✓								
Lac du Sauvage Creek	✓	✓				✓				
Paul Creek	✓	✓				✓				
Duchess Creek		✓								
Hammer Creek		✓								
Lynx Creek		✓								

✓ = Included in 2013 surveys or sampling methods.

In addition to conventional fish capture methods, two hydroacoustic surveys were completed to survey populations of fish in Lac du Sauvage using a Biosonics DT-X echosounder system oriented for horizontal and vertical split-beam sonar. Hydroacoustic surveys targeted species that were numerically abundant and pelagic (fish that live offshore in the middle or lower part of the water column), such as Cisco, and other species that may be demersal (found or living near the lake bottom) and only occasionally pelagic, such as Lake Trout, Arctic Grayling, Lake Whitefish, and Round Whitefish. The surveys were designed to detect larger fish, such as yearling and older fish, (i.e., fish greater than 90 millimetres [mm] in length in mid-summer) in deep-water locations. All surveys were performed at night along predetermined transects in each of the five internal basins of Lac du Sauvage (Aa to Ae), with the purpose of estimating fish population size in Lac du Sauvage. Data were analyzed using echo integration and fish tracking methods.

Lake and stream habitat evaluations were performed concurrently with the fish sampling efforts (Annex XIV; Fish and Fish Habitat Baseline Report). Habitats of representative shoreline sections were characterized in all lakes by identifying unique features on a map and with georeferenced photographs. Bathymetric surveys for identifying maximum water depths were also completed in Lake B1 (Christine), Lake B4 (Cujo), Lake D3 (Counts), and lakes Ad8, Ac17, B15, C1, C3, D2, and D4 (Annex XIV). Bathymetric surveys of Lac du Sauvage, Paul Lake, Lake E1, Duchess Lake, and Lake Af1 were completed by Aurora GeoSciences Ltd.

Shoreline substrate types were digitized for Lac du Sauvage using georeferenced orthophotos and ground-truthing methods for depths up to 5 m (Annex XIV). Substrate types for the entire area of Lac du Sauvage, including shallow and deep-water locations, were defined using hydroacoustic data; the analyzed data were then plotted in ArcGIS to interpolate the substrate types for the non-surveyed portions of each lake. The resulting substrate maps were overlaid with bathymetry data to calculate the area (hectares) of each substrate type (fines, mixed or scattered rock, and coarse) falling into each of the four depth strata (0 to 2 m, 2 to 6 m, 6 to 10 m, and greater than 10 m). Detailed methods are in provided in Annex XIV.

Streams in the BSA were evaluated and photographed from a helicopter. Habitat evaluations were conducted on the ground for watercourses with defined bed and banks. Watercourses with undefined or dispersed channels were identified as ephemeral watercourses and were not evaluated in detail on the ground for habitat and fish (i.e., ephemeral streams were evaluated only from helicopter). Potential barriers to fish movements in streams were noted and marked in Global Positioning System (GPS).

Stream characteristics were considered at each surveyed site and involved measurements of mean bankfull channel and wetted width (m), depth (m), and stream velocity (metres per second [m/s]). Substrate size was recorded. Habitat type identification followed a modified classification by Hawkins et al. (1993) for cascade, riffle, run, pool, flat, and boulder garden habitat types. Detailed maps of stream habitat were created for Stream E2, Stream B1 (Christine Creek), Stream C1, and Stream D1, and then used for qualitative descriptions of habitat and substrate types at those locations. Additional details on habitat methods used at streams in the BSA are provided in Annex XIV.

The 2013 field data for Lac du Sauvage, Lake B4 (Cujo), and Lake D3 (Counts) were supplemented with catch information from selected previous fish programs in the BSA. Data were obtained from the 2006 Jay Pipe Aquatic Baseline Report (Rescan 2007), the 2007 and 2012 Ekati Mine Aquatic Effects Monitoring Program (AEMP) reports (Rescan 2008; ERM Rescan 2013), and reports in support of the Diavik Mine 2008 and 2011 AEMPs (Golder 2009, 2012) (Table 9.2-4). Data from these reports, combined with 2013 data, provided a rigorous database for this DAR.

Table 9.2-4 Summary of Fish Sampling Methods Deployed per Waterbody, 2006 to 2012

Lake	Years of Method Deployment			
	Gill Net	**Backpack Electrofisher**	**Minnow Trap**	**Angling**
Lac du Sauvage	2006, 2011	—	2006	2008, 2011
Lake B4 (Cujo)	2007, 2012	2007, 2012	2007	—
Lake D3 (Counts)	2007, 2012	2007, 2012	2007	—

— = Method not used.

A total of 38 historical reports were reviewed for information on species abundance and distributions, life history, habitat use and availability, fish health, and fish tissue chemistry (Table 9.2-5; Map 9.2-5) to identify general trends in fish and fish habitat conditions in the BSA (Annex XIV, Appendix A). The primary sources of historical information were baseline assessments and environmental monitoring reports related to mining activities by the Ekati and Diavik mines in the BSA.

Table 9.2-5 Summary of Historical Reports that were Reviewed

Report	Information Provided and Summarized in Historical Report				
	Species Abundance and Distribution	Life History	Habitat Use and Availability	Fish Health	Fish Tissue Chemistry
BHP 1995a	✓	✓	✓		✓
Golder 1997a	✓		✓		
Golder 1997b			✓		
Golder 1997c	✓		✓		
Golder 1997d			✓		
Golder 1997e			✓		
Golder 1997f	✓	✓	✓		
CEA Agency 1998[(a)]					
DDMI 1998a	✓				
DDMI 1998b	✓	✓	✓		
Golder 1998a	✓	✓		✓	✓
Golder 1998b					✓
Jacques Whitford 2001	✓	✓		✓	
Jacques Whitford 2002	✓	✓			
Dillon 2002a			✓		
Dillon 2002b					✓
Dillon 2002c	✓	✓			
Dillon 2002d	✓	✓			
Golder 2002	✓		✓	✓	
Rescan 2002	✓	✓			✓
Dillon 2003	✓	✓			
DDMI 2003					✓
Rescan 2003	✓	✓	✓		✓
Dillon 2004	✓	✓			
DDMI 2004	✓				
Gray et al. 2005	✓	✓			✓
CRI 2006	✓	✓		✓	✓
DDMI 2006	✓	✓			✓
Rescan 2007	✓	✓	✓		✓
Golder 2008	✓	✓		✓	✓
Rescan 2008	✓	✓		✓	
Thistle and Tonn 2007	✓	✓			
DDMI 2008a			✓		
Golder 2009	✓	✓		✓	✓
Rescan 2009	✓	✓			
Rio Tinto 2009					✓
Golder 2010	✓	✓		✓	✓
Rio Tinto 2010					✓
Rio Tinto 2011		✓		✓	✓
Golder 2012	✓	✓			
Rio Tinto 2012					✓
ERM Rescan 2013	✓	✓		✓	✓

a) This report included only summary information from other reports; data were not re-analyzed for this summary. ✓ = Included in historical review. Note: excludes fish-out reports at Ekati Mine; these reports are summarized in the baseline summary below.

LEGEND

- EKATI MINE FOOTPRINT
- DIAVIK MINE FOOTPRINT
- PROPOSED JAY FOOTPRINT
- ELEVATION CONTOUR (10 m INTERVAL)
- WATERCOURSE
- WATERBODY
- GENERAL HISTORICAL REPORT LOCATION

REPORT NUMBER	REPORT CITATION
1	BHP 1995a
2	Golder 1997a
3	Golder 1997b
4	Golder 1997c
5	Golder 1997d
6	Golder 1997e
7	Golder 1997f
8	CEAA 1998
9	DDMI 1998a
10	DDMI 1998b
11	Golder 1998a
12	Golder 1998b
13	Jacques Whitford 2001
14	Dillion 20002a
15	Dillion 20002b
16	Golder 2002
17	Jacques Whitford 2002
18	Rescan 2002
19	DDMI 2003
20	Rescan 2003
21	DDMI 2004
22	Gray e t al. 2005
23	CRI 2006
24	DDMI 2006
25	Rescan 2007
26	Thistle and Tonn 2007
27	DDMI 2008
28	Golder 2008
29	Rescan 2008
30	Golder 2009
31	Rescan 2009
32	Rio Tin to 2009
33	Golder 2010
34	Rio Tin to 2010
35	Rio Tin to 2011
36	Golder 2012
37	Rio Tin to 2012
38	ERM Rescan 2013

REFERENCE

CANVEC © NATURAL RESOURCES CANADA, 2012
NATURAL RESOURCES CANADA, CENTRE FOR TOPOGRAPHIC INFORMATION, 2012
DATUM: NAD83 PROJECTION: UTM ZONE 12N

DOCUMENT

DEVELOPER'S ASSESSMENT REPORT

5 0 5
SCALE 1:225,000 KILOMETRES

PROJECT
DOMINION DIAMOND
JAY PROJECT
NORTHWEST TERRITORIES, CANADA

TITLE
GENERAL LOCATIONS OF SOURCES OF FISH AND FISH HABITAT INFORMATION PROVIDED IN THE HISTORICAL REPORTS

Golder Associates

PROJECT		13-1328-0041	FILE No. DAR_Aqua_018_GIS	
DESIGN	JV	31/07/14	SCALE AS SHOWN	REV 0
GIS	JE	20/10/14	MAP 9.2-5	
CHECK	CS	20/10/14		
REVIEW	KM	20/10/14		

G:\CLIENTS\DOMINION\DDEC Jay and Lynx Projects\Figures\13-1328-0041 Jay & Lynx EA\Aquatics\DAR\DAR_Aqua_018_GIS.mxd

9.2.4 Results

Results from sampling efforts, both recent and historical, are presented below with relevant fish and fish habitat data summarized by the following areas:

- Lac du Sauvage;
- small lakes and tributary streams to Lac du Sauvage;
- Lac de Gras; and,
- small lakes and tributary streams to Lac de Gras.

The presentation of baseline data considered the content and methods of previously completed baseline programs, including historical programs (Section 9.2.3), and the spatial extent of ESA(s) within the BSA (Section 9.1.4). For example, Lac du Sauvage and Lac de Gras comprise most of an ESA, whereas tributary small lakes and streams form an ESA for each of the affected sub-basins for the DAR. The proposed layout of Section 9.2.4 may also assist with the interpretation of the results given that historical programs were the main sources of information for Lac de Gras and its tributary small lakes and streams, whereas recent sampling programs were the primary sources of information for Lac du Sauvage and its tributary small lakes and streams.

Within each of the sections, summaries are provided for fish habitat, plankton, benthic invertebrates, and fish community and abundance. A summary of life history information for fish VC's and forage fishes in the BSA is also provided (Section 9.2.5). Life history trends are presented per waterbody where possible (i.e., where sample sizes are sufficient).

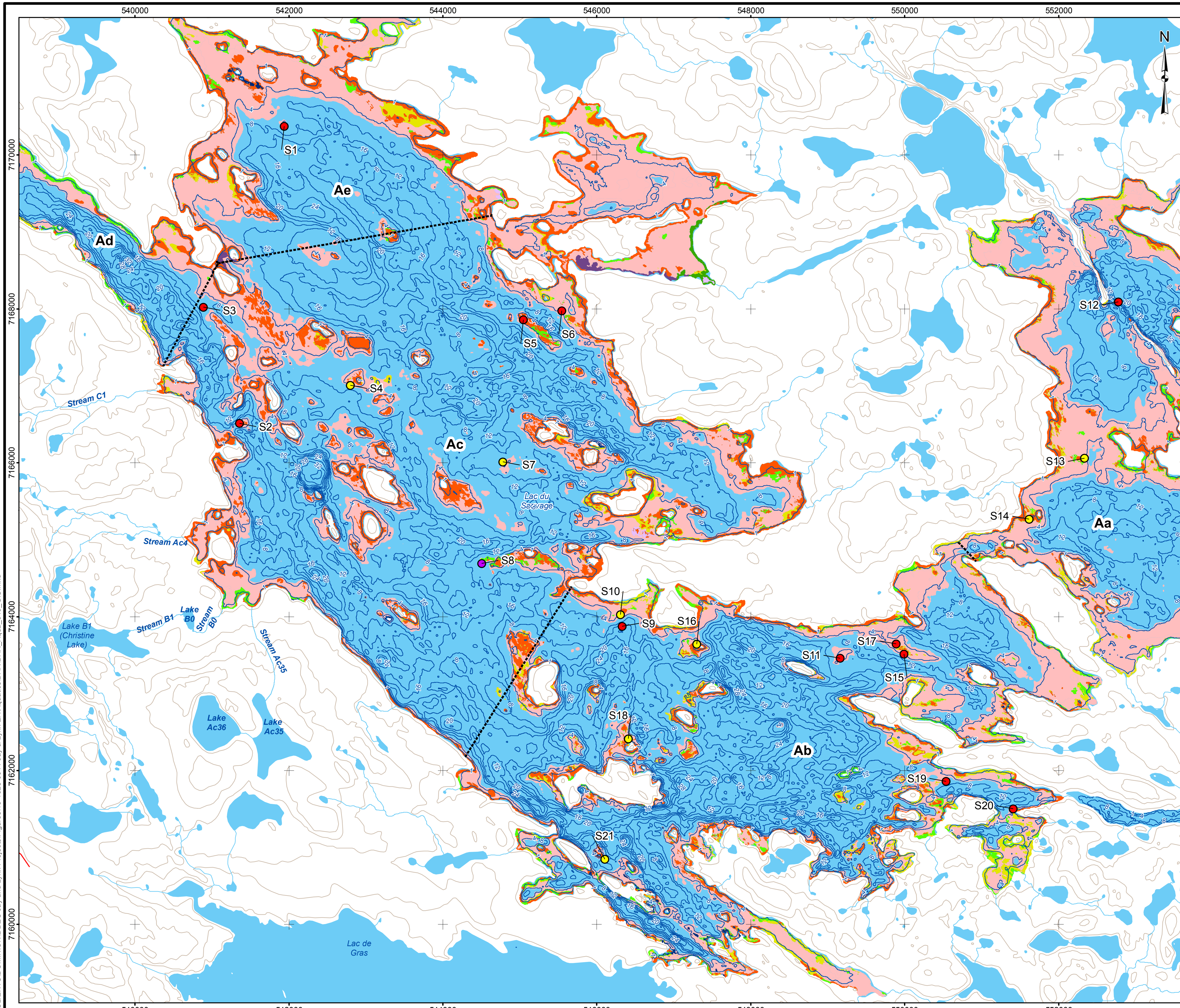
9.2.4.1 *Lac du Sauvage*

9.2.4.1.1 Fish Habitat

Habitat Types

Most of the visible substrate identified on geo-referenced orthophotos in Lac du Sauvage was fines (2,712 ha or 71.9% of the shoreline area evaluated in Lac du Sauvage), followed by boulder/cobble (699 ha or 18.5%), with fines/boulder (206.7 ha or 5.5%) and boulder/fines (126.3 ha or 3.4%) representing smaller portions of shoreline habitat (Map 9.2-6). Typically, fines (50.7%) and boulder/cobble (33.1%) were prevalent at shallow depths (0 to 2 m), with fines (89.7%) dominating within the 2 to 5 m depth stratum.

Other substrate types visually identified and quantified in shoreline habitats of Lac du Sauvage included boulder (less than 0.1%), bedrock (0.2%), cobble/boulder (0.2%), cobble/fines (less than 0.1%), and fines/cobble (0.2%). Substrates identified as cobble in the field often included small areas of gravel that could be used as potential spawning locations by whitefish species, Lake Trout, and Cisco.



LEGEND

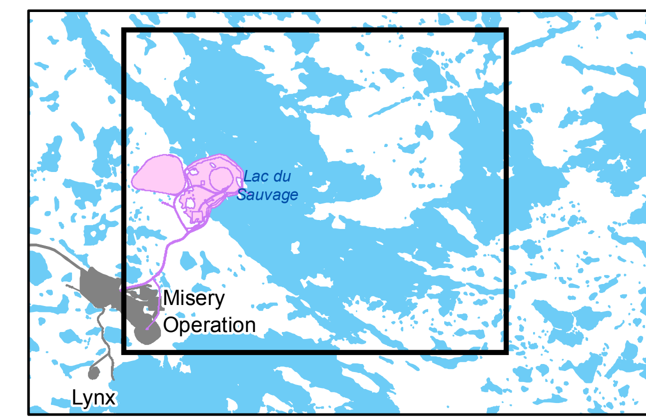
- EKATI MINE FOOTPRINT
- PROPOSED JAY FOOTPRINT
- BATHYMETRIC CONTOUR (4 m INTERVAL)
- ELEVATION CONTOUR (10 m INTERVAL)
- WATERCOURSE
- WATERBODY
- INTERNAL BASIN DIVIDE

SPAWNING SHOAL (S) HABITAT LAKE TROUT

- GOOD
- FAIR
- UNSUITABLE

SUBSTRATE TYPE

- Bo - BOULDER
- Bo/Co - BOULDER/COBBLE
- Bo/Fi - BOULDER/FINES
- Br - BEDROCK
- Co/Bo - COBBLE/BOULDER
- Co/Fi - COBBLE/FINES
- Fi - FINES
- Fi/Bo - FINES/BOULDER
- Fi/Co - FINES/COBBLE



NOTES

1. SPAWNING SHOAL HABITAT IDENTIFIED BY GOLDER (1997B)

REFERENCE

CANVEC © NATURAL RESOURCES CANADA, 2012
NATURAL RESOURCES CANADA, CENTRE FOR TOPOGRAPHIC INFORMATION, 2012
BATHYMETRIC DATA OBTAINED FROM AURORA, 2013
DATUM: NAD83 PROJECTION: UTM ZONE 12N

DOCUMENT

DEVELOPER'S ASSESSMENT REPORT

1,500 0 1,500
SCALE 1:50,000 METRES

PROJECT

DOMINION DIAMOND

JAY PROJECT
NORTHWEST TERRITORIES, CANADA

TITLE

REPRESENTATIVE SHORELINE HABITAT OF LAC DU SAUVAGE BASED ON ORTHOPHOTOGRAPHS AND GROUND-TRUTHED SURVEYS

Golder Associates

PROJECT		13-1328-0041	FILE No. DAR_Aqua_019_GIS
DESIGN	JV	31/07/14	SCALE AS SHOWN REV 0
GIS	JE	20/10/14	MAP 9.2-6
CHECK	CS	20/10/14	
REVIEW	KM	20/10/14	

Based on hydroacoustic data describing the lake bottom, the proportion of sediment in Lac du Sauvage was primarily fines (87.1%) with mixed and coarse substrates comprising 4.5% and 8.4%, respectively (Table 9.2-6). At shallower depths, ranging from 0 to 2 m, coarse and mixed substrates were as abundant as fines. The relative abundance of fines increased in deeper water. Depths greater than 10 m were assigned 100% fines due to the effects of deposition on substrate composition.

Table 9.2-6 Substrate Type Distribution by Depth Strata in Lac du Sauvage, 2013

Substrate Type	Depth Stratum				Total (% of 8,668 ha)
	0 to 2 m (% of 1,720 ha)	2 to 6 m (% of 2,610 ha)	6 to 10 m (% of 1,817 ha)	>10 m (% of 2,521 ha)	
Coarse	34.00	5.15	0.66	0	8.44
Mixed	15.17	3.69	1.75	0	4.49
Fines	50.83	91.16	97.59	100.00	87.08
Total	100	100	100	100	100

ha = hectare; m = metre;% = percent; >= greater than.

In addition to 2013 surveys, the combined results of four historical surveys provide a detailed inventory of habitat availability for fish in Lac du Sauvage (Golder 1997b,d,e; Rescan 2007; Map 9.2-2). Surveys identified 21 shoals in Lac du Sauvage (Golder 1997b). Of these, 43% of the shoal locations were determined to provide spawning habitat of "good" or "fair" quality for Lake Trout and Cisco, and only 10% were in these categories for Round Whitefish. Most of the shoal locations were identified as being unsuitable for Lake Trout, Cisco, and Round Whitefish spawning.

An estimated 1,800 ha of Lake Trout spawning habitat of good and fair quality was described in Lac du Sauvage, much as non-attached shoals and shoals extending from small islands. However, the narrow features of the east side of Lac du Sauvage also provide for a relatively large proportion of suitable habitat as shoreline-attached shoals. By comparison, Lac de Gras may provide as much as 5,800 ha of Lake Trout spawning habitat.

Compared to Lac de Gras, shoals in Lac du Sauvage are generally not as deep or numerous, and provide less potential spawning habitat of "good" to "fair" quality for Lake Trout, Cisco, and Round Whitefish (Golder 1997b; DDMI 1998a). However, Lac du Sauvage provides habitat for all life stages of Lake Trout and Lake Whitefish (Rescan 2007). Furthermore, the Narrows may provide an important corridor for fish movement between the two lakes. Based on bathymetry and flow characteristics, open water can remain in the Narrows year-round. The Narrows may also provide productive areas for spawning, rearing, and forage habitats (Dillon 2002a).

9.2.4.1.2 Plankton

In 2013, zooplankton hauls and depth-integrated phytoplankton and chlorophyll *a* samples were collected from Lac du Sauvage. The key findings of the baseline program are summarized below and the results are presented in detail in Annex XII. A summary of the historical plankton community data from baseline and monitoring programs related to the Ekati AEMP (Rescan 2012a; ERM Rescan 2014), the 2006 Jay pipe aquatic baseline study (Rescan 2007), and the Diavik Mine AEMP (Golder 2011; DDMI 2012, 2013) is also provided below. Additional details related to the review of historical information can be found in Annex XII.

Chlorophyll *a* and Trophic Status

The trophic status of Lac du Sauvage was evaluated during the 2013 baseline study by examining the concentrations of TP, chlorophyll *a*, and water transparency (Secchi depth). Mean annual chlorophyll *a* was 1.94 µg/L, mean TP was 8 µg/L, and mean Secchi depth was 7.3 m in 2013. The corresponding TSI values were 37 using chlorophyll *a*, 34 using TP, and 31 using Secchi depth, resulting in a rounded average value of 34. Based on these values, and the classification systems of Vollenweider (1970; based on Secchi depth and TP), CCME (2004; based on TP), and Carlson (1977; based on chlorophyll *a*), Lac du Sauvage can be classified as an oligotrophic lake.

Phytoplankton

Total phytoplankton abundance varied among sampling stations in Lac du Sauvage along seasonal and spatial gradients during the 2013 open-water sampling period (Figure 9.2-2). Total phytoplankton abundance peaked during summer at some stations and during fall at others, with some stations showing little variation between summer and fall. Total phytoplankton abundance was lowest in late spring at the majority of stations in 2013.

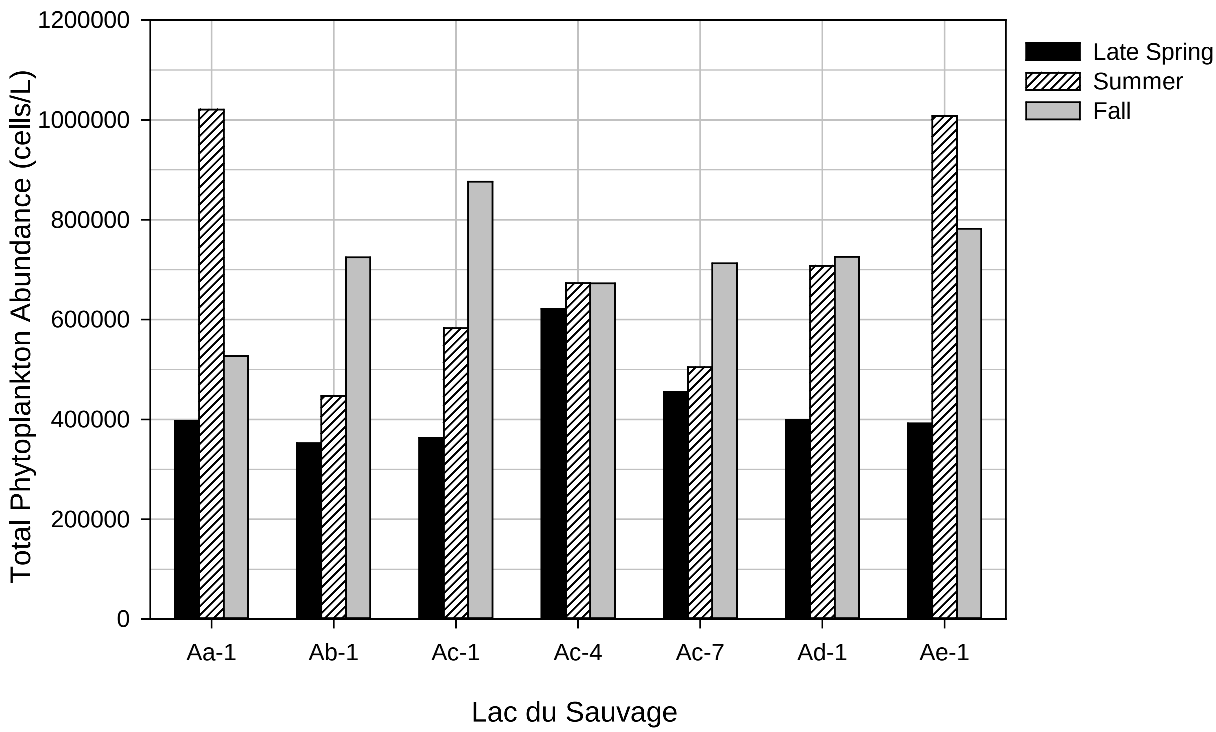
During the 2013 open-water sampling period, no clear seasonal trend in total phytoplankton biomass was observed at Lac du Sauvage sampling stations (Figure 9.2-3). Relatively high biomass values in summer were driven by the chrysophyte *Dinobryon divergens* at Station Ac-7 and by the chlorophyte *Eudorina elegans* at Station Ae-1. Aside from the relatively high values observed in summer at these stations, biomass values at the majority of stations in Lac du Sauvage ranged between 100 and 400 mg/m^3.

Chrysophytes consistently dominated the community by abundance in Lac du Sauvage throughout the 2013 open-water sampling period (Figure 9.2-4). Other major taxonomic groups were present in Lac du Sauvage at varying abundances, and followed no obvious trends throughout the open-water sampling period.

The phytoplankton community composition by biomass in Lac du Sauvage varied seasonally and spatially throughout the open-water sampling period (Figure 9.2-5). In late spring and summer, phytoplankton communities at most stations were dominated by chrysophyte or chlorophyte biomass. In fall, phytoplankton communities at most stations were dominated by chrysophytes, dinoflagellates, or diatoms.

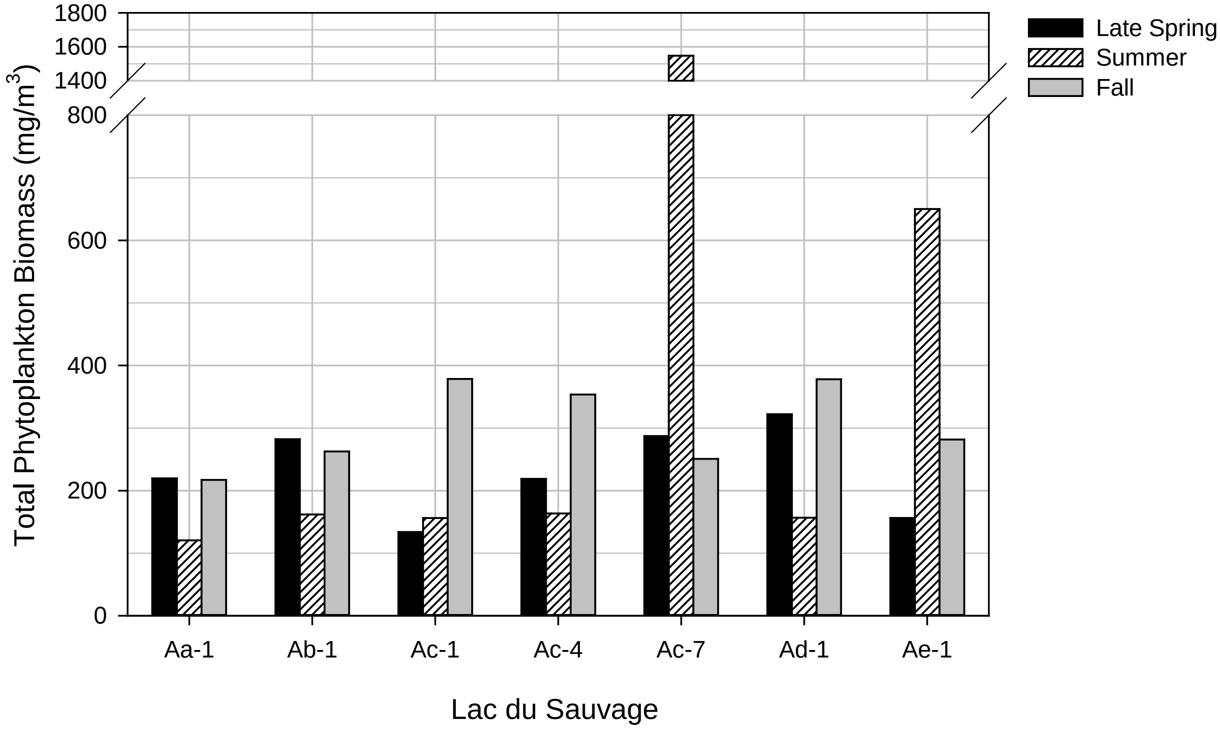
In total, 88 phytoplankton taxa were identified in Lac du Sauvage in 2013: 37 chlorophytes, 19 diatoms, 11 cyanobacteria, 9 chrysophytes, 4 dinoflagellates, 3 cryptophytes, 4 euglenoids, and 1 xanthophyte. The highest phytoplankton species richness was observed in the fall at all stations; however, there was no consistent seasonal succession pattern among stations (Figure 9.2-6).

Figure 9.2-2 Total Phytoplankton Abundance in Lac du Sauvage in Late Spring, Summer, and Fall, 2013



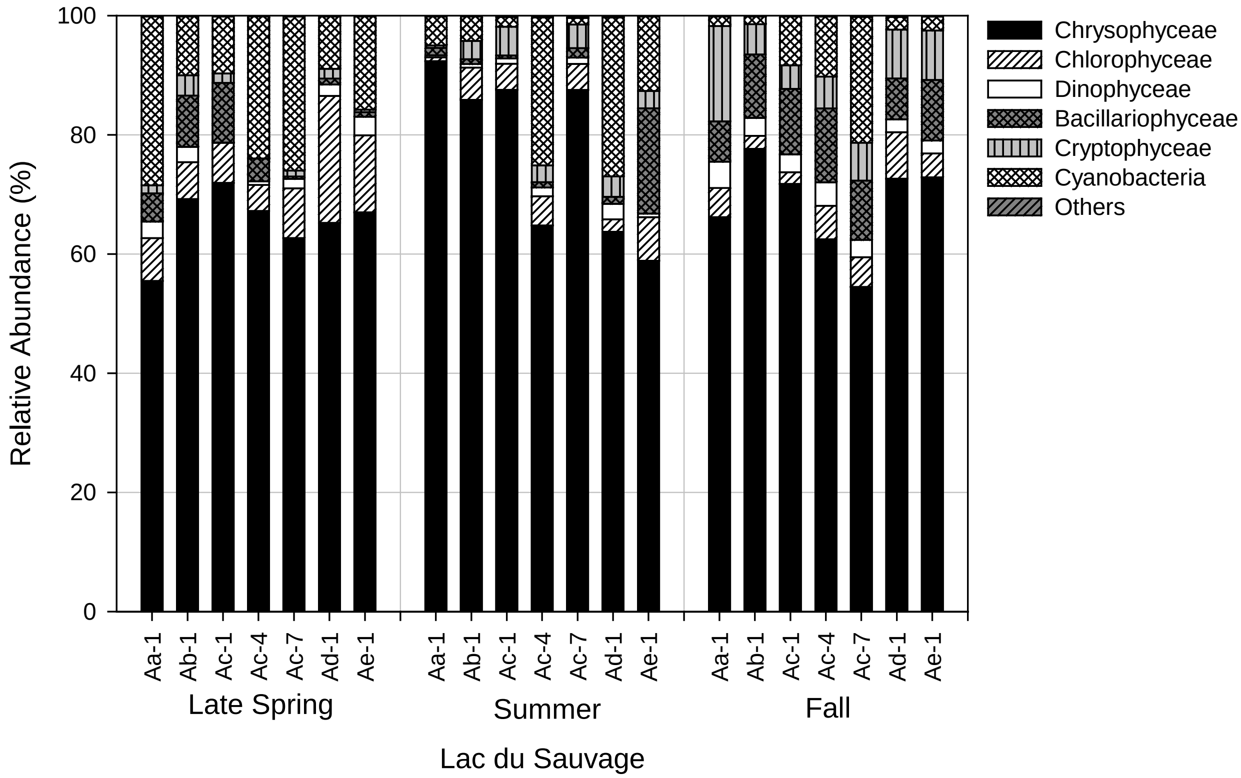
cells/L = cells per litre.

Figure 9.2-3 Total Phytoplankton Biomass in Lac du Sauvage in Late Spring, Summer, and Fall, 2013



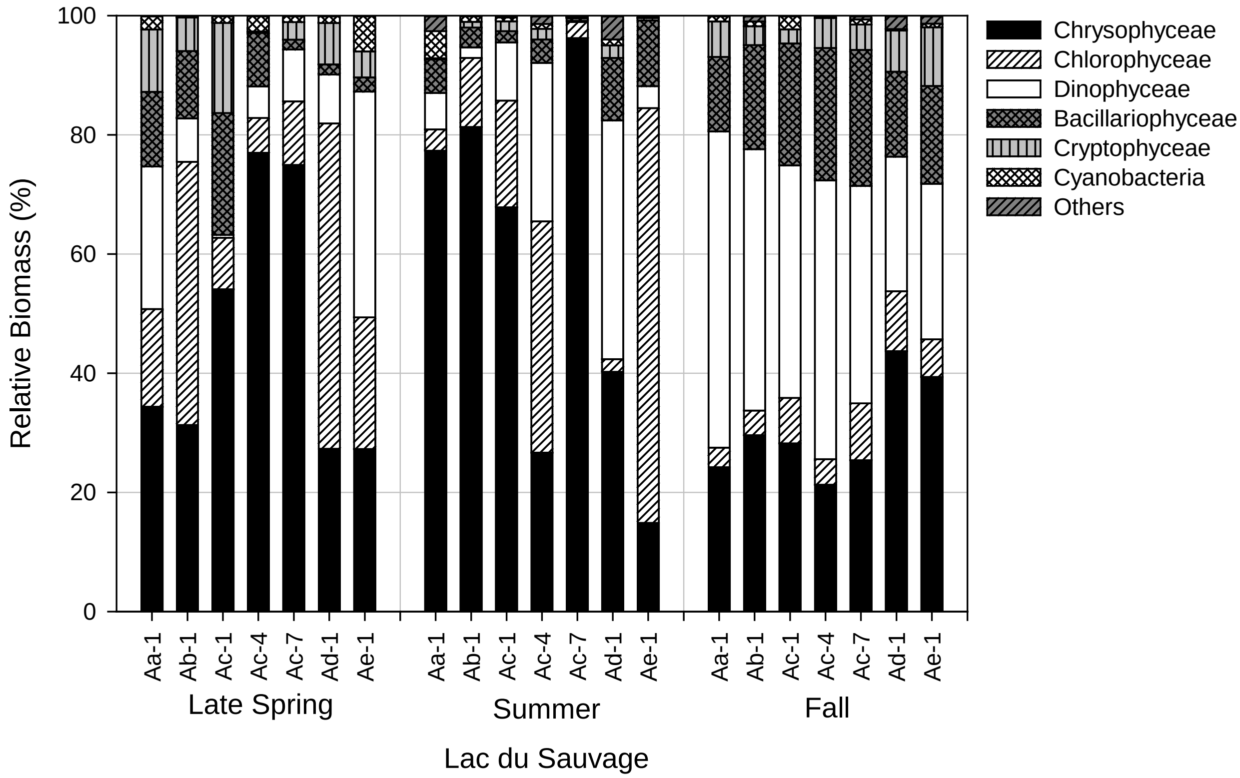
mg/m^3 = milligrams per cubic metre.

Figure 9.2-4 Relative Phytoplankton Abundance in Lac du Sauvage in Late Spring, Summer, and Fall, 2013



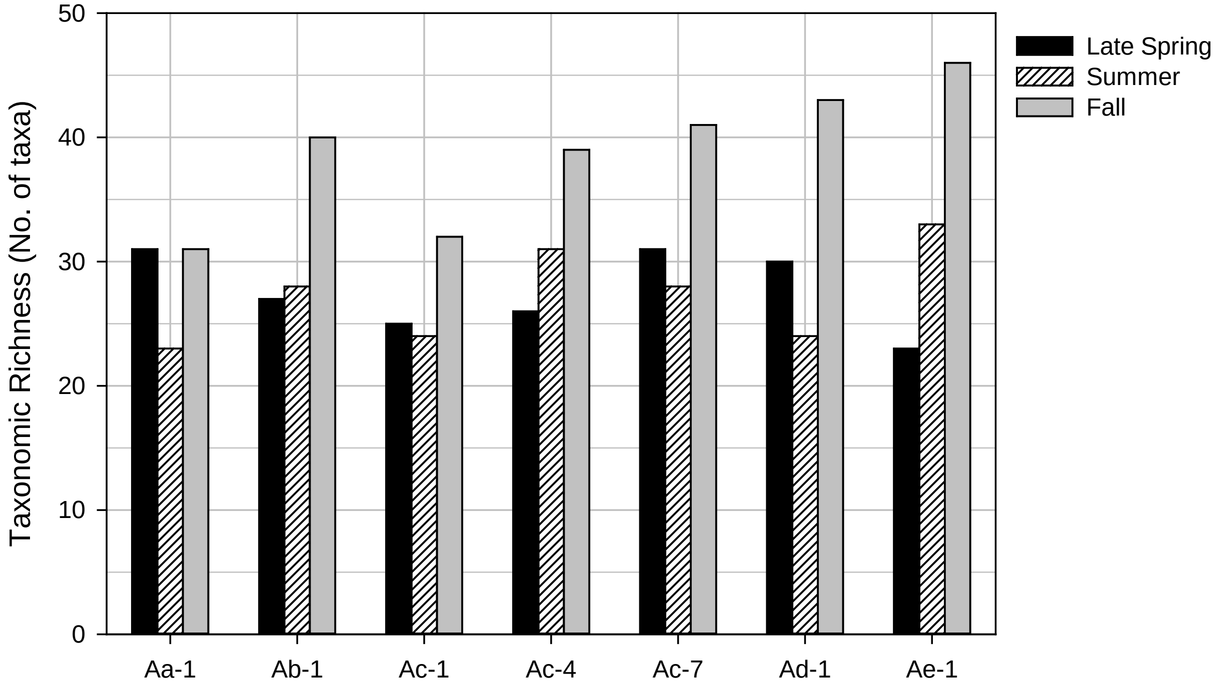
% = percent.

Figure 9.2-5 Relative Phytoplankton Biomass in Lac du Sauvage in Late Spring, Summer, and Fall, 2013



% = percent.

Figure 9.2-6 Total Phytoplankton Taxonomic Richness in Lac du Sauvage in Late Spring, Summer, and Fall, 2013



No. = number.

Zooplankton

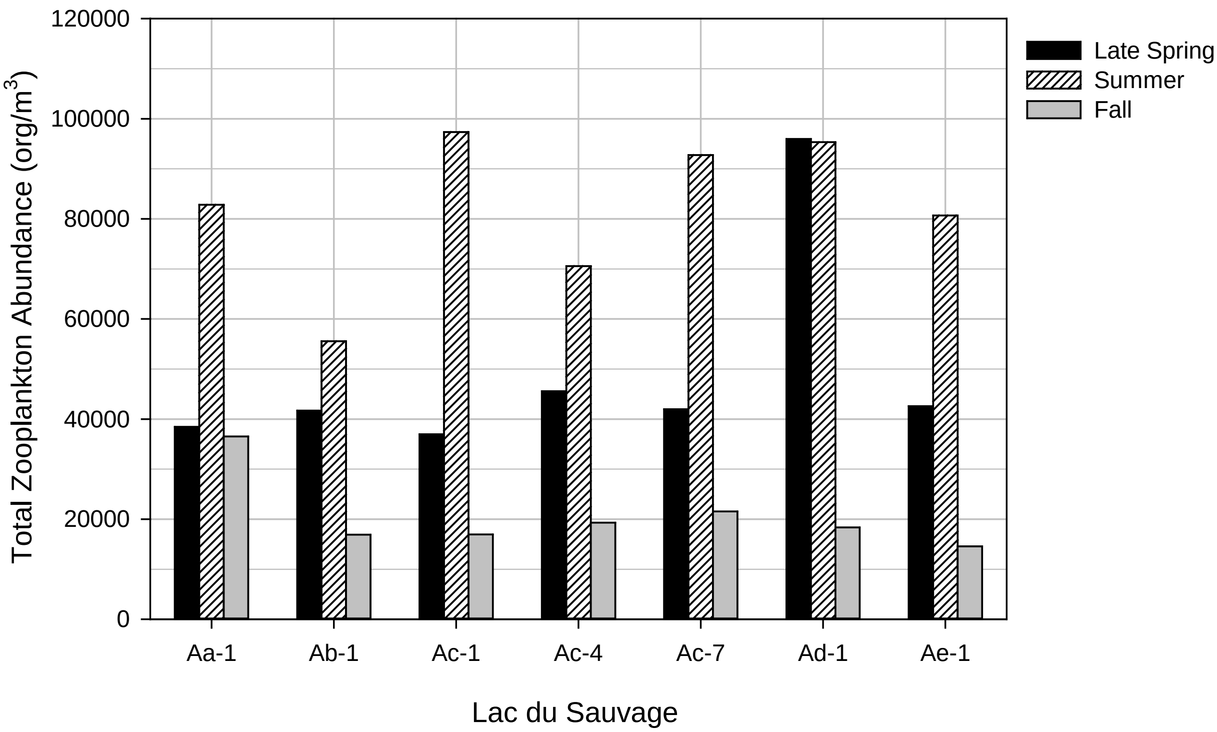
Total zooplankton abundance and biomass varied seasonally and spatially throughout the open-water sampling period (Figure 9.2-7 and 9.2-8). Seasonal peaks in total zooplankton abundance and biomass were observed in summer at all Lac du Sauvage stations. In general, total zooplankton abundance was lowest during the fall and total zooplankton biomass was lowest in late spring at Lac du Sauvage stations in 2013.

Zooplankton community composition by abundance in Lac du Sauvage was similar among all stations throughout the 2013 open-water sampling period (Figure 9.2-9). Rotifers dominated zooplankton abundance in Lac du Sauvage during all three sampling periods. Cladoceran abundance increased in summer, and the combination of cladoceran and copepod nauplii abundance accounted for approximately one third of the total zooplankton abundance at most stations during the fall.

Zooplankton community composition by biomass in Lac du Sauvage varied among stations and throughout the open-water sampling period (Figure 9.2-10). Rotifers accounted for a large amount of late spring biomass at the majority of stations. Cladocerans were the dominant taxonomic group in the summer. In the fall, copepod nauplii dominated the zooplankton composition by biomass at the majority of stations in Lac du Sauvage.

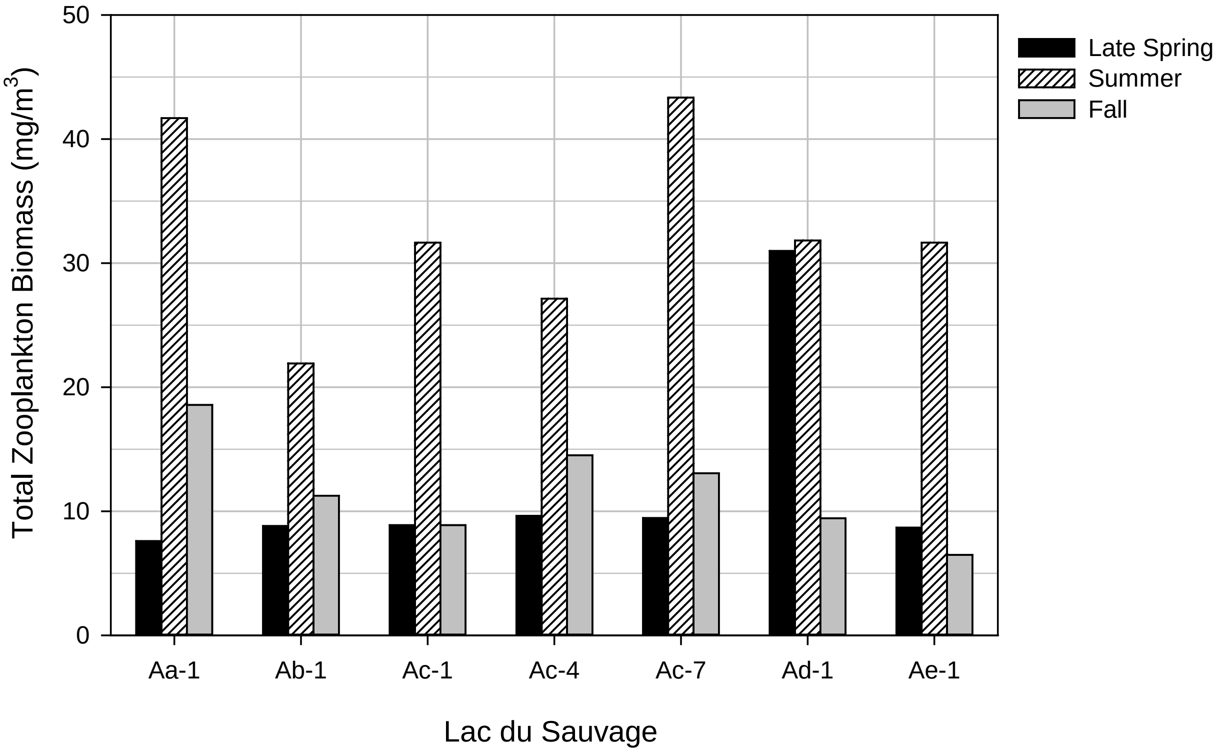
In total, 25 zooplankton taxa were identified in Lac du Sauvage in 2013: 15 rotifers, 6 cladocerans, 3 calanoid copepods, and 1 cyclopoid copepod. Taxonomic richness increased throughout the open-water sampling period, ranging between 13 and 15 taxa in the late spring and summer, and between 14 and 22 taxa in the fall (Figure 9.2-11). Within all sampling periods, zooplankton taxonomic richness was relatively similar among stations.

Figure 9.2-7 Total Zooplankton Abundance in Lac du Sauvage in Late Spring, Summer, and Fall, 2013



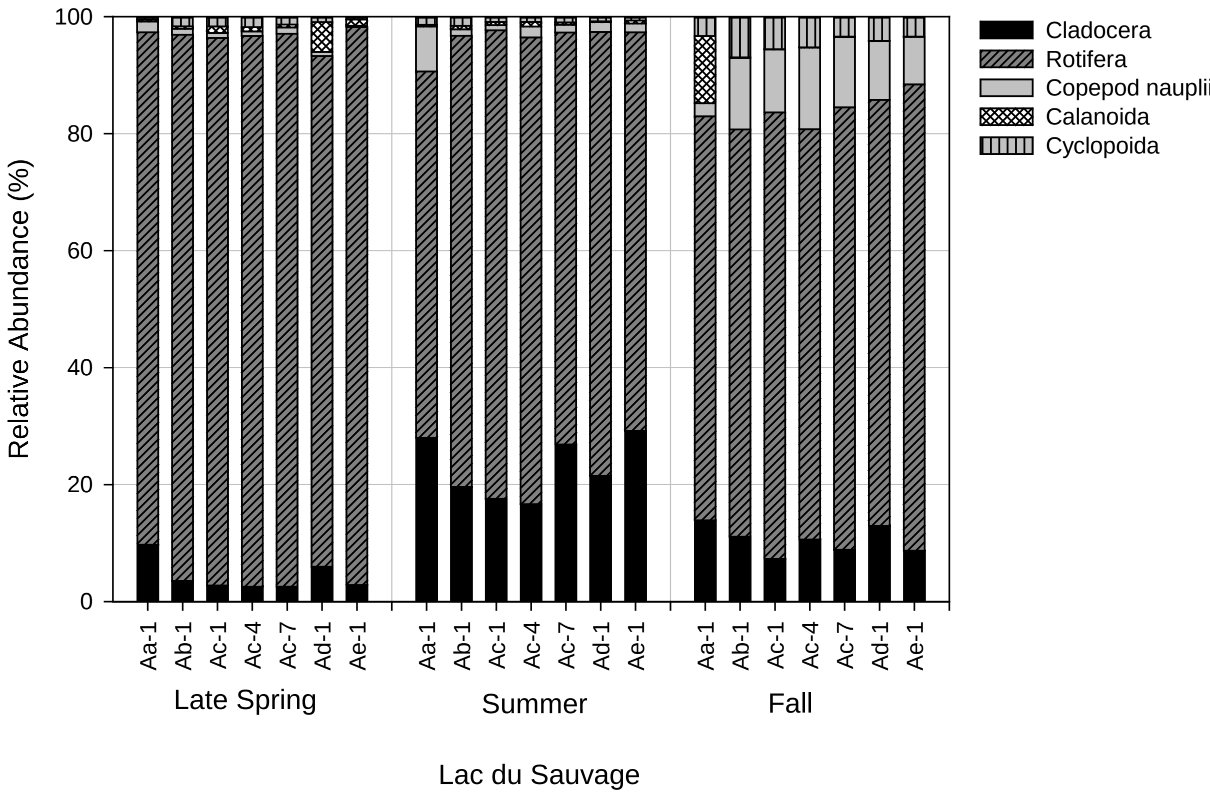
org/m^3 = organisms per cubic metre.

Figure 9.2-8 Total Zooplankton Biomass in Lac du Sauvage in Late Spring, Summer, and Fall, 2013



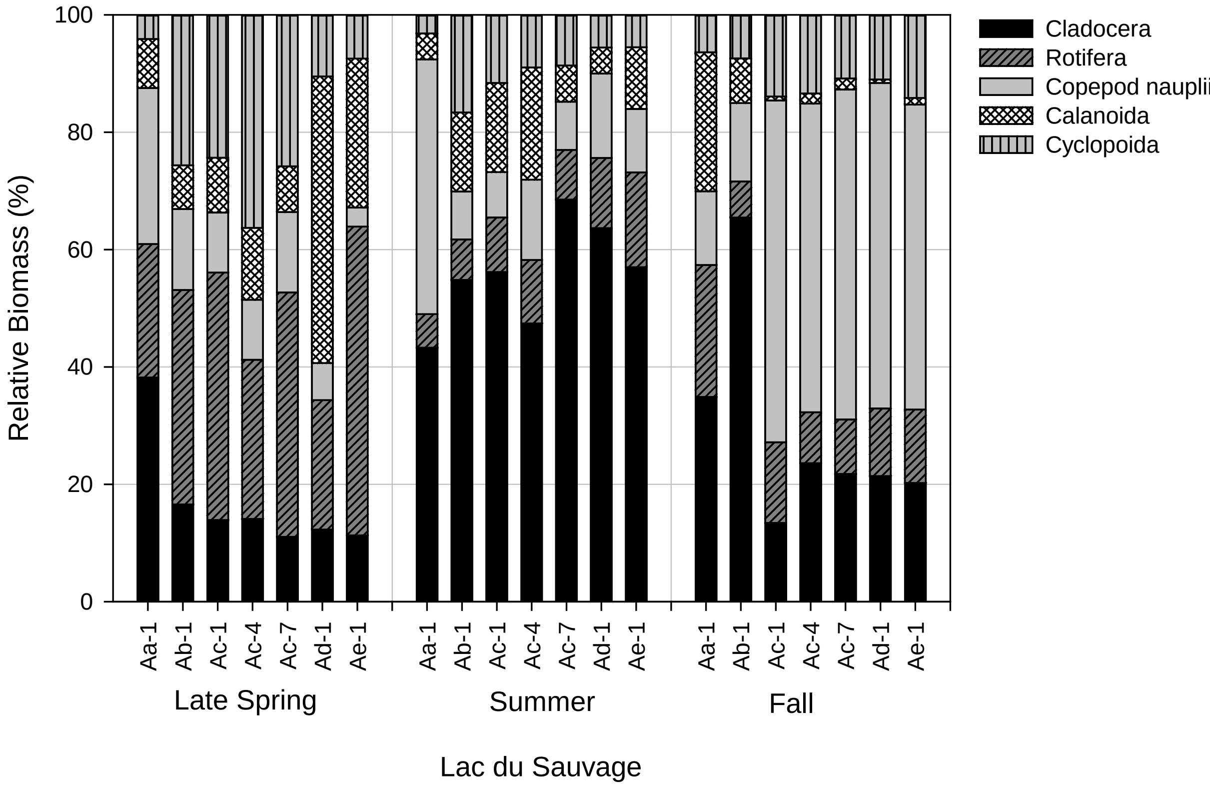
mg/m^3 = milligrams per cubic metre.

Figure 9.2-9 Relative Zooplankton Abundance in Lac du Sauvage in Late Spring, Summer, and Fall, 2013



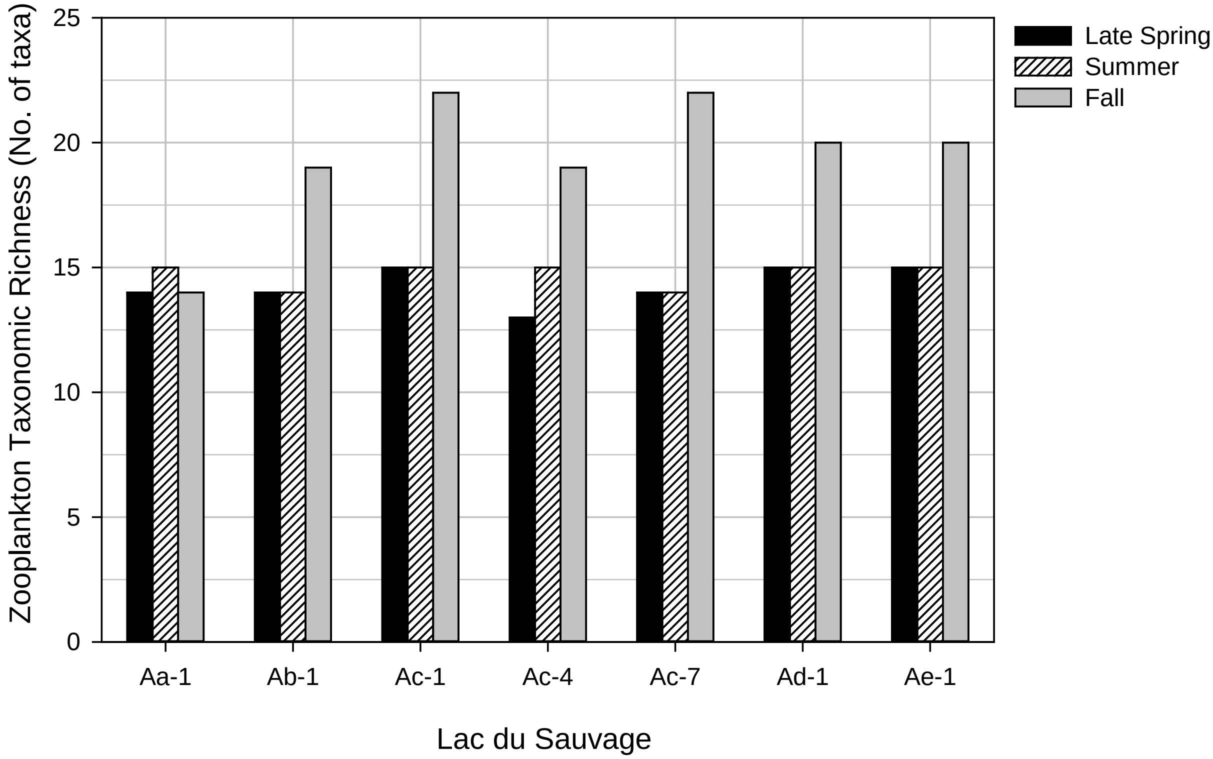
% = percent.

Figure 9.2-10 Relative Zooplankton Biomass in Lac du Sauvage in Late Spring, Summer, and Fall, 2013



% = percent.

Figure 9.2-11 Total Zooplankton Taxonomic Richness in Lac du Sauvage in Late Spring, Summer, and Fall, 2013



No. = number.

Summary of Previous Studies

The plankton community at station LDS1 (a mid-depth station; Map 9.2-7) has been sampled annually since 2000 as part of the Ekati AEMP (ERM Rescan 2014).

Summer chlorophyll *a* concentrations at Station LDS1 in Lac du Sauvage exhibited variability between 2000 and 2012. Chlorophyll *a* concentrations at LDS1 ranged between 0.20 micrograms per litre (µg/L) (2003) and 0.69 µg/L (2008). These chlorophyll *a* concentrations in Lac du Sauvage were consistent with a trophic status classification of oligotrophic (Wetzel 2001). Data were not available to address trophic status based on other methods of classification.

Summer total phytoplankton abundance at Station LDS1 in Lac du Sauvage was highly variable between 2000 and 2012, with no distinct temporal trend. Total phytoplankton abundance ranged from a minimum of 168,333 cells per litre (cells/L) (2001) to a maximum of 1,358,000 cells/L (2008).

In general, summer total phytoplankton biomass increased at Station LDS1 since the first year of sampling in 2000, although there was some year-to-year variability. Total phytoplankton biomass ranged from a minimum of 40 milligrams per cubic metre (mg/m^3) (2003) to a maximum of 302 mg/m^3 (2006).

LEGEND

- EKATI MINE FOOTPRINT
- DIAVIK MINE FOOTPRINT
- PROPOSED JAY FOOTPRINT
- ELEVATION CONTOUR (20 m INTERVAL)
- WATERCOURSE
- WATERBODY
- NOT INCLUDED HISTORICAL STATION
- INCLUDED HISTORICAL STATION
- QUALITATIVE DESCRIPTION IN DAR

REFERENCE

DIAVIK MINE (GOLDER 2013),
EKATI MINE (RESCAN 2013), AND
JAY KIMBERLITE PIPE, EKATI MINE (RESCAN 2007)
NATIONAL TOPOGRAPHIC BASE DATA (NTDB) 1:250,000
NATURAL RESOURCES CANADA, CENTRE FOR TOPOGRAPHIC INFORMATION, 2012
DATUM: NAD83 PROJECTION: UTM ZONE 12N

DOCUMENT

DEVELOPER'S ASSESSMENT REPORT

5 0 5

SCALE 1:225,000 KILOMETRES

PROJECT

DOMINION DIAMOND

JAY PROJECT
NORTHWEST TERRITORIES, CANADA

TITLE

HISTORICAL PLANKTON COMMUNITY SAMPLING LOCATIONS

Golder Associates

PROJECT		13-1328-0041	FILE No. DAR_Aqua_026_GIS	
DESIGN	SE	27/08/14	SCALE AS SHOWN	REV 0
GIS	JE/LR	03/10/14	MAP 9.2-7	
CHECK	SE	06/10/14		
REVIEW	ZK	06/10/14		

Between 2000 and 2012, phytoplankton total taxonomic richness at Station LDS1 ranged between 34 and 62 taxa. A total of 78 taxa were identified among the twelve stations sampled in Lac du Sauvage during the 2006 open-water season. Overall, the taxa present at Station LDS1 were relatively consistent over time. Phytoplankton total taxonomic richness was lower at the majority of Lac du Sauvage stations during most seasons of the 2013 baseline survey, although this difference may be attributed to differences in taxonomists between the baseline and historical work.

The open-water phytoplankton community in Lac du Sauvage was typically dominated by cyanobacteria, based on abundance. In 2006, seasonal variation in phytoplankton community composition was observed in the Jay pipe aquatic baseline study area (Rescan 2007). Cyanobacteria consistently dominated the phytoplankton community during the open-water sampling period in 2006. Cyanobacteria dominance was not observed at any Lac du Sauvage station at any point during the 2013 baseline survey.

Summer total zooplankton abundance at Station LDS1 in Lac du Sauvage was variable over the years, although zooplankton abundance was relatively stable from 2009 to 2012. In 2006, total zooplankton abundance was highly variable throughout the open-water season and there were no distinct seasonal or spatial trends (Rescan 2007).

In general, summer total zooplankton biomass increased at Station LDS1 since the first year of sampling in 2000, although there was year-to-year variability. Total biomass ranged from a minimum of 40 mg/m^3 (2003) to a maximum of 302 mg/m^3 (2006). In 2006, total zooplankton biomass was highly variable throughout the open-water season with no distinct seasonal or spatial trends (Rescan 2007).

The zooplankton community (based on relative abundance) in Lac du Sauvage was typically co-dominated by rotifers, and cyclopoid and calanoid copepods. In 2000, cyclopoid copepods accounted for the majority of the open-water zooplankton community. In general, cladocerans were present in low numbers with the exception of 2012, when this group accounted for almost half of the zooplankton community. In 2006, the Lac du Sauvage zooplankton community remained consistently co-dominated by rotifers and copepods (Rescan 2007).

Zooplankton taxonomic richness at Station LDS1 in Lac du Sauvage ranged from 9 to 12 taxa with little overall variation and no apparent trends between 2000 and 2012. In total, 14 zooplankton taxa were identified in Lac du Sauvage in 2006 (Rescan 2007).

9.2.4.1.3 Benthic Invertebrates

Benthic invertebrates were sampled in lakes and streams within the BSA in 2013. The lake stations included stations within shallow, mid-depth, and deep habitat. Littoral stations and several streams were also sampled; thus, a range of benthic invertebrate habitats comparable to those sampled historically was sampled in 2013. Key findings of the baseline program are summarized below by habitat type, with a more detailed presentation of the results in Annex XIII. A summary of the historical benthic invertebrate community data from baseline and monitoring programs related to the Ekati AEMP (Rescan 2012a; ERM Rescan 2014), the 2006 Jay pipe aquatic baseline study (Rescan 2007), and the Diavik AEMP (Golder 2011; DDMI 2012, 2013) are also provided below. Additional details related to the review of historical benthic invertebrate information can be found in Annex XIII.

Lake Stations

Mean total benthic invertebrate density at shallow and mid-depth stations in Lac du Sauvage was low to moderate (Figure 9.2-12). Mean total benthic invertebrate density observed in 2013 was lower at deep stations compared to shallower stations. Increased variability in total richness was also noted at the deep stations (Figure 9.2-13). In general, mean total density and total richness in Lac du Sauvage were highest at the shallow stations and lowest at deep stations, with the mid-depth stations having intermediate values.

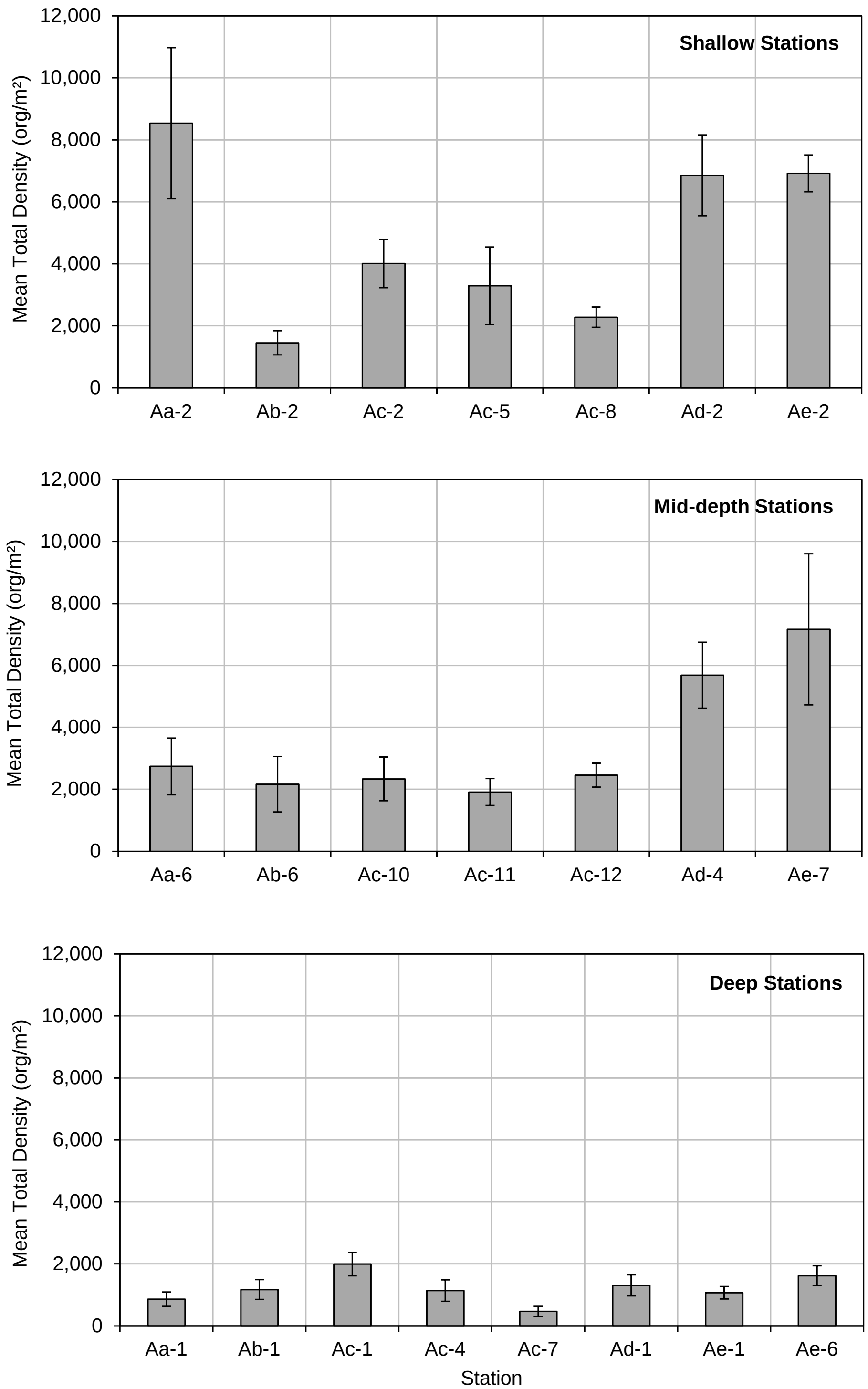
Chironomidae (non-biting midges) were observed to dominate benthic invertebrate communities at all lake stations in Lac du Sauvage (Figure 9.2-14). Total Chironomidae density was lower at deep stations compared to shallower station. The Chironomini and Tanytarsini tribes were the two dominant chironomid groups at shallow and mid-depth stations with the Chironomini and Tanypodinae being the dominant chironomid groups at the deep stations. Dominance of the benthic invertebrate community by Chironomidae is expected in sub-arctic lakes (Beaty et al. 2006; Northington et al. 2010). The Pisidiidae (fingernail clams) also accounted for a large proportion of the total density at each station.

Simpson's diversity index values at lake stations were high at all stations, ranging from 0.83 to 0.92 at shallow stations, from 0.81 to 0.89 at mid-depth stations, and from 0.59 to 0.87 at deep stations, indicating a diverse benthic invertebrate community. Evenness was variable, and ranged from low to moderate (0.2 to 0.49), indicating that a few taxa accounted for the majority of the total density at lake stations.

Littoral Stations

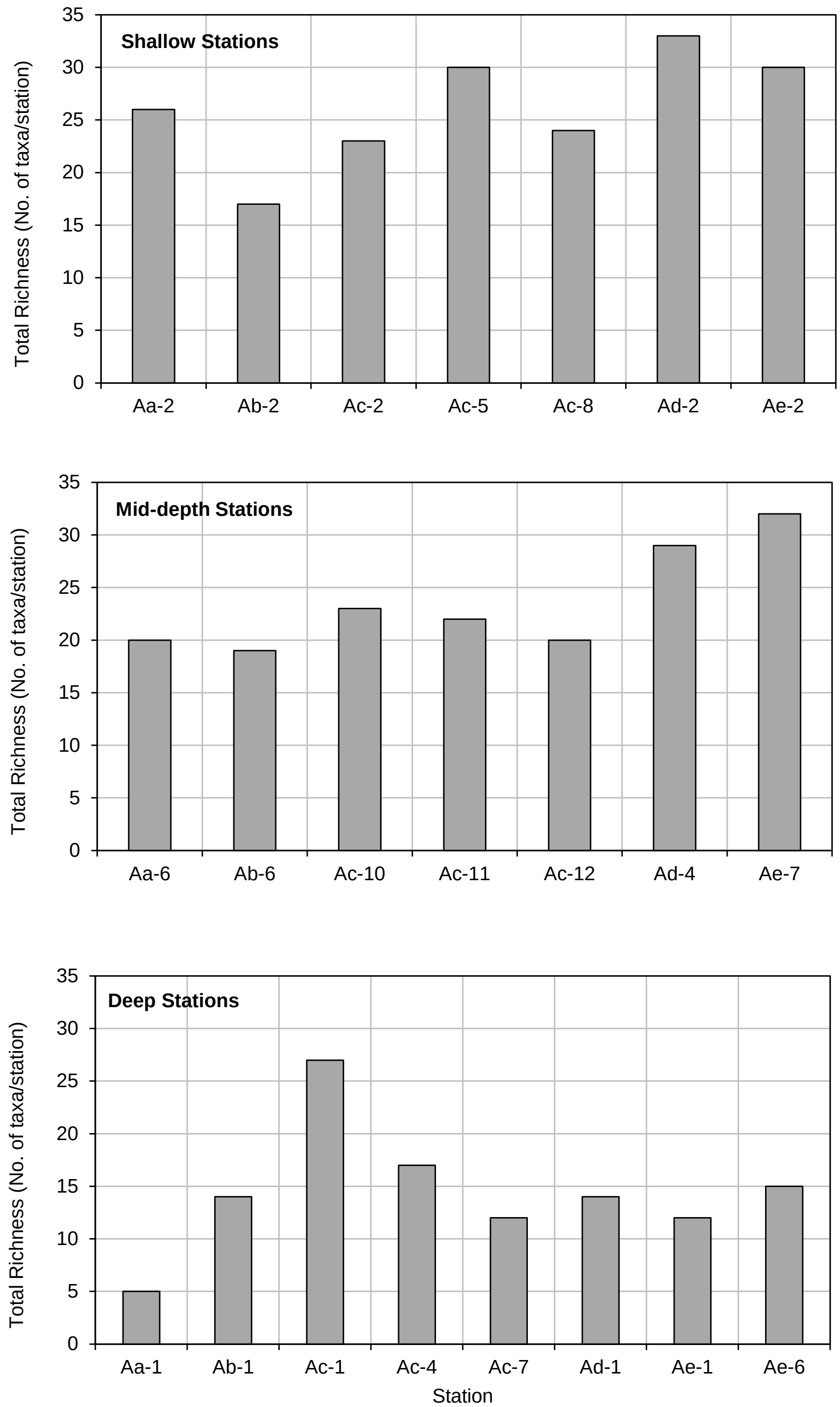
Total richness was moderate at the littoral stations in Lac du Sauvage in 2013 (Figure 9.2-15). Spatial variation in richness did not appear to be due to differences in habitat characteristics. The benthic invertebrate community at littoral stations in Lac du Sauvage was variously dominated by the Chironomidae and Gastropoda (snails) (Figure 9.2-16). The littoral community had a lower percentage of Chironomidae and higher percentage of Gastropoda compared to shallow, mid-depth, and deep lake stations. The Chironomidae at the littoral stations were dominated by the subfamily Orthocladiinae; this group was a minor component of the deeper water Chironomidae assemblage. The Acari (mites) and Plecoptera (stoneflies) were also present in higher numbers at littoral stations compared to the deeper stations.

Figure 9.2-12 Mean Total Density at Lake Stations in Lac du Sauvage, August 2013



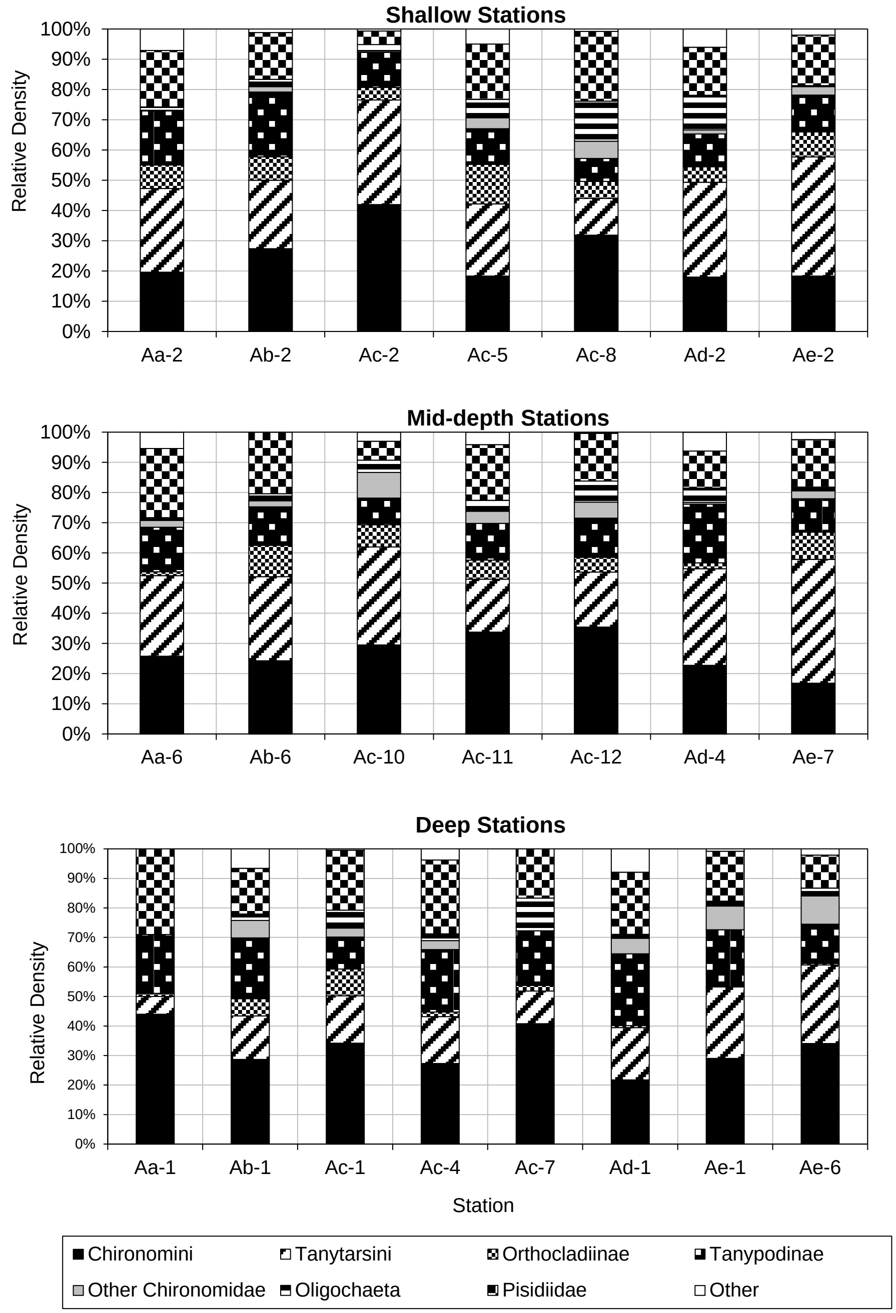
Note: Error bars represent one standard error of the mean.
org/m^2 = number of organisms per square metre.

Figure 9.2-13 Total Richness at Lake Stations in Lac du Sauvage, August 2013



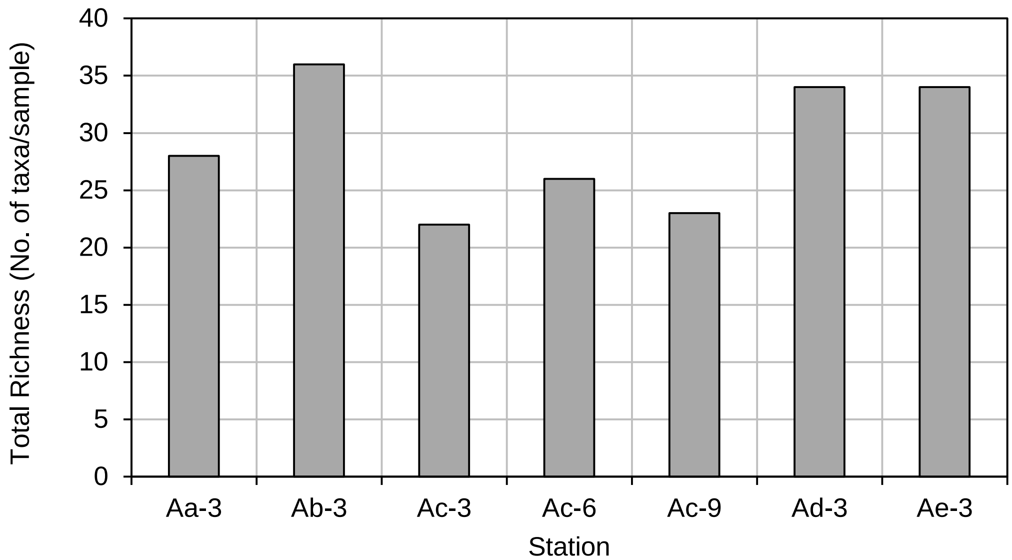
No. of taxa/station = number of taxa per station.

Figure 9.2-14 Relative Densities of Major Benthic Invertebrate Taxa at Lake Stations in Lac du Sauvage, August 2013



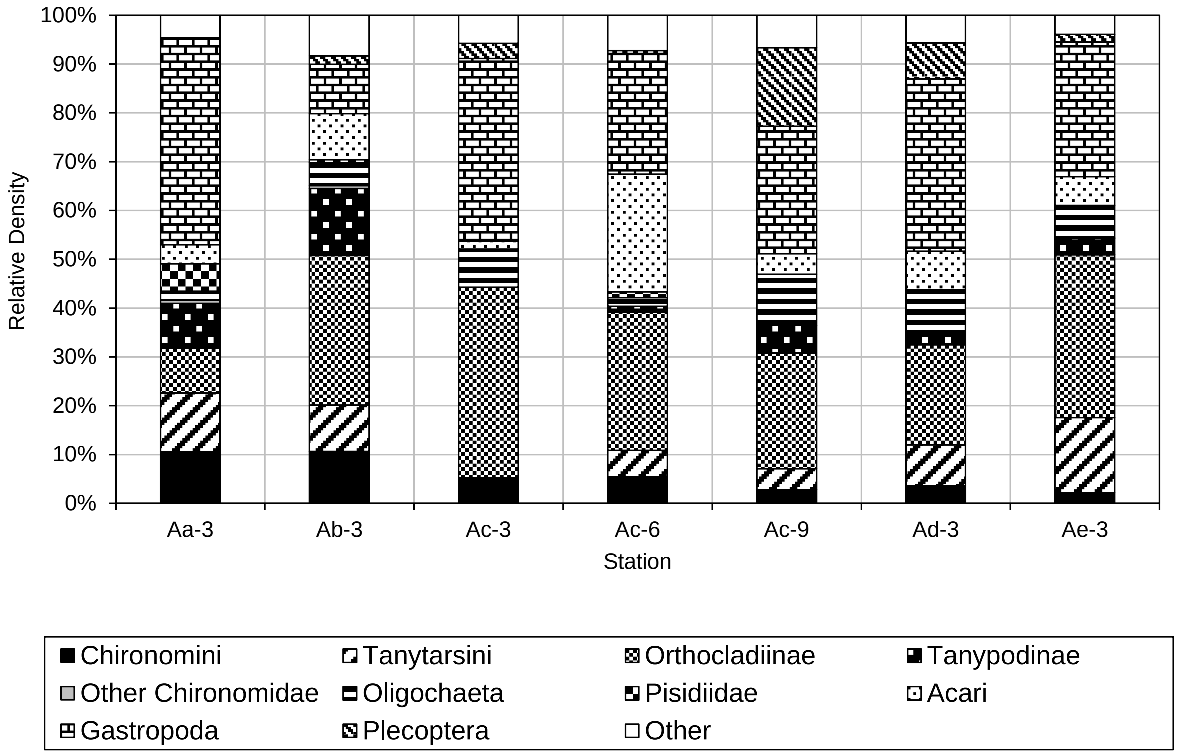
Note: "Other" taxa category includes Hydridae, Acari, Gastropoda, Turbellaria, Trichoptera, and Empididae.
% = percent.

Figure 9.2-15 Total Benthic Invertebrate Richness at Littoral Stations in Lac du Sauvage, August 2013



No. of taxa/sample = number of taxa per sample.

Figure 9.2-16 Relative Density of Major Benthic Invertebrate Taxa at Littoral Stations in Lac du Sauvage, August 2013



Note: "Other" taxa category includes Coleoptera, Trichoptera, Ceratopogonidae, Empididae, Muscidae, and Tipulidae.
% = percent.

Summary of Previous Studies

Long-term monitoring stations in Lac du Sauvage were sampled as part of the Ekati AEMP (ERM Rescan 2014). The benthic invertebrate community at station LDS1 (a mid-depth station; Map 9.2-4) was sampled annually from 2000 to 2012. Mean total density in Lac du Sauvage exhibited variability in historical samples. As also observed in 2013, mean total densities were found to be highest at the shallow stations and lowest at the deep stations. Moderate variability in total richness was observed between 2000 and 2012. Total richness was also found to vary by depth, with the lowest values observed at deep stations and the highest values observed at shallow stations.

Chironomidae consistently dominated the benthic invertebrate community at Station LDS1 from 2000 to 2012, accounting for greater than 50% of the total density. Pisidiidae have regularly accounted for between 10% and 25% of the benthic invertebrate community. The relative density of Oligochaeta (worms) varied annually, accounting for between 1% and 20% of the benthic invertebrate community at LDS1 between 2000 and 2012. Other groups including Acari, Gastropoda, and Trichoptera (caddisflies), were represented in small proportions (<10%) at several stations, although the proportions of each differed between the habitat types.

The benthic invertebrate taxa present in Lac du Sauvage were generally similar among years. Several major taxa, including Oligochaeta (family Lumbriculidae), Pisidiidae, and Chironomidae (Tanytarsus, Monodiamesa, and Procladius) were present in all years. The community composition observed in historical samples was similar to the community composition observed in 2013.

Simpson's diversity index and evenness values have remained relatively stable at the mid-depth station LDS1 in Lac du Sauvage since 2000. Overall, Simpson's diversity index values indicated a moderate to high level of community diversity at all depths. Evenness values were generally low, indicating that a few taxa accounted for the majority of the total density each year. During the years when Simpson's evenness Index values were slightly higher, Oligochaeta and Pisidiidae contributed to larger proportion of the benthic invertebrate community.

9.2.4.1.4 Fish Community and Abundance

The predicted population estimate based on a median statistic from hydroacoustic surveys was approximately 197,000 fish in Lac du Sauvage (Annex XIV). Densities (per 100,000 m^3) varied between the east and west internal basins of Lac du Sauvage and between 0 to 5 m and greater than 5 m depth strata (Table 9.2-7). For example, median densities were lower in the shallow stratum versus the deep stratum. Median densities were highest in the deep stratum of internal basin Aa/b, and almost 4-times higher than the lowest density recorded in the shallow stratum of internal basins Ac/d/e.

The predicted population estimate using the 75th percentile, as part of an environmentally conservative approach for an environmental assessment, was determined to be approximately 828,000 fish for Lac du Sauvage. However, the actual population estimate for fish (including Cisco, Lake Trout, Lake Whitefish, Round Whitefish, and Arctic Grayling) in Lac du Sauvage may be much lower and closer to the median values reported in Table 9.2-7 (e.g., approximately 197,000 individuals based on fish tracking).

Table 9.2-7 Percentile (Including Quartile) Statistics for Density and Abundance of Fish Estimated from Hydroacoustic Surveys

Percentile Statistics	Internal Basin Aa/b (Lac du Sauvage East)			Internal Basin Ac/d/e (Lac du Sauvage West)			Total Abundance
	Fish/100,000 m^3		Abundance	Fish/100,000 m^3		Abundance	
	>5 m	0 to 5 m		>5 m	0 to 5 m		
50%	80.63	27.40	104,106	31.69	21.16	93,316	197,422
75%	213.30	281.03	516,164	71.72	100.89	311,988	828,153

Note: Abundance derived for Aa/b basins using a volume of 89,883,788 m^3 at depths >5m, and 115,446,534 m^3 at depths 0 to 5 m, and for Ac/d/e/ basins using a volume of 167,468,165 m^3 at depths >5 m and 190,191,703 m^3 at depths 0 to 5 m.

% = percent; m^3 = cubic metre; >= greater than; m = metre.

Arctic Grayling, Lake Trout, Lake Whitefish, Round Whitefish, Burbot, Slimy Sculpin, Cisco, Ninespine Stickleback, and Northern Pike were captured or observed in Lac du Sauvage (Annex XIV). Based on fish sampling effort in Lac du Sauvage between 2006 and 2013, Lake Trout were the most abundant species (63%), followed by Lake Whitefish (18%), Round Whitefish (11%), Slimy Sculpin (4%), Cisco (3%), and Burbot (1%), with Arctic Grayling, Northern Pike, and Ninespine Stickleback captured least frequently (less than 1% each) (Table 9.2-8). This general dominance hierarchy was also observed in earlier historical reports (i.e., DDMI 1998a; Golder 1998a).

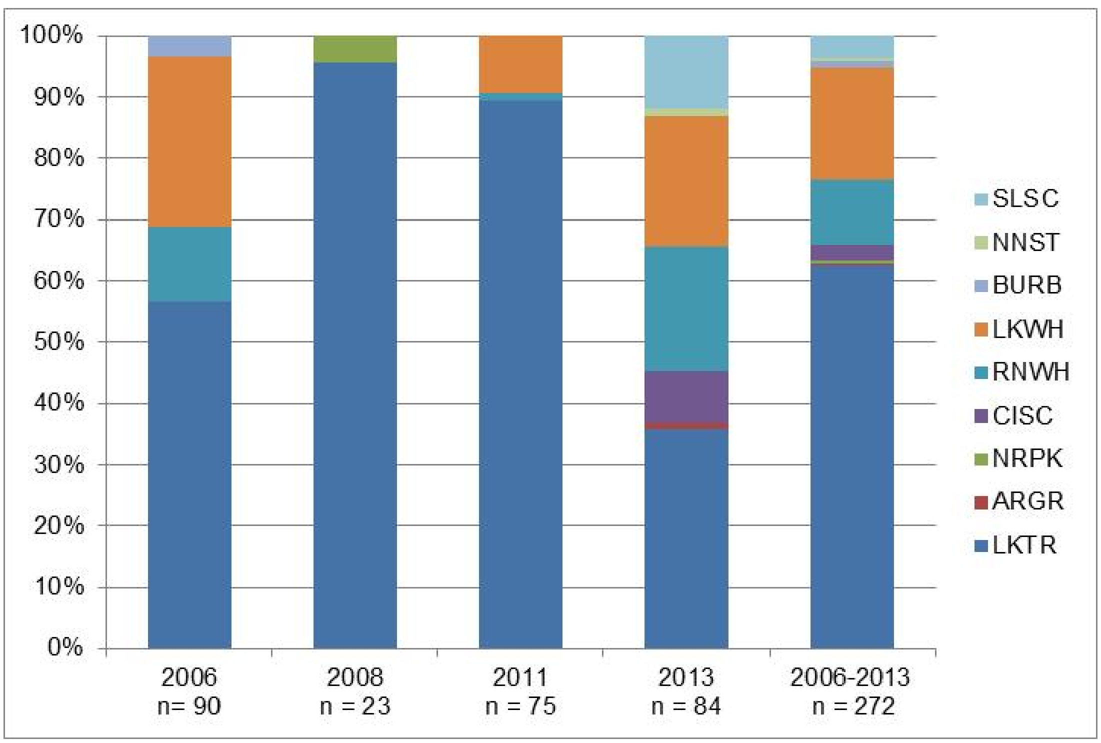
Table 9.2-8 Summary of Fish Sampling Effort and Catch in Lac du Sauvage, 2006 to 2013

Sampling Method	Effort	LKTR	ARGR	NRPK	CISC	RNWH	LKWH	BURB	LNSC	NNST	LKCH	SLSC	Total	Total CPUE
GN	131.28 net-units	87			7	27	50						171	1.30 fish/ net-unit
EF	3,231 s		1			1				1		9	12	0.37 fish/ 100 s
AN	108.77 rod-h	83		1									84	0.77 fish/ rod-h
MT	182.95 trap-d					1		3				1	5	0.03 fish/ trap-d
	Total	**170**	**1**	**1**	**7**	**29**	**50**	**3**	**0**	**1**	**0**	**10**	**272**	

CPUE = catch-per-unit-effort; GN = gill net, EF = backpack electrofishing, AN = angling, MT = minnow trapping; 1 net-unit = 100 square metres (m^2) of net set for 1 hour; s = seconds; rod-h = rod hour; 1 trap-day unit = one minnow trap set for 24 hours; LKTR = Lake Trout; ARGR = Arctic Grayling; NRPK = Northern Pike; CISC = Cisco; RNWH = Round Whitefish; LKWH = Lake Whitefish; BURB = Burbot; NNST = Ninespine Stickleback; SLSC = Slimy Sculpin.

Community composition of fish varied across sampling years, which likely reflected the different methods and level of effort deployed (Figure 9.2-17). In 2008 and 2011, Lake Trout were targeted with angling and gill nets. In 2006 and 2013, baseline sampling targeted Lake Trout, and other species, using a variety of methods. During 2013 field sampling, Lake Trout were the most abundant (36%), followed by Lake Whitefish (22%), Round Whitefish (20%), Slimy Sculpin (12%), Cisco (8%), Arctic Grayling (1%), and Ninespine Stickleback (1%).

Figure 9.2-17 Fish Species Composition in Lac du Sauvage, 2006 to 2013



% = percent; n = number of samples; SLSC = Slimy Sculpin; NNST = Ninespine Stickleback; BURB = Burbot; LKWH = Lake Whitefish; RNWH = Round Whitefish; CISC = Cisco; NRPK = Northern Pike; ARGR = Arctic Grayling; LKTR = Lake Trout.

By applying the relative abundances values for species captured or observed in 2013 to the total fish population estimate of 828,000, populations of individual species in Lac du Sauvage can be estimated as follows: 298,080 Lake Trout; 182,160 Lake Whitefish; 165,600 Round Whitefish; 99,360 Slimy Sculpin; 66,240 Cisco; 8,280 Arctic Grayling; and 8,280 Ninespine Stickleback.

9.2.4.2 *Small Lakes and Tributary Streams to Lac du Sauvage*

9.2.4.2.1 Fish Habitat

Fish habitat conditions in Lac du Sauvage lakes and tributary streams were assessed for a representative sub-sample of streams and lakes in the BSA (Annex XIV). There are approximately 2,216 waterbodies within the Lac du Sauvage sub-basin, with a total surface area of 49,419 ha (Table 9.1-3). Sampled lakes were small compared to Lac du Sauvage. Lac du Sauvage is almost eight times larger than the next biggest lake sampled in the BSA (i.e., Duchess Lake = 1,016 ha, with maximum depth of 16 m). Duchess Lake has a cumulative drainage basin area of 34,633 ha. Smaller lakes included Lake E1 with a surface area of 169 ha, a maximum depth of 12 m, and a cumulative drainage basin area of 20,650 ha. The other 13 small lakes surveyed are in the Ab, Ac, B, C, and D basins that drain into Lac du Sauvage; they range in size from 5 ha (Lake Ac20) to 163 ha (Lake C1), and their cumulative drainage basin areas range from 158 ha (Lake D4) to 1,340 ha (Lake B1).

Several lakes, including Duchess Lake, Lake E1, and Lake C3 had steep drop-offs from shore where depth provided cover for fish. Cover was also provided by coarse substrates (boulder) in the majority of the lakes. Other types of cover were overhanging vegetation (shrubs) in Duchess Lake, and lakes E1, B4, Ab2, Ac17, and Lake Ad8, undercut banks in lakes B4 and B15, and submergent vegetation in lakes C1, D2, and Ad8). Emergent vegetation included sedge (e.g., *Carex aquatilis aquatilis*) wetlands, which were present in Duchess Lake and lakes E1, B1, B4, B15, D3, D4, Ac17, and Ad8.

Cumulative watershed areas of the 17 study streams evaluated in the BSA were small (ranging from 104 ha for Stream Ad8 to 1,458 ha for Stream B1), with the exception of Stream E2 (15,972 ha) and Stream E1 (20,650 ha), which empty into Duchess Lake before flowing into Lac du Sauvage. Streams with a cumulative watershed area of less than 300 ha were typically dry in August and lacked a defined bed and banks (i.e., ephemeral). Surveyed streams with defined bed and banks were generally narrow (2 m or less) with shallow to moderately deep runs (maximum depths from 0.5 to 2.0 m) bordered by thick willows and substrate dominated by organics or fines. However, the dominant substrate was mostly gravel/cobble and boulder/bedrock in Streams C3 and Ab2, respectively. Arctic Grayling spawning habitat (gravel/cobble) was identified in streams B1, C3, and D1, with juvenile and young-of-the-year (YOY) captured in streams B1, B15, C1, C3, and D1.

Habitat connectivity between Lac du Sauvage and the B, C, and D sub-basins is maintained by Streams B1 and C1 (into internal basin Ac), and D1 (into internal basin Ad). However, minimal connectivity is likely maintained by streams Ac4 and Ac35, as the reconnaissance surveys indicated both streams are ephemeral with undefined bed and banks, and the contributing drainage basins are small (less than 300 ha) (Rescan 2007). Similarly, Rescan (2007) observed very low flows in small, streams in the Ac sub-basins (including Stream Ac4) in 2006.

Potential barriers to upstream movements of fish (extensive boulder gardens) were identified in streams Ab2, B1, C1, and C3. Stream E2 differed from other streams sampled in the BSA because it was a long (7.7 km), wide (approximately 19.2 m), entrenched, meandering watercourse consisting of deep runs. Riffle habitat was observed in aerial photographs at upstream locations of Stream E2. Stream gradients were low to moderate; most streams were less than 1% in slope. Streams with very low gradients (0.1% or lower) included the outlets of Lac du Sauvage, Duchess Lake, Lake C3, and Lake E2. The Lac du Sauvage outlet (i.e., the Narrows) is a relatively wide (minimum bankfull width of approximately 45 m) and short (210 m in length) stream. Similarly, Duchess Creek is a wide stream (minimum bankfull width of approximately 125 m) with a reach length of 1,371 m.

A historical survey of Arctic Grayling habitat was completed in 1996 at two streams (L1 and J2) in the eastern section of Lac du Sauvage (Golder 1997a). Habitat in Stream L1 was typically of low quality, deep runs, but it also contained portions of moderate and high-quality run habitat, and low to moderate quality pools for Arctic Grayling. Habitat in Stream J2 was more uniform, with 100% of the habitat ranked as high-quality run habitat braided through thick willows, with no pools.

Sub-Basin B

Sub-basin B is west of Lac du Sauvage internal basin Ac, and has a drainage area of 1,458 ha. Potentially providing habitat for fish from Lac du Sauvage, Stream B1 (Christine Creek) drains east from Lake B1 (Christine) for approximately 1.6 km before the watercourse empties into internal basin Ac of Lac du Sauvage (Map 9.2-1). Lake B1 (Christine) sub-catchment covers 1,340 ha, of which Lake B1 (Christine) itself represents 49 ha. Major tributaries to Lake B1 include Stream B2, flowing in northerly direction from a small pond (Lake B2) and downstream of Lake B4 (Cujo), which is approximately 46 ha in size. Stream B15 is another major tributary to Lake B1 (Christine) and drains southeast from Lake B15 (63 ha) for distance of approximately 0.4 km before entering Lake B1 (Christine).

Lake B1 (Christine) is a typical lake in the region and consists of similar habitats throughout the lake. Based on 2013 observations, the shoreline was boulder and bedrock dominant with submerged mosses and grasses. The littoral zone (the shallow, shoreline area of a lake) consisted mainly of boulder and cobble substrates with traces of silt and gravel. Boulder/cobble shoals were common and often had macrophyte (aquatic plants) growth. Sandy shorelines were observed at the south shore and northwest corner of the lake. At the west shoreline of the lake, steep boulder and bedrock habitats were present where depths reached 4 m within short distances of shore. Sedge wetlands comprised of *Carex aquatilis* var. *aquatilis* were also present around the shoreline. The deepest area surveyed was 14.6 m. Shoreline cover for fish was provided by substrate, depth, and vegetation (macrophytes).

The outlet of Lake B1 (Christine Creek) has a length of 1.6 km and flows through Lake B0 (a large pond 2.7 ha in area) before entering Lac du Sauvage. The highest flow month is June, and low flows may fall to zero under ice-covered conditions. Median flood peak discharge is predicted to be 0.44 m^3/s. The watercourse, including Lake B0 habitat dimensions, had a mean bankfull width of 20.3 m, with a wetted width of 18.1 m and a maximum depth of 2.0 m. Excluding Lake B0, Christine Creek had a mean bankfull width of 6.4 m, with a mean wetted width of 3.9 m and a maximum depth of 1.0 m.

Stream B1 (Christine) was characterized by shallow run habitat (84%) with occasional flats (12%) and riffles (3%). Stream cover was abundant, particularly as aquatic and riparian vegetation at the lower end of the stream below Lake B0. The substrate was dominated by organics and silts with similar contributions from boulder and the occasional patch of cobble. Potential barriers to upstream movements of fish from Lac du Sauvage were identified (e.g., boulder gardens, sub-surface flows downstream of Lake B0) at the time of sampling in summer 2013. The slope of the creek was less than 1%, as determined by light detection and ranging (LiDAR) data evaluated in Geographic Information System (GIS). The highest flow month is June, and low flows may fall to zero under ice-covered conditions.

9.2.4.2.2 Plankton

Plankton communities and trophic status were assessed in several lakes of the Lac du Sauvage basin during the 2013 baseline program for the Project (Map 9.2-1) and during long-term monitoring as part of the Ekati AEMP (Map 9.2-7). Data were collected in Duchess Lake and Lakes Af1 and E1 as part of the 2013 baseline survey. Data were collected from Lake D3 (Counts) during summer from 1997 to 2012 as part of the Ekati AEMP (ERM Rescan 2013) As part of the Jay Pipe Aquatic Baseline Program, data were collected in Lake B1 (Christine) and Ursula Lake throughout the 2006 open-water period (Rescan 2007).

Chlorophyll *a* and Trophic Status

The discrete and depth integrated water sampling programs integrated TP, Secchi and chlorophyll *a* data to determine that based on TSI values, Duchess Lake would be classified as mesotrophic, Lake Af1 as mesotrophic to eutrophic, and Lake E1 as a mesotrophic system (Vollenweider 1970; Carlson 1997; CCME 2004).

Phytoplankton

Seasonal trends in total phytoplankton abundance and biomass were variable throughout the three Lac du Sauvage area lakes sampled as part of the 2013 baseline study. Total phytoplankton abundance in Lake E1 showed very little difference between summer and fall, whereas total phytoplankton abundance increased from late spring through the fall at both Duchess Lake stations and decreased from late spring through the fall in Lake Af1 (Figure 9.2-18).

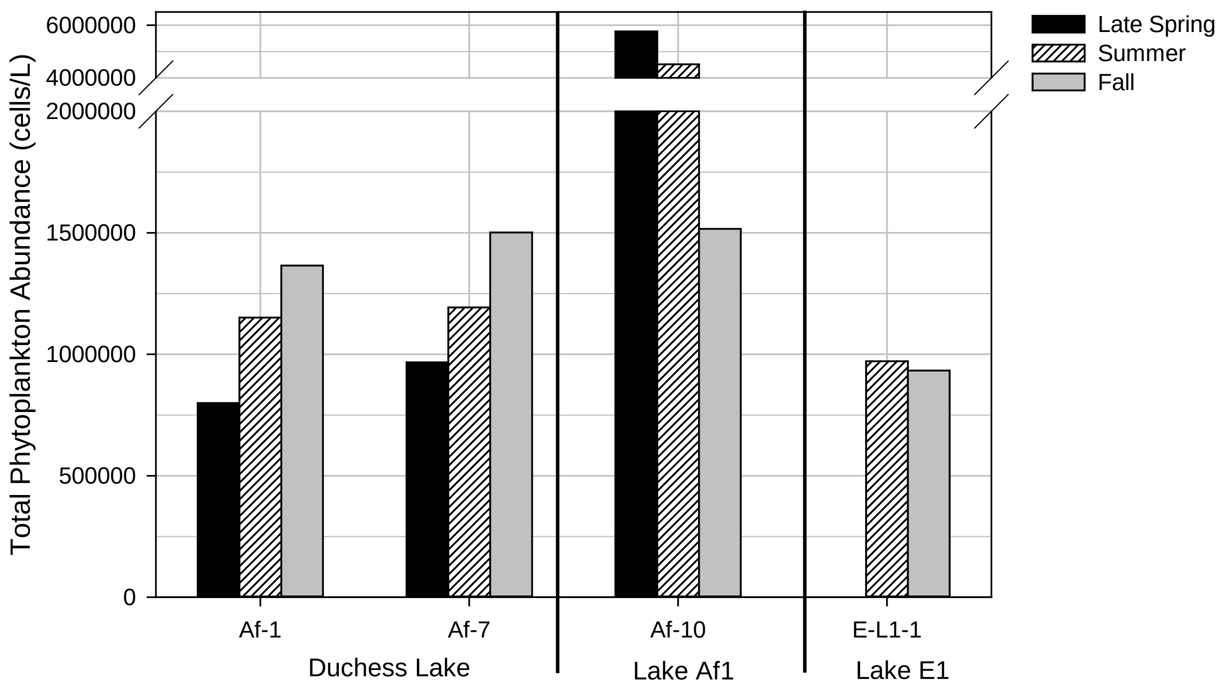
Total phytoplankton biomass decreased from summer to fall in Lake E1 and from late spring through fall in Lake Af1. Total phytoplankton biomass in Duchess Lake was similar among sampling periods and between stations, and increased from late spring through fall (Figure 9.2-19).

In terms of relative abundance, the Duchess Lake and Lake Af1 phytoplankton communities were dominated by cyanobacteria, chrysophytes, and chlorophytes throughout 2013 sampling (Figure 9.2-20). The phytoplankton community of Lake E1 was dominated by chrysophytes in the summer and by cyanobacteria and chrysophytes in the fall.

In terms of relative biomass, dinoflagellates and chrysophytes, dominated the 2013 Lake E1 phytoplankton community, dinoflagellates, chlorophytes, chrysophytes, and cyanobacteria dominated the Duchess Lake phytoplankton community at different points throughout the open-water period (Figure 9.2-21). In Lake Af1, cyanobacteria, chlorophytes, and chrysophytes dominated the phytoplankton community.

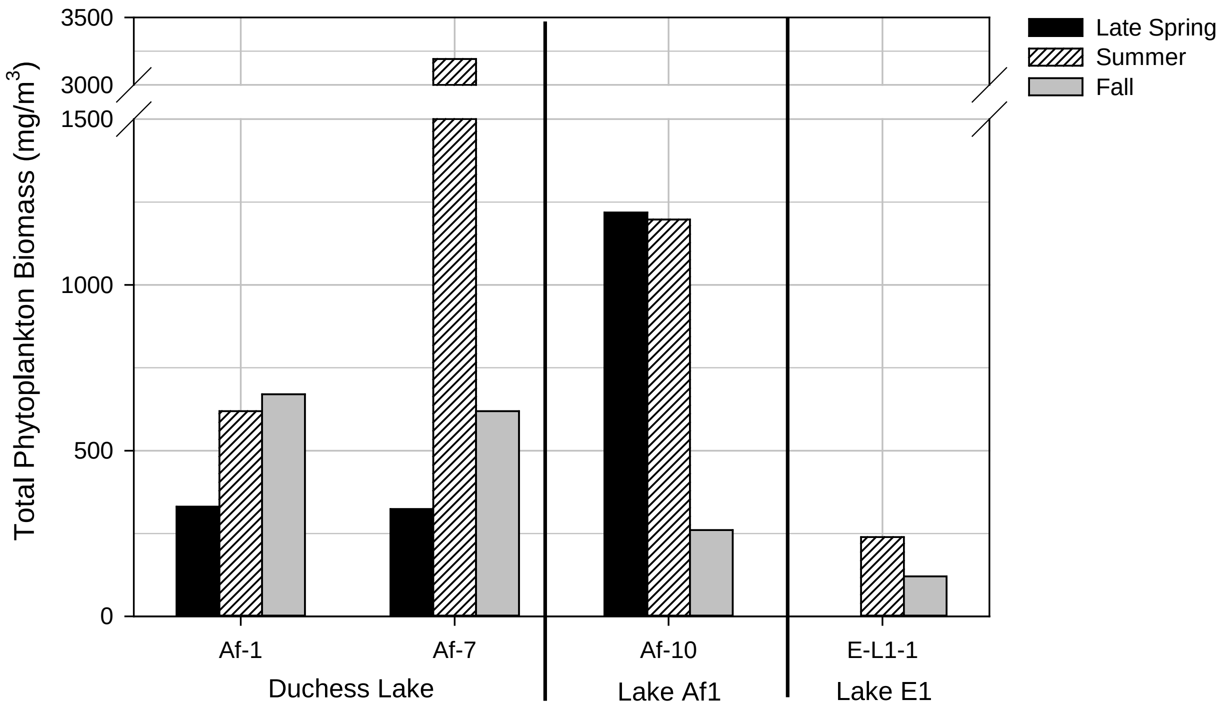
In 2013, taxonomic richness in Lac du Sauvage basin lakes varied seasonally as well as geographically, increasing in Lake E1, decreasing in Lake Af1, and showing no consistent seasonal trend in Duchess Lake (Figure 9.2-22). In total, 52, 67, and 63 phytoplankton taxa were identified in Lake E1, Lake Af1, and Duchess Lake, respectively. At Station Af-1, phytoplankton richness was similar between late spring and summer and then increased in the fall. At Station Af-7, phytoplankton richness was highest in late spring decreasing in summer and increasing slightly in fall.

Figure 9.2-18 Total Phytoplankton Abundance in Duchess Lake, Lake Af1, and Lake E1 in Late Spring, Summer, and Fall, 2013



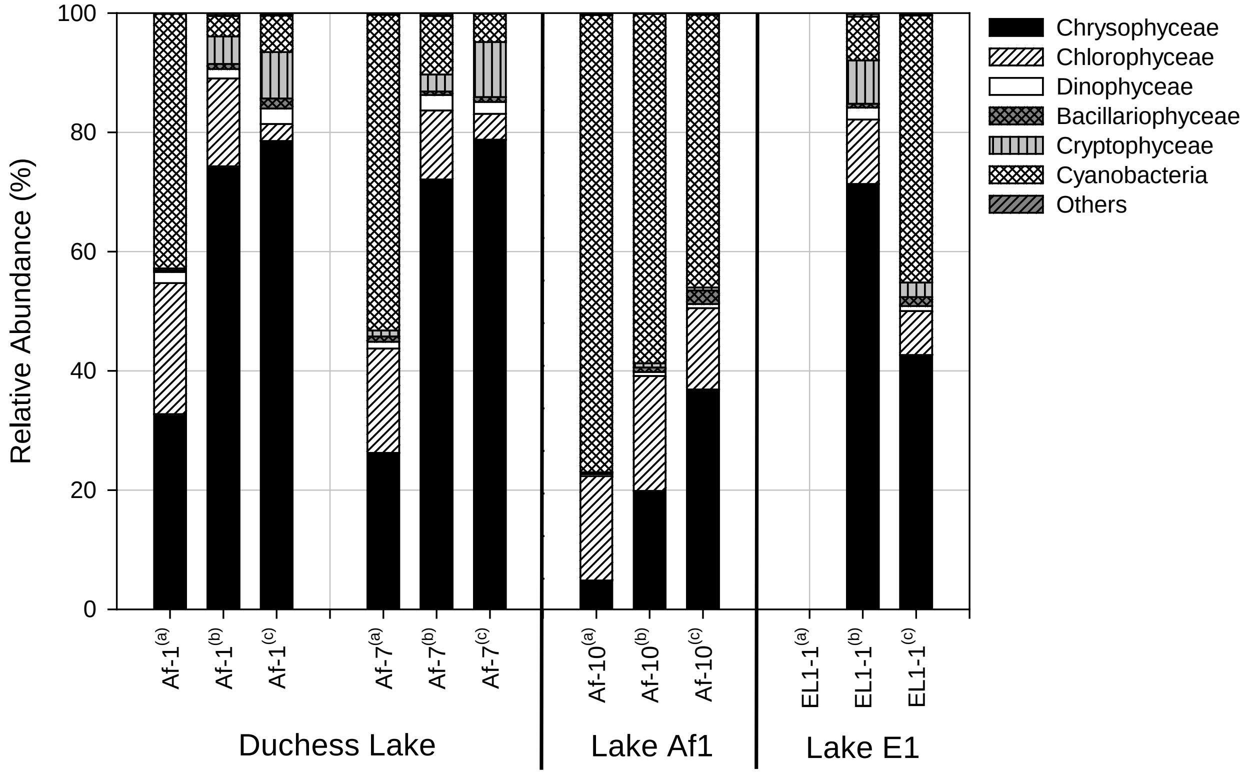
cells/L = cells per litre.

Figure 9.2-19 Total Phytoplankton Biomass in Duchess Lake, Lake Af1, and Lake E1 in Late Spring, Summer, and Fall, 2013



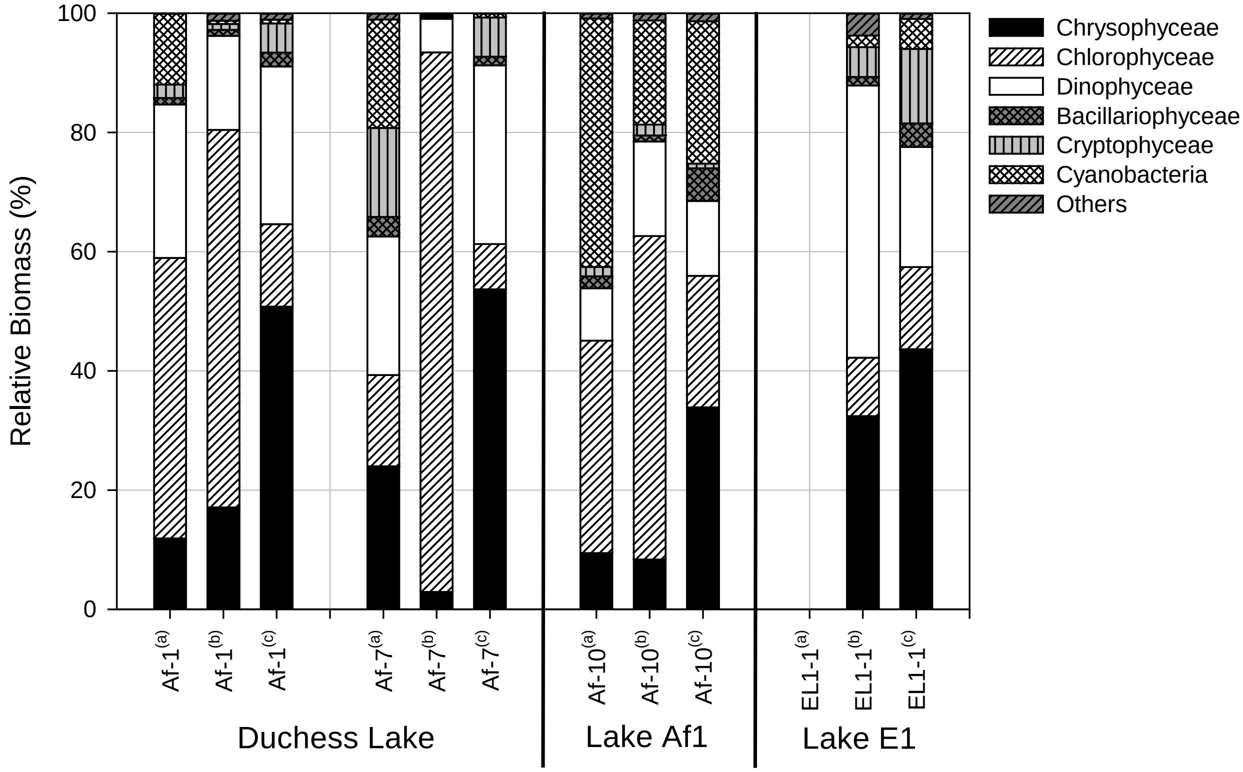
mg/m^3 = milligrams per cubic metre.

Figure 9.2-20 Relative Phytoplankton Abundance in Duchess Lake, Lake Af1, and Lake E1 in Late Spring, Summer, and Fall, 2013



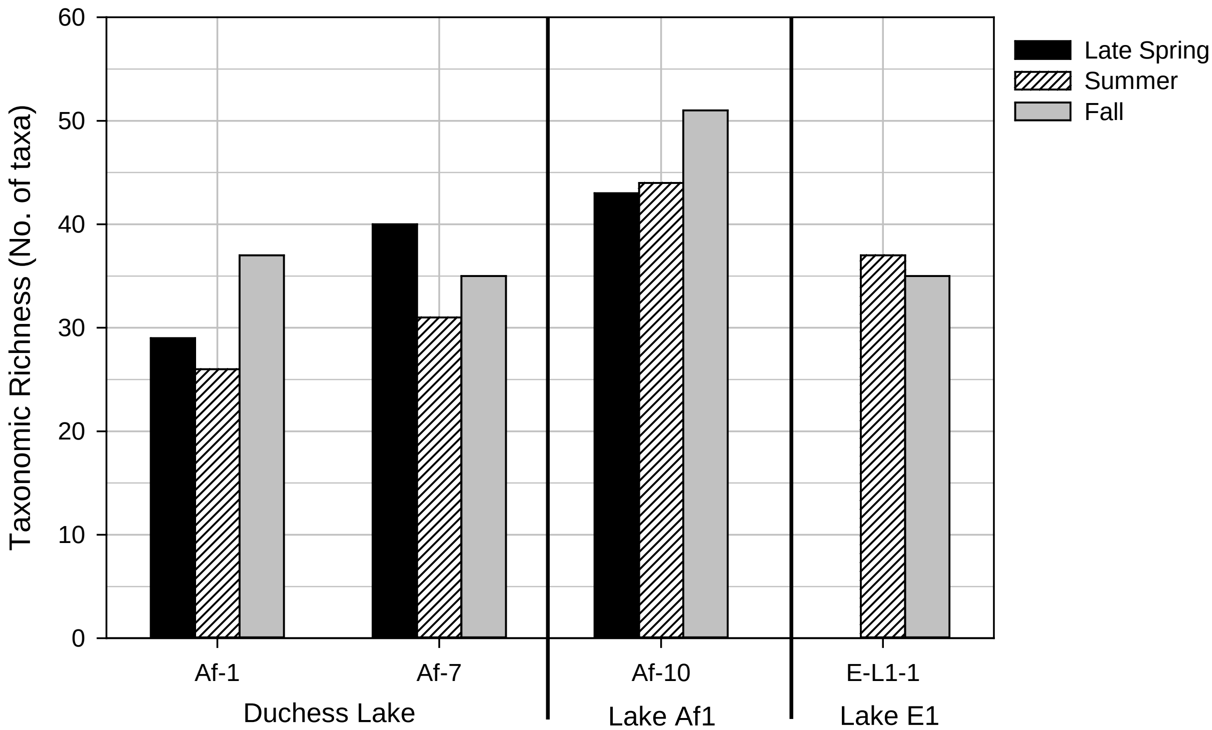
a) late spring sampling event.
b) summer sampling event.
c) fall sampling event.
% = percent.

Figure 9.2-21 Relative Phytoplankton Biomass in Duchess Lake, Lake Af1, and Lake E1 in Late Spring, Summer, and Fall, 2013



a) late spring sampling event.
b) summer sampling event.
c) fall sampling event.
% = percent.

Figure 9.2-22 Total Phytoplankton Taxonomic Richness in Duchess Lake, Lake Af1, and Lake E1 in Late Spring, Summer, and Fall, 2013



No. = number.

Zooplankton

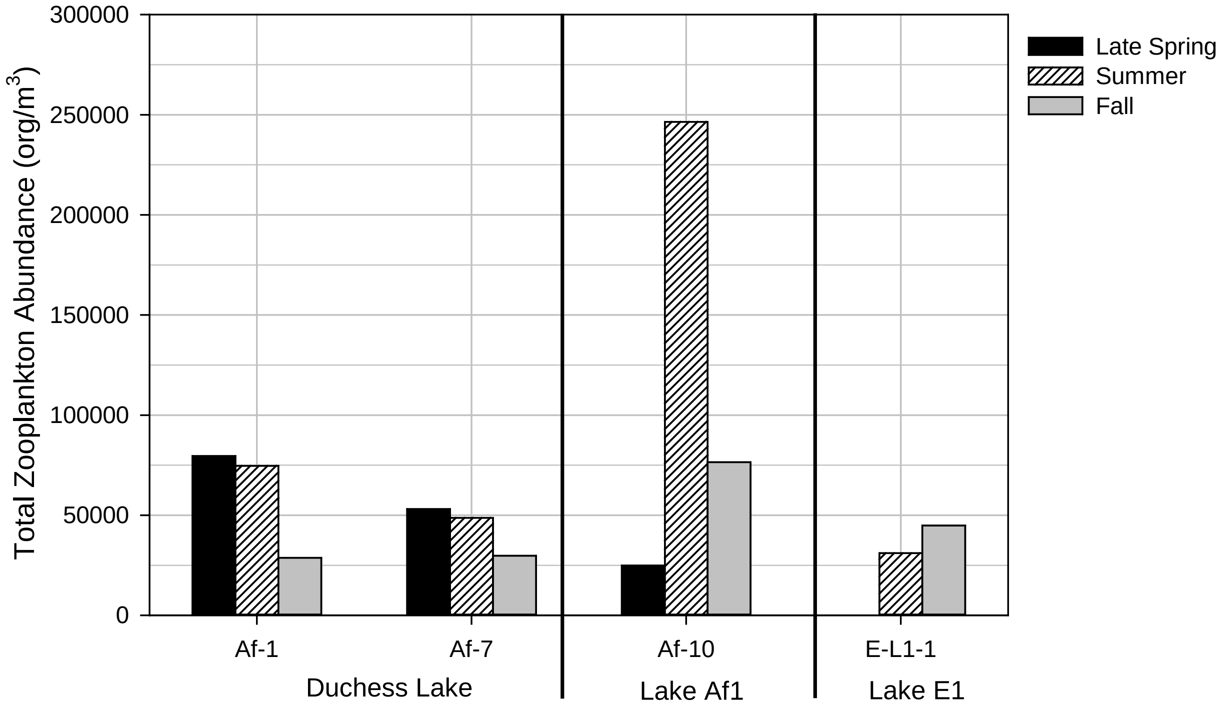
Total zooplankton abundance peaked during summer 2013 in Lake Af1, but remained consistent between sampling seasons in Lake E1 and was similar in Duchess Lake between late spring and summer, before decreasing from summer to fall (Figure 9.2-23). Total zooplankton biomass peaked in the summer in all three lakes (Figure 9.2-24).

Rotifers dominated the zooplankton community by abundance in Lake E1 and Lake Af1 during the 2013 open-water sampling program (Figure 9.2-25). Zooplankton community composition by abundance was relatively similar between stations in Duchess Lake in 2013 with rotifers and cladocerans dominating throughout the open-water sampling period.

In terms of biomass, Lake E1 was dominated by copepod nauplii in the summer and co-dominated by rotifers and cladocerans in the fall (Figure 9.2-26). Rotifers dominated the zooplankton community by biomass in Duchess Lake in late spring, while cladocerans dominated in summer and fall. Zooplankton community composition by biomass in Lake Af1 varied throughout the open-water sampling period with copepod nauplii, calanoid copepods, copepod nauplii, and rotifers all dominating the zooplankton community at different times, with no obvious trend.

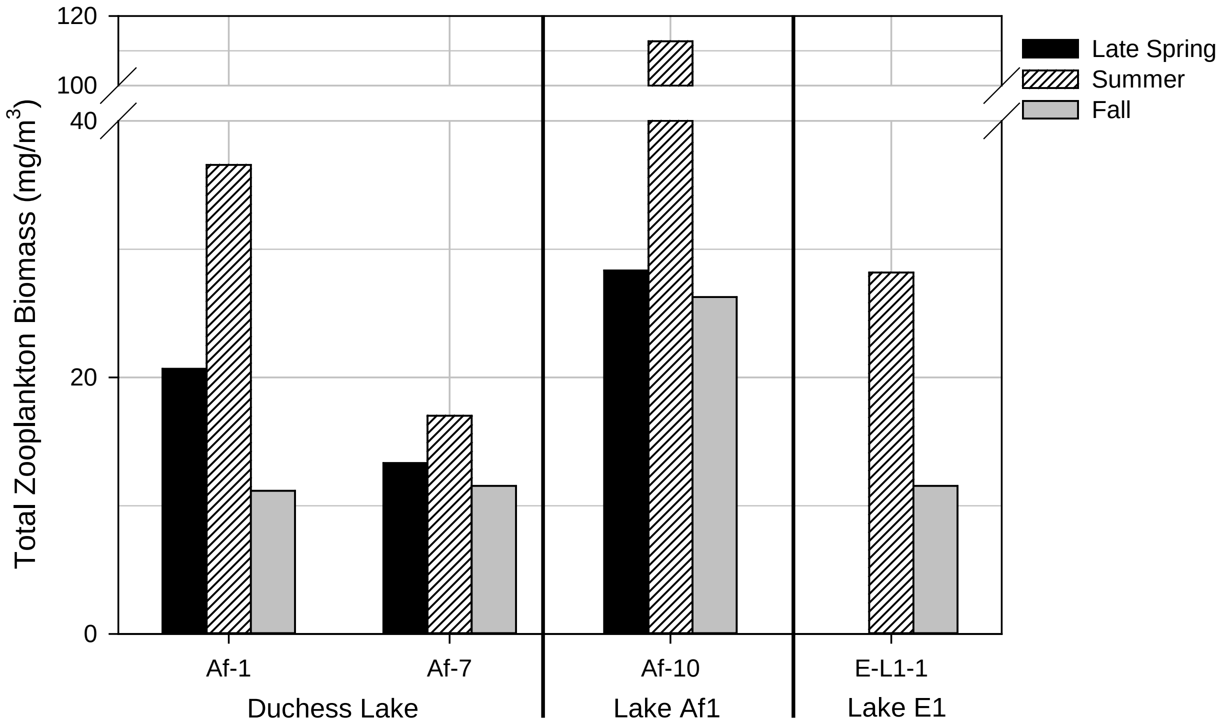
In total, 19 zooplankton taxa were identified in Lake E1 in the summer and fall in 2013, with taxonomic richness identical in the summer and fall (Figure 9.2-27). In Lake Af1, a total of 20 zooplankton taxa were identified in 2013, with identical taxonomic richness in late spring and fall, but a lower value in summer. In Duchess Lake, a total of 21 zooplankton taxa were identified in 2013 and taxonomic richness was similar at the two stations and during all three sampling periods.

Figure 9.2-23 Total Zooplankton Abundance in Duchess Lake, Lake Af1, and Lake E1 in Late Spring, Summer, and Fall, 2013



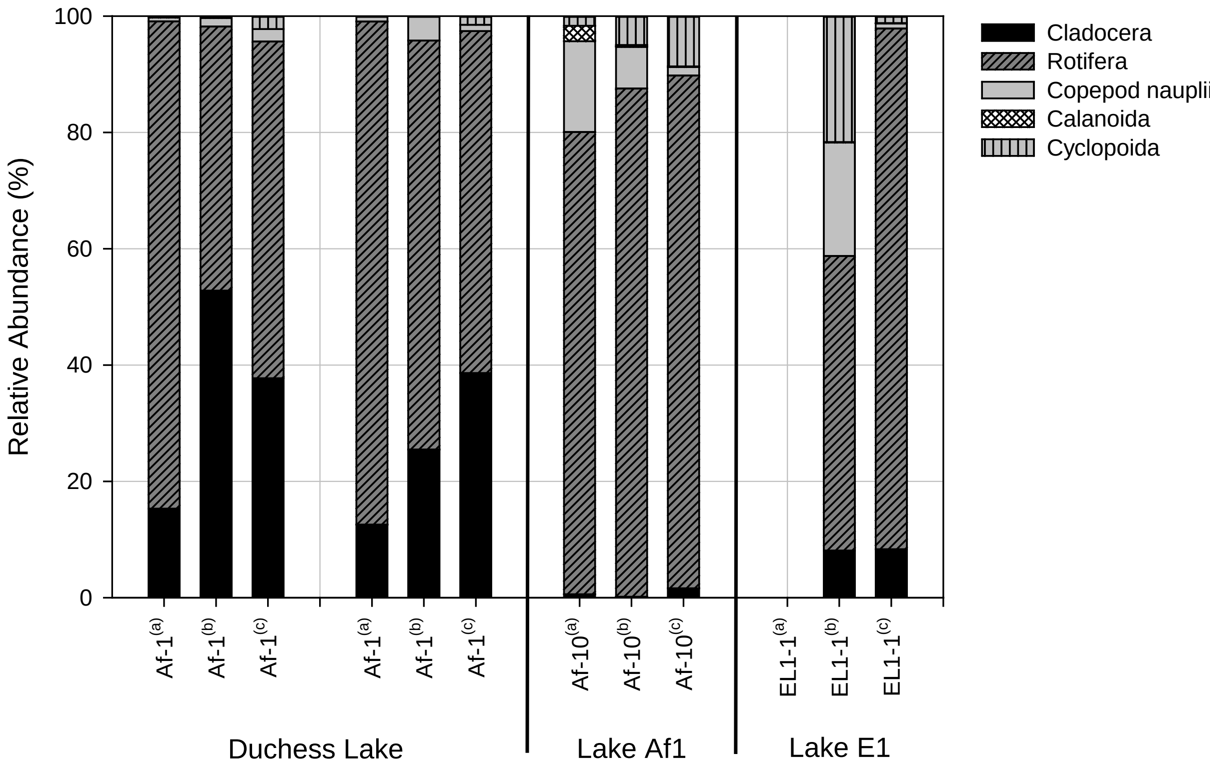
org/m^3 = organisms per cubic metre.

Figure 9.2-24 Total Zooplankton Biomass in Duchess Lake, Lake Af1, and Lake E1 in Late Spring, Summer, and Fall, 2013



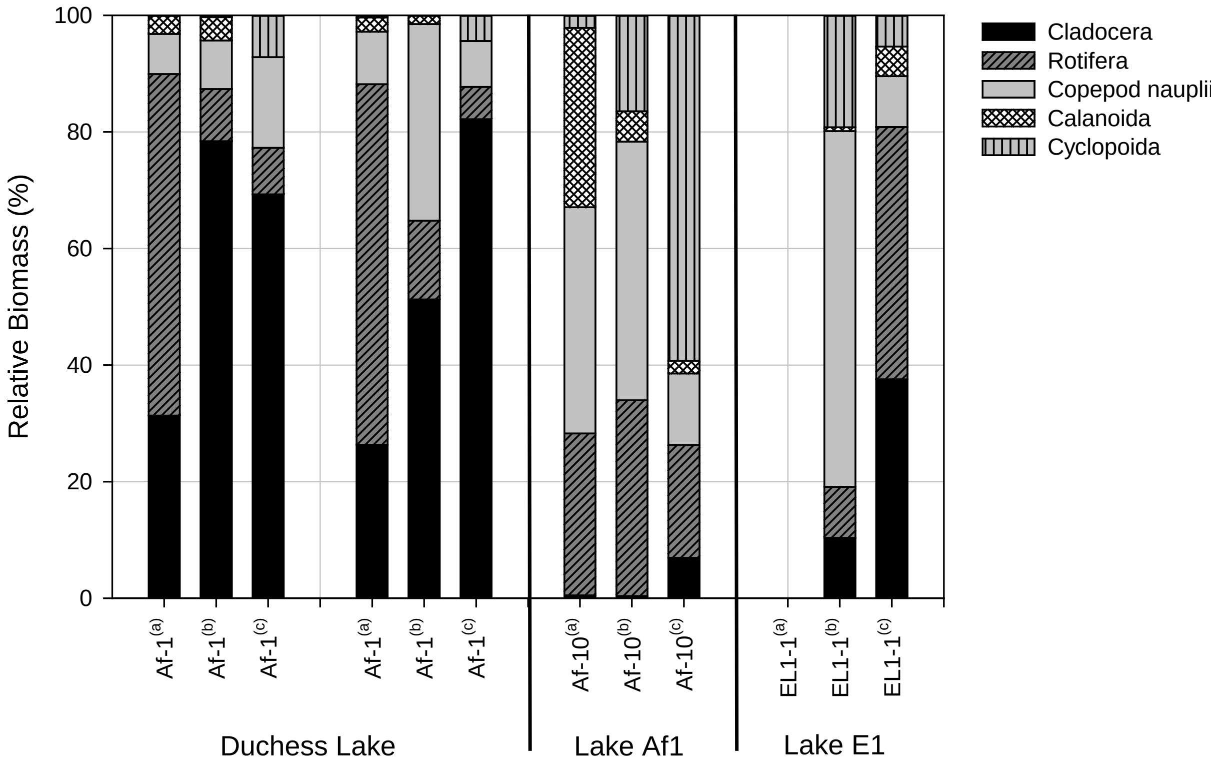
mg/m^3 = milligrams per cubic metre.

Figure 9.2-25 Relative Zooplankton Abundance in Duchess Lake, Lake Af1, and Lake E1 in Late Spring, Summer, and Fall, 2013



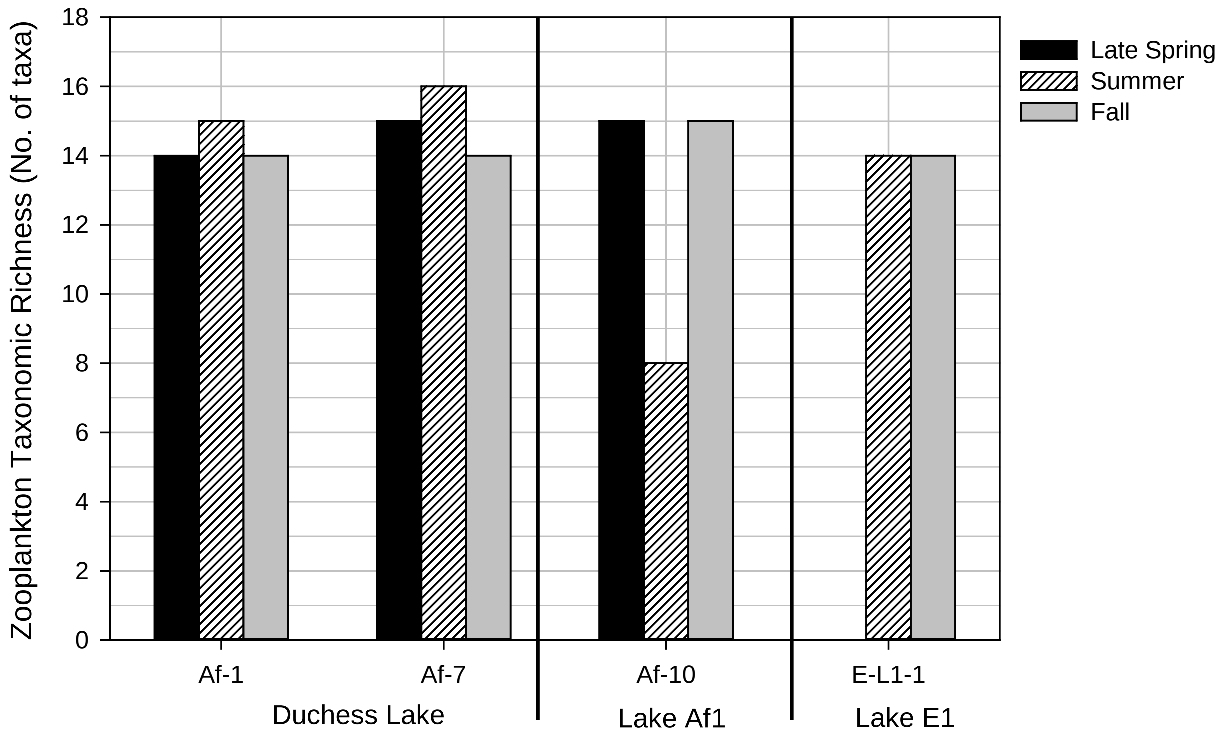
a) late spring sampling event.
b) summer sampling event.
c) fall sampling event.
% = percent.

Figure 9.2-26 Relative Zooplankton Biomass in Duchess Lake, Lake Af1, and Lake E1 in Late Spring, Summer, and Fall, 2013



a) late spring sampling event.
b) summer sampling event.
c) fall sampling event.
% = percent.

Figure 9.2-27 Total Zooplankton Taxonomic Richness in Duchess Lake, Lake Af1, and Lake E1 in Late Spring, Summer, and Fall, 2013



No. = number.

Summary of Previous Studies

Chlorophyll *a* concentrations in Lake D3 ranged from a minimum of 0.21 µg/L (2006) to a maximum of 1.05 µg/L (1999). Chlorophyll *a* concentrations in Lake B1 and Ursula Lake were highest in fall (1.46 and 0.47 µg/L, respectively) and lowest in summer (0.33 and 0.18 µg/L, respectively). Although chlorophyll *a* concentrations in Lake B1 were higher than the other two lakes, all chlorophyll *a* values remained within the oligotrophic range (Wetzel 2001).

Summer total phytoplankton abundance in Lake D3 was highly variable from 1997 to 2004, peaking in 2002, but has subsequently declined and remained consistent since 2010. In 2006, no consistent seasonal trend in phytoplankton abundance was observed in Lake B1 and Ursula lakes, with abundance peaking in summer in Lake B1 and during fall in Ursula Lake.

The composition of the phytoplankton community (based on abundance) in Lake D3 has been inconsistent over time. Cyanobacteria and chrysophytes dominated the Lake D3phytoplankton community (by abundance) during most summers, although chlorophyte abundance has steadily increased, reaching a peak in 2012. Seasonal variability was observed in phytoplankton community composition (based on abundance) in Lake B1 and Ursula Lakes during the 2006 open-water sampling period, with chrysophyte abundances decreasing, cyanobacteria abundances increasing, and chlorophytes consistently sub-dominant throughout the open-water period.

Between 1997 and 2001, total phytoplankton taxonomic richness in Lake D3 reached a minimum of 35 taxa during 2001 and has generally increased since then, reaching a peak in 2012. During 2006, total phytoplankton taxonomic richness in Lake B1 was 67 taxa, and ranged between 60 and 64 taxa among the three stations in Ursula Lake.

Summer total zooplankton abundance in Lake D3 was highly variable during 1997 to 2012. Highest total zooplankton abundances were observed in 2007 (172,365 org/m^3) and 2008 (174,581 org/m^3). Total abundance declined in subsequent years, fluctuating between approximately 45,000 and 60,000 org/m^3 since 2010. In 2006, total zooplankton abundance peaked during late spring in Lake B1 and during summer in Ursula Lake.

In Lake D3, summer total zooplankton biomass was highest in 1998 (319 mg/m^3) and lowest in 1999 (69 mg/m^3) and has been relatively stable since 2000, typically fluctuating between 150 and 200 mg/m^3. In 2006, total zooplankton biomass was higher in Lake B1 compared to Ursula Lake, increasing throughout the open-water sampling period in Lake B1 but peaking during summer in Ursula Lake.

The summer zooplankton community (based on relative abundance) in Lake D3 was typically dominated by calanoid copepods with rotifers consistently subdominant. In 2006, the Lake B1 zooplankton community (based on relative abundance) was dominated by rotifers in late spring and cyclopoid copepods in fall, whereas the Ursula Lake zooplankton community was dominated by calanoid copepods throughout the open-water period, with cyclopoid copepods and rotifers each accounting for approximately 20% of total zooplankton abundance during all seasons.

Community composition was not assessed using biomass data during historical surveys of Lake D3, Lake B1, or Ursula Lakes.

Total zooplankton taxonomic richness in Lake D3 ranged between 7 and 9 taxa, with little variation between 1997 and 2012. Total zooplankton taxonomic richness in 2006 ranged from 9 to 10 taxa in both Lake B1 and Ursula Lake.

9.2.4.2.3 Benthic Invertebrates

Benthic invertebrate communities were also assessed in several surrounding lakes and tributary streams to Lac du Sauvage during the 2013 baseline program (Map 9.2-2). Sample collection was conducted in Duchess Lake and Lake Af1 in the A sub-basin, Lake C1 in the C sub-basin, and Lake E1 in the E sub-basin. Four streams in the Lac du Sauvage basin were also sampled, including one station in each of Stream Ab1, Stream G1, and Stream L1, and five stations in Stream E2.

Benthic invertebrate communities from three lakes in the area surrounding Lac du Sauvage were also evaluated as part of the historical data review (Map 9.2-4). Lake B1 (Christine) and Ursula Lake were sampled as part of the Jay Pipe Aquatic Baseline Program (Rescan 2007). The Ekati Mine benthic invertebrate baseline survey and AEMP evaluated Lake D3 and its outflow stream (Rescan 1995; ERM Rescan 2013).

Small Lakes

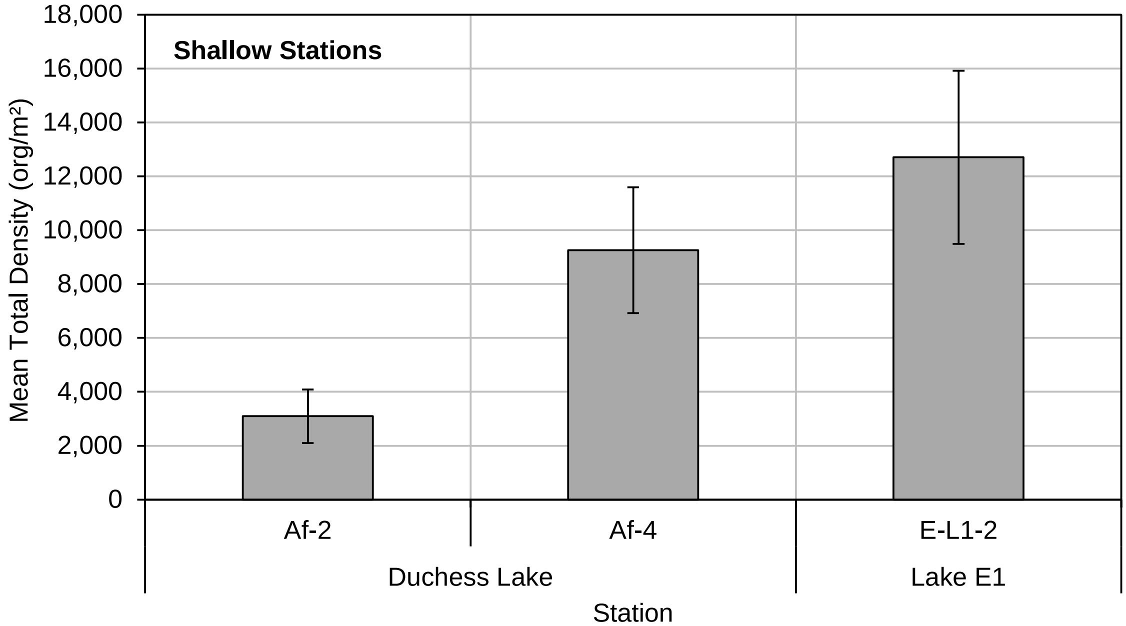
Mean total benthic invertebrate density was low to moderate at the shallow stations in Duchess Lake and Lake E1, and was low at the mid-depth and deep stations in Duchess Lake, Lake Af1, Lake E1, and Lake C1 (Figure 9.2-28). Total richness was moderate to high at the shallow stations sampled in the small lakes surrounding Lac du Sauvage. Mid-depth and deep stations had lower richness and less variability among locations compared to shallow stations (Figure 9.2-29). As also observed at stations sampled in Lac du Sauvage, the mean total density and richness were generally higher at shallow stations compared to deep stations.

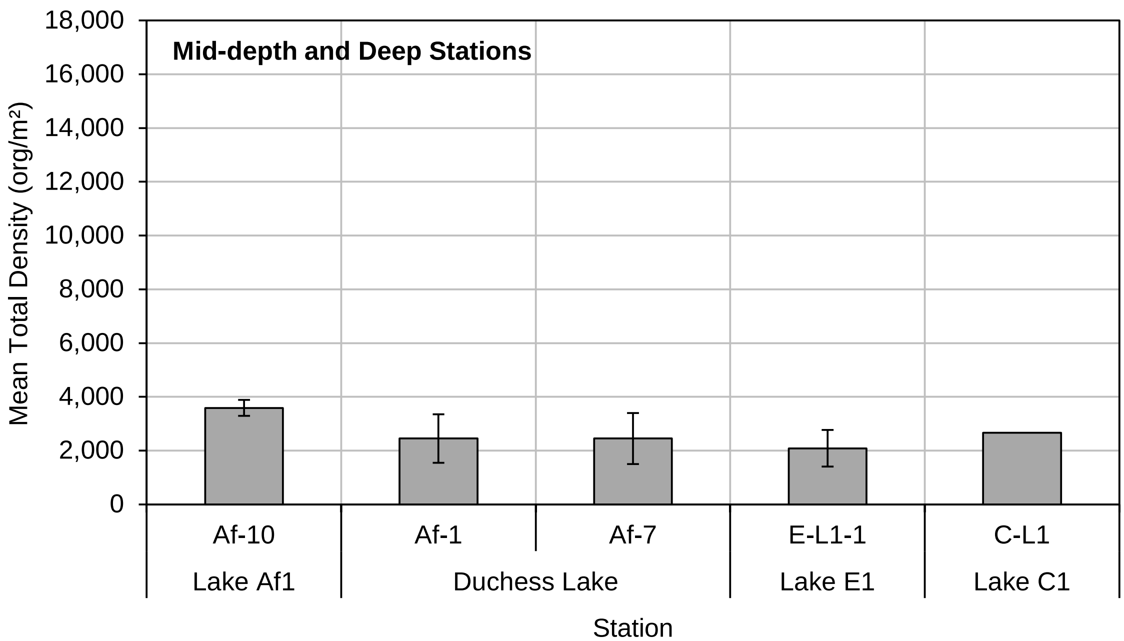
Total richness at the littoral stations in Duchess Lake, Lake Af1, and Lake E1 was moderate and the Chironomidae typically dominated the benthic invertebrate communities. The taxa present at littoral stations in the surrounding lakes were similar to those present at the littoral stations sampled in Lac du Sauvage.

As seen in Lac du Sauvage and throughout the BSA, the Chironomidae dominated the benthic invertebrate community at all the stations in Duchess Lake, Lake Af1, Lake C1, and Lake E1 (Figure 9.2-30). The Orthocladiinae and the Chironomini were the two dominant chironomid groups at these stations. The Pisidiidae also accounted for a large proportion of the total density at all stations and was the dominant benthic invertebrate community at Station C-1 (Figure 9.2-30).

Overall, diversity values indicated a diverse benthic invertebrate community. Evenness values were generally low, indicating that a few taxa accounted for the majority of the total density at each station. Diversity tended to be slightly lower at deep stations compared to shallow stations, while the evenness was similar among shallow and deep stations.

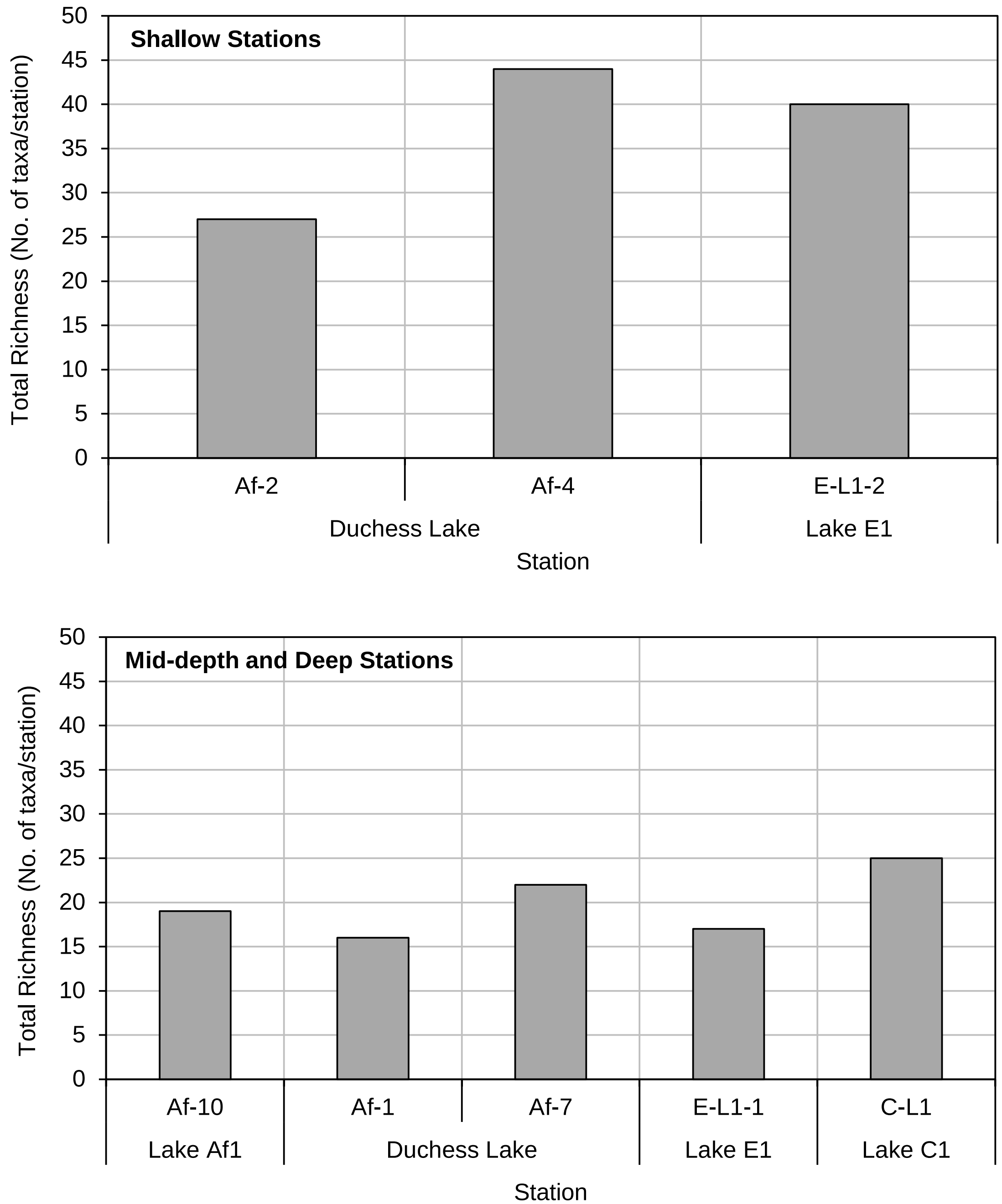
Figure 9.2-28 Mean Total Benthic Invertebrate Density in Duchess Lake, Lake Af1, Lake C1, and Lake E1, August and September 2013





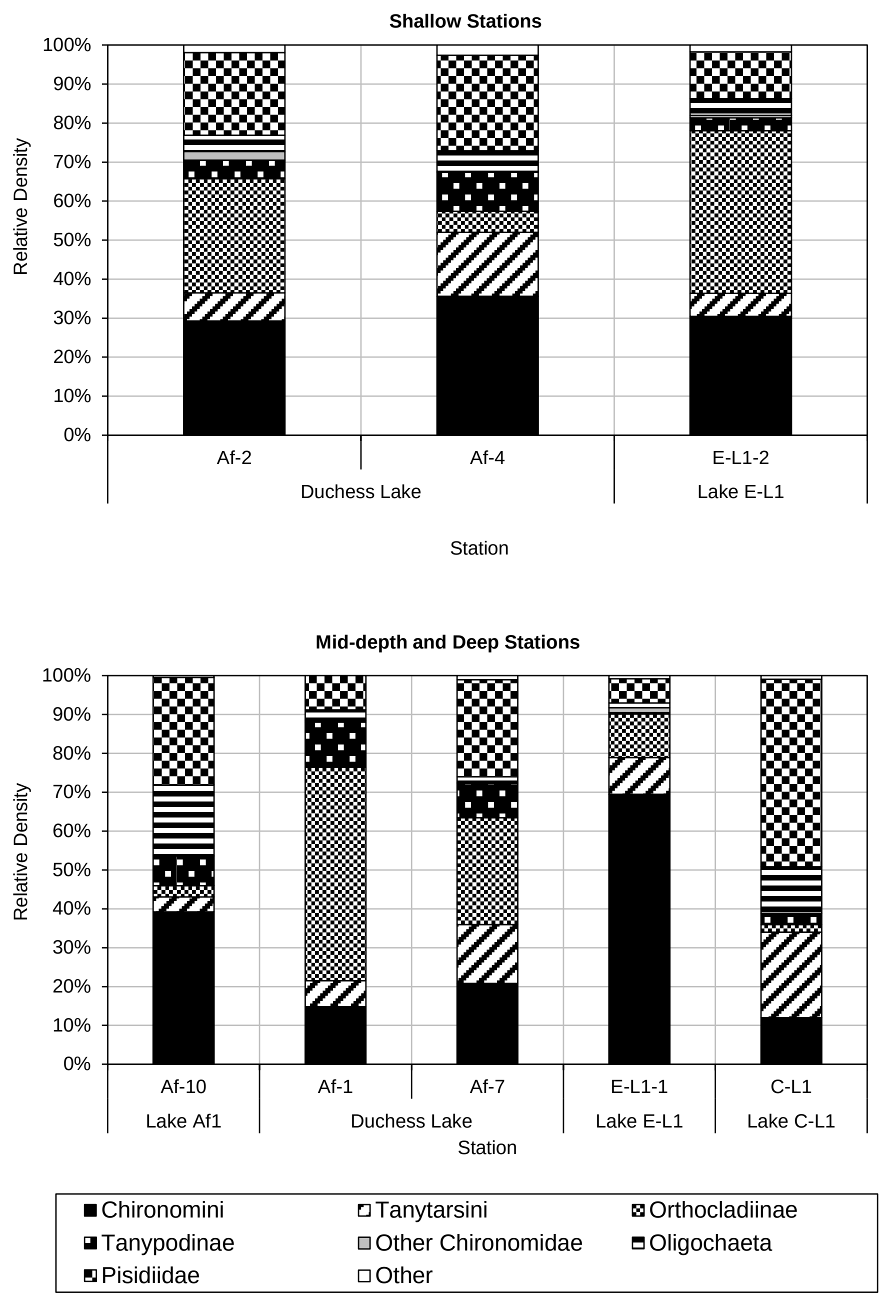
Note: Error bars represent one standard error of the mean.
org/m^2 = number of organisms per square metre.

Figure 9.2-29 Total Benthic Invertebrate Richness in Duchess Lake, Lake Af1, Lake C1, and Lake E1, August and September 2013



No. of taxa/station = number of taxa per station.

Figure 9.2-30 Relative Density of Major Benthic Invertebrate Taxa in Duchess Lake, Lake Af1, Lake C1, and Lake E1, August and September 2013



Note: "Other" taxa category includes Hydridae, Acari, Gastropoda, Turbellaria, Trichoptera and Empididae.
% = percent.

Tributary Streams

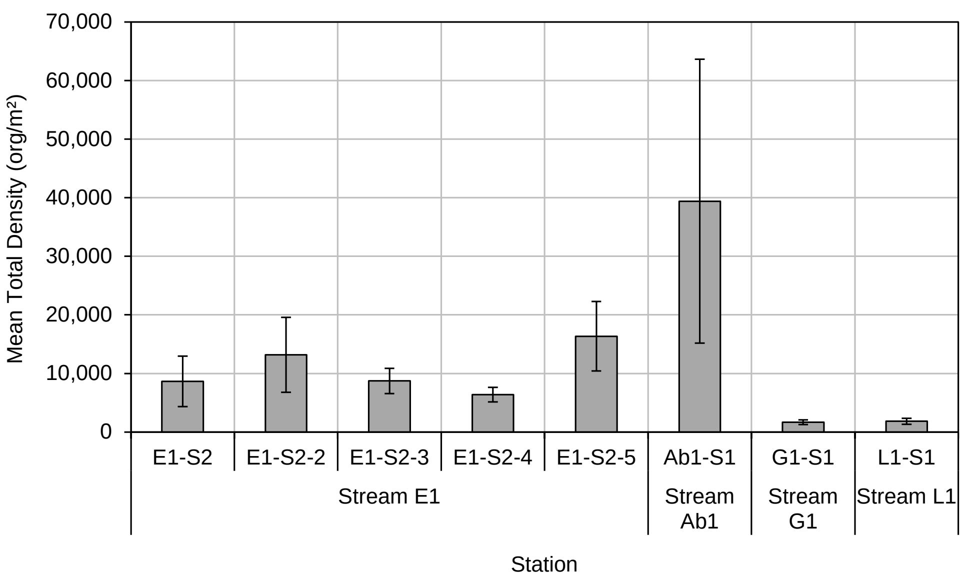
The benthic invertebrate communities sampled in tributary streams to Lac du Sauvage were variable in mean total density, with numbers ranging from low to moderate (Figure 9.2-31). The highest mean total density was observed in Stream Ab1 (the Narrows that connects Lac du Sauvage to Lac de Gras). Total richness was less variable among stream stations and ranged from moderate to high (Figure 9.2-32). Differences among tributary stream benthic communities may reflect variability among stream habitats, as, for example, channel widths ranged from 2 m (Stream L1) to 30 m (Stream Ab1) and mean current velocity ranged from <0.01 m/s (Stream L1) to 0.56 m/s (Stream G1).

The benthic invertebrate community was dominated by the Chironomidae at all stream stations in the Lac du Sauvage basin (Figure 9.2-33), which is expected in sub-arctic streams. The dominant chironomid groups were the Tanytarsini, Orthocladiinae, and Chironomini, depending on the station. Nematoda, Hydrozoa, and Plecoptera also accounted for a significant proportion of the total density at a few streams.

Taxa present were similar among streams, with the exception of the Ephemeroptera, Plecoptera, and Trichoptera (EPT taxa), which were absent from Stream L1. This result is likely related to sampling in an area with no measureable flow. The EPT taxa are typically characteristic of fast flowing stream environments (Barbour et al. 1999).

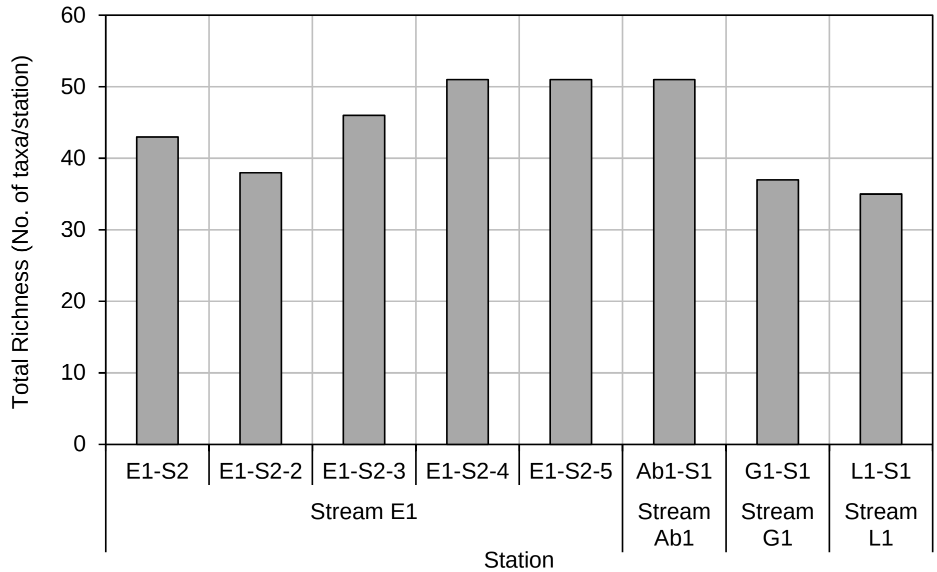
Simpson's diversity index values were high (0.75 to 0.90), indicating a diverse benthic invertebrate community. Evenness was variable and ranged from low to moderate (0.09 to 0.22), indicating that a few taxa accounted for the majority of the total density.

Figure 9.2-31 Mean Total Benthic Invertebrate Density at Stream Stations in the Lac du Sauvage Basin, August and September 2013



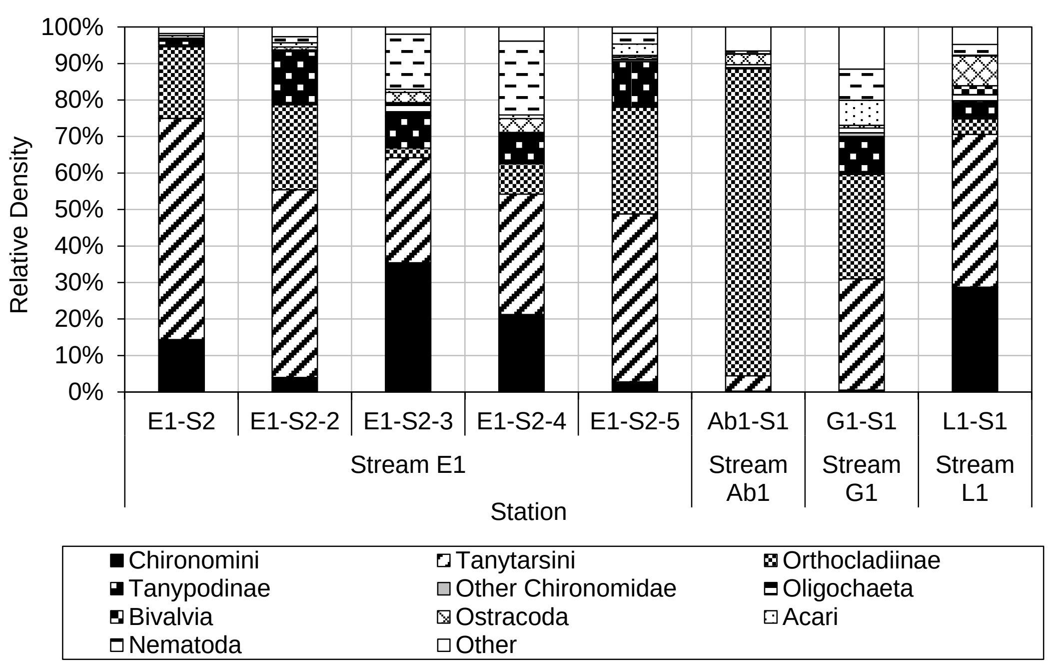
Note: Error bars represent one standard error of the mean.
org/m^2 = number of organisms per square metre.

Figure 9.2-32 Total Benthic Invertebrate Richness at Stream Stations in the Lac du Sauvage Basin, August and September 2013



No. of taxa/station = number of taxa per station.

Figure 9.2-33 Relative Density of Major Benthic Invertebrate Taxa at Stream Stations in the Lac du Sauvage Basin, August, and September 2013



Note: "Other" taxa category includes Gastropoda, Turbellaria, Coleoptera, Ephemeroptera, Plecoptera, Trichoptera, Ceratopogonidae, Empididae, Muscidae, Simuliidae, and Tipulidae.

% = percent.

Summary of Previous Studies

The evaluation of multiple benthic community metrics indicated spatial and temporal differences in benthic communities in lakes surrounding Lac du Sauvage. Within the lake habitats, mean benthic invertebrate densities tended to be greater at the shallow and mid-depth stations compared to the deep stations, as also observed in Lac du Sauvage. Although temporal trends were observed (lower densities recorded in 1997 and 2003 at many of the mid-depth and deep stations and peak densities observed in 2007 and 2008), overall densities have generally remained consistent among lakes over time (ERM Rescan 2013). Benthic invertebrate communities sampled over time in Stream D3 (Counts) exhibited high variability in total density and total richness, but did not indicate a temporal trend.

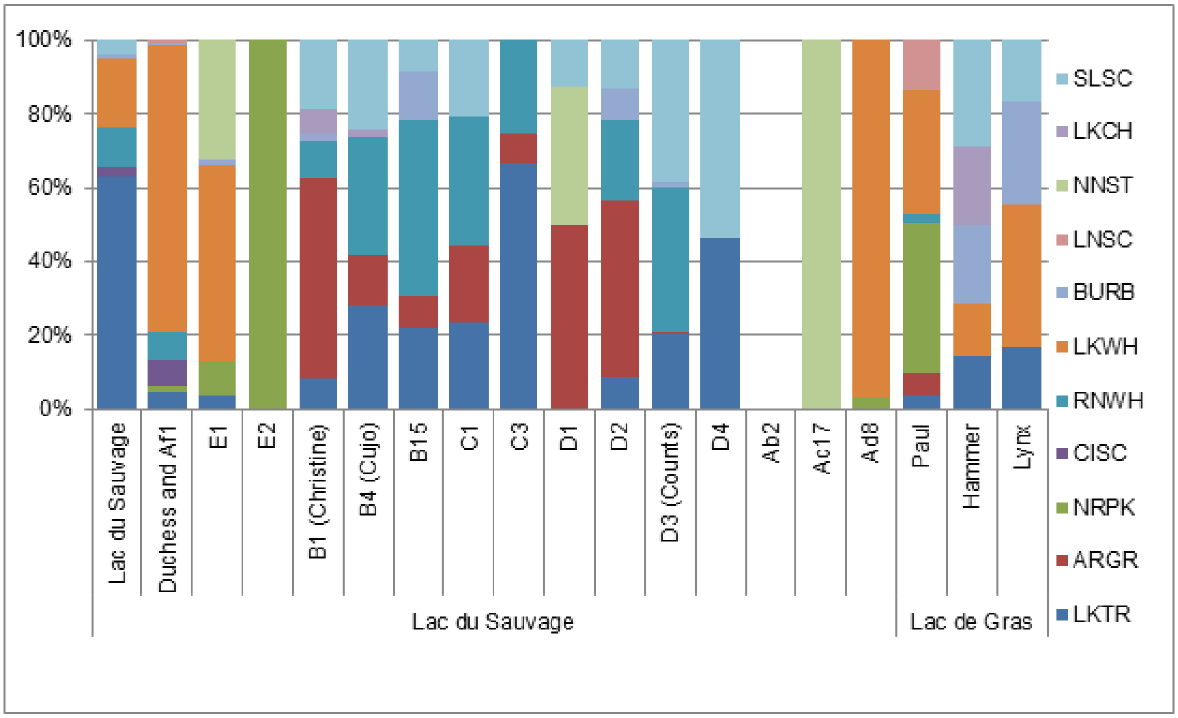
Dipterans mainly of the family Chironomidae and bivalve molluscs from the subfamily Pisidiidae dominated benthic invertebrate communities in lakes surrounding Lac du Sauvage. Chironomidae dominated the majority of the lakes examined in this historical summary; however, the Pisidiidae were the dominant group at several deep stations. Other groups such as Oligochaeta, Hydra, Acari, Turbellaria, Eubranchiopoda, Gastropoda, Ostracoda (seed shrimp), Trichoptera, Ephemeroptera (mayflies), other Diptera (true flies), and Coleoptera (beetles) contributed to smaller proportions of the benthic community in the lake habitat. The dominance of the benthic invertebrate community by the Chironomidae is common in lakes in the sub-arctic region (Beaty et al. 2006; Northington et al. 2010).

Diversity tended to be greater at the shallow and mid-depth stations, compared to the deep stations. Overall diversity was high and evenness was low at both stream and lake stations. Both diversity and evenness varied over time but did not indicate a temporal trend.

9.2.4.2.4 Fish Community and Abundance

Based on all capture methods combined (including angling, backpack electrofishing, gill netting, and minnow trapping during 2006 to 2013), fish were recorded in all sampled waterbodies and watercourses in the BSA, except for Lake Ab2 (Figure 9.2-34). Lake Trout, Arctic Grayling, Round Whitefish, and Slimy Sculpin were the dominant species found in waterbodies and watercourses in the B, C, and D sub-basins; Lake Whitefish were not captured in these sub-basins. Lake Whitefish were caught in Lake Ad8, Duchess Lake, and Lake E1 (and Lac du Sauvage). Very few Arctic Grayling were captured outside of the B, C, and D sub-basins in the BSA. Ninespine Stickleback was the dominant species in lakes of the smallest sub-basins (Ab, Ac, Ad) of Lac du Sauvage.

Figure 9.2-34 Fish Species Composition in Lakes and Streams Sampled in the Baseline Study Area, 2006 to 2013



Note: total catch in Lake Af1 was 1 NRPK.

% = percent; SLSC = Slimy Sculpin; LKCH = Lake Chub; NNST = Ninespine Stickleback; LNSC = Longnose Sucker; BURB = Burbot; LKWH = Lake Whitefish; RNWH = Round Whitefish; CISC = Cisco; NRPK = Northern Pike; ARGR = Arctic Grayling; LKTR = Lake Trout.

Gill net catch-per-unit effort (CPUE) was relatively high in Lake Ad8 and Duchess Lake, where the catches were composed mostly of Lake Whitefish. The lowest CPUE was in Lake Ac17, where no fish were caught in gill nets. In the lakes that were dominated by Lake Trout and Round Whitefish, Lake D2 and Lake B4 had the highest CPUE, while Lake D4 had the lowest. Lake Trout and Round Whitefish were the dominant species caught by gill nets in lakes of the B, C, and D sub-basins.

Backpack electrofishing CPUE was the highest in Lake B1 (Christine Lake) and Stream D1, where the catches were predominately of Arctic Grayling. Backpack electrofishing also captured Arctic Grayling in lakes and streams of the B, C, and D sub-basins. Historical records of Arctic Grayling in the BSA include Stream L1 and J2 (in the east basins of Lac du Sauvage) (Golder 1997a). Only Northern Pike were captured by electrofishing in Duchess Lake and Stream E2. One Northern Pike was captured during electrofishing in Lake Af1 and five in Stream E2. The lowest backpack electrofishing CPUE was in Lake Ab2 and Lake Ad8 where no fish were captured using this method. Similarly, Rescan (2007) observed no fish presence in small, unnamed streams in the Ac basins using backpack electrofishing methods.

Sub-Basin B

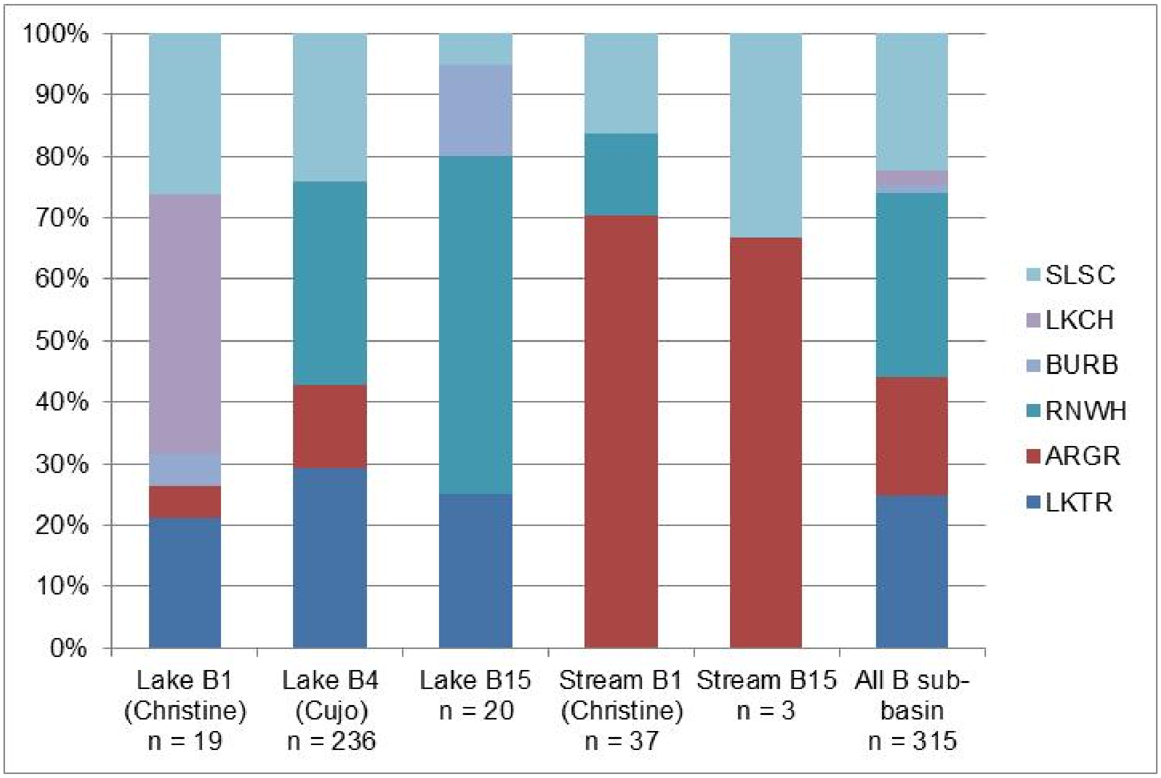
A total of 315 fish were captured or observed in the B sub-basin lakes and streams in 2007 to 2013 (Table 9.2-9; Figure 9.2-35). Round Whitefish were the most abundant (30%), followed by Lake Trout (25%), Slimy Sculpin (22%), Arctic Grayling (19%), Lake Chub (3%), and Burbot (1%).

Table 9.2-9 Summary of Fish Sampling Effort and Catch in the B Sub-Basin, 2007 to 2013

Location	Method	Effort	LKTR	ARGR	NRPK	CISC	RNWH	LKWH	BURB	LNSC	NNST	LKCH	SLSC	Total	Total CPUE
Lake B1 (Christine)	GN	1.83 net-units	3	-	-	-	-	-	-	-	-	-	-	3	**1.64 (fish/ net-unit)**
	EF	698 s	-	1	-	-	-	-	-	-	-	5	2	8	**1.15 (fish/100s)**
	MT	27.67 trap-d	1	-	-	-	-	-	1	-	-	3	3	8	**0.29 (fish/ trap-d)**
Lake B4 (Cujo)	GN	46.68 net-units	66	10	-	-	78	-	-	-	-	-	-	154	**3.30 (fish/ net-unit)**
	EF	14,177 s	3	22	-	-	-	-	-	-	-	-	57	82	**0.56 (fish/100 s)**
	MT	34.86 trap-d	-	-	-	-	-	-	-	-	-	-	-	0	**0.00 (fish/ trap-d)**
Lake B15	GN	7.80 net-units	5	-	-	-	11	-	-	-	-	-	-	16	**2.05 (fish/ net-unit)**
	EF	843 s	-	-	-	-	-	-	1	-	-	-	1	2	**0.24 (fish/100 s)**
	MT	35.85 trap-d	-	-	-	-	-	-	2	-	-	-	-	2	**0.056 (fish/ trap-d)**
Stream B1	EF	575 s	-	26	-	-	5	-	-	-	-	-	6	37	**6.43 (fish/100 s)**
Stream B15	EF	603 s	-	2	-	-	-	-	-	-	-	-	1	3	**0.50 (fish/100 s)**
		Total	**78**	**61**	**0**	**0**	**94**	**0**	**4**	**0**	**0**	**8**	**70**	**315**	

CPUE = catch-per-unit-effort; GN = gill net, EF = backpack electrofishing, AN = angling, MT = minnow trapping;1 net-unit = 100 m^2 of net set for 1 hour; s = seconds; rod-h = rod hour; 1 trap-d = 1 minnow trap set for 24 hours; LKTR = Lake Trout; ARGR = Arctic Grayling; NRPK = Northern Pike; CISC = Cisco; RNWH = Round Whitefish; LKWH = Lake Whitefish; BURB = Burbot; LNSC = Longnose Sucker; NNST = Ninespine Stickleback; LKCH = Lake Chub; SLSC = Slimy Sculpin; "-" = not captured

Figure 9.2-35 Fish Species Composition for Lakes and Streams in the B Sub-Basin, 2007 to 2013



% = percent; n = number of samples; SLSC = Slimy Sculpin; LKCH = Lake Chub; BURB = Burbot; RNWH = Round Whitefish; ARGR = Arctic Grayling; LKTR = Lake Trout.

A total of 19 fish were captured or observed in Lake B1 (Christine) in 2013, with the catch consisting of five species. Lake Chub were the most abundant (42%), followed by Slimy Sculpin (27%), and Lake Trout (21%). The least abundant species were Arctic Grayling and Burbot (5% each). Streams B1 and B15 were dominated by Arctic Grayling in 2013, with Slimy Sculpin being the second most abundant species. Round Whitefish were also present in Stream B1.

Sub-Basin C

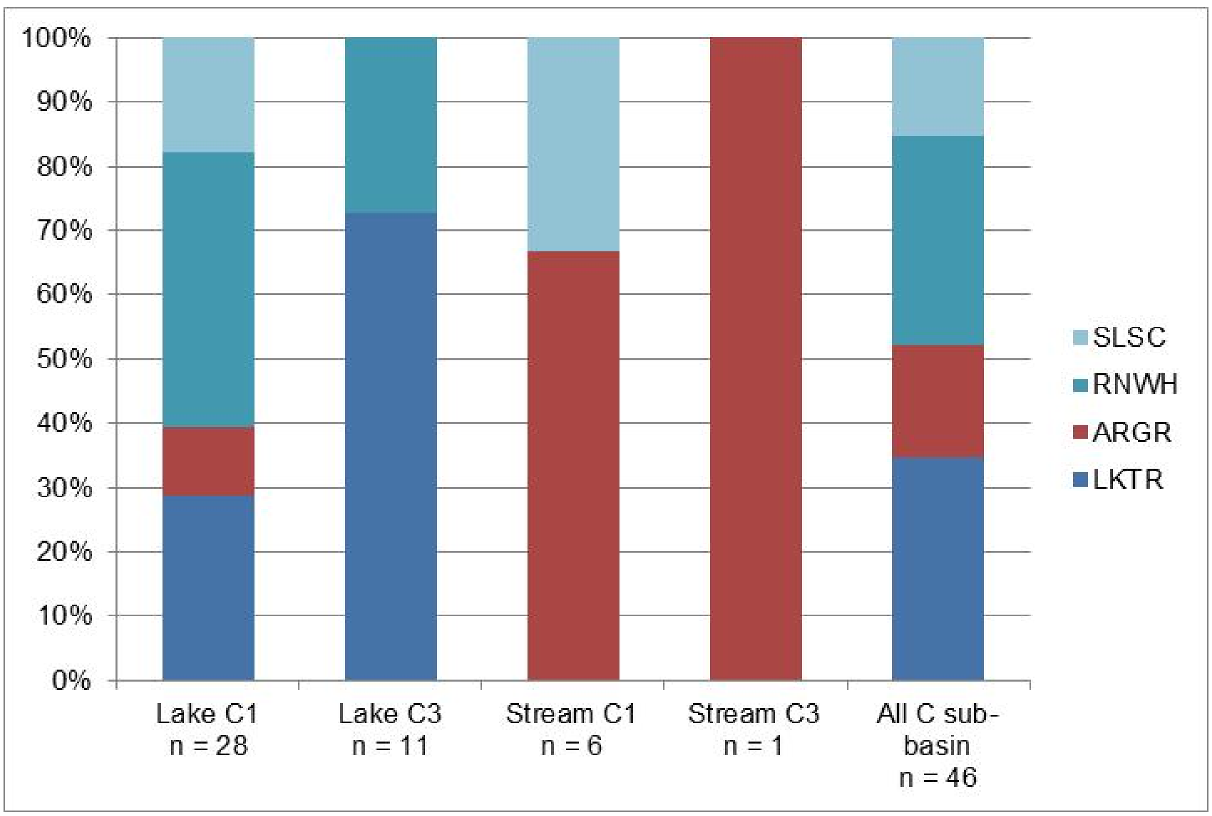
A total of 46 fish were captured or observed in the C sub-basin lakes and streams in 2013 (Table 9.2-10, Figure 9.2-36). The catch consisted of four species. Lake Trout were the most abundant (35%), followed by Round Whitefish (33%), Arctic Grayling (17%), and Slimy Sculpin (15%).

Table 9.2-10 Summary of Fish Sampling Effort and Catch in the C Sub-Basin, 2007 to 2013

Location	Method	Effort	LKTR	ARGR	NRPK	CISC	RNWH	LKWH	BURB	LNSC	NNST	LKCH	SLSC	Total	Total CPUE
Lake C1	GN	9.74 net-units	4	-	-	-	12	-	-	-	-	-	-	16	**1.64 (fish/ net-unit)**
	EF	1,510 s	-	3	-	-	-	-	-	-	-	-	5	8	**0.53 (fish/100 s)**
	AN	3.25 rod-h	4	-	-	-	-	-	-	-	-	-	-	4	**1.23 (fish/rod-h)**
	MT	38.54 trap-d	-	-	-	-	-	-	-	-	-	-	-	0	**0.00 (fish/ trap-d)**
Lake C3	GN	10.56 net-units	5	-	-	-	3	-	-	-	-	-	-	8	**0.76 (fish/ net-unit)**
	AN	0.8 rod-h	3	-	-	-	-	-	-	-	-	-	-	3	**3.75 (fish/rod-h)**
	MT	17.14 trap-d	-	-	-	-	-	-	-	-	-	-	-	0	**0.00 (fish/rod-h)**
Stream C1	EF	758 s	-	4	-	-	-	-	-	-	-	-	2	6	**0.79 (fish/100 s)**
Stream C3	EF	542 s	-	1	-	-	-	-	-	-	-	-	-	1	**0.18 (fish/100 s)**
		Total	**16**	**8**	**0**	**0**	**15**	**0**	**0**	**0**	**0**	**0**	**7**	**46**	

CPUE = catch-per-unit-effort; GN = gill net, EF = backpack electrofishing, AN = angling, MT = minnow trapping;1 net-unit = 100 m^2 of net set for 1 hour; s = seconds; rod-h = rod hour; 1 trap-d = 1 minnow trap set for 24 hours; LKTR = Lake Trout; ARGR = Arctic Grayling; NRPK = Northern Pike; CISC = Cisco; RNWH = Round Whitefish; LKWH = Lake Whitefish; BURB = Burbot; LNSC = Longnose Sucker; NNST = Ninespine Stickleback; LKCH = Lake Chub; SLSC = Slimy Sculpin; "-" = not captured.

Figure 9.2-36 Fish Species Composition in Lakes and Streams of the C Sub-Basin, 2013



% = percent; n = number of samples; SLSC = Slimy Sculpin; RNWH = Round Whitefish; ARGR = Arctic Grayling; LKTR = Lake Trout.

In 2013, 28 fish of four species were captured or observed in Lake C1. Round Whitefish were the most abundant species caught (43%), followed by Lake Trout (28%), Slimy Sculpin (18%), and Arctic Grayling (11%). In Lake C3, 11 fish of only two species were captured, with Lake Trout making up 73% of the catch, and Round Whitefish 27%. In Stream C1, four Arctic Grayling and two Slimy Sculpin were captured. Only one Arctic Grayling was captured in Stream C3.

9.2.4.3 *Lac de Gras*

Many studies of fish and fish habitat within the Lac de Gras watershed have been conducted since 1993 in relation to the existing Diavik and Ekati mines. The following sub-sections summarize historical information on fish habitat, abundance, and life history in Lac de Gras and its tributary lakes and streams.

9.2.4.3.1 Fish Habitat

Habitat Types

The shorelines of Lac de Gras are rugged with numerous bays and inlets (BHP 1995a). Historical studies of aquatic habitat in Lac de Gras were primarily shoal and shoreline surveys for Lake Trout habitat and other dominant fish species. Golder (1997b) provided a detailed assessment of the spawning habitat quality of 160 shoals in Lac de Gras; the study identified a high occurrence of potential spawning habitat in shallow areas of Lac de Gras, with approximately 52%, 61%, and 30% of shoals displaying characteristics to support Lake Trout, Cisco, and Round Whitefish spawning activity, respectively. An estimated 5,800 ha of Lake Trout spawning habitat ("good" and "fair" quality) was described.

Additional, finer-scale detail of shoreline habitat types was provided for Lac de Gras by Golder (1997d,e) when approximately 631 km of shoreline habitat was categorized as one of five types, based on substrate composition:

- Type 1: Boulder ledge at shoreline; drop-off composed of boulders leading into sand and boulder patches.
- Type 2: Gravel ledge at shoreline, shifting to cobble, then boulders. Drop-off composed of boulders leading to mixed sand and boulders.
- Type 3: Bedrock outcrops surrounded by boulder and cobble leading to a mixture of large boulders and sand.
- Type 4: Mixture of boulders and sand. (4a. boulders dominant over sand; 4b. sand dominant over boulder).
- Type 5: Mixture of boulder, cobble, and gravel. Elevated gravel mounts alternate through the other substrates in linear, winding fashion.

The surveyed area was dominated by Type 1 shorelines (53.1%), with Type 3 bedrock shorelines second (20.4%), and Type 4b shorelines ranked third (7.3%) (Golder 1997e). Lac de Gras has a very uneven bottom, and a prevalence of shallow shoals dominated by large boulders to cobble and gravel, but also shoals with steep rocky sides down to a depth of 6 to 8 m before changing to silt (DDMI 1998a). By comparison, shoals in Lac du Sauvage were generally not as deep or as numerous, and Lac de Gras had more potential spawning habitat for Lake Trout, Cisco, and Round Whitefish ("good" to "fair" quality shoals) compared to Lac du Sauvage (DDMI 1998a).

The Narrows connecting Lac du Sauvage to Lac de Gras was identified as potentially productive and important habitat for fish (Dillon 2002a). Because of bathymetry and flow characteristics, open water remains in the Narrows year-round. This open water, combined with the substrate types identified there, may provide above average spawning, rearing, and forage habitats for a diversity of fish species (Dillon 2002a).

9.2.4.3.2 Plankton

The majority of the plankton data collected from Lac de Gras has come from the Diavik and Ekati AEMPs. Lac de Gras has been the focus of the plankton component of the AEMP at the Diavik Mine and the most recent data are available from the 2013 AEMP annual report (DDMI 2014). Diavik AEMP data were evaluated for far-field exposure area 2 (FF2) and three far-field reference areas (FF1, FFA, and FFB; Map 9.2-7). The Ekati AEMP also includes sampling of plankton communities at two stations, S2 and S3, in Lac de Gras at the northern end of the lake, downstream of the Long Lake Containment Facility (Map 9.2.4).

Chlorophyll *a* and Trophic Status

Lac de Gras is an oligotrophic lake, and the Diavik Mine has had a slight enrichment effect in the near-field and mid-field areas of the lake close to the mine discharge, which is reflected in increased chlorophyll *a* concentrations (DDMI 2013). Chlorophyll *a* concentrations at Lac de Gras far-field reference areas (FFA and FFB), the FF2 area, and stations in Slipper Bay (S2 and S3) have not exhibited any clear temporal trends from 1997 to 2012, and have consistently stayed within the oligotrophic range of 0.3 to 4.5 µg/L (Wetzel 2001).

Phytoplankton

Mean annual total phytoplankton abundance has been consistently highest in the FF2 area, ranging between 1,228,280 cells/L and 2,142,160 cells/L. Although there have been no consistent temporal trends in this area in Lac de Gras, an increase in total abundance between 2007 and 2009, followed by a decrease until 2012, was observed in all far-field areas. This type of variation suggests that, while there is likely enrichment occurring in the FF2 area, there is also a regional factor influencing phytoplankton abundance in Lac de Gras.

Total phytoplankton biomass was also consistently higher in the FF2 exposure area compared to the other three far-field/reference areas in Lac de Gras. A decreasing trend in phytoplankton biomass was observed in all areas monitored by the Diavik Mine AEMP between 2008 and 2011, consistent with the total phytoplankton abundance results. This trend suggests that a regional factor beyond Mine-related effects was influencing the phytoplankton community.

Phytoplankton community composition varied among Lac de Gras sampling stations and among years, although cyanobacteria, chlorophytes, and chrysophytes were commonly the dominant taxonomic groups. Temporal trends were observed in community composition. In recent years, the proportion of chrysophytes at Station S2 decreased, while the proportion of diatoms increased at stations S2 and S3. In the FFA and FFB reference areas, composition shifted from chrysophyte dominance (2003 to 2006), to cyanobacteria dominance (2007 to 2010). The communities in the FF2 and FF1 areas consisted predominantly of chrysophytes and cyanobacteria.

In general, in areas of Lac de Gras monitored by the Diavik AEMP, total phytoplankton taxonomic richness increased between 2003 and 2009, and then decreased from 2009 to 2011. Between 1997 and 2011, richness ranged between 17 and 58 genera, with the highest number of genera typically occurring in the FF2 area. There was less variability over time in the areas of Lac de Gras monitored by the Ekati AEMP, where total phytoplankton taxonomic richness at stations S2 and S3 ranged between 38 and 64 taxa. There was a slight increasing trend over time at both stations monitored by the Ekati Mine (ERM Rescan 2013).

Zooplankton

Mean annual zooplankton abundance has varied in Lac de Gras since 2007. Zooplankton abundances in the reference areas of Lac de Gras ranged between 8,912 org/m^3 at station S2 (1999) to 42,184 org/m^3 in the FFA area (2008). Peak abundances were observed in the reference areas in 2008, followed by a sharp decline in 2009.

As part of the Diavik AEMP, zooplankton biomass was measured as dry weight and wet weight was estimated as a microscope-based length-weight biomass. No clear trends were observed in either estimate of mean annual zooplankton biomass in the far-field areas of Lac de Gras between 2008 and 2012.

The zooplankton community in the far-field areas of Lac de Gras was dominated by rotifers, based on abundance. Cyclopoid copepods were sub-dominant in these areas between 2008 and 2012. The relative proportions of cladocerans and calanoid copepods were low. The zooplankton community at stations S2 and S3 in Lac de Gras was also dominated by rotifers. The relative abundance of cyclopoid copepods has increased over time at stations S2 and S3.

Based on biomass, the zooplankton community in the far-field areas of Lac de Gras was dominated by calanoid copepods. Cyclopoid copepods were the sub-dominant zooplankton group in the far-field areas of Lac de Gras between 2008 and 2012.

9.2.4.3.3 Benthic Invertebrates

The majority of the benthic invertebrate data available for Lac de Gras was collected by the Diavik and Ekati AEMPs. Lac de Gras has been the focus of the benthic invertebrate component of the Diavik AEMP, and the most recent data are available from the 2013 AEMP annual report (DDMI 2014). Diavik AEMP data were evaluated for the far-field reference areas (FF1, FFA, and FFB) and the far-field exposure area (FF2; Map 9.2-4). All stations sampled by the Diavik AEMP were deep (approximately 20 m). The Ekati AEMP also includes sampling of benthic invertebrate communities in Lac de Gras at one mid-depth (S2) and one deep (S3) station (Map 9.2-4).

Mean total benthic invertebrate density has been relatively stable and low in the far-field areas of Lac de Gras sampled by the Diavik AEMP since 2001. Densities at the shallower Lac de Gras stations (S2 and S3) sampled by the Ekati AEMP were higher and more variable compared to those sampled at the Diavik far-field stations. As seen in Lac du Sauvage and its surrounding lakes, mean benthic invertebrate densities and richness in Lac de Gras tended to be greater at the shallow stations and mid-depth stations compared to the deep stations.

The benthic invertebrate communities at the far-field stations in Lac de Gras were dominated by Chironomidae, followed by Oligochaeta, Pisidiidae, and Acari. Other groups, such as Hydra, Gastropoda, Eubranchiopoda, Amphipoda (freshwater shrimp), and other Diptera (mostly Empididae; dance flies), together contributed a small proportion of the overall benthic invertebrate community. Similar to the Diavik sampling areas, Chironomidae also dominated the community at stations S2 and S3. Tanytarsini and Tanypodinae were the dominant midge groups, although dominance varied among years. Oligochaeta and Pisidiidae were present at both stations, although in higher densities at the deep (S3) station. Hydra, Turbellaria, Acari, Eubranchiopoda, Trichoptera, Harpacticoida, Plecoptera, Gastropoda, and other Diptera each contributed less than 10% to the total community in all years with available data. Several Chironomidae taxa, including Procladius, Micropsectra, Heterotrissocladius, and Monodiamesa, were present in Lac de Gras samples during the majority of years.

Generally, diversity and evenness mirrored one another in all the lakes. Diversity tended to be greater at the shallow and mid-depth stations, compared to the deep stations. Overall diversity was high and evenness was low, indicating that a few taxa accounted for the majority of the total density. There were no apparent spatial patterns in diversity and evenness, and both diversity and evenness were typically variable over time.

9.2.4.3.4 Fish Community and Abundance

Lake Trout, Cisco, Round Whitefish, Lake Whitefish, Arctic Grayling, Burbot, Longnose Sculpin, Slimy Sculpin, and Ninespine Stickleback were captured or observed in Lac de Gras. There is a general consensus among historical reports that the dominant large-bodied species in the lake are Lake Trout, Cisco, and Round Whitefish (DDMI 1998a; Jacques Whitford 2001, 2002; CRI 2006), although the order of dominance varied between studies and capture methods. Fish were captured primarily by gill nets, with limited angling to supplement Lake Trout sample sizes.

A fish salvage of the Dike A154 area of Lac de Gras in July and August 2002 confirmed that Cisco, Lake Trout, and Round Whitefish were dominant species in that area of the lake (McEachern et al. 2003). In total, 5,049 fish were removed from the Dike A154 study area. Cisco were the most abundant species (80.6%), followed by Round Whitefish (8.4%), Lake Trout (8.0%), Burbot (2.9%), Slimy Sculpin (0.1%), and lastly Arctic Grayling (less than 0.1%). Relative abundance of species was similar to that of the North Inlet Fish Salvage Project conducted in in Lac de Gras in 2001 (Jacques Whitford 2001).

While many Lake Whitefish have been captured or observed in lakes of the east and west islands of Lac de Gras, and in other tributary lakes (Section 9.2.3.4), there are very few reported occurrences of this species in Lac de Gras in historical reports (Golder 1998a, 2002, 2012; CRI 2006). Golder (1998a) reported gill net captures for Lake Whitefish in Lac de Gras, but fish were only captured near the Lac du Sauvage-Lac de Gras Narrows, thus suggesting that they may be limited to this area of the lake.

Other species, including Ninespine Stickleback, Longnose Sucker, and Slimy Sculpin were for the most part, only captured with minnow traps and by backpack electrofishing. Based on electrofishing results along the shoreline of the east island of Lac de Gras, the dominant species was Slimy Sculpin, followed by species such as Burbot, Lake Trout, and Ninespine Stickleback (Gray et al. 2005). Golder (2008) presented a similar dominance hierarchy based on backpack electrofishing at four sites in Lac de Gras with boulder and cobble substrate.

9.2.4.4 *Small Lakes and Tributary Streams to Lac de Gras*

9.2.4.4.1 Fish Habitat

The Lac de Gras sub-basin spans a total area of 413,570 ha, and includes 6,336 waterbodies of varying sizes that total 135,034 ha in waterbody area (Table 9.1-3). Baseline surveys in the region typically have been completed on lakes and streams in close proximity to existing Ekati and Diavik mine developments near Lac de Gras. The habitat for Hammer Lake, Lynx Lake, Paul Lake, and their respective outlet streams is described in detail in Annex XIV. Hammer Lake and Lynx Lakes are considered representative small lakes in the region (within the 10 to 100 ha size category). There are approximately 663 similar-sized lakes within the Lac de Gras sub-basin (Table 9.1-3).

Hammer Lake is a relatively small, shallow lake (22.4 ha) with a mean depth of 1.2 m and a maximum depth of 6.4 m. The cumulative drainage area for Hammer Lake is 201 ha. Substrate in Hammer Lake was dominated by boulder/cobble and fines/boulder, with boulder/fines also present.

Lynx Lake is 10.7 ha in area, with a mean depth of 4.6 m and a maximum depth of 25.8 m. The cumulative drainage area of Lynx Lake is 40 ha. Lynx Lake substrate was primarily composed of boulder/cobble, and fines/boulder, with fines being the dominant substrate type in deeper portions of the lake.

Suitable spawning, rearing and overwintering habitat for Lake Whitefish was identified in Hammer and Lynx lakes (Rescan 2003). Adequate substrate to support Lake Trout was also identified in the littoral zones of the lakes (BHP 1995a; Rescan 2003). Outlets for Hammer and Lynx lakes had undefined bed or banks with minimal flows in summer 2013. Thus, Hammer and Lynx creeks were described as ephemeral, providing low-quality habitat for fish.

Paul Lake was characterized as medium in size (964 ha) compared to other waterbodies in the BSA. The cumulative drainage area of Paul Lake is 12,506 ha. Based on 2013 surveys, the deepest area in the lake is approximately 19 m (Annex XIV). Many islands and shoals are present throughout the lake. Habitat in the lake is similar to other medium-sized lakes in the region. Several areas of Paul Lake have steep drop offs in the littoral zone but most areas have less pronounced slopes. The littoral zone consists mainly of boulder substrate with areas of cobble and fines, and areas of emergent (i.e., sedge wetlands with *Carex aquatilis* var. *aquatilis*) and submergent vegetation. Shoreline area cover is mostly provided by substrate (boulder), depth, areas of emergent/submergent vegetation, and overhanging shrubs, likely providing suitable foraging habitat for fish species such as Northern Pike.

The Koala watershed has an area of approximately 18,500 ha. It consists of a system of connected lakes extending from Vulture Lake in the northeast to Slipper Lake in the southwest where water drains into Lac de Gras. Kodiak, Leslie, Moose, Nema, and Slipper lakes are located downstream of the Koala and Panda Pits at the Ekati Mine. Of these lakes, the smallest lake is Moose Lake (44 ha), and the largest is Slipper Lake (189 ha). Maximum depths range from 9.0 m in Nema Lake to 16.0 m in Slipper Lake. The lakes are characterized by rocky shorelines, boulder and cobble littoral zones, with fines at greater depths (BHP 1995a). Patches of gravel substrate are present in littoral zones of Kodiak Lake. Outlet streams have predominantly boulder substrate, indistinct drainage patterns (e.g., dispersed flows), low gradient slopes, and subsurface flows. The average gradient from the uppermost lake in the Koala watershed (Vulture Lake) to Lac de Gras is approximately 0.3%. During freshet, most streams had sufficient flow to allow migration of adult fish between lakes, but by fall many isolated pools remained and flow was minimal. Instream cover was provided mainly by boulders and pools, with minimal organic debris and undercut banks. Aquatic vegetation was sparse in streams, and only a few streams had overhanging vegetation

A detailed inventory of habitat, with a focus on Arctic Grayling spawning habitat, was performed for a total of 34 small tributary streams in Lac de Gras in 1996 (Golder 1997a). Run class 3 habitats, which are characterized by strong flows, moderate depth (0.5 to 0.75 m deep), and potential substrates for spawning Arctic Grayling, were present on approximately 69% of tributary streams and contributed 42% to overall habitat (Golder 1997a). However, based on the findings of previous studies in Lac de Gras and tributary lakes and streams (Golder 1997a, 1998a), DDMI (1998b) concluded that migration by fish species between small lakes is limited, possibly a result of physical barriers in streams. For example, the presence of a potential barrier for upstream migrations in small streams (e.g., boulder gardens, cascade, falls) was recorded for approximately 46% of the streams surveyed in Lac de Gras. On average, approximately 12.3% of the habitats in small Lac de Gras tributary streams were boulder gardens, 8.2% were cascade habitats, and 4.5% were falls, all of which represent potential barriers to upstream migration (Golder 1997a).

9.2.4.4.2 Plankton

The 2013 plankton community baseline study for the Project included sampling in Paul Lake in the Lac de Gras basin (Annex XII). The Ekati Mine baseline program and AEMP also evaluated plankton communities in lakes within the Lac de Gras basin (ERM Rescan 2013). The historical data review included detailed evaluation of plankton communities of two reference lakes in the Lac de Gras watershed (Nanuq and Vulture Lakes; Map 9.2-7).

The Koala watershed (the watershed surrounding Ekati operations) has been studied extensively through the Ekati AEMP, and the most recent data are available from 2013 AEMP annual report (ERM Rescan 2014). Six lakes from the Koala watershed were sampled as part of the Ekati AEMP (Vulture Lake [reference lake], and Kodiak, Leslie, Moose, Nema and Slipper lakes [exposure lakes]). The waterbodies in the Koala watershed are situated downstream of treated effluent from the Ekati mine operations. A high-level overview of 2013 plankton data for lakes within the Koala watershed sampled as part of the Ekati Mine AEMP is included below. A direct comparison between current and historical data is not possible due to differences in analytical methods.

Current (2013)

Discrete and depth integrated water sampling in Paul Lake generated TSI values of 43 using chlorophyll *a*, 41 using TP, and 40 using Secchi depth, for a rounded average of 41. Based on these values and the classification systems of Vollenweider (1970), CCME (2004), and Carlson (1977), Paul Lake was classified as an oligotrophic to mesotrophic lake.

Total phytoplankton abundance in Paul Lake varied seasonally and spatially throughout the 2013 open-water period. Total phytoplankton abundance was lowest in late spring at all stations with available data, ranging from 596,621 to 1,235,889 cells/L. Phytoplankton abundance at Paul Lake stations PL-1, PL-2, and PL-3 peaked in summer, whereas a fall peak was observed at Station PL-5. Seasonal and spatial variability were observed in total phytoplankton biomass in Paul Lake, but no consistent seasonal trend was observed. Peaks in total phytoplankton biomass occurred in summer at stations PL-2 and PL-3. Total biomass was highest in fall at stations PL-4 (263 mg/m^3) and PL-5 (360 mg/m^3).

In general, chrysophytes and cyanobacteria dominated the phytoplankton assemblage by abundance in Paul Lake throughout the open-water sampling period, but the percentages of these groups varied among stations and sampling periods. Chrysophytes and chlorophytes dominated the phytoplankton composition by biomass at most Paul Lake sampling stations throughout the 2013 open-water period.

In total, 75 phytoplankton taxa were identified in Paul Lake in 2013. Taxonomic richness peaked in late spring at all stations in Paul Lake. Richness decreased throughout the open-water sampling period at all stations, with the exception of Station PL-5, where it increased between summer and fall.

Seasonal and spatial variability in total zooplankton abundance was observed in Paul Lake in 2013. Total zooplankton abundance peaked in the fall at the majority of the stations in Paul Lake (58,265 to 83,559 org/m^3). In general, total zooplankton abundance ranged from 26,363 org/m^3 at Station PL-3 in the summer to 83,559 org/m^3 at Station PL-2 in the fall. Clear seasonal or spatial patterns in total zooplankton biomass were not observed in Paul Lake in 2013. Total zooplankton biomass peaked in late spring at three stations (PL-2, PL-3, and PL-4), in the summer at Station PL-1, and in the fall at Station PL-5. Overall, total zooplankton biomass in Paul Lake ranged from 48 to 109 mg/m^3 throughout the open-water period.

Rotifers dominated the zooplankton community by abundance at most Paul Lake stations throughout the open-water season. The relative abundance of cyclopoid copepods in Paul Lake increased throughout the open-water sampling period, ranging from 4% to 9% in late spring, to 12% to 20% in the fall. Zooplankton community composition by biomass varied among stations in Paul Lake. In the late spring, the community consisted of similar proportions of major taxonomic groups. Copepod nauplii and cyclopoid copepods were dominant at the majority of stations in summer and fall.

In total, 22 zooplankton taxa were identified in Paul Lake in 2013, with little seasonal or spatial variability. Taxonomic richness ranged from 11 to 14 taxa (Annex XII).

Summary of Previous Studies

All of the lakes of the Koala watershed had chlorophyll *a* concentrations within the oligotrophic range of 0.3 to 4.5 µg/L (ERM Rescan 2014). Summer chlorophyll *a* concentrations in Nanuq and Vulture lakes were variable over time, but remained in the oligotrophic range throughout the 1996 to 2012 monitoring period (ERM Rescan 2013).

Phytoplankton data were only collected in summer in the Koala watershed and not throughout the open-water period. Summer 2013 total phytoplankton abundances in these lakes were variable but generally similar to Paul Lake values (586,000 to 1,235,000 cells/L), with the exception of Nema Lake (2,004,000 cells/L) and Kodiak Lake (4,845,000 cells/L) (ERM Rescan 2014). Phytoplankton biomass data were not available for lakes in the Koala watershed for 2013.

Phytoplankton communities in all lakes within the Koala watershed were dominated by diatoms and chlorophytes based on abundance, with the exception of Kodiak Lake, which was dominated by cyanobacteria (ERM Rescan 2013). Phytoplankton species richness was similar among the lakes of the Koala watershed in 2013, although a direct comparison of these data to Paul Lake values is not possible due to differences in taxonomic methods.

In Nanuq Lake, an increase in summer total phytoplankton abundance occurred between 1997 (384,983 cells/L) and 1999 (848,733 cells/L), followed by a general decreasing trend (ERM Rescan 2013). Since 2009, summer total phytoplankton abundance in Nanuq Lake has ranged between 221,200 cells/L and 392,933 cells/L. In Vulture Lake, summer total phytoplankton abundance was more variable over time (133,233 to 1,552,867 cells/L), but was often close to 1997 values (269,367 cells/L).

In Nanuq Lake, composition of the phytoplankton community (based on abundance) was variable between 1997 and 2012, but the community was typically dominated by a mixture of cyanobacteria (20% to 57%), chrysophytes (20% to 60%), and chlorophytes (21% to 46%). Diatoms rarely accounted for more than 20% of the Nanuq Lake phytoplankton community.

Total phytoplankton taxonomic richness fluctuated in Nanuq and Vulture lakes, but no temporal trend was apparent in either lake. In Nanuq and Vulture Lakes, total phytoplankton richness varied between 35 and 56 taxa throughout previous sampling programs.

Total zooplankton abundance values for all lakes within the Koala watershed fell within Paul Lake values in 2013 (27,987 to 51,040 org/m^3) with the exception of the lower abundance in Moose Lake (18,312 org/m^3). Zooplankton total biomass data for the Koala watershed lakes were calculated using dry mass estimates, and thus are not comparable with other data summarized herein (ERM Rescan 2014).

The zooplankton communities (by abundance) of the Koala watershed lakes were mostly dominated by copepod nauplii during summer 2013 sampling, with the exception of Slipper Lake, which was dominated by cyclopoid copepods. All Koala watershed lakes were dominated by copepods in summer 2013, accounting for more than 65% of total abundance (ERM Rescan 2014). Zooplankton taxonomic richness in the lakes of the Koala watershed ranged from 11 to 15 taxa during the summer 2013 sampling program (ERM Rescan 2014).

Summer total zooplankton abundances in Nanuq and Vulture lakes have remained stable and similar since 1997 (ERM Rescan 2013). Summer total zooplankton abundance in Nanuq Lake ranged between 11,751 org/m^3 (2007) and 56,848 org/m^3 (2010). In Vulture Lake, summer total zooplankton abundances were slightly lower, ranging between 6,684 org/m^3 (2007) and 50,318 org/m^3 (2004). Similarly, summer total zooplankton biomass was relatively stable and similar in Nanuq and Vulture Lakes. In Nanuq Lake, the majority of the values fell within the range of 19 to 60 mg/m^3, with a peak value in 1999 (136 mg/m^3). Summer total zooplankton biomass in Vulture Lake was typically in the range of 23 and 83 mg/m^3, with the exception of 2007 and 2010, which had peak values of 158 and 241 mg/m^3, respectively.

The zooplankton communities of Nanuq and Vulture lakes have consistently differed from one another throughout historical sampling programs. Calanoid copepods, cyclopoid copepods, and rotifers co-dominated the zooplankton community (by abundance) of Nanuq Lake. The zooplankton community of Vulture Lake has been consistently dominated by cyclopoid copepods since 1997.

Total zooplankton taxonomic richness has remained stable in both Nanuq and Vulture lakes, with values in both lakes ranging between 7 and 10 taxa between 1997 and 2012.

9.2.4.4.3 Benthic Invertebrates

The 2013 benthic invertebrate community baseline study for the Project included sampling in Paul Lake in the Lac de Gras basin (Annex XIII). The Ekati Mine baseline program and AEMP also evaluated benthic invertebrate communities in lakes within the Lac de Gras basin (ERM Rescan 2013). The historical data review included evaluation of benthic invertebrate communities in two reference lakes, Nanuq and Vulture lakes and their corresponding outflows (Map 9.2-4).

Lakes from exposure areas of the Koala watershed were also sampled as part of the Ekati AEMP, including Kodiak, Leslie, Moose, Nema, and Slipper lakes. A high-level overview of benthic communities in these lakes is provided below. A direct comparison between current and historical data is not possible due to differences in analytical methods.

Current (2013)

Mean total densities in 2013 in Paul Lake were low to moderate at the mid-depth stations and low at the deep stations. Moderate values of total richness were observed at all stations. As observed in the majority of lakes in the BSA, Chironomidae dominated the benthic invertebrate community in Paul Lake. Chironomini, Tanytarsini, and Orthocladiinae were the dominant chironomid groups. Pisidiidae accounted for a large proportion of the total density at the Paul Lake stations, as also observed in other lakes in the BSA. Diversity values were high at stations in Paul Lake, and evenness was low at the majority of stations. This pattern was commonly observed in other lakes within the BSA.

Summary of Previous Studies

Mean total density in both Nanuq and Vulture lakes has been variable over time and among stations (ERM Rescan 2013). Higher densities were typically observed at mid-depth and shallow stations compared to deep stations. Total richness was also variable at Nanuq and Vulture lakes. Total richness was consistently found to decline with increasing depth. The benthic invertebrate community at both Nanuq and Vulture lake stations consisted primarily of Chironomidae. Pisidiidae and Oligochaeta were periodically dominant at some locations in these lakes. Gastropoda accounted for up to 30% of the benthic invertebrate community at the shallow station in Vulture Lake but had relatively low abundance at the deeper locations. Gastropods were not documented at any of the stations in Nanuq Lake.

Mean total density and total richness were extremely variable in the Nanuq Outflow and Vulture-Polar Stream. Chironomidae has dominated the benthic invertebrate community at the Nanuq Outflow since 1998, and in the Vulture-Polar Stream in all years of sampling. Nematoda and Oligochaeta have also periodically contributed a high proportion of the community at this outflow location.

Mean benthic invertebrate density has been temporally variable at all exposed and reference lakes during the AEMP period (ERM Rescan 2014). Unlike in other lakes in the region, Pisidiidae generally dominated the benthic communities in the exposure lakes with the exception of Moose Lake, and Chironomidae contributed the second largest proportion of the total density. In Vulture and Moose lakes, similar to the majority of the lakes in the BSA, Chironomidae was the dominant invertebrate group. Furthermore, the relative densities of these Chironomidae groups, in particular in the exposure lakes, have been observed to vary over time and this shift in taxonomic composition has been attributed to changes in macronutrient availability (ERM Rescan 2014). Changes in nutrients can have an effect on the composition of biological communities and the ratio of available nutrients (in particular, nitrogen) has increased over time in the Koala watershed (ERM Rescan 2014).

9.2.4.4.4 Fish Community and Abundance

Slimy Sculpin were the most abundant species captured in Hammer Lake in 2013 (29%), followed by Burbot and Lake Chub (22% each), and Lake Trout and Lake Whitefish (14% each). The population of Lake Whitefish was estimated to be between 1,290 and 3,000 individuals (Rescan 2003). As only 2% of the catch was Lake Trout, Rescan (2003) estimated a minimum population of 34 Lake Trout in Hammer Lake. In Lynx Lake, Lake Whitefish were the most abundant species captured in 2013 (39%), followed by Burbot (28%), Slimy Sculpin, and Lake Trout (17% each). The population of Lake Whitefish in Lynx Lake was estimated to be between 1,460 and 2,020, with a minimum estimate of 880 (Rescan 2003); Lake Trout were estimated to make up 16% to 20% of the population in Lynx Lake with a minimum of 220 individuals.

The fish assemblage in Paul Lake was different than that described for Hammer and Lynx lakes. Northern Pike were the most abundant species captured in Paul Lake in 2013 (41%), followed by Lake Whitefish (33%), Longnose Sucker (14%), Arctic Grayling (6%), Lake Trout (4%), and Round Whitefish (2%) (Annex XIV).

Fish species abundance and distribution information were provided by historical reports for the lakes and streams on islands of Lac de Gras, and for several mainland tributary lakes and streams. Observed community composition across the different lakes and streams of the Lac de Gras watershed was quite variable; this variability was generally attributed to habitat availability and connectivity to other fish-bearing waters, seasonality of habitat use, and the timing of surveys (Golder 1997c; DDMI 1998a). Lake Trout were the most frequently captured large-bodied species, followed by Arctic Grayling. Golder (1997a) observed adult Arctic Grayling in 52% of the 31 streams surveyed in the Lac de Gras area. BHP (1995a) recorded Slimy Sculpin, Arctic Grayling, and Burbot in Ursula Stream, and Arctic Grayling and Slimy Sculpin in Slipper Creek.

Seven fish species were reported by Rescan (2013) in Kodiak, Leslie, Moose, Nema, and Slipper lakes of the Koala watershed, which discharges into Lac de Gras: Arctic Grayling, Lake Trout, Round Whitefish, Longnose Sucker, Burbot, Lake Chub, and Slimy Sculpin (Rescan 2013). Based on mean gill net CPUE values, Nema Lake had the highest CPUE (CPUE of 4.10 fish / 100 square metre [m^2] of net / 24 hours), followed by Leslie Lake (CPUE of 3.34), Slipper Lake (CPUE of 2.45), Kodiak Lake (CPUE of 2.11), and Moose Lake (CPUE of 1.69). Based on gill net results, Round Whitefish was the most abundant species in all of the lakes, with a relative abundance between 48% and 71%. Lake Trout was the second most abundant species captured by gill net (25% to 33%), followed by Arctic Grayling (4% to 24%) in all lakes except Nema Lake, where Arctic Grayling was more abundant (22%) than Lake Trout (13%). Arctic Grayling and Slimy Sculpin have been recorded in Slipper Creek (BHP 1995a).

9.2.4.4.5 Fish-Out Programs

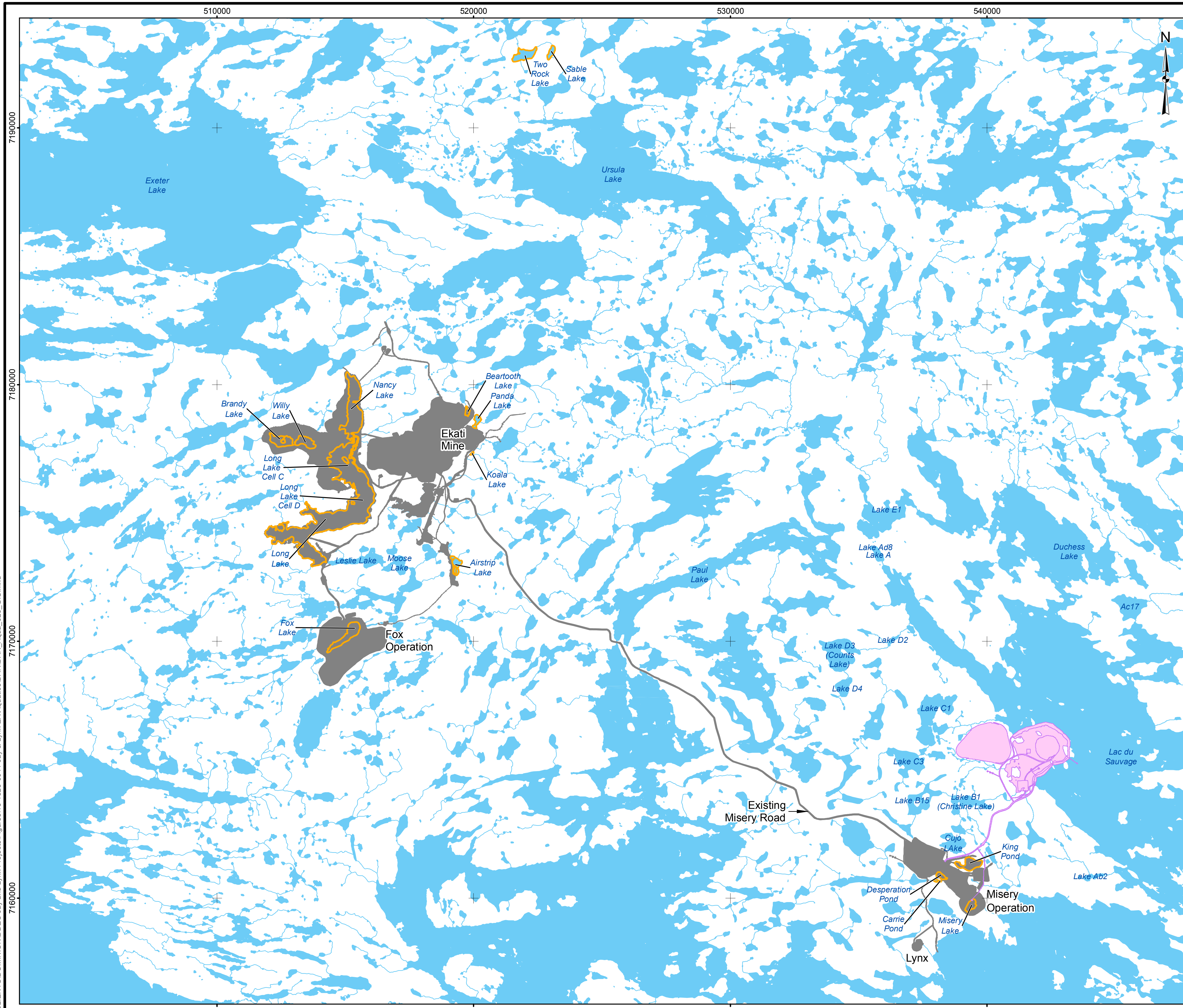
Fish-out programs were carried out in 15 waterbodies in the Lac de Gras sub-basin in the Ekati Mine area from 1997 to 2001 (Table 9.2-11, Map 9.2-8) (BHP 1998a,b,c, 2000; Dillon 2002c,d, 2003, 2004; Rescan 1998a,b,c, 1999, 2000). The fish-out programs provide additional information on fish species presence and abundance in lakes in the Lac de Gras area. Lakes ranged in depth and size from small, shallow lakes with mean depths less than 2 m, to large deep lakes like Long Lake and Fox Lake.

Long Lake was substantially greater in area (614 ha) than all other lakes fished-out in the Ekati Mine area, which were less than 50 ha. The most common fishing gear type used in fish-outs was gill nets, but trap nets, minnow traps, and long-lines were also used in several lakes. The fishing effort and objectives of the fish-outs also varied among lakes. The difference in gear types and fishing effort would have affected the catch and calculations of density and species composition. Trends in fish densities and species composition are discussed below, but because of the differences in objectives, gear types, and fishing effort, data from these previous studies may not be directly comparable between lakes and should be interpreted with caution.

Table 9.2-11 Summary of Physical Habitat, Gear Types, and Total Catch for Fish-Outs Conducted at Lakes in the Ekati Mine Area, 1997 to 2001

Lake Name	Area (ha)	Maximum Depth (m)	Mean Depth (m)	Volume (m^3)	No. of Fish	Gear Type[(a)]
Airstrip Lake	19.33	3.0	1.5	453,104	1,006	GN, TN
Beartooth Lake	4.80	13.0	N/A	N/A	191	GN
Brandy Lake	N/A	N/A	N/A	N/A	449	GN
Carrie Pond	N/A	3.0	1.5	N/A	3	GN
Desperation Pond	N/A	5.7	1.2	N/A	70	GN
Fox Lake	43.66	29.0	6.9	3,030,154	1,324	GN, TN, MT
King Pond	29.96	N/A	<2.0	N/A	40	GN
Koala Lake	38.04	20.0	5.9	2,254,152	6,705	GN, TN
Long Lake	614.41	32.0	7.4	45,287,370	6,701	GN, TN, LL
Long Lake - Cell C	N/A	N/A	N/A	N/A	7,564	GN
Long Lake - Cell D	N/A	N/A	N/A	N/A	3,663	GN
Misery Lake	13.67	28.0	7.5	1,023,560	146	GN
Nancy Lake	14.19	5.0	1.0	146,582	23	GN
Panda Lake	34.99	19.0	3.8	1,312,921	1,085	GN, TN
Sable Lake	8.90	18.0	N/A	N/A	130	GN
Two Rock Lake	28.60	11.0	3.6	N/A	1,170	GN
Willy Lake	N/A	N/A	N/A	N/A	510	GN

Sources: BHP 1998a,b,c, 2000; Dillon 2002c,d, 2003, 2004; Rescan 1998a,b,c,d, 2000.
Gear types: GN = gill net; LL = long-line; MT = minnow trap; TN = trap net.
ha = hectare; m = metre; m^3 = cubic metres; No. = number; N/A = not available; <= less than.



LEGEND

- EKATI MINE FOOTPRINT
- PROPOSED JAY FOOTPRINT
- WATERCOURSE
- WATERBODY
- FISHED OUT LAKE

REFERENCE

CANVEC © NATURAL RESOURCES CANADA, 2012
NATURAL RESOURCES CANADA, CENTRE FOR TOPOGRAPHIC INFORMATION, 2012
DATUM: NAD83 PROJECTION: UTM ZONE 12N

DOCUMENT

DEVELOPER'S ASSESSMENT REPORT

3 0 3
SCALE 1:150,000 KILOMETERS

PROJECT

DOMINION DIAMOND

JAY PROJECT
NORTHWEST TERRITORIES, CANADA

TITLE

FISHED-OUT LAKES AS PART OF THE EKATI MINE, 1997 TO 2001

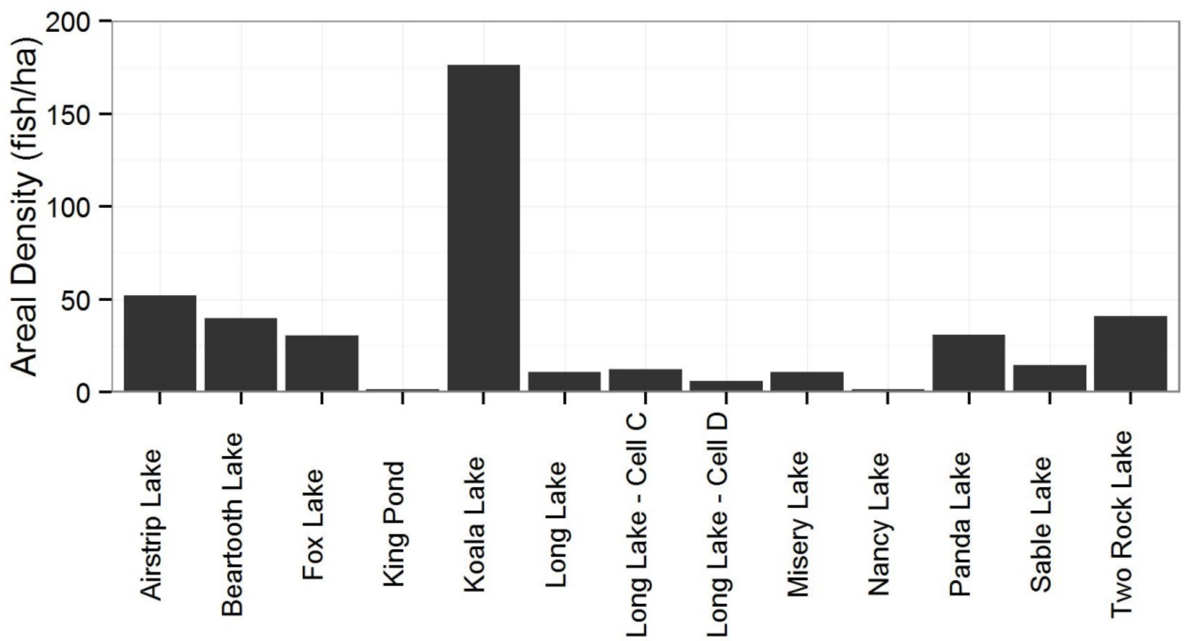
Golder Associates

PROJECT		13-1328-0041	FILE No. DAR_Aqua_023_GIS	
DESIGN	CS	28/07/14	SCALE AS SHOWN	REV 0
GIS	JE	20/10/14	MAP 9.2-8	
CHECK	CS	20/10/14		
REVIEW	KM	20/10/14		

G:\CLIENTS\DOMINION\DDEC Jay and Lynx Projects\Figures\13-1328-0041 Jay & Lynx EA\Aquatics\DAR\DAR_Aqua_023_GIS.mxd

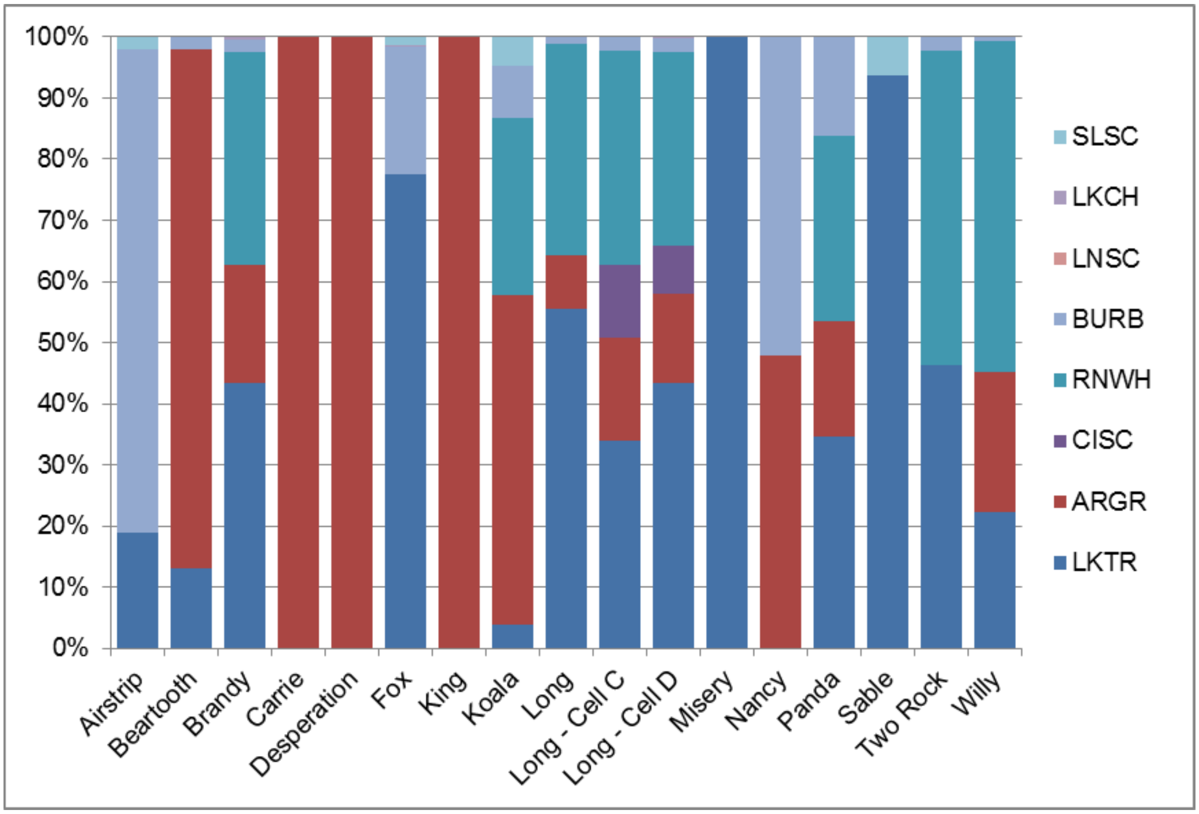
Areal density of fish caught during the fish-outs at lakes in the Ekati Mine area ranged from less than 2 fish/ha in small lakes like King Pond and Nancy Lake, to 176 fish/ha in Koala Lake (Figure 9.2-37). Volumetric densities showed the same general pattern as areal densities. The most abundant species captured were Arctic Grayling, Burbot, Lake Trout, and Round Whitefish (Figure 9.2-38). Other species captured were Cisco, Lake Chub, Longnose Sucker, and Slimy Sculpin. Catch composition in each lake was influenced by the gear type. In most lakes, only gill netting was conducted during the fish-out, which would be expected to bias the catch towards large-bodied fish species; small-bodied fish, such as Slimy Sculpin, were only captured in lakes where trap nets or minnow traps were used.

Figure 9.2-37 Areal Density of Fish (All Species) Caught During Fish-Outs at Lakes in the Ekati Mine Area, 1997 to 2001



fish/ha = number of fish per hectare.

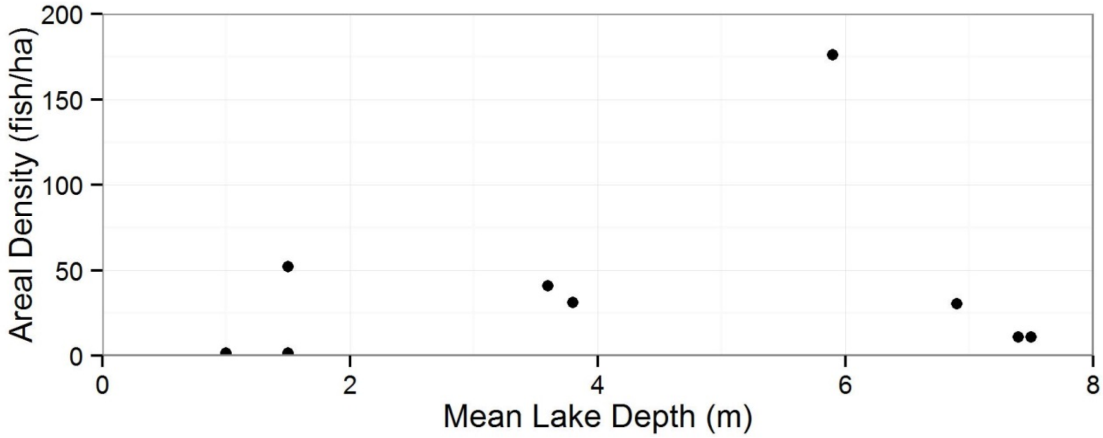
Figure 9.2-38 Species Composition of Fish Removed During Fish-Outs at Lakes in the Ekati Mine Area, 1997 to 2001



Note: ARGR = Arctic Grayling; BURB = Burbot; CISC = Cisco; LKCH = Lake Chub; LKTR = Lake Trout; LNSC = Longnose Sucker; RNWH = Round Whitefish; SLSC = slimy sculpin;% = percent.

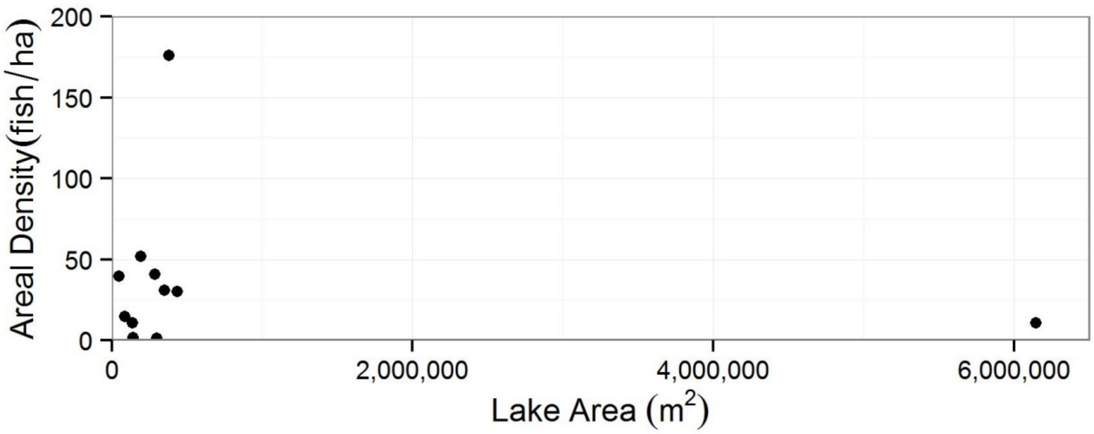
Densities of fish captured during fish-outs appeared to be unrelated to mean lake depth and lake area based on a visual assessment of scatterplots (Figure 9.2-39, Figure 9.2-40). This finding could be because other habitat attributes, such as water temperature and primary productivity may have been more important to fish density than lake depth and size. For instance, density of fish was much greater in Koala Lake than all other lakes, although this lake was moderate in terms of depth and area compared to other lakes (Table 9.2-11). However, Koala Lake had much greater concentrations of phosphorus and nitrogen than the other lakes (Rescan 1998a). For example, total phosphorous concentrations exceeded 9.0 mg/L in Koala Lake, whereas concentrations ranged from 2.5 to 8.0 mg/L in Beartooth, Fox, Long, Two Rock, and Sable lakes (BHP 1998b; Dillon 2002d, 2003, 2004). Although the correlation suggests that nutrients may be an important predictor of fish density in these lakes, results may be confounded by differences in sampling effort during fish-outs.

Figure 9.2-39 Mean Lake Depth and Areal Density of Fish Captured During Fish-Outs (All Species Combined) in the Ekati Mine Area, 1997 to 2001



fish/ha = number of fish per hectare; m = metre.

Figure 9.2-40 Lake Area and Areal Density of Fish Captured During Fish-Outs (All Species Combined) in the Ekati Mine Area, 1997 to 2001



fish/ha = number of fish per hectare; m^2 = square metre.

9.2.5 Fish Life History

Life history data were collected for 1,037 fish between 2006 and 2013, including the three VC species: Lake Trout (*n* = 261, length range 57 to 947 mm), Lake Whitefish (*n* = 202, length range 104 to 615 mm), and Arctic Grayling (*n* = 58, length range 50 to 385 mm) (Table 9.2-12, Annex XIV). There was a general lack of YOY and juvenile large-bodied fish captured per species in the BSA, with the exception of YOY and juvenile Arctic Grayling captured in several streams, and Lake Whitefish and Round Whitefish captured in Duchess Lake.

Table 9.2-12 Sample Size, Length, and Weight of Lake Trout, Lake Whitefish, and Arctic Grayling Collected in the Baseline Study Area, 2006 to 2013

Species	Location	Fork Length (mm)					Weight (g)				
		n	Mean	SD	Min	Max	n	Mean	SD	Min	Max
Lake Trout	all waterbodies	261	522	159	57	947	246	1,894	1,604	2	9,750
	Lac du Sauvage	115	599	109	299	850	111	2,345	1,029	261	4,601
	Duchess Lake	9	436	126	240	595	9	1,070	734	168	2,440
	Lake E1	2	682	11	674	689	2	3,415	346	3,170	3,660
	Paul Lake	3	639	67	587	715	3	2,506	942	1,566	3,450
	Lake B4 (Cujo)	63	467	176	69	947	52	1,699	2,290	2	9,570
	Lake D3 (Counts)	35	433	158	62	910	35	1,246	1,865	2	9,750
	Lynx Lake	3	388	49	331	422	3	738	304	420	1,025
	Hammer Lake	2	525	21	510	540	2	2,123	357	1,870	2,375
	other lakes	29	460	171	57	772	29	1,493	1,486	2	5,200
Lake Whitefish	all waterbodies	202	376	134	104	615	188	903	741	13	3,199
	Lac du Sauvage	39	477	51	354	560	36	1,398	402	437	2,027
	Duchess Lake	64	252	118	104	509	64	325	448	13	1,738
	Lake E1	39	379	133	134	565	30	838	806	30	2,530
	Paul Lake	26	437	56	297	514	24	1,147	410	549	1,949
	Lake Ad8	26	467	74	358	615	26	1,567	832	555	3,199
	Hammer Lake	2	263	138	165	360	2	290	354	39	540
Arctic Grayling	all waterbodies	58	178	127	50	385	57	178	237	1	734
	Paul Lake	4	233	57	155	289	4	192	114	47	322
	Lake B4 (Cujo)	17	219	139	50	383	17	287	277	1	734
	Lake D3 (Counts)	1	78	n/a	78	78	1	5	n/a	5	5
	Lake D2	11	269	128	71	385	11	355	255	4	663
	other Lakes	4	83	38	61	139	4	9	13	2	28
	Stream B1 (Christine Creek)	11	89	93	55	369	10	2	0	2	3
	other streams	10	129	79	60	268	10	54	85	2	265

mm = millimetre; g = gram; n = number of samples; SD = standard deviation; Min = minimum; Max = maximum; n/a = not applicable.

A summary of fish life history information for the three VC species is provided below. Fish life history information for Lac de Gras was based on historical reports because no sampling was conducted in Lac de Gras in 2013 for the Project (Annex XIV).

Length-weight regression models were established and calculated for species by waterbody (Table 9.2-13) to provide a general understanding of patterns in growth. A slope of 3.0 suggests isometric growth across length categories. All slopes were within the typical range between 2.5 and 4.0, except for the slope calculated for YOY Arctic Grayling in Stream B1 (Christine Creek; 1.74) (Table 9.2-13). General results of this analysis are further described by species under the following subheadings.

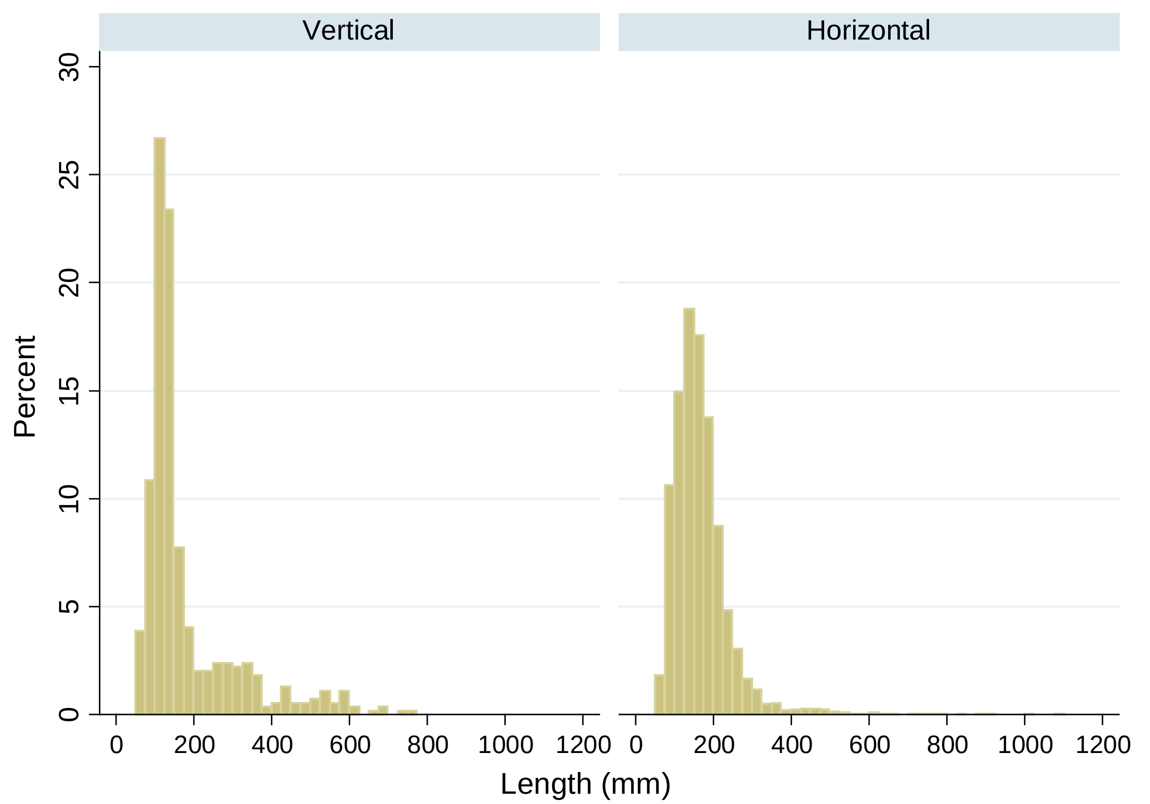
Table 9.2-13 Length-Weight Relationships for Lake Trout, Lake Whitefish, and Arctic Grayling Species in the Baseline Study Area, 2006 to 2013

Species	Waterbody	Year	Slope	Intercept	n	r^2	Minimum fork length (mm)	Maximum fork length (mm)
Lake Trout	all waterbodies	2006-2008, 2011-2013	3.00	-5.00	246	0.98	57	947
	Lac du Sauvage	2006, 2008, 2011, 2013	2.68	-4.13	111	0.90	299	850
	Lake D3 (Counts)	2007, 2012, 2013	3.10	-5.24	35	0.99	62	910
	Lake B4 (Cujo)	2007, 2012, 2013	3.06	-5.17	52	0.99	69	947
		2007	3.03	-5.06	13	0.98	355	947
		2012, 2013	3.05	-5.14	39	0.99	69	819
Lake Whitefish	all waterbodies	2006, 2013	3.17	-5.34	188	0.99	104	615
	Lac du Sauvage	2006, 2013	3.12	-5.23	36	0.83	354	560
	Paul Lake	2013	2.96	-4.78	24	0.87	355	514
	Duchess Lake	2013	3.09	-5.17	64	0.99	104	509
	Lake Ad8	2013	3.50	-6.19	26	0.98	358	615
	Lake E1	2013	3.15	-5.28	30	0.99	134	565
Arctic Grayling	all waterbodies	2012, 2013	3.18	-5.35	57	0.99	50	385
	Lake B4 (Cujo)	2012, 2013	3.23	-5.47	17	0.99	50	383
	Lake D2	2013	3.11	-5.19	11	0.99	71	385
	Stream B1 (Christine Creek)	2013	1.74	-2.75	10	0.50	55	68

n = number of samples; r^2 = coefficient of determination for regression; mm = millimetre.

Based on the 2013 acoustic surveys conducted in Lac du Sauvage, the mean length of fish was calculated at approximately 166 mm. Approximately 5% of all fish tracks were greater than 300 mm in length and, of these, 25 individuals were longer than 1.0 m (Figure 9.2-41). In the west section of Lac du Sauvage (i.e., internal basins Ac, Ad, and Ae), approximately 7% of the fish tracks were greater than 300 mm in length; in the east section of Lac du Sauvage (i.e., internal basins Aa and Ab), only 3.6% of the fish tracks were greater than 300 mm.

Figure 9.2-41 Length Distribution Derived from Target Strengths of Fish Recorded from Vertical and Horizontal Beaming, 2013



mm = millimetre.

9.2.5.1 *Lake Trout*

9.2.5.1.1 General Life History

Lake Trout primarily use lake habitats and remain in freshwater systems throughout their lifecycle (reviewed in Scott and Crossman 1973; Evans et al. 2002; Richardson et al. 2001; McPhail 2007). They are found throughout NWT and Nunavut, mostly in deep lakes, such as Lac de Gras and Lac du Sauvage. Based on Traditional Knowledge, Lake Trout are often caught at the Lac du Sauvage-Lac de Gras Narrows, or near the mouth of the Narrows in Lac de Gras (Annex XVII).

In northern populations, Lake Trout are especially long-lived and fish older than 20 years old are common. For example, a 36-year old fish was recorded in the BSA (during 2013 baseline sampling). Lake Trout spawn in the fall (September or October) when water temperatures fall below approximately 10 degrees Celsius (°C) (Scott and Crossman 1973; Richardson et al. 2001; McPhail 2007). In northern populations, Lake Trout typically mature between the ages of 7 and 10 years. Spawning occurs at night, and females deposit eggs over beds of large boulder or rubble at depths up to 12 m. The fertilized eggs settle into the interstitial spaces within the substrate to incubate. Lake Trout eggs are relatively large (4 to 5 mm), and fecundity is low compared to other fish species in the BSA (McPhail 2007). Eggs remain in the substrate over winter, and hatch during spring. Young Lake Trout feed in shallows for several months before they are large enough to venture into deeper water. There is evidence that adults in some populations return to their natal spawning sites.

Small Lake Trout primarily feed on plankton and aquatic insect larvae until they reach adequate size to prey on other fish, such as Cisco, juvenile Lake Whitefish, and juvenile Round Whitefish (Scott and Crossman 1973; Richardson et al. 2001; McPhail 2007). Seasonal changes in diet are common and are often associated with water temperature. For example, in the spring, adults may feed on forage fish and terrestrial insects in shallow water. If the lake warms and stratifies, Lake Trout can be separated from these sources by a thermal barrier (i.e., temperatures above 15°C in the upper layer of the lake). Under these conditions in lakes, they can switch back to planktivory.

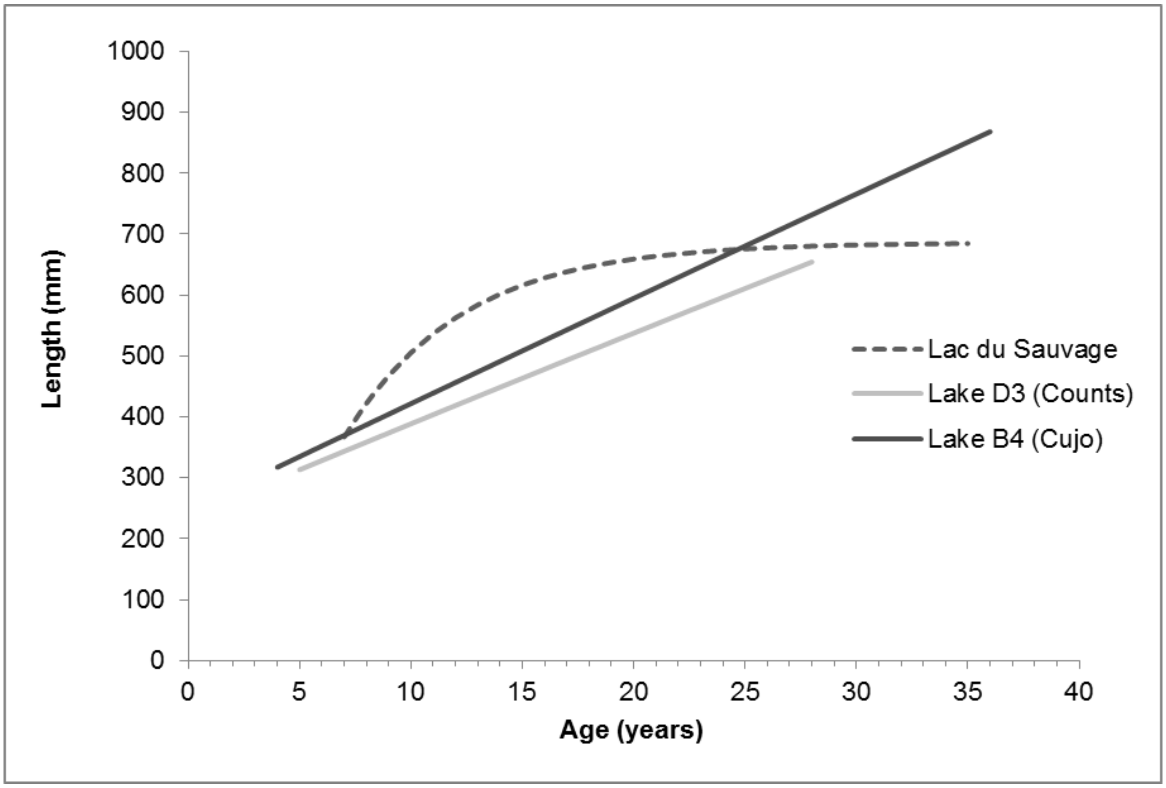
9.2.5.1.2 Life History in the Baseline Study Area

Lake Trout had the widest ranging and most evenly distributed ages, and were, on average, older than all other species in the BSA. Age classes between 4 to 36 years were represented in the aged sample from 2013 (n = 218). Using data collected between 2006 and 2013, Lake Trout was represented by a wide range of size-classes (57 to 947 mm fork length); however, most were adults larger than 300 mm (Table 9.2-12).

Young-of-the-year Lake Trout (fork length less than 150 mm) were captured in Lake B1 (Christine) and Lake D4 in 2013, and in Lake D3 (Counts) and Lake B4 (Cujo) in 2012. Juvenile Lake Trout (fork length between 150 and 299 mm) were captured in Lac du Sauvage in 2006, Duchess Lake in 2013, and Lake D3 (Counts) in 2007 and 2012. The heaviest Lake Trout (9,750 grams [g]) was captured in Lake D3 (Counts) in 2013. In the Koala watershed, Rescan (2013) reported that, on average, Lake Trout were largest in Nema Lake and smallest in Slipper Lake. Mean fork lengths and weights were similar to that observed in Lac du Sauvage tributary lakes.

Growth, as determined by von Bertalanffy equations, varied between Lac du Sauvage versus Lakes D3 (Counts) and B4 (Cujo) (Figure 9.2-42). Although data for larger fish is required to show stabilization or reduction in growth rates in Lake D3 and B4, the theoretical maximum length of fish appeared to be much larger in Lakes D3 (Counts) and B4 (Cujo), versus Lac du Sauvage. In addition, the growth constant (K) is larger in Lac du Sauvage suggesting that it takes less time to produce a mature adult Lake Trout, compared to Lakes D3 (Counts) and B4 (Cujo). The results of the length-weight regressions identified a low slope (i.e., below 3.0; 3.0 = isometric growth) for Lake Trout in Lac du Sauvage (2.68) (Table 9.2-13). The slopes for Lake Trout in all other waterbodies were above 3.0.

Figure 9.2-42 von Bertalanffy Relationships for Lake Trout Caught in Lac du Sauvage, Lake D3 (Counts), and Lake B4 (Cujo), 2006 to 2013

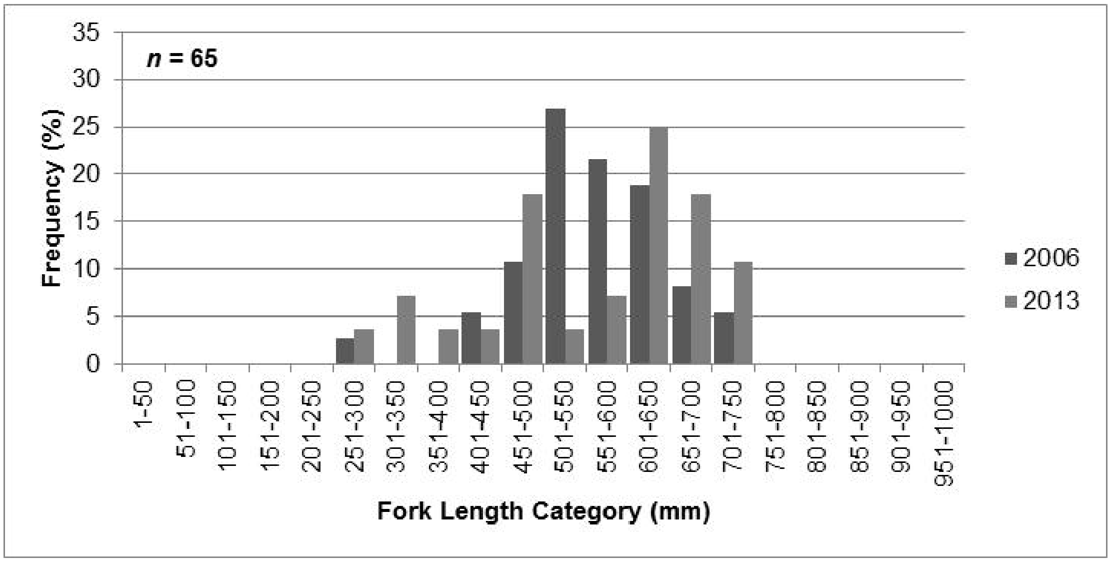


mm = millimetre.

Lac du Sauvage

Lake Trout fork length ranged from 299 to 850 mm (n = 115) from 2006 to 2013 in Lac du Sauvage, with a mean fork length of 599 mm (Annex XIV). Over half of the fish (51%, n = 59) were between 601 and 800 mm long (Figure 9.2-43). On average. Lake Trout captured from 2006 and 2013 in Lac du Sauvage were 14.8% larger by length than Lake Trout from all waterbodies in the BSA combined. In 2013, almost half (43%, n = 12) of the fish were between 601 and 700 mm compared to almost half (49%, n = 18) between 501 and 600 mm in 2006. This may be evidence of recruitment into the population, but the overall distribution may reflect sampling biases towards larger fish sizes (i.e., gill nets).

Figure 9.2-43 Length-Frequency of Lake Trout Caught in Lac du Sauvage, 2006 and 2013



% = percent; n = number of samples; mm = millimetre.

In Lac du Sauvage, female Lake Trout were on average slightly younger than males (Golder 1998a), and first reached sexual maturity (4 years) earlier than males (10 years), but sexual maturity of all fish was reached at the same time for males and females (11 years) (Golder 1998a). Rescan (2007) found that the sex ratios of all species were skewed towards males. Based on maturity analysis, Rescan (2007) suggested that Lake Trout reproduction may not occur annually in Lac du Sauvage. This finding may indicate inadequate energy reserves, which is the typical case in cold water systems (Martin 1966). Stomach contents of Lake Trout in Lac du Sauvage showed a diet abundant in fish; Rescan (2007) found that 74% by weight of the total stomach contents were fish. Condition factors indicated a healthy population of Lake Trout in Lac du Sauvage (DDMI 1998a; Golder 2009).

Lac de Gras

Golder (1998a) found that Lake Trout had the widest ranging and most evenly distributed ages of the dominant species in Lac de Gras (Cisco, Round Whitefish, and Lake Trout). Female Lake Trout were, on average, younger than male Lake Trout in Lac de Gras (Golder 1998a). The mean age, weight, length and condition factor of male Lake Trout in Lac de Gras was 11.1 years, 1,845 g, 484 mm, and 1.29, respectively (Table 9.2-14). The mean age, weight, length and condition factor of female Lake Trout in Lac de Gras was 10.3 years, 1,880 g, 486 mm, and 1.21, respectively. Golder (2012) reported slightly older and larger Lake Trout, with a mean age, weight, length and condition factors of 15 years, 2,627 g, 634 mm, and 1.02, respectively, while CRI (2006) reported slightly older Lake Trout, ranging from 17 to 22 years between three sites sampled. CRI (2006) also reported that there were 1.61 females to every one male captured in Lac de Gras. Average lengths and weights of adult Lake Trout were found to be similar in Lac de Gras and Lac du Sauvage (DDMI 1998b; Golder 2012), and condition factors of Lake Trout in both lakes indicated healthy fish (DDMI 1998b).

Based on the fish salvage at A154 Dike in 2002, the mean size of Lake Trout captured in gill nets was 230 mm, weighing 201 g (n = 382); the mean size of fish captured in trap nets was 144 mm, weighing 67 g (n = 15) (Jacques Whitford 2002). Body size and mass measurements during the fish salvage were noticeably smaller versus those calculated for other studies in Lac de Gras (e.g., Golder 1998a).

Stomach content analyses indicated a diet composed of fish and insects, particularly caddisfly larvae and dipteran adults, the most common in the summer, and a diet composed of more zooplankton and dipterans in the fall (DDMI 1998b). Seasonal changes in diet of Lake Trout have been observed elsewhere (reviewed in Scott and Crossman 1973; Richardson et al. 2001; McPhail 2007).

Table 9.2-14 Select Life History Characteristics of Lake Trout in Lac de Gras, and Lac du Sauvage for Comparison

Variable		Male		Female		Unknown	
		LDS	LDG	LDS	LDG	LDS	LDG
Sample size		**47**	**39**	**29**	**27**	**31**	**59**
Age (years)	Mean	11.7	11.1	9.0	10.3	11.6	12.5
	SD	4.6	5.0	4.4	5.2	3.8	4.6
Length (mm)	Mean	537	484	457	486	588	596
	SD	158	163	180	172	133	173
Weight (g)	Mean	2,068	1,845	1,552	1,880	2,567	2,903
	SD	1,264	1,446	1,447	1,646	1,168	1,846
Condition	Mean	1.13	1.29	1.19	1.21	1.16	1.18
	SD	0.14	0.29	0.28	0.17	0.32	0.29

Source: Golder 1998a.

LDS = Lac du Sauvage; LDG = Lac de Gras; SD = standard deviation; mm = millimetre; g = gram.

Historical reports also provided details on sexual development and reproductive condition of Lake Trout in Lac de Gras. Golder (1998a) found that male Lake Trout first matured at 8 years, and all fish reached sexual maturity at 17 years in Lac de Gras, 6 years later than in Lac du Sauvage. Female Lake Trout first matured at age 7 in Lac de Gras and were all sexually mature at age 12 (Golder 1998a). Fecundity was higher in Lake Trout from Lac de Gras than Lac du Sauvage, but egg diameter did not differ between the lakes (Golder 1998a). CRI (2006) reported that 26% of Lake Trout captured were immature, 42% were resting, and 32% were pre-spawners. In 1996, Golder (1997f) observed that Lake Trout spawning occurred at dusk or during the night between September 3 and 13 in Lac de Gras.

Golder (1997f) identified a preference for open-water shoals bordered by deep waters by Lake Trout in Lac de Gras. However, Lake Trout habitat use, including shoals, appears to be quite variable in Lac de Gras, which is indicative of the migratory nature of Lake Trout within the lake (Dillon 2002a; DDMI 2008). Dillon (2002a) observed Lake Trout moving considerable distances in the lake throughout the year, for example from L1 (near the proposed A154 dike) and L2 (11 km northeast of Diavik Mine site) to Slipper Creek outfall, and from the Lac du Sauvage-Lac de Gras Narrows (the Narrows) to the inlet north of the Lac de Gras west island. Golder (1997f) identified the most common areas of observed spawning activity as relatively shallow and composed primarily of large coarse substrate with many interstitial spaces.

These habitats also tended to be on relatively steep slopes and in areas of high wind and wave action, which resulted in substrate free of silt. The report concluded that spawning habitat is not limited for Lake Trout populations within Lac de Gras.

9.2.5.2 *Lake Whitefish*

9.2.5.2.1 General Life History

Lake Whitefish are found throughout much of the central Canadian Arctic (reviewed in Scott and Crossman 1973; Evans et al. 2002; Richardson et al. 2001). They are most commonly found in lakes, although they can be found in larger rivers and brackish waters (Evans et al. 2002). According to Traditional Knowledge, Lac du Sauvage is often fished for Lake Whitefish at the Narrows, or near the mouth of the narrows in Lac de Gras (Annex XVII). They are one of the most valuable species for commercial, Aboriginal, and recreational fisheries in Canada (Scott and Crossman 1973).

In northern populations, Lake Whitefish may only spawn every two or three years (Scott and Crossman 1973). Lake Whitefish can spawn from late summer to December; however, spawning usually occurs from mid-September to mid-October in northern regions (Richardson et al. 2001). They may spawn in lake or river systems and over a variety of substrates from large boulders to gravel, and occasionally sand (Richardson et al. 2001). Although Lake Whitefish appear to avoid using soft-bottomed substrates for spawning, spawning in areas with silt substrates or emergent vegetation has been documented (Richardson et al. 2001).

Spawning usually takes place in shallow water areas at depths less than 8 m, but deeper spawning has been reported (Scott and Crossman 1973; Evans et al. 2002; Richardson et al. 2001). Eggs are released over a hard or stony substrate (Scott and Crossman 1973), and settle into crevices where they incubate for several months before hatching in approximately March to May (Richardson et al. 2001).

Juvenile Lake Whitefish are commonly found near the surface in shallow water close to spawning areas. Within these shallow water zones, young Lake Whitefish are frequently associated with boulder, cobble, or sand substrates, emergent vegetation, and woody debris (Ford et al. 1995). In contrast to the juveniles, adult Lake Whitefish often leave the spawning grounds shortly after spawning for deep-water locations to over winter (Ford et al. 1995). They are often found at depths greater than 10 m for most of the year and can occur at depths in excess of 100 m (McPhail and Lindsey 1970). Despite being primarily bottom dwelling, they may occasionally be found in the pelagic zone of lakes (Ford et al. 1995).

Lake Whitefish are known to move into shallow water habitats at night to feed (McPhail and Lindsey 1970). The diet of Lake Whitefish includes snails, clams, terrestrial insects, aquatic insects, plankton, and small fish (Scott and Crossman 1973). Lake Whitefish are preyed upon by Lake Trout and Burbot in both the juvenile and adult life-stages (Scott and Crossman 1973). Growth rates of Lake Whitefish are variable across lakes, affected by temperature, primary production and population density (McPhail 2007). Northern populations typically grow slower and live longer than southern populations. For example, a maximum lifespan of 19 years is recorded in British Columbia (McPhail 2007), whereas, a maximum lifespan of 34 years is recorded in the BSA (during 2013 baseline sampling).

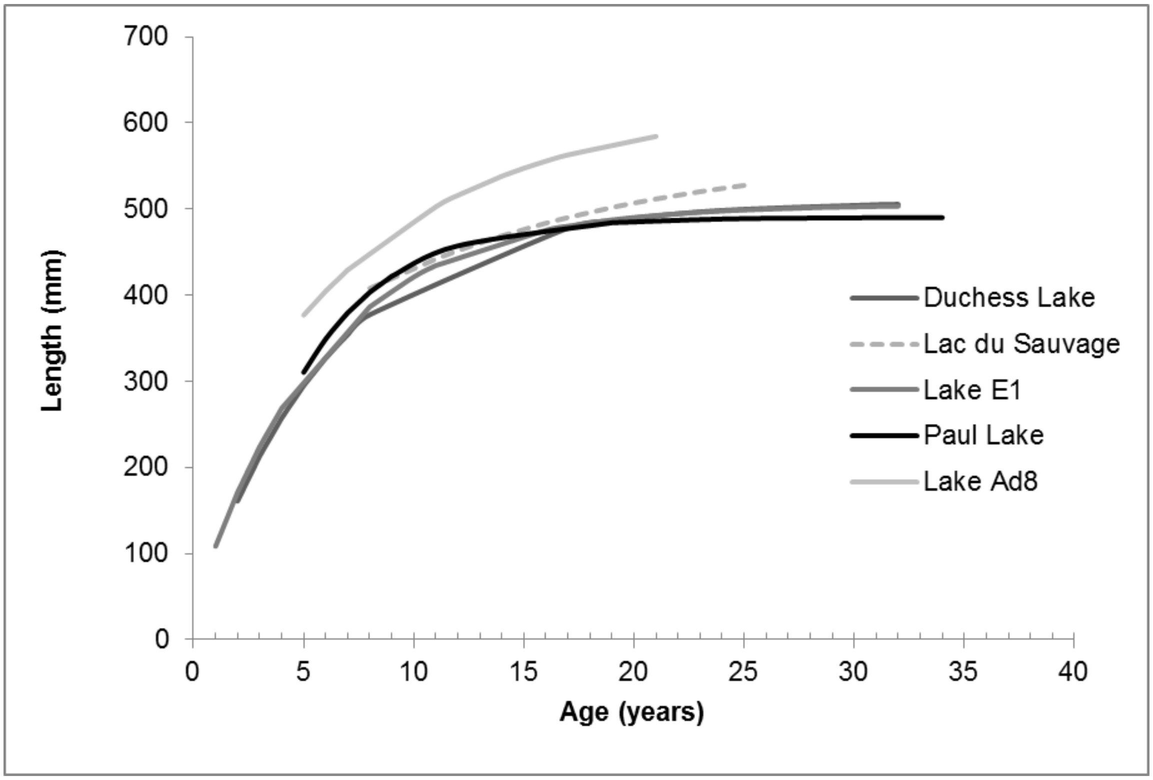
9.2.5.2.2 Life History in the Baseline Study Area

Lake Whitefish in the BSA (n = 202) during the 2006 and 2013 field programs ranged from 104 to 615 mm in fork length (Table 9.2-10). The mean fork length was 376 mm. Medium-sized Lake Whitefish (fork length between 301 to 500 mm) made up 51% of the Lake Whitefish caught (n = 103), while small-sized (fork length between 101 to 300 mm) fish represented 32% (n = 63) of the species catch. Large-sized Lake Whitefish (fork length between 501 to 650 mm) made up 18% (n = 36) of the catch). Underlying mechanisms of trends in the histogram are unclear. Sampling biases likely have a large role, but the histogram may also represent an unbalanced population (e.g., slow growth, low annual recruitment). The largest Lake Whitefish was caught in Lake Ad8 in August 2013 and had a fork length of 615 mm.

In 2013, age was determined for 163 Lake Whitefish and ranged from 1 to 34 years (n = 163, mean = 12 years, standard deviation [SD] ± 8.6)). The oldest fish (34 years old) was caught in Paul Lake in 2013 and had a fork length of 487 mm. The two youngest fish (1 year old) were caught in Lake E1 and Hammer Lake. Most of the fish were captured in Duchess Lake and Lake E1 (both n = 39).

Lake Whitefish growth, as determined by von Bertalanffy equations, varied between Lake Ad8 versus other lakes in the BSA (Figure 9.2-44). For example, the theoretical maximum length of fish appeared to be much larger in Ad8, versus Lac du Sauvage, Lake E1, Paul Lake, and Duchess Lake. In addition, the growth constant (K) was largest in Paul Lake and smallest in Lac du Sauvage. In other words, it may take more time to produce a mature adult Lake Whitefish in Lac du Sauvage, compared to other lakes in the BSA. The results of the length-weight regressions identified a low slope (i.e., below 3.0; 3.0 = isometric growth) for Lake Whitefish in Paul Lake (2.96) (Table 9.2-13). The slopes for Lake Whitefish in all other waterbodies were above 3.0, and highest in Lake Ad8 (3.5).

Figure 9.2-44 von Bertalanffy Relationships for Lake Whitefish Caught in Lac du Sauvage, Duchess, E1, Paul, and Ad8 lakes, 2006 to 2013



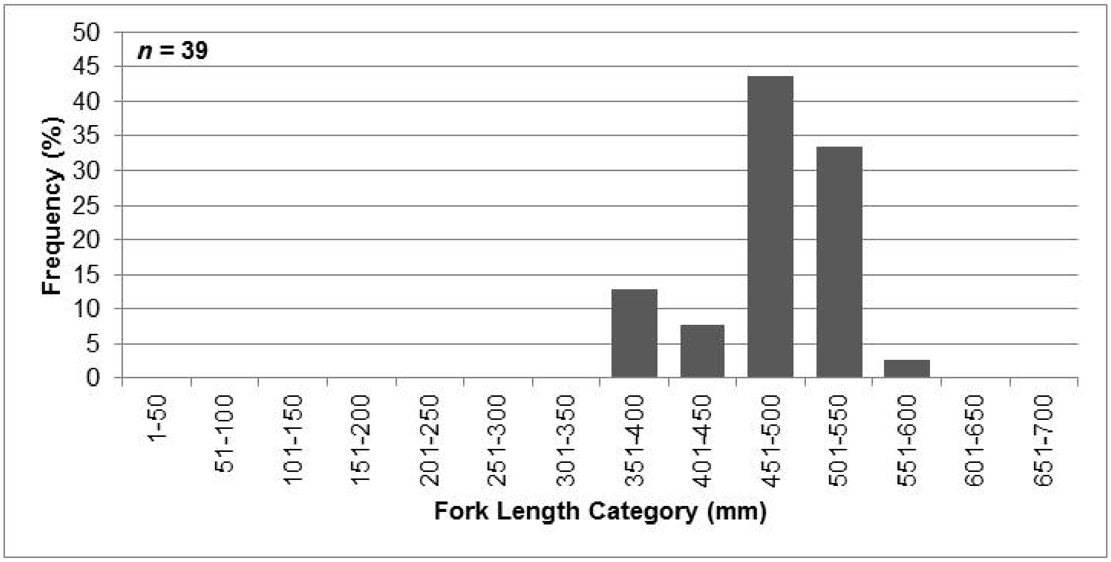
mm = millimetre.

Lac du Sauvage

Lake Whitefish fork length ranged from 354 to 560 mm (n = 39) in Lac du Sauvage in 2006 and 2013 (combined), with almost half of the fish (43%, n = 17) in the 451 to 500 mm size class (Table 9.2-12, Figure 9.2-45). The mean fork length of Lake Whitefish in Lac du Sauvage in 2006 and 2013 (combined) was 477 mm.

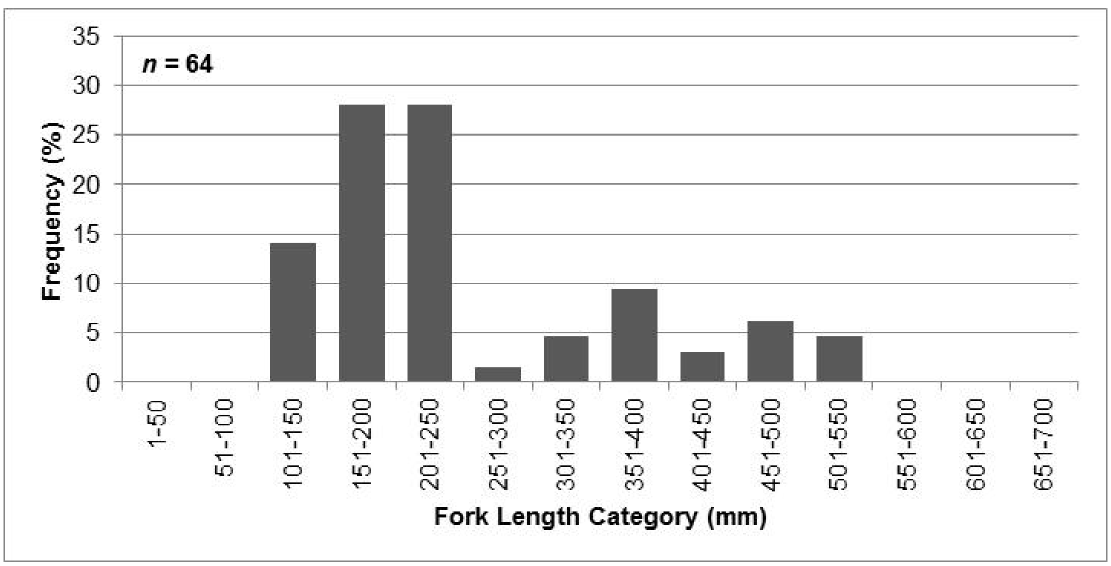
The catch in Lac du Sauvage did not include any small size classes of fish potentially representing YOY and yearlings. However, small size classes of fish potentially representing yearlings were included in the catch for Duchess Lake. The mean fork length of Lake Whitefish in Duchess Lake in 2013 was 252 mm, approximately 47% smaller than in Lac du Sauvage (Table 9.2-12, Figure 9.2-46).

Figure 9.2-45 Length-Frequency of Lake Whitefish Caught in Lac du Sauvage, 2006 and 2013



% = percent; n = number of samples; mm = millimetre.

Figure 9.2-46 Length-Frequency of Lake Whitefish Caught in Duchess Lake, 2013



% = percent; n = number of samples; mm = millimetre.

Lac de Gras

Very few Lake Whitefish have been reported in studies of Lac de Gras, with the exception of Lake Whitefish captured at the Lac du Sauvage-Lac de Gras Narrows, or near the outlet narrows in Lac de Gras. A brief summary of life history information for Lake Whitefish in Lac de Gras tributary lakes is provided below, specifically Hammer, Lynx, and Paul lakes (Rescan 2003; Annex XIV). However, life history characteristics for Lake Whitefish in Lac de Gras may be more similar to Lac du Sauvage, rather than in small, tributary lakes. Based on the 63 Lake Whitefish captured, fish length was, on average, 383 mm, and ranged from 82 to 535 mm fork length. Fish weight was, on average, 940 g, and ranged from 10 to 1,680 g.

Rescan (2003) reported a mean Lake Whitefish fork length and weight of 345 mm and 525 g (n = 31) in Lynx Lake, and 304 mm and 319 g (n = 104) in Hammer Lake in 2002. Lake Whitefish in Lynx Lake were dominated by young mature fish of 270 mm to 309 mm, followed by older, larger fish in the 350 mm to 369 mm size range (Rescan 2003). Age of Lake Whitefish was highly variable, but young mature fish (five to six years old) were the most abundant age class. Condition factor of Lake Whitefish was relatively uniform for size classes. The sex ratio for Lake Whitefish was close to one to one.

Multiple size classes of Lake Whitefish were also present in Hammer Lake, with young, mature fish the most abundant size class (Rescan 2003). Weight was highly variable within and among year-classes, particularly in younger mature fish. Condition of Lake Whitefish in Hammer Lake was relatively uniform for size-classes. The condition factor was slightly lower than in Lynx Lake, and similar to other Lake Whitefish populations in the Lac de Gras watershed. The sex ratio of Lake Whitefish was close to one to one. Lake Whitefish in Lynx and Hammer lakes appeared to spawn earlier than southern counterparts, as is common with other fall-spawning northern populations (Scott and Crossman 1973).

In Paul Lake in 2013, Lake Whitefish fork length ranged from 297 to 514 mm (n = 26). Half of the fish (50%, n = 13) were in the 351 to 400 mm and 401 to 450 mm size range bins combined and a large proportion of fish (38%, n = 10) were between 451 and 500 mm. The mean fork length of Lake Whitefish in Paul Lake from 2013 was 437 mm, approximately 8% smaller than in Lac du Sauvage. The results of the length-weight regressions identified a slope approaching 3.0 (where 3.0 = isometric growth) for Lake Whitefish in Paul Lake (2.96), less than the slope reported for Lac du Sauvage (3.13) (Table 9.2-13). There were no small size classes of fish potentially representing YOY and yearlings in the catch in Paul Lake.

9.2.5.3 *Arctic Grayling*

9.2.5.3.1 General Life History

Arctic Grayling are found in freshwater systems throughout the central Canadian Arctic and typically rely on a variety of habitats including lakes, rivers, and streams to complete their life cycle (reviewed in Scott and Crossman 1973; Evans et al. 2002; Richardson et al. 2001). Adult and juvenile fish spend the winter sheltered in lakes, or deeper pools of rivers. During spring break up, adults of some Arctic Grayling populations will begin their migration from lakes and larger rivers to smaller streams and tributaries with areas of small gravel or rocky substrates to spawn (Scott and Crossman 1973).

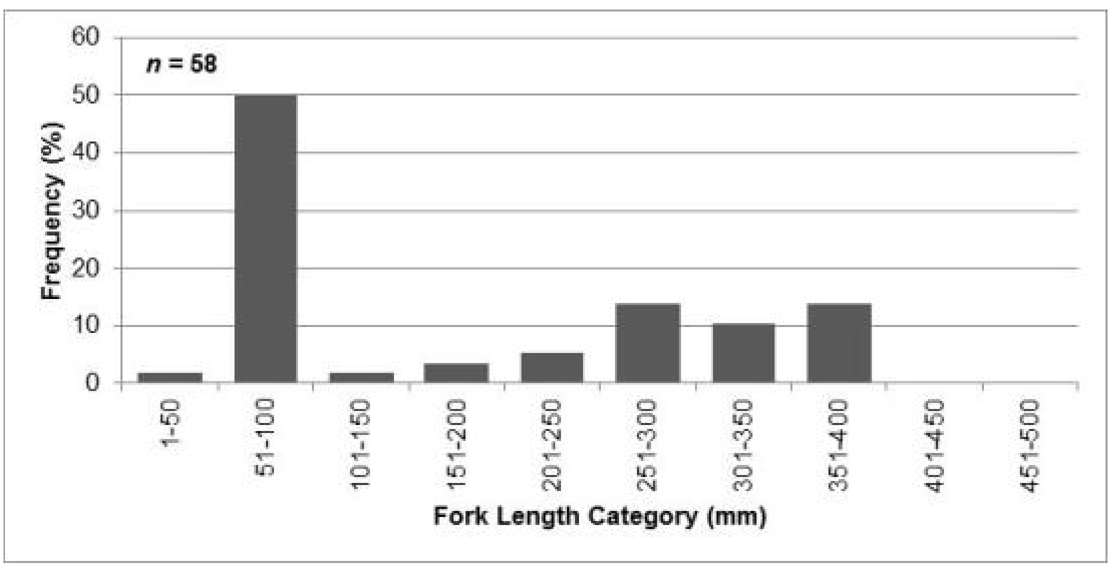
Spawning can occur over several weeks in the spring. They spawn during the warmer part of the day, as water temperatures reach 5°C to 10°C. Females deposit eggs over small gravel and cobble to be fertilized, and then adults return to larger rivers and lakes. Eggs incubate for 13 to 18 days. Upon hatching, young fish, approximately 8 mm in length, spend the next eight days sheltered in the substrate while absorbing their yolk sac and starting to feed. Male and female Arctic Grayling have been noted to reach maturity at 3 to 6 years of age, but most spawners are between 6 and 9 years of age (Bishop 1971; Scott and Crossman 1973). Arctic Grayling may live as long as 12 years.

Young Arctic Grayling feed primarily on zooplankton in streams and shallow water of lakes, shifting to immature insects as they grow in size (reviewed in Stewart et al. 2007a). Adult Grayling are primarily planktivorous (Schmidt and O'Brien 1982), although they will feed on a large assortment of invertebrates, including aquatic and terrestrial insects in streams and shallow water of lakes (Scott and Crossman 1973). In general, they are opportunistic in their feeding habits and their diet is extremely variable compared to other species (Bishop 1967; de Bruyn and McCart 1974).

9.2.5.3.2 Life History in the Baseline Study Area

In the BSA from 2006 to 2013, Arctic Grayling ranged from 50 to 385 mm in length and approximately half of the catch comprised YOY and yearling age classes (Annex XIV; Table 9.2-12, Figure 9.2-47). Most of the YOY Arctic Grayling (fork length less than 100 mm) were captured in streams [B1 (Christine), B15, C1, C3, D1], but were also found in Lake C1, Lake D2, and Lake D3 (Counts). Juvenile Arctic Grayling (fork length between 101 and 385 mm) were typically found in lakes [Paul Lake, Lake D2, and Lake B4 (Cujo)], with a few captured in streams (C1 and D1).

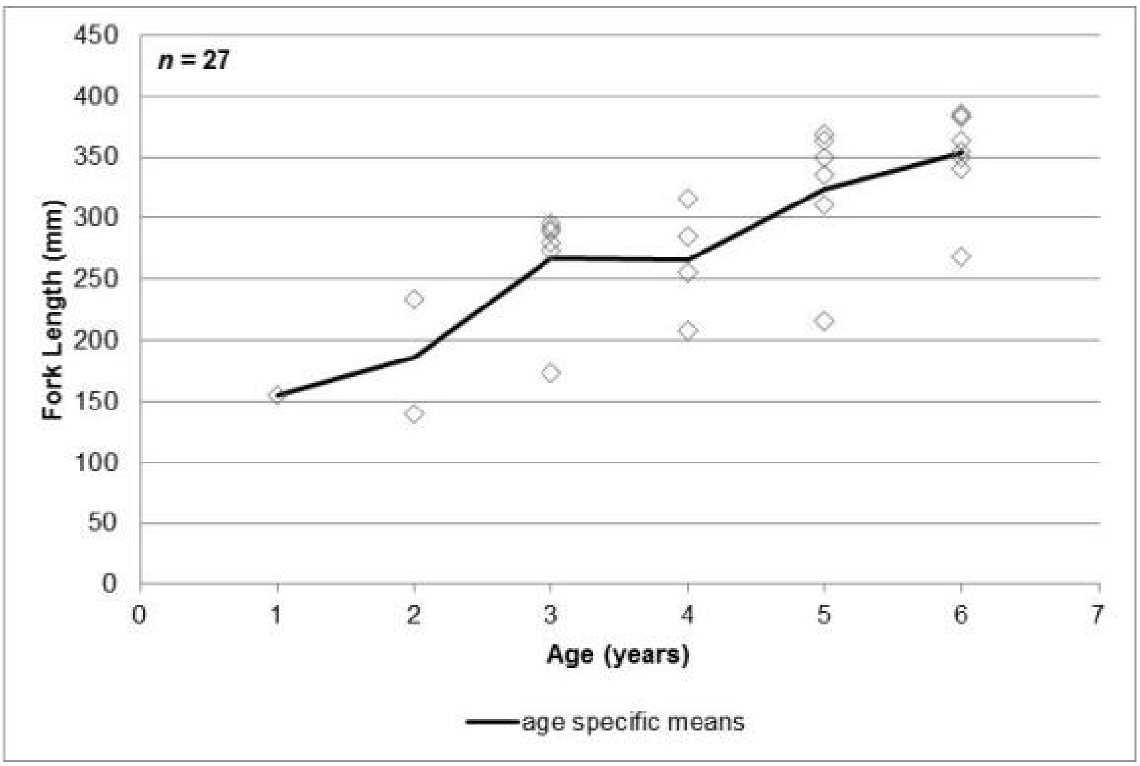
Figure 9.2-47 Overall Length-Frequency of Arctic Grayling Caught in the Baseline Study Area, 2012 and 2013



% = percent; n = number of samples; mm = millimetre.

In 2013, Arctic Grayling ages ranged from 1 to 6 years (n = 27, mean = 4 years, SD ± 1.5) (Figure 9.2-48). Most of the fish were aged 3 years and up (n = 24). The youngest fish (1 year old) was caught in Paul Lake and was approximately 150 mm in length. Most of the fish in the aged sample were captured in Lake B4 (Cujo) (n = 9) and Lake D2 (n = 8). The results of the length-weight regressions identified a low slope (i.e., below 3.0; 3.0 = isometric growth) for Arctic Grayling in Stream B1 (Christine Creek) (1.75) (Table 9.2-13). All of the captured Arctic Grayling in Stream B1 were YOY. The slopes for Lake Whitefish in other waterbodies in the BSA were above 3.0, with the highest slope recorded in Lake B4 (Cujo) (3.23).

Figure 9.2-48 Overall Age-Length Relationship for Arctic Grayling Caught in the Baseline Study Area, 2013



n = number of samples; mm = millimetre.

Lac du Sauvage

Only one Arctic Grayling was captured or observed in Lac du Sauvage from 2006 to 2013. However, Golder (1998a) provided detailed life history information for 49 Arctic Grayling captured in Lac du Sauvage (Table 9.2-15). The mean age, length, and weight of males (n = 27) was 6.1 years, 379 mm, 712 g, respectively, with a mean condition factor of 1.23. The mean age, length, and weight of females (n = 12) was 5.8 years, 367 mm, and 692 g, respectively, with a mean condition factor of 1.36. Ten individuals with their sex not identified had mean age, length, and weights of 4.7 years, 303 mm, and 353 g, with a mean condition factor of 1.17. On average, the Arctic Grayling in Lac du Sauvage were shorter and lighter than fish from Lac de Gras, but had a slightly higher condition factor (Golder 1998a) (Table 9.2-15).

Table 9.2-15 Select Life History Characteristics of Arctic Grayling in Lac de Gras, and Lac du Sauvage for Comparison

Variable		Male		Female		Unknown	
		LDS	LDG	LDS	LDG	LDS	LDG
	n	27	25	12	12	10	4
Age (years)	Mean	6.1	6.2	5.8	6.6	4.7	2.8
	SD	0.9	1.5	0.8	0.5	1.9	0.5
Length (mm)	Mean	379	396	367	409	303	164
	SD	50	67	36	13	86	28
Weight (g)	Mean	712	806	692	891	353	38
	SD	308	287	196	109	185	14
Condition	Mean	1.23	1.20	1.36	1.29	1.17	0.86
	SD	0.13	0.08	0.15	0.10	0.35	0.17

Source: Golder 1998a

LDS = Lac du Sauvage, LDG = Lac de Gras, n = sample size, SD = standard deviation; mm = millimetre; g = gram.

The mean fork length and weight of Arctic Grayling captured in 2013 in Lake B4 was 219 mm, and 287 g (Table 9.2-12). This was approximately 23% larger by length than Arctic Grayling from all waterbodies in the BSA combined. Fish captured in Lake D2 in 2013 had the highest reported mean fork length (269 mm) and weight (355 g). The mean fork length and weight of Arctic Grayling captured in Stream B1 were 89 mm and 2 g, slightly smaller than those captured in other streams sampled in the BSA (129 mm and 54 g) (Table 9.2-12).

Lac de Gras

Life history information for Arctic Grayling in Lac de Gras was summarized in Golder (1998a) (Table 9.2-15). Additional information for Lac de Gras tributary lakes and streams is also provided below. Golder (1998a) reported that male Arctic Grayling in Lac de Gras had a mean age, weight, length, and condition factor of 6.2 years, 806 g, 396 mm, and 1.20, respectively. The mean age, weight, length, and condition factor of female Arctic Grayling in Lac de Gras was 6.6 years, 891 g, 409 mm, and 1.29, respectively. Arctic Grayling were found to first reach sexual maturity at 5 years of age in Lac de Gras.

Golder (1997a) observed adult Arctic Grayling in 13 of the 32 Lac de Gras tributary streams surveyed in June 1996, and fertilized eggs provided evidence of their occurrence in three additional streams. In these streams, Arctic Grayling spawned over a wide range of habitats, including gravel, cobble, boulder, sand/silt, and organic material, but showed a preference for distinct habitat features such as shallow runs with low instream cover and boulder/cobble substrate, and pools greater than 1.5 m deep with high instream cover. The highest densities of spawning Arctic Grayling were observed in streams containing several pools with fast-moving run habitat just above or below them.

9.2.5.4 *Forage Species*

Forage fish species are an important component of the diets of predatory fish species, such as Lake Trout (VC species), as well as Northern Pike and Burbot. Lake Whitefish (VC species) are generally bottom feeders, but may occasionally feed on small forage fish. Arctic Grayling (VC species) feed primarily on aquatic and terrestrial insects, but may consume small fish on rare occasions. The availability of forage fish species as a food source in lakes and rivers of the BSA is therefore essential in assessing aquatic health, and viability of VC species populations. The following subsections describe the general life history and distribution of common forage species in the BSA: Round Whitefish, Cisco, Slimy Sculpin, Ninespine Stickleback, and Lake Chub.

9.2.5.4.1 Round Whitefish

Round Whitefish populations can be fluvial, adfluvial, or anadromous, and are commonly found in large rivers and lakes in NWT and Nunavut (reviewed in Scott and Crossman 1973; Richardson et al. 2001; Stewart et al. 2007b). They have been captured or observed in most of the lakes of the BSA, including Lac du Sauvage, Lac de Gras, Duchess Lake, Paul Lake, Lynx Lake, Hammer Lake, Lakes B4, B15, C1, C3, D2, and D3, and in lakes of the Koala watershed (Annex XIV; ERM Rescan 2013).

Round Whitefish spawning occurs from fall to early winter, when water temperatures cool to less than 2.5°C. Gravel and cobble-sized rubble substrates are preferred for spawning (Normandeau 1969; Richardson et al. 2001). Males usually arrive on the spawning grounds first. Once the females arrive, the fish will form pairs, rather than large spawning schools (Scott and Crossman 1973). Round Whitefish broadcast their eggs over the substrate, typically in water less than 1 m deep (Normandeau 1969). Hatching time will vary, depending on water temperatures, but generally occurs between March and May (Goodyear et al. 1982).

After emerging from the eggs, the young are generally found near the bottom and are associated with rock, sand, and gravel substrates (Goodyear et al. 1982). Adult Round Whitefish tend to be found over rocky substrates and often in association with boulders (McPhail and Lindsey 1970). They are commonly found in shallow areas of lakes or slow-flowing rivers and streams, and in brackish waters (McPhail and Lindsey 1970; Scott and Crossman 1973). Preferred habitats include areas with currents, such as outlets of lakes.

The diet of Round Whitefish consists of a variety of benthic invertebrates, primarily mayfly, caddisfly, chironomid larvae, small crustaceans, fishes, and molluscs (Scott and Crossman 1973). Round Whitefish are suspected to feed on the eggs of other fish species (Scott and Crossman 1973). They are known to be a key component of the diet of Lake Trout in northern environments (Scott and Crossman 1973).

9.2.5.4.2 Cisco

Common Cisco (also known as Lake Herring) have the most extensive North American distribution of any Cisco species and are found throughout much of Canada, including the central Canadian Arctic (reviewed in Scott and Crossman 1973; Evans et al. 2002; Richardson et al. 2001). Cisco are largely a lake species, and within the BSA they were found in large to medium sized lakes, including Lac de Gras, Lac du Sauvage, and Duchess Lake (Scott and Crossman 1973; Annex XIV).

Common Cisco primarily inhabit the pelagic zone of lakes but move below the thermocline in the summer and into shallow waters as the water temperature cools in fall (Scott and Crossman 1973). Cisco are an important prey species for larger predatory fish in northern fish communities, especially Lake Trout and Burbot.

Cisco spawn in the fall (September/October) with water temperatures between 3°C and 5°C. During the spawn, large numbers of fish gather in shallow water (1 to 3 m deep) to deposit their eggs over gravel or stony substrates (Nelson and Paetz 1992; Scott and Crossman 1973). Eggs incubate over winter and hatch in the spring. Cisco typically reach maturity when approximately five years old.

9.2.5.4.3 Slimy Sculpin

Slimy Sculpin are found throughout much of the central Canadian Arctic (reviewed in Scott and Crossman 1973; Richardson et al. 2001). They exhibit both lacustrine and riverine life histories, and can be found in deep lakes, cool-water rivers, and rocky or gravelly streams (Craig and Wells 1976; Lee et al. 1980; McPhail and Lindsey 1970; Scott and Crossman 1973). In the BSA they have been captured or observed in almost all streams and lakes sampled: Lac du Sauvage, Lac de Gras, Lakes B1, B4, B15, D2, D3, D4 and C1, Hammer Lake, Lynx Lake, streams B1, B15, C1, and D1, and in lakes of the Koala watershed (Annex XIV; ERM Rescan 2013).

Slimy Sculpin are usually associated with coarse substrate that provides in situ cover (Nelson and Paetz 1992). They spawn in spring (June/July) as water temperatures increase to more than 5°C (Scott and Crossman 1973). Spawning habits are not well known; however, Slimy Sculpin will spawn in lakes and streams, beneath large rocks and outcroppings, adhering eggs to the substrate (Scott and Crossman 1973). Sculpin typically reach maturity at age three.

Slimy Sculpin feed on a variety of benthic invertebrates, small fishes, and plant materials (McPhail and Lindsey 1970; Mohr 1984; Scott and Crossman 1973). Slimy Sculpin are eaten by a variety of predaceous fishes including Burbot, Lake Trout, and Northern Pike, the top predators in the fish communities in Lac du Sauvage and Lac de Gras (Scott and Crossman 1973).

9.2.5.4.4 Ninespine Stickleback

Ninespine Stickleback occur in freshwater lakes, rivers, streams, estuaries, and river mouths (reviewed in Scott and Crossman 1973; Richardson et al. 2001). In the BSA they were captured or observed in Lac du Sauvage, Lac de Gras, Lake E1, Lake AC17, and Stream D1 (Annex XIV).

Ninespine Stickleback spawn in freshwater throughout the summer (reviewed in Scott and Crossman 1973; Richardson et al. 2001). Males construct a tubular nest of aquatic vegetation and anchor the nest to vegetation, off the bottom substrates. Males may build two nests in one season. Ninespine Stickleback reach maturity at the end of their first year. They feed on invertebrates, including insects and small crustaceans. Ninespine Stickleback are likely important prey for larger predatory fish species in the BSA.

9.2.5.4.5 Lake Chub

Lake Chub inhabit a wide variety of habitats, including lakes and rivers, but seem to prefer lakes (Scott and Crossman 1973), and exhibit lacustrine, adfluvial, and riverine life history types (Brown et al. 1970; Scott and Crossman 1973; Stein et al. 1973). In the BSA, Lake Chub have been captured or observed in Lake B1, Hammer Lake, and in lakes of the Koala watershed (Annex XIV; Rescan 2013).

Lake Chub mature in their third or fourth year (Carl et al. 1967), and spawn from April to early August in streams or along lake shores (Carl et al. 1967; Scott and Crossman 1973). As many as 500 eggs are laid, which hatch after approximately two weeks (Carl et al. 1967; Scott and Crossman 1973).

Lake Chub occur close to shore in the bottom water zone, but may seek deeper water in the summer as lakes warm (Carl et al. 1967; McPhail and Lindsey 1970; Scott and Crossman 1973; Lee et al. 1980). Adults prefer sand, cobble, and boulder substrates (Brown 1969; Machniak and Bond 1979; Becker 1983) and generally occur in shallow water (Becker 1983), but are also knows to use deep-water habitats (Brown 1969). Their diet is mostly composed of terrestrial and aquatic insects, algae, and zooplankton (McPhail and Lindsey 1970; Tripp et al. 1981).

9.2.6 Summary of Fish Tissue Chemistry

A consistent theme across previously completed tissue chemistry studies in the vicinities of the Diavik Mine and the Ekati Mine was natural variation in metal concentrations across time, space (both within and across lakes), and species (Appendix A, Historical Report Review in Annex XIV).

For fish tissue mercury levels, increases in the study lakes may reflect widespread increases in mercury in this part of northern Canada. Golder (2012) reported differences in mercury concentrations in Lake Trout muscle in Lac du Sauvage between 2008 and 2011, and general increases in mercury concentrations in Lac de Gras and Lac du Sauvage before the development of the Diavik Mine to 2011. Importantly, the increase in mercury concentration in Lac du Sauvage trout since baseline was greater than that observed in trout from Lac de Gras; thus, there was no clear indication that the mercury increase in Lac de Gras trout was a result of the Diavik Mine. Similar findings were reported for the Koala watershed and Lac de Gras areas as part of monitoring for the Ekati Mine.

Rescan (2008) reported that concentrations of several metals in Round Whitefish liver (barium, mercury, molybdenum, strontium) and muscle (aluminum, barium, mercury, molybdenum, strontium), and in Lake Trout liver (arsenic, mercury, molybdenum) and muscle (barium, mercury) were higher in 2007 versus levels recorded during baseline years, and that most increases appear to be due to natural variation. The mechanisms underlying changes in metal concentrations in tissue may be shifts in diet, increased metabolism, and/or natural changes in water and sediment chemistry.

Mine-related effects on fish tissue chemistry have also been reported in several historical reports. A tissue chemistry study completed by Golder (2008) concluded that there were several low-level and moderate-level effects observed for Slimy Sculpin in Lac de Gras. The moderate-level effects included elevated mercury concentrations in tissues in exposure areas, which were linked to the mine through observed changes in water quality and sediment quality. Golder (2010) also reported increases in tissue concentrations of bismuth, strontium, titanium, and uranium in Slimy Sculpin from near-field exposure areas in Lac de Gras. These increases were linked to mine-related activities through observed changes in water and sediment chemistry.

As expected, trends in fish tissue chemistry were species-specific. Lake Trout were consistently reported as having high concentrations of mercury, owing to its top trophic position in the food web and susceptibility to effects from bioaccumulation as a relatively large, long-lived species. Rescan (2008) also reported elevated mercury concentrations in Slimy Sculpin in Lac de Gras, but there was no clear indication that the mercury increase in Lac de Gras Lake Trout was a result of the Diavik Mine.

From a human health perspective, with the exception of the largest fish, mercury levels found in Lake Trout from Lac de Gras and Lac du Sauvage were generally below Health Canada's maximum acceptable levels for the edible portion of retail fish (0.5 micrograms per gram wet weight [µg/g ww]) (Golder 2012).

9.2.7 Summary of Local and Traditional Knowledge

The proposed Project is located within lands that have traditionally been used by members of the present-day Inuit, Dene, and Métis communities in NWT and Nunavut, as described in detail in Annex XVII (Traditional Land Use and Traditional Knowledge Baseline Report). Traditionally, Aboriginal groups supported themselves by harvesting resources from the land through activities such as hunting, fishing, trapping, and gathering berries and other plant materials.

In the Lac de Gras area, people often camped near areas where caribou, fish, and water were available such as on small bays along the shore, on protected islands, and areas where channels with swift currents kept the water open in winter, including the Lac du Sauvage-Lac de Gras Narrows. The Narrows (a relatively short stream connection between Lac du Sauvage and Lac de Gras) was identified as a fishing location, particularly during winter because of the swift currents that keep that channel open (Weledeh Yellowknives Dene 1997). Traditional knowledge also identifies this area as potential spawning habitat. Other potential spawning locations include locations above and below the Narrows, and adjacent to the western shoreline of Lac du Sauvage in internal basin Ac.

Fishing was a secondary but important activity (after hunting caribou) that was traditionally practiced at Lac de Gras and the surrounding area. Lac de Gras is known as a good source of large, fat fish. Fish were the main commodity in summer for people and dogs. Fish were also routinely dried and saved for use during the fall and winter hunts since they were light and easy to pack. In the winter, fishers used nets made of willow and babiche under the ice (Weledeh Yellowknives Dene 1997).

Previously completed environmental assessments in the NWT have noted several concerns about the effects of mining near Lac de Gras on local aquatic resources:

- The Tłįchǫ Dene have expressed their concern with the destruction of the lands and waters and the effects the mine will have on their ability to fish at Ek'atì area (DCI 1995). Protecting the sediment, vegetation, and migration routes for the resident species is important to maintain the fish health and productivity in the area (Weledeh Yellowknives Dene 1997).
- The Yellowknives Dene have noted concerns about the effects on fish populations of spilled oil and winter roads.

The potential effects on fish, in particular, have been identified as including the overall sustainability of fish populations and the long-term impacts on fish health as a result of lost habitat and changes in migration patterns, including:.

- Although the Lac du Sauvage-Lac de Gras Narrows are not being directly disturbed, the Métis have expressed concern about the effects that mining will have on fish and fish habitat in Lac de Gras (BHP 1995b). The Métis have also identified blasting, dust, sedimentation during runoff, and increased metals and nutrients as having potential effects for fish in the waters around Lac de Gras.
- The Inuit have expressed similar concerns about the effect of contaminants from the tailings pond, leaks, spills, and dust. They want to ensure that the quality of the water and the health of the fish throughout the Coppermine River watershed are protected. Fish remain a main staple for the Inuit and a decrease in the health and populations of fish would be detrimental (BHP 1995c).

9.3 Pathway Analysis

9.3.1 Methods

Pathway analysis identifies and assesses the linkages between Project components or activities, and the corresponding changes to the environment and potential residual effects (after mitigation) to fish and fish habitat VCs. The first part of the analysis identifies all potential effects pathways for the Project. Each pathway is initially considered to have a linkage to potential effects on the VCs. Potential pathways through which the Project could affect VCs were identified from the following sources:

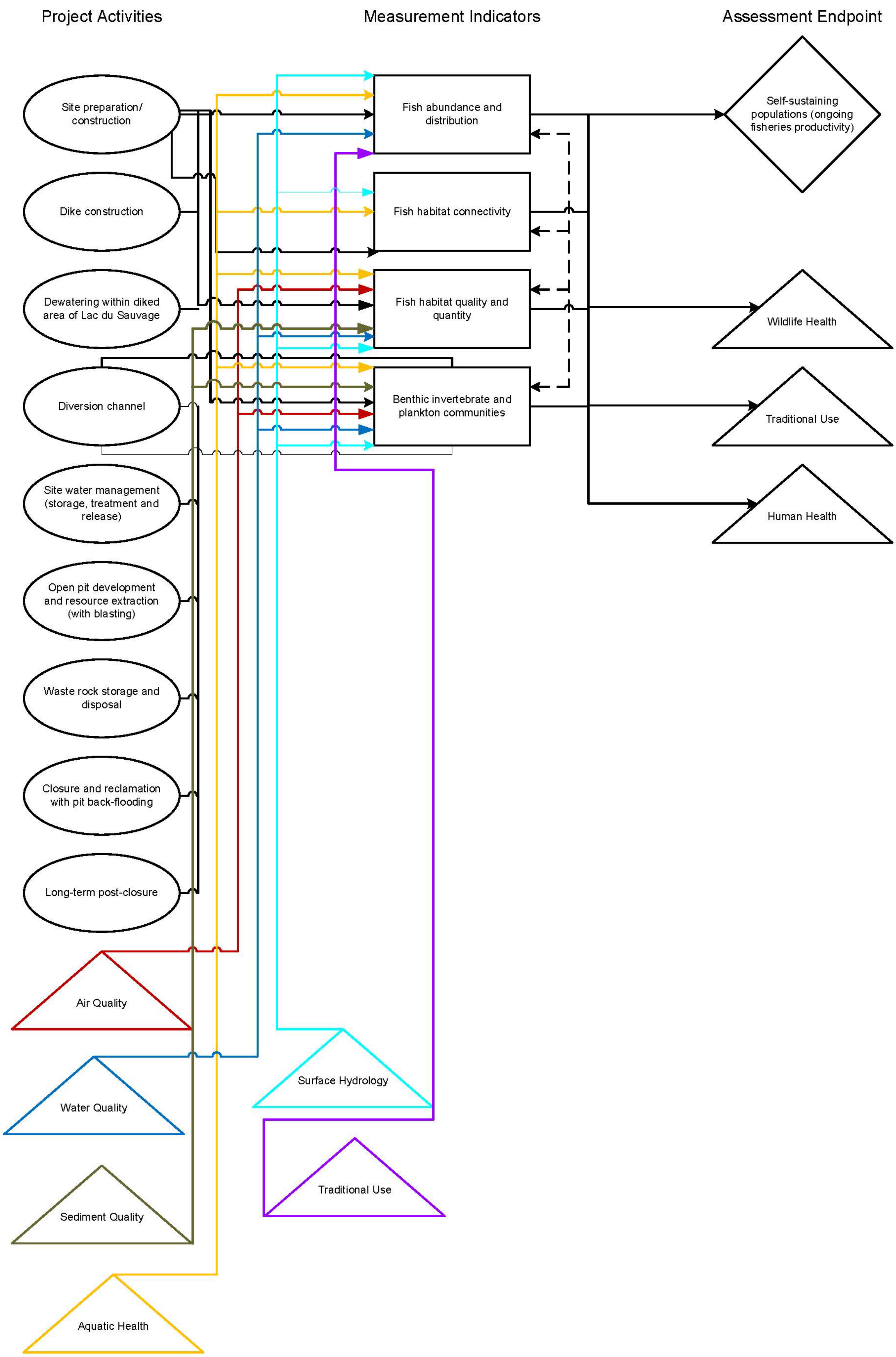
- a review of the Project Description and scoping of potential effects by the environmental and engineering teams for the Project;
- local and traditional knowledge obtained from community scoping sessions in Behchokǫ̀, Yellowknife, and Łutselk'e, and a technical scoping session in Yellowknife (Section 4);
- scientific knowledge and experience with other mines in the NWT; and,
- consideration of potential effects identified from the TOR.

For an effect to occur there has to be a source (Project component or activity) that results in a measurable change to the environment (pathway or measurement indicator) and a corresponding effect on the VC.

Project Activity → **Change in Environment** → **Effect on VC**

Figure 9.3-1 depicts potential effects from Project activities on fish and fish habitat VCs before mitigation. Each pathway or line in the diagram was initially considered to have a linkage to these VCs.

Figure 9.3-1 Linkage Diagram Identifying Potential Effects on Valued Components for Fish



Note: Ovals represent Project activities, rectangles represent measurement indicators, triangles represent connections to and from other disciplines, and the diamond represents the assessment endpoint.

A key aspect of the pathway analysis is to identify environmental design features and mitigation that might reduce or eliminate potential effects of the Project to VCs, and includes application of the precautionary principle (Section 6.2.1). Environmental design features include engineering design elements, environmental best practices, management policies and procedures, and spill response and emergency contingency plans. Environmental design features and mitigation were developed as an integral part of the Project's design through an iterative process between the Project's engineering and environmental teams to avoid or mitigate adverse effects identified by the pathways analysis.

After applying environmental design features and mitigation, a screening level analysis is used to determine the existence and magnitude of linkages from the initial list of potential effects pathways for the Project. This screening step is largely a qualitative assessment and is intended to focus the effects analysis on pathways that require a more comprehensive assessment of effects on fish and fish habitat VCs. Pathways are determined to be primary, secondary (minor), or as having no linkage, using scientific, local and traditional knowledge, logic, and experience with similar developments and environmental design features and mitigation. Each potential pathway is assessed and described as follows:

- no linkage – analysis of the potential pathway reveals that there is no linkage or the pathway is removed by environmental design features or mitigation such that the Project would not be expected to result in a measurable environmental change and would therefore have no residual effect on VCs relative to the Base Case or guideline values; or,
- secondary – pathway could result in a measurable minor environmental change, but would have a negligible residual effect on VCs relative to the Base Case or guideline values and is not expected to contribute to effects of other existing, approved, or reasonably foreseeable projects to cause a significant effect; or,
- primary – pathway is likely to result in environmental change that could contribute to residual effects on VCs relative to the Base Case or guideline values.

Pathways with no linkage to fish and fish habitat VCs are not assessed further because environmental design features or mitigation will remove the pathway. Pathways that are assessed to be secondary and demonstrated to have a negligible residual effect on VCs through simple qualitative or semi-quantitative evaluation of the pathway are also not advanced for further assessment. In summary, pathways determined to have no linkage to fish and fish habitat VCs or those that are considered secondary are not expected to result in environmentally significant effects to self-sustaining and ecologically effective fish populations. Primary pathways require further evaluation through more detailed quantitative and qualitative effects analysis (Section 9.4).

9.3.2 Results

9.3.2.1 *Review of Mitigation Effectiveness*

The mine plan utilizes a number of environmental design features and mitigation to eliminate or reduce the potential for Project activities to result in adverse environmental effects to fish and fish habitat. The effectiveness of mitigation related to blasting, fish screens, and diversion channels specific to fish and fish habitat is discussed below. In addition, mitigation to minimize effects to surface hydrology and water quality will also minimize potential effects to fish and fish habitat. A summary of the mitigation measures and associated effectiveness for the hydrology and water quality pathways is provided in Section 8.4.2.1.

9.3.2.1.1 Blasting

Mitigation measures will be implemented to minimize the effects of blasting in the Jay open pit on fish VCs in nearby waterbodies (i.e., Lac du Sauvage). All applicable Fisheries and Oceans Canada (DFO) recommended measures to avoid causing harm to fish from the use of explosives (DFO 2014b) will be considered when necessary to protect fish, and may include the following:

- avoiding the use of explosives in water;
- minimized blast charge weights and subdivided charges into a series of smaller charges in blast holes, with a minimum 25 millisecond delay between charge detonations;
- back-filling blast holes to grade with sand or gravel to confine blasts;
- placement of blasting mats over tops of blast holes to minimize scattering of blast debris;
- avoiding the use of ammonia nitrate based explosives to avoid the production of toxic by-products; and,
- removal of all blasting debris and associated materials from the blast area.

In addition to the above recommended measures, DFO also provides guidelines for the use of explosives in or near fish-bearing waters (Wright and Hopky 1998), which includes a maximum recommended limit for blast-induced overpressure (100 kilopascals [kPa]) and peak particle velocity (PPV) (13 millimetres/second [mm/s]). The guidelines provide a method for calculating setback distances to avoid impacts to fish from pressure changes and to incubating eggs from increased PPVs (i.e., vibrations in spawning beds) (Wright and Hopky 1998). Several studies have demonstrated the effectiveness of setback distances in preventing impacts to fish (e.g., Faulkner et al. 2006; Faulkner et al. 2008).

Faulkner et al. (2006) assessed the effects of blasting at the Diavik Mine on incubating Lake Trout eggs in Lac de Gras. The report found that after 20 days (period of greatest egg sensitivity to physical disturbance), mortality was lower at two of three sites within 220 m of the A154 Pit dike where PPVs exceeded guidelines, than at a reference location (2 km away from the pit). Mortality at the third site did not differ from the reference site. Analysis of eggs retrieved after ice-out showed that only 10% of eggs from one site (one that used non-natural substrate from dike construction) had higher mortality than at the reference site, while mortality at the other two sites did not differ from the reference level. The largest blast exposure (28.5 mm/s) throughout the incubation period was more than double the DFO guideline for PPV, and since it produced egg mortality levels similar to the reference location, Faulkner et al. (2006) concluded that current DFO guidelines provide ample protection.

There are currently procedures at the Ekati Mine for the storage and handling of explosives, as well as for blasting. Based on the findings of Faulkner et al. (2006) and other monitoring of fish populations at Lac de Gras, DDMI concluded that direct effects of the use explosives on fish at the Diavik Mine were less than predicted in the environmental assessment (DDMI 1998a), and were negligible (DDMI 2007a). Monitoring of mine-related effects on fish and fish habitat at the Ekati Mine, likewise provides no evidence of direct effects of explosives on fish (Rescan 2002, 2007, 2009; ERM Rescan 2013).

9.3.2.1.2 Fish Screens

Water pumping or withdrawals from fish-bearing waterbodies will be required during construction of the dike around the Jay Pit area in Lac du Sauvage, during dewatering, for operational needs, and during back-flooding of the Jay Pit and dewatered area at closure. Fish screens will be placed on all water intake pipes in fish-bearing waterbodies to minimize potential harm to fish. Where water withdrawal occurs within a fish-bearing waterbody, fish can be at risk of entrainment or impingement from the intake pipe. Entrainment occurs when a fish is drawn into a water intake and cannot escape, and impingement occurs when a fish becomes entrapped on an intake screen and is unable to free itself. All measures recommended by DFO to avoid causing harm to fish at screened water intake pipes (DFO 2014b) will be considered as potential mitigation to minimize entrainment and impingement of fish, and may include the following:

- the screened intake and outlet located in areas and at depths with low fish concentrations throughout the year;
- screens located away from natural or artificial structures that may attract fish that are migrating, spawning, or in rearing habitat;
- openings in the guides and seals less than the opening criteria to make “fish tight”;
- screens located a minimum of 300 mm above the bottom of the waterbody to prevent entrainment of sediment and aquatic organisms associated with the bottom area;
- screens designed with structural support that prevents the screen panels from sagging and collapsing;
- if using a large cylindrical or box-type screen, a manifold installed to ensure even water velocity distribution across the screen surface. The ends of the structure made out of a solid material and the end of the manifold will be capped; and,

- regular cleaning, maintenance, and repair of screens carried out to prevent debris-fouling and impingement of fish. Pumps shut down when screens removed.

DFO guidelines for fish screens on freshwater intake pipes (DFO 1995) provide further details on design recommendations. All guidelines will be considered in design, installation, and maintenance of fish screens on intake pipes for the Project. For example, fish screen selection may target protection of fish over 25 mm fork length. Fish smaller than 25 mm fork length are expected to be in rearing locations and not in close proximity to the intake pipes. Final details for design and implementation of DFO Guidelines will be finalized in discussion with DFO.

Several studies demonstrate the effectiveness of fish screens in preventing impingement and entrainment of fish at intake pipes with maximum approach velocities suitable to the species present (e.g., Katopodis 1994; Savitz et al. 1998; Peake 2004; Boys et al. 2013). Furthermore, the use of fish screens on intakes in fish-bearing waterbodies is already in place at the Ekati Mine, as well as other mine sites in the region (i.e., Diavik Mine) and is typically a condition of water licences. As a result, it is technically and economically feasible to use appropriately designed fish screens for the Project. Water intake monitoring results at Diavik Mine have also shown the effectiveness of fish screens in preventing fish entrainment during both normal and high flow scenarios (DDMI 2004, 2007a), and no significant impacts to fish from intake pipes at Diavik and Ekati mines have been identified by monitoring programs (Rescan 2009; Rio Tinto 2011).

9.3.2.1.3 Diversion Channel

A diversion channel (Sub-Basin B Diversion Channel) will be constructed (approximately 1,275 m in length) to divert water that originally flowed from sub-basin B into the dewatered portion of Lac du Sauvage, away from the pit and into the area of Lac du Sauvage outside of the dewatered area. The diversion channel will convey water from two fish-bearing streams, Stream B0 downstream of Christine Lake and Stream Ac35, a small ephemeral stream downstream of Lake Ac35. The diversion channel will be designed as a mitigation measure to facilitate fish passage to upstream locations. The use of artificial fishways, such as diversion channels, for fish passage is a common method of maintaining habitat connectivity when interrupted by human developments (i.e., roads, mines, irrigation, and hydropower facilities) (DFO 2007; MDNR 2010; Roscoe and Hinch 2010; Noonan et al. 2012).

The proposed Sub-Basin B Diversion Channel will be trapezoidal in shape with a bottom width of 1.5 m, a lined depth of 1.5 m, 2H:1V side slopes, and a 0.1% minimum longitudinal slope. The channel will be lined with rip-rap, underlain by a 0.15 m thick drainage layer of cobble-sized substrate and non-woven geotextile. The diversion channel slopes will also be designed for water velocities (goal of less than 1.0 m/s, on average) which permit upstream passage of target species (i.e., adult Arctic Grayling, and to a lesser extent, Lake Trout), based on their swimming abilities (Jones et al. 1974; Katopodis 1994; Peake 2008; Katopodis and Gervais 2012). In particular, maintaining minimal flows that coincide with life histories (e.g., spawning migrations, young-of-year migrations) will be considered in channel design, as appropriate.

The proposed diversion channel site crosses relatively flat topography starting at approximately 419.4 m within sub-basin B, emptying in Lac du Sauvage at an elevation of approximately 415 m above sea level. This path is similar to naturally occurring streams in the BSA (see Annex XIV; Jones et al. 2003).

Estimated velocities in the channel for the 1 in 2 year design flow (1.37 m^3/s for both sub-basins combined) is 0.53 m/s along the minimum channel slope (0.1%) and 1.70 m/s along the 50 m section of the channel near the mouth at Lac du Sauvage (2.5%).

To prevent potential barriers to fish passage at any of the proposed road crossings of the channel or upstream, culverts will be designed and installed in such a manner to maintain adequate flows and velocities for fish passage, using appropriate federal and territorial guidelines (e.g., Government of Alberta 2009; DFO 2014b). A double barrel design, offset by approximately 600 mm, will mitigate the risk of ice blockages occurring simultaneously in both barrels. Furthermore, during low flow periods, the discharge will be conveyed in the lower culvert, which will facilitate fish passage. Small rock weirs will be placed immediately downstream of the culvert outlets to backwater the culverts, further facilitating fish passage at low flow. The following maintenance activities will be considered for the life of the mine to further support the success of the diversion channel in providing fish passage:

- regular inspection and maintenance of outlet channels and culverts to remove accumulated sediment and soil/rock fall material;
- inspection of culvert inlets and outlets for ice and snow build-up before freshet, and removal of any accumulated ice and/or snow; and,
- repair of damaged channel linings immediately to limit the potential for erosion and breach of channels.

Designing the Sub-Basin B Diversion Channel to facilitate fish passage between Lac du Sauvage and upstream watercourses and waterbodies is an effective, technically and economically feasible option to mitigate for lost habitat connectivity. As a diversion channel is necessary to divert water around the dewatered/pit area of Lac du Sauvage, this option only requires additional design features within the channel to moderate water velocities.

Passage structures and channels that attempt to mimic natural stream morphology and hydraulics have been effective for allowing upstream and downstream passage of a wide range species in Canada. For example, Arctic Grayling were found to migrate through nature-like culverts on the Liard highway in northern Canada (Katopodis 2005). Previously constructed diversion channels at the Ekati Mine have been effective in providing passage corridors for fish, and are examples from the BSA that demonstrate the successful application of fish biology principles to the construction of man-made channels (BHP Billiton 2010; Rescan 2012b). Baker Creek, a tributary of Great Slave Lake, NWT, provides another example of an artificial channel providing a migration corridor for Arctic Grayling. Baker Creek was diverted through a designed channel to separate the stream from contamination from an abandoned gold mine. The new reach of Baker Creek has successfully allowed passage of Arctic Grayling.

Overall, there is relatively low uncertainty associated with the effectiveness of the proposed diversion channel as a migration corridor for the main target species, adult Arctic Grayling. This assumes that the channel is constructed such that velocities and slopes are similar to natural streams in the area, there are adequate resting areas, and water velocities are within the published swimming capabilities of the target species. There is relatively more uncertainty associated with use of the channel by other species (e.g., Lake Trout) or juvenile life-stages, which may depend on instream cover, and rates of colonization by fish and other aquatic organisms.

9.3.2.2 *Pathway Screening*

Project components and activities, effects pathways and environmental design features and mitigation are summarized in Table 9.3-1. Classification of effects pathways (no linkage, secondary and primary) to fish and fish habitat VCs is also summarized in Table 9.3-1, and detailed descriptions are provided in the subsequent sections.

9.3.2.2.1 Pathways with No Linkage

A pathway may have no linkage to environmental effects if the activity does not occur, or if the pathway is removed by mitigation or environmental design features so that the Project results in no measurable change in measurement indicators. Subsequently, no residual effect to fish and fish habitat is expected. The pathways described below have no linkage to fish and fish habitat and will not be carried forward in the assessment.

Spills (i.e., fuels, petroleum products, reagents) on site may cause a change in surface water quality, affecting fish and other aquatic life

Spills during construction, operations, or decommissioning and reclamation activities have the potential to runoff and affect surface water quality, and therefore, fish and aquatic life. Spills that occur in high enough concentrations could contaminate water and cause direct toxicity to fish and aquatic life. Spills are generally preventable and local in nature.

Mitigation identified in the existing Ekati Mine Spill Contingency Plan and environmental design features will be in place to limit the frequency and extent of spills that have potential to occur during Project activities. Hazardous materials and fuel will be stored according to regulatory requirements to protect the environment and workers. Fuel storage for the Project is the existing Misery dispensing facility where fuel storage tanks are located in lined and bermed containment areas. Emergency spill kits will be provided wherever hazardous materials or fuel are stored and transferred. Hydrocarbon-impacted soil with average particle size less than 4 centimetres (cm) will be contained in the existing landfarm. Hydrocarbon-impacted soil that is unsuitable for on-site bioremediation will be temporarily stored in the landfarm until it is shipped off site for proper disposal (Section 3.4.1.8.5). Hydrocarbon-impacted snow and ice will be contained in the contaminated snow containment facility (Section 3.4.1.8.6). Individuals working on site and handling hazardous materials will be trained in spill response as per the spill contingency plan.

Failure of pipelines that are part of the minewater management areas (Lynx and Misery pits, pumping and pipeline systems, and sumps) could result in the release of sediment-laden and/or saline water to the surrounding environment. During the dewatering phase, the Lynx and Misery pits will be used as total suspended solids (TSS) management facilities. During operations, the Misery Pit will be used as the main water management facility for minewater management. The Jay sump will collect surface runoff water draining toward the diked area, which will be pumped to the Misery Pit for management. The mine inflows sump will collect groundwater inflows to the Jay Pit and direct precipitation, which will be pumped to the base of the Misery Pit.

Table 9.3-1 Potential Pathways for Effects to Fish and Fish Habitat

Project Activity	Valued Component	Effects Pathway	Relevant Environmental Design Features or Mitigation Practices	Pathway Assessment
Surface disturbance and construction activities • Construction or development of site access roads, pit, waste rock storage areas, quarries, support buildings	Fish Other Aquatic Life	Changes to local hydrology (subsurface water flows, drainage, lake levels, sediment yield) from surface disturbances during the construction phase may cause changes to water levels and flows, affecting channel/bank stability and habitat for fish and other aquatic life in downstream waterbodies	• The Project footprint disturbance area will be limited to the extent practical • Design of the Jay Project minimizes the construction of new buildings, roads, pads, or excavations • Where possible, road crossing construction in areas of potential spawning habitat will take place outside the spawning period for Arctic Grayling (approximately early May to mid-June) • Erosion and sediment control management practices (e.g., silt fences, runoff management) applicable to northern environments and already in place at the Ekati Mine will be used during construction around disturbed areas, where appropriate • Runoff and seepage from Project facilities will be managed where appropriate • Culverts will be installed or upgraded along site access roads, as necessary, to maintain drainage • Access roads will be as narrow as possible, while maintaining safe construction and operation practices • The road route alignment will be designed to minimize stream crossings and avoid sensitive habitat as feasible; where feasible, crossings will be perpendicular to watercourses • Where practical, natural drainage patterns will be used to reduce the use of ditches and diversion berms • The Project footprint will be reclaimed at closure according to the approved Closure Plan	No Linkage
	Fish Other Aquatic Life	Changes to local hydrology (surface water flows, drainage patterns, lake levels, sediment yield) from surface disturbance may cause changes in water and sediment quality, affecting fish and other aquatic life in Lac du Sauvage, and contributing sub-basins (Ac35, B, and C)		No Linkage
	Fish Other Aquatic Life	Release of sediment during road construction at watercourse crossings and from land disturbance may cause a change in habitat quality, affecting fish and aquatic life in downstream lakes and streams and Lac du Sauvage	• Standard practices of erosion and sediment control (e.g., silt curtains, runoff management) already in use at the Ekati Mine will be used during construction around disturbed areas, where appropriate • Monitoring programs will be implemented to provide information to prompt corrective action if necessary • Where possible, road crossing construction in areas of potential spawning habitat will take place outside the spawning period for Arctic Grayling (approximately early May to mid-June) • Instream works will either be avoided or limited to when watercourses are not flowing, where possible • Runoff from facilities will be managed where appropriate to settle out suspended sediments before release	Secondary
	Fish	Cross-drainage structures for the mine site roads may alter stream hydraulics and geomorphology, affecting fish habitat and passage at stream crossings in sub-basins of Lac du Sauvage (sub-basin Ac35 and B)	• The road route alignment will minimize stream crossings and avoid sensitive habitat as feasible • Culverts will be designed to allow for fish passage where appropriate • Cross-drainage structures will be designed and constructed such that structures will provide a design conveyance for the 1:50 year event without overtopping the roadway • Regular inspections of roads and cross-drainage structures will be performed	Secondary
Construction of dike and diversion channel	Fish Other Aquatic Life	Release of sediment during construction of the horseshoe-shaped dike in Lac du Sauvage may cause changes in water quality, affecting fish and other aquatic life	• A detailed dike construction plan will be developed and implemented • Erosion and sediment control measures will be implemented in Lac du Sauvage during dike construction where appropriate (e.g., installation of silt curtains for turbidity control)	Secondary
	Fish Other Aquatic Life	Displacement of Lac du Sauvage water by dike material during construction may cause changes to water levels, flows and channel/bank stability in Lac du Sauvage and downstream waterbodies, affecting fish and other aquatic life		No Linkage
	Fish	The construction of the horseshoe dike may isolate populations of fish in contributing sub-basins of Lac du Sauvage, affecting local populations of Arctic Grayling, Lake Trout, and Lake Whitefish in the diverted sub-basins	• A diversion channel will be constructed to maintain habitat corridors between Lac du Sauvage and waterbodies in the sub-basin B and Ac35 area	No Linkage
	Fish Other Aquatic Life	The construction of the horseshoe dike and diversion channel may alter access to tributary stream habitats to Lac du Sauvage, resulting in habitat loss for Arctic Grayling, Lake Trout, and Lake Whitefish	• A diversion channel will be constructed to maintain habitat connections for target fish species between Lac du Sauvage and the sub-basin B and Ac35 area	Primary
	Fish Other Aquatic Life	The construction of the horseshoe dike will result in the direct loss or alteration of habitat within Lac du Sauvage, affecting fish and other aquatic life within Lac du Sauvage and Lac de Gras	• The spatial extent of the mine footprint will be minimized, where possible • An offsetting plan will be developed with Fisheries and Oceans Canada (DFO) and with engagement of the local Aboriginal communities	Primary

Table 9.3-1 Potential Pathways for Effects to Fish and Fish Habitat

Project Activity	Valued Component	Effects Pathway	Relevant Environmental Design Features or Mitigation Practices	Pathway Assessment
	Fish	The construction of the diversion channel will result in loss of habitat downstream of the diversion, potentially affecting Arctic Grayling, Lake Trout, and Lake Whitefish in the diverting sub-basins (i.e., Ac35 and B)	• The diversion channel will be constructed to maintain habitat connections for target fish species between Lac du Sauvage and the sub-basin B and Ac35 • The diversion channel will be in place for operations only, and at closure, the natural stream channel will be re-established	Secondary
	Fish	The dike isolating the Jay pipe may provide spawning habitat for fish where any potential contaminants within interstitial spaces may affect survival of eggs or fry in Lac du Sauvage	• The dike will be constructed using granite rock and will not contain any potentially acid-generating rock or metal leaching material • Bentonite and other materials used for dike construction are sequestered within the central core of the dike	Secondary
Dewatering within the diked area of Lac du Sauvage	Fish	Dewatering Lac du Sauvage within the diked area will require removal of fish from the area	• A Fish-Out Plan will be developed and the fish-out will occur according to DFO guidance and with active participation of the local Aboriginal communities	Primary
	Fish	Dewatering Lac du Sauvage within the diked area may result in stranding and mortality of fish moving downstream from tributaries flowing into the diked area	• A diversion channel will be constructed to divert flows and fish migrating downstream to Lac du Sauvage • The spatial extent of the mine footprint will be minimized, where possible	No Linkage
	Fish Other Aquatic Life	Pumped dewatering discharges from the diked area of Lac du Sauvage may cause erosion of lake bottom sediments near the outfall in Lac du Sauvage and cause changes in water and sediment quality, affecting fish and other aquatic life	• The pumped discharge of water from the diked area to Lac du Sauvage will be limited to water that meets regulated water discharge criteria for total suspended solids (TSS) • Discharge water will be regularly sampled and monitored as part of the Dewatering Plan to enable corrective actions if necessary • If suspended solids concentrations are too high for the direct release of water to the natural environment, the water will be pumped to the Lynx or Misery pits • Discharge will be directed through properly designed structures to the lake environment to prevent erosion and sediment entrainment in the receiving waterbodies • The diffuser will be engineered to avoid excess sediment mobilization and turbulence	No Linkage
	Fish	The area of turbulence around the diffuser may affect fish distribution in Lac du Sauvage		No Linkage
	Fish Other Aquatic Life	Discharges from the dewatering of the diked area of Lac du Sauvage may change flows, water levels, and channel/bank stability in Lac du Sauvage, the Lac du Sauvage-Lac de Gras Narrows, and Lac de Gras, affecting fish and other aquatic life	• A Dewatering Plan will be prepared for the Wek’èezhìi Land and Water Board (WLWB) that will include locations for flow rates and water quality monitoring to meet regulatory requirements and enable corrective action if necessary • Discharge water will be regularly sampled and monitored as part of the Dewatering Plan • Direct discharge flow rates will be developed and maintained to eliminate potential for erosion • Channel banks at the Lac du Sauvage and Lac de Gras outlet channels will be monitored for evidence of erosion • Defined limits/pumping conditions will remain within Lac du Sauvage outlet capacity	Secondary
	Fish Other Aquatic Life	Discharges from the dewatering of the diked area of Lac du Sauvage may change flows, water levels, and channel/bank stability downstream in the Coppermine River, affecting fish and other aquatic life		No Linkage
	Fish Other Aquatic Life	Discharges from the dewatering of the diked areas of Lac du Sauvage may change water quality (suspended sediments) in the receiving waterbodies and affect fish and other aquatic life	• A Dewatering Plan will be prepared for the WLWB that will include locations and water quality monitoring to meet regulatory requirements and enable corrective action if necessary • Discharge water TSS concentrations will be regularly sampled and monitored as part of the Dewatering Plan • If suspended solids concentrations are too high for the direct release of water to the natural environment, the water will be pumped to Lynx or Misery pits	Secondary
	Fish Other Aquatic Life	The dewatering of the diked area will result in the direct loss or alteration of habitat in Lac du Sauvage, affecting fish and other aquatic life within Lac du Sauvage and Lac de Gras	• The spatial extent of the mine footprint will be minimized, where possible • An offsetting plan will be developed in consultation with DFO and with engagement of the local Aboriginal communities • The diked area will be back-flooded at closure and the area will be accessible for use by fish upon breaching of the dike • The rock slopes of the residual sections of dike that remain in the lake for closure may provide habitat for fish	Primary
Pit development	Fish	The use of explosives near fish-bearing water may cause injury or mortality to fish in Lac du Sauvage	• Blasting operations will follow DFO’s “Guidelines for the Use of Explosives in or Near Canadian Fisheries Waters” (Wright and Hopky 1998) for setback distances from fish-bearing waterbodies • Blasting and excavation will occur in the dewatered areas of Lac du Sauvage where no water or fish will be present	No Linkage

Table 9.3-1 Potential Pathways for Effects to Fish and Fish Habitat

Project Activity	Valued Component	Effects Pathway	Relevant Environmental Design Features or Mitigation Practices	Pathway Assessment
General operational activities • Pit development • Site water management • Surface infrastructure and support facilities • Storage of industrial, domestic, hazardous, and contaminated waste • Vehicle traffic along the access road and winter road	Fish Other Aquatic Life	Altered site drainage and runoff from facilities during operations may cause direct changes to water levels, flows, and channel/bank stability in Lac du Sauvage and the Narrows, affecting fish and other aquatic life	• The dike alignment has been designed to minimize the area within Lac du Sauvage as practicable and represents less than 5% of the Lac du Sauvage surface area • The water management plan was developed to minimize effects to hydrologic conditions • Defined limits/pumping conditions will remain within Lac du Sauvage outlet capacity	Secondary
	Fish Other Aquatic Life	Indirect effects from dewatering and placement of the waste rock storage area may cause changes in water levels and surface discharges in nearby tributary lakes and streams (i.e., sub-basin C), affecting available habitat for fish and other aquatic life	• The mine footprint will be minimized where possible	Secondary
	Fish Other Aquatic Life	Water supply requirements (mining and potable) for the Project may cause changes to water levels, flows and channel/bank stability in downstream waterbodies and streams, affecting fish and other aquatic life	• The Project will use existing potable water system at site; demand is not anticipated to increase beyond the currently authorized amounts • Freshwater for Ekati Mine operations is permitted to be drawn from Grizzly Lake, Little Lake, Thinner Lake (Misery Camp); the Long Lake Containment Facility provides recycled water for operation of the processing plant • Potable water is trucked from the Ekati Mine to the Misery camp • Raw water required for processing plant operations is taken from the Long Lake Containment Facility, where the fine tailings have settled and clear water is available • Site water management system is designed to recycle water, where practicable • Water withdrawal rates will be controlled to avoid adverse effects on the source water lakes	Secondary
	Fish Other Aquatic Life	Air and dust emissions (including sulphur dioxide, nitrogen oxides, and particulate matter) and subsequent deposition may cause a change in water quality which may affect fish and aquatic life in nearby surface waters	• Operating procedures for equipment and Project activities will be developed and adhered to reduce the potential for dust generation and air emissions (e.g., regular maintenance of equipment, use of low-sulphur diesel fuel) • Regular maintenance of equipment utilized for the Project will continue at the Ekati and Misery sites • Dust suppression measures will be applied as appropriate to haul roads, airstrip, laydown areas • Speed limits will be established on all roads to reduce production of dust • Equipment and vehicles will be equipped with industry-standard emission control systems • Conveyance and processing facilities will be enclosed	Secondary
	Fish	Impingement and entrainment of fish in intake pumps during construction and operation activities (e.g., dewatering) may cause injury and mortality to fish in Lac du Sauvage	• During pumping of water from areas that contain fish, appropriately sized fish screens that meet DFO guidelines will be fitted to pumps to limit fish impingement and entrainment	

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Table 9.3-1 Potential Pathways for Effects to Fish and Fish Habitat

Project Activity	Valued Component	Effects Pathway	Relevant Environmental Design Features or Mitigation Practices	Pathway Assessment
	Fish Other Aquatic Life	Operational activities and discharge (e.g., discharge of treated domestic wastewater, altered drainage, runoff from facilities, including waste rock storage areas, pit inflows, dike seepage, release of nitrogen compounds from blasting residues, fine processed kimberlite management) may change surface water quality and affect fish and other aquatic life in Lac du Sauvage and Lac de Gras	• Rock mined from the Jay open pit will be managed according to established procedures (i.e., thermal cover over metasediment rock) to limit acidic seepage from these facilities • Rock used to construct the dikes will be non-potentially acid generating • Seepage management will be addressed as described in the Waste Rock and Ore Storage Management Plan (regular monitoring and adaptive management actions as necessary) • Minewater will be collected and managed • Appropriate explosive management practices (e.g., storage and handling controls, spill and waste management, blast design efficiency, minimize overloading, minimizing misfires) will be undertaken on site, consistent with practices already in place at the Ekati Mine • Use of Misery Pit allows for minewater to be stored and not discharged until Year 5 of operations • Operational discharge will meet water quality discharge criteria • Discharge water will be regularly sampled and monitored • Water and sediment quality in the receiving waterbodies will be monitored under the Aquatic Effects Monitoring Program, enabling adaptive management actions if necessary • The pumped discharge will be directed through a properly designed diffuser to prevent erosion • Discharge flow rates will be developed and maintained to eliminate erosion concerns • The diffuser discharge ports will be located above the lake bed to minimize erosion • The diffuser will be located in a sufficient depth of water with the ports directed at such an angle as to minimize the potential influence on surface ice • Sewage from the Jay/Misery sites will be trucked to the main camp sewage facility where the existing enclosed sanitary sewage treatment plant treats all domestic wastewater to primary and secondary levels of treatment • Treated effluent from the sewage treatment plant is pumped to the processing plant and discharged to the Long Lake Containment Facility as per existing Ekati operations • Fine processed kimberlite will be managed at existing Ekati facilities (deposited into mined-out Panda and Koala open pits with minewater from the processing plant pumped to the Long Lake Containment Facility during operations) • The Ekati Mine Wastewater and Processed Kimberlite Management Plan, which already anticipates the use of Panda and Koala open pits for fine processed kimberlite deposition, will be updated to incorporate the Project	Primary
	Fish	The area of turbulence around the diffuser may affect fish distribution in Lac du Sauvage	• The pumped discharge will be directed through a properly designed diffuser to minimize effects from changes in velocity • Direct discharge flow rates will be developed and maintained to address erosion concerns	No Linkage
Back-flooding Jay Pit and dewatered area of Lac du Sauvage	Fish	Impingement and entrainment of fish in intake pumps during refiling activities may cause injury and mortality to fish in source waterbodies including Lac du Sauvage	• During pumping of water from areas that contain fish, appropriately sized fish screens that meet DFO guidelines will be fitted to pumps to limit fish impingement and entrainment	Secondary
	Fish Other Aquatic Life	Pumping water to back-flood the Jay Pit and diked area of Lac du Sauvage may affect water levels and riparian habitat in Lac du Sauvage and Lac de Gras, and water levels, flows, and riparian habitat in the Lac du Sauvage-Lac de Gras Narrows, affecting fish and other aquatic life	• Back-flooding rates and volumes will be managed to minimize effects in source waterbodies and downstream	Primary
	Fish Other Aquatic Life	Pumping water to back-flood the Jay Pit and diked area of Lac du Sauvage may affect flows, water levels, and channel integrity in the Coppermine River, affecting fish and aquatic life		Secondary
	Fish Other Aquatic Life	Pumping water to back-flood the Jay Pit and diked area of Lac du Sauvage may affect water quality in the source waterbody and downstream		No Linkage

Table 9.3-1 Potential Pathways for Effects to Fish and Fish Habitat

Project Activity	Valued Component	Effects Pathway	Relevant Environmental Design Features or Mitigation Practices	Pathway Assessment
	Fish Other Aquatic Life	Back-flooding of the dewatered diked area of Lac du Sauvage may generate or release mercury, nutrients or other substances from flooded sediments and vegetation and may cause a change in water quality, affecting fish and aquatic health	• The Project will be included in the Ekati Interim Closure and Reclamation Plan; this plan will be updated as per regulatory requirements through operations and adhered to through closure • Water quality monitoring will be conducted during the back-flooding period • The dike will not be breached to provide connectivity to Lac du Sauvage until water quality meets acceptability criteria	No Linkage
General closure and decommissioning activities • Removal of project infrastructure • Breaching/removal of dikes • Seepage from facilities, groundwater inflows, back-flooded Jay Pit	Fish Other Aquatic Life	Release of sediment during dike breaching/removal activities may affect water quality, affecting fish and other aquatic life in Lac du Sauvage	• Disturbed areas will be reclaimed and the surface stabilized for closure • Erosion and sediment control management practices, applicable to northern environments, will be implemented where appropriate • A closure plan will be developed which will include management of dike breaching / removal activities to limit the potential for effects on the environment • Breaching and removal of dikes will only occur when water quality within the diked area meets acceptability criteria • Drainage patterns will be re-established where practicable, including the Sub-Basin B Diversion Channel	Secondary
Post-closure, reconnection of back-flooded area with Lac du Sauvage and downstream	Fish Other Aquatic Life	Reconnection of the back-flooded area of Lac du Sauvage to the remaining watershed and post-closure releases of water (e.g., Misery Pit overflow and seepage, waste rock storage area runoff, Long Lake Containment Facility discharge) may change long-term water quality in Lac du Sauvage and Lac de Gras and affect fish and other aquatic life	• At closure, natural water levels in Lac du Sauvage will be re-established, restoring the natural groundwater flow gradient towards the lake • Water quality in the back-flooded area will meet acceptability criteria before the dike is breached to allow a reconnection with the main Lac du Sauvage basin • At the completion of mining of the Jay pipe, a portion of the minewater contained within the Misery Pit will be pumped to the bottom of the Jay Pit and the Jay and Misery pits will be covered with freshwater from Lac du Sauvage • The water quality in the Misery Pit will meet acceptability criteria before reconnection with Lac de Gras • The Panda and Koala open pits will be reclaimed by pumping freshwater into the pits as a 'cap' (approximately 30 m deep) overlying the fine processed kimberlite • The Ekati Interim Closure and Reclamation Plan will be updated to include Project components • Scheduled withdrawals will be managed so that combined withdrawal rates in source lakes (for all Jay, Ekati, and Diavik activities) do not cause significant adverse effects to fish habitat in the source lakes, as described in the Ekati Interim Closure and Reclamation Plan (ICRP) • Metasediment rock will be encapsulated within a 5 m thick encapsulating cover of granite to prevent seepage that would cause negative effects in the receiving environment	Primary
	Fish Other Aquatic Life	Modification to Panda and Koala Pit closure may cause changes to flows, water levels, and channel/bank stability in downstream and source waterbodies which may affect fish and fish habitat	• The Panda and Koala open pits will be reclaimed by pumping freshwater into the pits as a 'cap' (approximately 30 m deep) overlying the fine processed kimberlite • The Ekati Interim Closure and Reclamation Plan will be updated to include Project components • The volume of freshwater required to flood the Panda/Koala pits at closure is much less under the Jay Project than the volume currently authorized through the ICRP, representing a reduction in environmental risks to source lake(s) • Scheduled withdrawals will be managed so that combined withdrawal rates in source lakes (for all Jay, Ekati, and Diavik activities) do not cause negative impacts in the source lakes, as described in the Ekati ICRP	
	Fish Other Aquatic Life	Reconnection of the back-flooded area of Lac du Sauvage to the remaining watershed and drainage conditions at closure may change long-term hydrology in local waterbodies, Lac du Sauvage, Lac de Gras, and downstream	• The Ekati Interim Closure and Reclamation Plan will be updated to include Project components • Natural drainage patterns will be re-established as practicable for closure	No Linkage
Spill and accidents	Fish Other Aquatic Life	Spills (i.e., fuels, petroleum products, reagents) on site may cause a change in surface water quality, affecting fish and aquatic life	• A Spill Contingency Plan is in place for the Ekati Mine and will incorporate the Jay Project • Regular equipment maintenance (e.g., regular checks for leaks) • Drip trays and/or absorbent pads are used during servicing and refuelling • All hazardous substances are stored and handled on site in accordance with applicable regulations • Fuel is stored at central bulk fuel farms and fuel tanks are housed within bermed areas • The Project will follow standard policies used at the Ekati mine in the event of a spill; spill response training is provided and updated • Hydrocarbon impacted material will continue to be handled in accordance with the approved management plan	No Linkage

Water will be transferred between minewater management areas via pumping and pipeline systems. Mitigations and management identified in Ekati's existing Wastewater and Processed Kimberlite Management Plan (WPKMP) and environmental design features will be in place to limit the potential for pipeline failure. The integrity and performance of the pumping and pipeline systems will be monitored throughout the Project construction and operations phases to prevent the unintentional release of minewater to the environment. In the event of any leaks and spills from the pipeline, clean up will follow existing procedures in place at the Ekati Mine.

The implementation of the Ekati Mine Spill Contingency Plan and existing mitigation and environmental design features are anticipated to reduce the likelihood and extent of the release of spills and hazardous materials on-site, and prevent the unintentional release of minewater from pipelines to the environment. Due to the implementation of emergency response and contingency plans, environmental design features, and monitoring programs, spills occurring from Project construction and operations are not expected to change water quality and affect fish or fish habitat. Therefore, this pathway was determined to have no linkage to fish VCs.

The use of explosives near fish-bearing water can cause injury or mortality to fish in Lac du Sauvage

Pressure changes and vibrations caused by blasting can cause injury or mortality of fish. Post-detonation compression shock waves caused by detonations of explosives in or near water can cause internal damage to the swim bladder and other soft organs of fish, and cause changes to fish behaviour (Wright 1982; Wright and Hopky 1998; Godard et al. 2008). The severity of effects is related to the type of explosive, method of detonation, distance away from fish, water depth, and the weight and pattern of the charge(s). The species, size and life stage of fish also plays a role in the severity of effects of blasting. Fish eggs incubating in spawning beds near blasting zones can also be damaged by movement of the substrate in which eggs are imbedded, causing mortality or disrupting development (Wright 1982, Faulkner et al. 2006, 2008). Peak particle velocities (i.e., vibrations) can increase mortality of incubating eggs close to blasting zones (Wright 1982).

All applicable DFO recommended measures to avoid causing harm to fish from the use of explosives will be considered for the Project (DFO 2014b; also see Section 9.3.2.1.1). The DFO guidelines for the use of explosives in or near fish-bearing waters (Wright and Hopky 1998) provide a maximum allowable limit for overpressure (100 kPa) and PPV (13 mm/s). For example, assuming a detonation of a confined explosive with a heavy charge weight of 100 kg, this translates into a conservative setback distance of 50.3 m to avoid impacts to fish from pressure changes, and 150.9 m to avoid impacts to incubating eggs from increased PPVs (Wright and Hopky 1998). However, all blasting will occur in the isolated and dewatered area of Lac du Sauvage (i.e., in the Jay open pit and not in water). Additionally, blasting in the Jay open pit will be beyond the recommended setback distances referenced above. If these setback distances are approached, then site-specific operating mitigations could be implemented if necessary to protect fish. Several studies have demonstrated the effectiveness of DFO recommended setback distances for detonations in avoiding impacts to fish (e.g., Faulkner et al. 2006, 2008).

Thus, survival and reproduction rates of fish in nearby surface waters during Project operation will remain unchanged. In Lac du Sauvage, the effect of pressure changes and vibrations from blasting on fish is considered a no linkage pathway because all blasting and excavation will occur in the dewatered areas of the lake where no fish VCs will be present, and at a considerable distance from the fish-bearing portions of the lake outside of the dike. Consequently, this pathway was determined to have no linkage to Arctic Grayling, Lake Trout, and Lake Whitefish populations.

The construction of the horseshoe dike may isolate contributing sub-basins of Lac du Sauvage, affecting local populations of Arctic Grayling, Lake Trout, and Lake Whitefish in the diverting sub-basins

The Sub-Basin B Diversion Channel will be constructed to divert water that originally flowed from sub-basin B (i.e., ESA-B) and Ac35 (i.e., ESA-Ac35) into the dewatered portion of Lac du Sauvage, away from the pit and into the area of Lac du Sauvage outside of the dewatered area. In addition to maintaining downstream movement, another ecological function of the diversion channel is maintaining connectivity of the diverted sub-basins with source populations (i.e., in Lac du Sauvage) during operation for regional processes such as demographic rescue (through dispersal and colonization events). At closure, the diversion channel will be reclaimed to return flow into the natural flowpath to Lac du Sauvage.

Within the sub-basins, populations of Arctic Grayling, Lake Trout, and Lake Whitefish and the forage fish species they rely on likely have suitable habitat to sustain populations of these fish species year-round (i.e., spawning, rearing, and overwintering habitat). Based on available habitat, a high-magnitude disturbance event (e.g., winterkill or drought conditions) that affects the population is highly unlikely, precluding the need for demographic rescue from a neighbouring population (i.e., colonization from Lac du Sauvage). There are many examples of small isolated lakes in the BSA with self-sustaining populations of species such as Lake Trout (e.g., Lynx Lake, Hammer Lake). Existing overwintering, foraging, spawning, and rearing habitat will be maintained in the lake and streams above the Sub-Basin B Diversion Channel.

However, the Sub-Basin B Diversion Channel will be designed and constructed to allow upstream movement from Lac du Sauvage to upstream tributary lakes in sub-basin B (e.g., Lake B1 [Christine], Lake Ac35) so that fish from Lac du Sauvage will be able to continue to access these watersheds. The use of artificial fishways, such as diversion channels, for fish passage is a common method of maintaining habitat connectivity when interrupted by human developments (i.e., roads, mines, irrigation, and hydropower facilities) (DFO 2007; MDNR 2010; Roscoe and Hinch 2010; Noonan et al. 2012). Furthermore, passage structures and channels that attempt to mimic natural stream hydraulics have been effective for allowing up- and down-stream passage for various species in Canada, including Arctic Grayling (Katopodis 2005; Rescan 2012b; Tonn et al. 2012; Scrimgeour et al. 2014).

As concluded in the mitigation review for the Sub-Basin B Diversion Channel (Section 9.3.2.1.3), there is relatively low uncertainty associated with the effectiveness of the proposed diversion channel as a migration corridor for the target species: adult Arctic Grayling, Lake Trout, and Lake Whitefish. The proposed channel will be designed and constructed such that velocities and slopes are similar to natural streams in the area, there are adequate resting areas, and water velocities are within the published swimming capabilities of the target species. The design specifications for the channel to facilitate upstream fish passage for target species will be discussed DFO during the detailed design phase of the Project. The channel design will utilize locally sourced boulder and cobble-sized substrates, which will diversify the hydraulic conditions (i.e., velocities, depths) in the stream (Pander et al. 2013).

Thus, the connectivity of adjacent populations during the implementation of the diversion channel is expected to be maintained and be similar to baseline conditions through the duration of the life of the diversion channel. Changes, if any, to upstream migration are expected to have no effects to the dynamics of resident populations of Arctic Grayling and Lake Trout residing in sub-basin B (i.e., ESA-B) and Arctic Grayling, Lake Trout, and Lake Whitefish that may reside in sub-basin Ac35 (i.e., ESA-35). Based on the mitigation associated with the Sub-Basin B Diversion Channel, there will be no measurable effects to upstream movements of dispersing fish and ongoing fisheries productivity in the ESAs. Therefore, pathway was determined to have no linkage to effects on Arctic Grayling, Lake Trout, and Lake Whitefish.

Displacement of Lac du Sauvage water by dike material during construction may cause changes to water levels, flows and channel/bank stability in Lac du Sauvage and downstream waterbodies, affecting fish and other aquatic life

Dike construction will involve the deposition of dike infill material in Lac du Sauvage and will take place from 2016 to 2017. Although the footprint disturbance area will be limited to the extent practical, the dike infill will displace water in Lac du Sauvage and temporarily increase water levels in Lac du Sauvage and water levels and flows in the Lac du Sauvage-Lac de Gras Narrows.

The regional water balance model, described in Appendix 8D, was used to evaluate cumulative effects from the Project, including dike construction, to hydrological measurement indicators (Section 8.5.3.1). The mean monthly water levels and peak daily water levels for Lac du Sauvage will be similar to baseline for most of the year with a slight increase (0.02 m) predicted in January and a slight decrease (-0.01 m) in October. The mean monthly discharge at the outlet of Lac du Sauvage will increase slightly compared to baseline, and the peak daily discharge will increase by approximately 1% (2-year flood predictions) or be unchanged compared to baseline (100-year flood predictions). The Lac du Sauvage-Lac de Gras Narrows (i.e., the outlet stream from Lac du Sauvage) mean monthly top surface water width is expected to increase by 0.03 m to 0.33 m, which represents less than a 1% change from baseline conditions.

The very low magnitude effect and short duration of flow increase (2016 to 2017) is within the range of natural variability of water levels for Lac du Sauvage and water levels and flows for the Narrows. As a result, changes in water levels and flows during the deposition of dike infill material is not expected to measurably alter channel/bank stability, riparian conditions, and habitat conditions for fish and other aquatic life. Therefore, this pathway was determined to have no linkage to fish and other aquatic life VCs.

Changes to local hydrology (subsurface water flows, drainage, lake levels, sediment yield) from surface disturbances during the construction phase may cause changes to water levels and flows, affecting channel/bank stability and habitat for fish and other aquatic life in downstream waterbodies

Changes to local hydrology (surface water flows, drainage patterns, lake levels, sediment yield) from surface disturbance may cause changes in water and sediment quality, affecting fish and other aquatic life in Lac du Sauvage, and contributing sub-basins (Ac35, B, and C)

The construction phase begins in 2016 with the addition of Project infrastructure. The placement of the infrastructure will modify the surface runoff from sub-basin Ac4 and sub-basin B due to reduced infiltration and surface storage compared to undisturbed areas. Project infrastructure includes roads, buildings, waste rock and ore stockpiles, and the waste rock storage area (WRSA), which are expected to affect surface hydrology throughout construction and operations. The Project infrastructure will be decommissioned during the closure phase.

To minimize effects to downstream water levels and flows, the footprint disturbance area for the Project will be limited to the extent practical for both the geographical and temporal scope. This includes: using existing Ekati Mine infrastructure, where possible, to minimize the construction of new buildings, roads, and pads; building access roads as narrow as possible while maintaining safe construction and operation practices; and, aligning roads to minimize stream crossings and avoid habitat supporting fish VCs. Culverts will be installed and monitored during all Project phases, along site access roads, as necessary, to use and maintain natural drainage patterns and reduce the use of ditches and diversion berms.

As the Project infrastructure is developed near Lac du Sauvage (i.e., surface facilities, pump stations and associated pipelines, site access roads and pads, quarries, and the WRSA), natural drainage may be affected resulting in changes to surface water flow volumes and timing, and water levels in receiving waterbodies. Altered runoff patterns can lead to increased potential for soil erosion, and subsequently increased TSS (and associated adsorbed constituents) in watercourses and receiving waterbodies (e.g., small lakes within the watershed, Lac du Sauvage).

Effects from changes to local hydrology will be mitigated, in part, by the management of surface runoff that enters the diked area. As appropriate, natural drainage patterns will be utilized to collect and conduct water; constructed drainage channels, sumps, pumps, and surface pipelines will be used where required to facilitate movement of water, and appropriate mitigation (e.g., silt fences) to manage flow rates and erosion potential, and sediment mobilization.

To manage natural runoff water, one of the key Project developments will be the Sub-Basin B Diversion Channel. The proposed Jay Pit will be located within the dewatered area of Lac du Sauvage, which under existing conditions, receives natural runoff from sub-basin B and two small catchments to the south and the north of sub-basin B. The Sub-Basin B Diversion Channel will be constructed to divert water from sub-basin B to an area immediately to the south of the diked area of Lac du Sauvage. The channel has been designed to accommodate the natural range of flows from the sub-basins, with appropriately sized culverts at road crossings, and system maintenance.

Erosion and sediment control management practices (e.g., silt curtains, runoff management, collection ponds) applicable to northern environments, and already in place at the Ekati Mine will be used during construction around disturbed areas, where appropriate. However, some site disturbance (such as development of ore transfer pads and the WRSA) is anticipated during the construction and operation phases of the Project; the placement of these Project features may affect natural drainage patterns.

Project infrastructure will not have a measureable effect on the hydrology of Lac du Sauvage and downstream surface waters due to the small footprint disturbance area relative to the Lac du Sauvage watershed (Section 8.5.3.2). The water balance outcome for Lake B0 show that surface disturbances during the construction phase will result in similar or slightly decreased mean monthly discharge at the lake outlet compared to baseline values. The 2-year peak daily flood discharge will remain unchanged, whereas the 2-year 30-day averaged low flows will decrease by 2% from the baseline value. Similarly, modelling results for Lake B0 outlet water levels show minimal to no changes compared to baseline conditions. The 2-year peak daily water level is expected to decrease by approximately 0.02 m.

The very low magnitude effect is within the range of natural variability of water levels and flow for Lake B0 and Lake Ac35 and lake outlets. As a result, changes in water levels and flows from surface disturbances during the construction phase are not expected to measurably affect habitat conditions for fish and other aquatic life. The application of environmental design features and mitigation to manage and collect surface runoff as appropriate to reduce erosion potential and sediment loading means that effects to habitat quality in receiving waterbodies will be minimized or prevented. Therefore, these pathways were determined to have no linkage to fish and other aquatic life VCs.

Pumped dewatering discharges from the diked area of Lac du Sauvage may cause erosion of lake bottom sediments near the outfall in Lac du Sauvage and cause changes in water and sediment quality, affecting fish and aquatic life

The area of turbulence around the diffuser outfall in Lac du Sauvage may affect the fish distribution in Lac du Sauvage

Dewatering discharge from the diked area in Lac du Sauvage during construction and piped discharge from the Misery Pit to Lac du Sauvage in operations will be pumped to Lac du Sauvage via a diffuser to disperse discharge energy and rapidly attenuate the discharge. The diffuser type and location may differ between the dewatering and operational discharge phases.

During the initial dewatering, when water in the diked area is sufficiently clear of TSS, it will be pumped directly into two locations in the main basin of Lac du Sauvage via three separate pumping stations (PS1, PS2, and PS3). This will reduce flow velocities at the discharge locations and reduce risk of re-suspension of lake bed sediments. Placement of a floating structure (i.e., flexi-floats) under the piped outfall, may also assist in reducing plunging velocities of the piped outfall that could extend to the lake bottom and disturb the bottom sediments. Additional erosion protection strategies (e.g., placement of rockfill at the pipe discharge locations, expansion of pipe diameter at the discharge) may also be considered during detailed design. The duration of diked area dewatering to Lac du Sauvage is estimated to be approximately 3 months.

The velocity of pumped minewater discharge entering Lac du Sauvage during the operational phase of the Project (i.e., Years 5 to 10) will be reduced by the use of an engineered submerged diffuser. The discharge to Lac du Sauvage will occur through a diffuser outfall, which will be placed in a deep area of the lake and located above the lake bed to provide an appropriate distance between the diffuser outflow and bottom sediments. This design will maximize dispersion and attenuation of the discharge from the diffuser, and reduce the potential for resuspension of sediments and any potential effects to water and sediment quality and aquatic habitat. Despite these measures, sediment may be mobilized, but resuspension of sediments is likely to decrease after the initial discharge after sediment near the diffuser is re-deposited away from the diffuser. There could also be a measureable reduction in ice development potential at the diffuser location, but habitat changes would be localized and not necessarily negative for fish. The diffuser location will be selected in an area where fish densities are low (e.g., away from spawning or rearing locations) and fish will be also able to avoid the immediate vicinity of the diffuser. The site selection and final design will consider minimizing effects to fish habitat, both in terms of water quality and habitat avoidance due to the zone of turbulence.

As a result of the design and mitigation measures associated with the dewatering outfalls and the diffuser, pumped discharge into Lac du Sauvage is not expected to result in measureable changes in fish habitat for Arctic Grayling, Lake Trout, and Lake Whitefish; therefore, this pathway was determined to have no linkage to the effects on fish and fish habitat.

Dewatering Lac du Sauvage within the diked area may result in stranding and mortality of fish moving downstream from supporting tributaries into the diked area

A diversion channel (Sub-Basin B Diversion Channel) will be constructed (approximately 1,275 m in length) to divert water that originally flowed from sub-basin B and sub-basin Ac35 into the diked area of Lac du Sauvage, away from the pit and into the area of Lac du Sauvage outside of the dewatered area. The diversion channel will convey water from two small, fish-bearing streams: Stream B0, downstream of Christine Lake; and the lower section of Stream Ac35, a small ephemeral stream downstream of Lake Ac35 (Section 9.2.5.2; Annex XIV). Stream Ac4, the third small ephemeral watercourse flowing into the diked area, is not a fish-bearing stream based on previously completed sampling (Rescan 2007). This watercourse will continue to flow into the dewatered area of Lac du Sauvage and flows (when present) will be pumped from the dewatered area as part of the proposed Jay sump pumping system.

Design features for the diversion channel will permit upstream and downstream passage of target species (i.e., Arctic Grayling, and to a lesser extent, Lake Trout and Lake Whitefish), based, in part, on their swimming abilities (Section 9.3.2.1.3). In particular, maintaining minimal downstream flows that coincide with life histories (e.g., young-of year out-migrations) will be considered in channel design. The design specifications for the channel to facilitate downstream fish passage will be discussed with DFO during the detailed design phase of the Project. The use of the Sub-Basin B Diversion Channel at the Project will eliminate stranding and mortality of fish moving downstream from supporting tributaries in the diked area. Thus, this pathway was determined to have no linkage to effects on Arctic Grayling, Lake Trout, and Lake Whitefish.

Discharges from the dewatering of the diked area of Lac du Sauvage may change flows, water levels, and channel/bank stability downstream in the Coppermine River, affecting fish and other aquatic life

Discharges from dewatering the diked area directly to Lac du Sauvage have the potential to cause an increase in flow downstream. Increased peak flows can result in channel erosion, which has the potential to change fish habitat conditions. The water balance results for Lac de Gras presented in the hydrology assessment (Section 8.5.3.3.1) show that during dewatering, monthly mean Lac de Gras outlet flows will increase compared to baseline. The 2-year daily peak flood discharge during dewatering will increase by approximately 5% above the baseline value, and the 100-year peak daily flood discharge will increase by approximately 4% above the baseline value. Defined limits on pumping conditions will be put in place as mitigation to ensure flows during dewatering remain within the channel banks at the Lac de Gras outlet, and downstream channels will be monitored for evidence of erosion. No outlet or bank stability effects are expected as a result of the small increases in discharge and water level.

The duration of increased flow due to pumping water directly to Lac du Sauvage is expected to be approximately 3 months from May through July and will not affect the seasonal timing of flows. The expected changes in monthly flow are within 5% of baseline flow condition. Maintaining flows within 10% of the natural condition is thought to have a low probability of detectable impacts (DFO 2013b) and a departure from the natural flow conditions of less than or equal to 10% would result in a high level of ecological protection whereby the natural structure and function of the ecosystem would be maintained (Richter et al. 2012).

The low magnitude (i.e., less than 10%) and short duration of flow increase is within the range of natural flow variability that would be expected at the outlet of Lac de Gras and downstream in the Coppermine River. As a result, changes in flow during dewatering are not expected to measurably alter channel/bank stability, and riparian and habitat conditions for fish or affect fish population dynamics at the Lac de Gras outlet channel or downstream in the Coppermine River. Therefore, this pathway was determined to have no linkage to fish and other aquatic life VCs.

Back-flooding of the dewatered diked area of Lac du Sauvage may generate or release mercury, nutrients or other substances from flooded sediments and vegetation and may cause a change in water quality, affecting fish and aquatic health

Following operations, the top portion of the Jay Pit and the diked area of Lac du Sauvage will be back-flooded with fresh water. Approximately 170 ha of habitat in the dewatered area will be inundated during back-flooding in the closure phase of the Project. The rock and soils in this area will include dust accumulated form aerial deposition. Establishment of vegetation in the dewatered area is expected over a period of approximately 10 to 15 years from construction to reclamation and closure. Back-flooding is predicted to take approximately four years.

Back-flooding of the dewatered area of Lac du Sauvage has the potential to affect water quality in the diked area from the physical erosion and potential release of water quality constituents. The gradual flooding of the area may result in a surge in nutrient concentrations, particularly in the nearshore region of the lake. Changes to nutrient dynamics in the back-flooded area of Lac du Sauvage will be primarily driven by the inundation of the surrounding vegetation and, to a more limited extent, soil. Nitrogen, phosphorus, and carbon are likely to be released to the water column through decompositional processes and sediment-water interactions. Sources of phosphorus and carbon are not likely to be substantial, but a larger source of nitrogen may be available from blasting residues, which will be a source of ammonia and nitrate to the back-flooded area.

Initial colonization of lower trophic communities is expected to occur during the back-flooding period. Phytoplankton and zooplankton will colonize from the water pumped from Lac du Sauvage, whereas benthic invertebrates will colonize mostly as aerial adult insects (primarily Chironomidae) during this period. The initial composition of the phytoplankton community will likely reflect the source waters of Lac du Sauvage, which has been typically dominated by chrysophytes or cyanobacteria. The arrival sequence of zooplankton species may influence species composition during this time. Cohen and Shurin (2003) observed high rates of zooplankton dispersal into newly formed ponds. However, differences in dispersal abilities between broad taxonomic groups (such as rotifers, cladocerans, and copepods) were not observed (Coehn and Shurin 2003). In some cases, cyclopoid copepods have been found to be among the first zooplankton to colonize new areas (Frisch and Green 2007). The colonization of zooplankton species is likely to be dependent on their ability to tolerate local conditions, such as the presence or absence of fish (Cohen and Shurin 2003). Benthic invertebrate communities are expected to be colonized initially by chironomids (Layton and Voshell 1991). Increases in the availability of nutrients could cause an initial increase in primary (i.e., phytoplankton) and secondary (i.e., zooplankton and benthic invertebrate) production, as communities adjust to the nutrient regime in the back-flooded area.

Metals may be released from the sediment of the dewatered area, from the suspension of sediments (i.e., particulate metals associated with sediment particles) resulting from erosion and washing of sediments from inundated rock surfaces. It is anticipated that total suspended solids (TSS) concentrations in runoff may be elevated during spring freshet inflows into Lac du Sauvage and as a result of wave action. However, any elevation in the concentration of metals and nutrients associated with TSS from these sources is anticipated to be temporary. Within the first few years of back-flooding, fine sediments that accumulated in shallow areas of the lake and on dike surfaces will be re-distributed to deeper areas. This is expected to occur before the dike is breached to connect the back-flooded area to Lac du Sauvage. Therefore, a long-term effect on the metal and nutrient dynamics in Lac du Sauvage is not expected following breaching of the dike, with the possible exception of the release of nitrogen from the pit area, which is evaluated under a different pathway (Section 9.4.3) based on the water quality modelling results.

Inundation of soils and vegetation in the diked area during back-flooding may also increase the concentration and availability of mercury to aquatic biota though enhanced methylation. The back-flooding of the dewatered diked area of Lac du Sauvage is not expected to result in increases in mercury concentrations that would be adverse to fish in Lac du Sauvage because of the following:

- The area to be flooded will have a limited time (approximately 10 years) to allow for vegetation to establish, and as a result, is very unlikely to contain coarse woody vegetation.

- The relative area of the dewatered area is small (less than 3%) of the area of Lac du Sauvage.
- The diked area will remain isolated from Lac du Sauvage and without fish until the dike is breached.
- The diked area will not be reconnected until the back-flooded area meets acceptable water quality criteria.

The period of time that the elevated metal and nutrient concentrations will remain in the lake will depend on site-specific conditions, such as the mass of inundated organic material, the hydrological regime (i.e., retention time, flushing rates, wave action) and rates of microbiological and biological activity (e.g., low temperatures may reduce the potential for decomposition and assimilation). Although there is potential for temporary changes to surface water with the back-flooding of the dewatered area, monitoring of the back-flooded area to confirm that acceptable water quality criteria are met before reconnection will limit the potential for long-term nutrient and metals releases to the lake and mercury methylation.

Changes in water quality in the back-flooded area before reconnection to Lac du Sauvage are predicted to be minor relative to baseline conditions. Fish will not be present in the back-flooded area before the dike is breached and reconnection to the lake occurs. Therefore, this pathway was determined to have no linkage to fish and other aquatic life VCs. Once the dewatered area is back-flooded and the dike has been breached, the effects or reconnecting the back-flooded area during closure is assessed as a primary pathway in the residual effects analysis (Section 9.4.3.4).

Reconnection of the back-flooded area of Lac du Sauvage to the remaining watershed and drainage conditions at closure may change long-term hydrology in local waterbodies, Lac du Sauvage, Lac de Gras, and downstream

Breaching of the dike and reconnection of the back-flooded area of Lac du Sauvage to the remaining watershed and drainage conditions at closure may change long-term hydrology in the ESA for fish. However, natural drainage patterns will be re-established as practicable, resulting in minimal effects to long-term hydrology and fish habitat conditions. Project infrastructure will be reclaimed according to the methods described in the Ekati Mine Interim Closure and Reclamation Plan (ICRP; BHP Billiton 2011), including the removal of stockpiles, buildings, decommissioning of roads, roadway safety berms, and culverts, and reclamation of roads and pads. These activities are expected to return overall basin snowmelt and rainfall runoff coefficients to pre-Project coefficients. The Sub-Basin B Diversion Channel will be decommissioned and re-graded to promote a return to natural flow regimes.

The water balance results for the Lac du Sauvage outlet (Section 8.5.3.2.5) show that during post-closure, monthly mean discharges will be similar to baseline values. The 2-year peak daily discharge and the 100-year peak daily discharge during post-closure will remain unchanged from baseline values. Post-closure will cause the median 30 day averaged low flows and the median 90 day averaged low flows to remain unchanged from baseline values. Given the predictions for Lac du Sauvage outlet flows, no changes are expected for Lac du Sauvage outlet water levels, and outlet channel/bank stability, and no changes are expected to the hydrology of downstream locations. The Lac du Sauvage Narrows surface water top widths are expected to be similar to baseline values in post-closure, as well as maximum and mean depths. The water balance results for Lac de Gras also show that post-closure conditions will be similar to baseline conditions.

Therefore, this pathway was determined to have no linkage to fish and other aquatic life VCs.

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9.3.2.2.2 Secondary Pathways

In several cases, both a source and a pathway exist, but because the change caused by the Project is anticipated to be minor relative to Base Case or guideline values, it is expected to have a negligible residual effect on fish and fish habitat. The pathways described below are expected to be secondary and will not be carried forward in the assessment.

Cross-drainage structures for the mine site roads may alter stream hydraulics and geomorphology, affecting fish habitat and passage at stream crossings in sub-basins of Lac du Sauvage (ESA-Ac35 and ESA-B)

Release of sediment during road construction at watercourse crossings and from land disturbance may cause a change in habitat quality, affecting fish and aquatic life in downstream lakes and streams and Lac du Sauvage

The Project has been designed to minimize the effects to the aquatic ecosystem through minimizing the intersection of Project infrastructure and streams or lakes, and minimizing the alteration of natural drainage paths. To support Project construction and operations, the installation of cross-drainage structures to prevent roads from impeding water flows is required. Where appropriate, the watercourse crossings will be designed to allow for fish passage.

Road crossings are proposed upstream of the diverted channels and in the sub-basins above the diked area of Lac du Sauvage (Table 9.3-2). Seven small streams will be affected by road crossings. One crossing will be located on Stream Ac35 immediately above the Sub-Basin B Diversion Channel (40 m wide), and one crossing will be located on Stream B0 where the diversion channel connects to the natural channel. There will be two other crossings over the diversion channel. There will be four crossings over small, ephemeral watercourses in the headwaters of sub-basin B near the Misery site (i.e., streams B5, B7, B8, and B26). In addition, Stream Ac4 will be altered by a road crossing (30 m wide).

Table 9.3-2 Summary of Streams Affected by Road Crossings

Effects Study Area (ESA)	Name	Crossing Type	VC-Bearing Status[(1)]
ESA-B	Stream B5	Haul, Power	unlikely
	Stream B7	Access Road, Pipeline	unlikely
	Stream B8	Access Road, Pipeline	unlikely
	Stream B26	Haul, Pipeline, Power	unlikely
ESA-B, ESA-1	Diversion #1	Haul[(2)]	yes
ESA-B, ESA-1	Diversion #2	Operations[(2)]	yes
ESA-B, ESA-35, ESA-B	Diversion #3	Haul, Pipeline, Power[(2)]	yes
ESA-Ac35, ESA-1	Stream Ac35	Haul, Pipeline, Power	yes
ESA-1	Stream Ac4	Haul	unlikely

1) Based on previous and ongoing baseline studies (Annex XIV).
2) Crossing for Sub-Basin B Diversion Channel.
VC = valued component.

To minimize the potential for sediment entrainment and deposition, where possible, road crossing construction in areas of potential spawning habitat will take place outside the spawning period for Arctic Grayling (approximately early May to mid-June; DFO 2014b). Instream works will be minimized, and when possible, restricted to frozen or non-flowing conditions. All construction activities will be subject to a sediment control plan, and management practices will include standard erosion and sediment control measures (e.g., erosion mats, silt curtains). Erosion and sedimentation protection will also be implemented during the decommissioning phase of the watercourse crossings. Construction and decommissioning practices will follow DFO's advice on erosion and sediment control to avoid causing serious harm to fish (DFO 2014b). Through the use of appropriate management practices and monitoring during construction, operation, and decommissioning activities, effects to water quality are expected to be negligible.

The installation of cross-drainage structures can also result in a constriction of the stream channel, which could affect flow velocities. Changes in flow velocities could also affect channel aggradation, degradation, erosion, or bankfull width or depth. The freezing and plugging of culverts during low temperature periods may also result in ponding of water adjacent to road embankment fills, over-topping and erosion of road surfaces, potential instability and thaw settlement of road shoulders, thaw settlement beneath and adjacent to culverts, and ice lens growth. Where culverts are to be installed at fish-bearing streams, the culverts will be designed and constructed to allow for fish movement as appropriate to meet DFO guidelines (DFO 2014b). The fish passage requirements for each proposed crossing will be determined during detailed design.

Proposed mitigation to reduce effects to stream flows, beds, and banks, includes the following as appropriate at each location:

- Cross-drainage structures implemented in such a way that, for fish-bearing watercourses, they provide sufficiently low flow velocity that the slowest local fish of a target species can navigate the structure under a particular design flow condition (e.g., 3-day delay; 1:10 year return flood condition).
- Design conveyance for 1:50 year event without overtopping the roadway, which will result in minor changes in stream velocity.
- Use of a staggered culvert configuration to prevent ice blockages and to better convey water during low flow for fish passage.
- For road crossings for the diversion channel, small rock weirs immediately downstream of the culvert outlets to backwater the culverts, further facilitating fish passage at low flow.
- Regular inspections of roads and cross-drainage structures.
- Removal of snow and ice at the culvert inlet and outlet (and within the culvert if necessary) before the freshet, to promote drainage during spring thaw and freshet.

Due to the mitigation and design features, the implementation of appropriate cross-drainage structures at watercourse crossings is expected to result in minor changes to stream flow velocity and geomorphology in the vicinity of the structures relative to baseline conditions. The risk of an ice blockage is expected to be low.

The road crossings are expected to have no to negligible effects on migration conditions for fish, including Arctic Grayling, Lake Trout, and Lake Whitefish. Furthermore, the effects to fish habitat would be negligible, due to the sediment control plan and management practices to be used for all construction activities. These pathways were determined to be secondary pathways for fish and other aquatic life.

Water supply requirements (mining and potable) for the Project may cause changes to water levels, flows and channel/bank stability in downstream waterbodies and streams, affecting fish and other aquatic life

Water supply needs for the Project include potable water for the camp and plant, and raw water for the processing plant (1,370,000 m^3 per year, Water Licence W2012L2-0001). No changes are anticipated to management of the freshwater intake to accommodate the needs of the Project (Section 3.4.1.8.8).

At the existing Ekati Mine facilities, water is recycled to reduce freshwater withdrawal needs. In 2012, over 4.5 million m^3 of water was recycled from the the Long Lake Containment Facility (LLCF) (Dominion Diamond 2013). The LLCF currently provides recycled water for use at Ekati's processing plant. It is expected that this practice of recycling water will continue under proposed plans for processing material from the Project.

The Project will also use existing potable water systems at the Ekati and Misery sites. Freshwater is currently supplied to the Ekati Mine from Grizzly Lake, within the Koala watershed (i.e., ESA-K). Grizzly Lake (58.9 ha in area) has an upstream watershed of 6.13 km^2, and flows into the Panda Diversion Channel, which has a total drainage area of approximately 21.3 km^2 at the confluence. Seven fish species have been captured in lakes in the Koala watershed: Arctic Grayling, Lake Trout, Round Whitefish, Longnose Sucker, Burbot, Lake Chub, and Slimy Sculpin (ERM Rescan 2013).

From Grizzly Lake, water is piped to a treatment plant for potable water located at the Ekati main camp. Treated potable water from the plant is then trucked to the Misery camp. A change in this process is not anticipated for the Project. Freshwater for Ekati Mine operations is also permitted to be drawn from Little Lake, Thinner Lake (Misery Camp), Falcon Lake, and Lac de Gras. Water withdrawals are primarily from Grizzly Lake, with approximately 95% of freshwater withdrawal from Grizzly Lake between 2006 and 2008 (BHP Billiton 2009). Reported average annual withdrawals from Grizzly Lake over the period 2003 to 2012 were 107,220 m^3, and were 101,944 m^3 in 2012 (BHP Billiton 2005, 2006, 2007, 2008, 2010, 2011, 2012; Dominion Diamond 2013). The annual volume withdrawn from Grizzly Lake is approximately 0.01% of the total lake volume. These changes in Grizzly Lake are well within the natural variability of lake levels.

As a result of the Project, demand for freshwater during winter or summer seasons for potable use is not anticipated to increase beyond the authorized amounts, and therefore, no modification or refurbishment to the management of freshwater intake at the Ekati Mine is anticipated to accommodate the Project. The operating life of the water supply facilities at Grizzly Lake and the other lakes that are licenced freshwater sources, and the water withdrawal infrastructure, will be extended to encompass the life of the Project. Monitoring of lake water levels in Grizzly Lake and other withdrawal waterbodies will be continued into the future with the application of the Project. Winter water withdrawals will be managed with consideration of minimizing effects to under-ice habitat for fish and the DFO Protocol for Winter Water Withdrawal from Ice-covered Waterbodies in the Northwest Territories and Nunavut (DFO 2010).

The annual requirements of water from these lakes to meet the raw water demand are expected to result in a small change to water level and the predicted outflows of these lakes during winter (ice cover) or summer (open water) conditions. Furthermore, any minor effects to surface hydrology within the Grizzly Lake watershed are expected to be even smaller in all downstream waterbodies. Withdrawal of raw water from source water lakes for water supply requirements may cause a minor, local change to water levels and outflows, but are expected to remain within natural variability. Changes to local and downstream surface hydrology are determined to be minor, and therefore, this pathway is a secondary pathway for fish and fish habitat.

Acidifying air emissions and the deposition of dust and metals from air emissions may affect water quality and lake bed sediments, affecting habitat quality for fish and other aquatic life in waterbodies within the Lac du Sauvage and Lac de Gras watersheds

The air emissions assessment for surface waters considered the effects of aerial deposition from the Project and surrounding developments on the surface water chemistry of small lakes in the area. Aerial deposition of acids, metals, and dust to lake catchments were predicted by air modelling, and in-lake concentrations of alkalinity, metals, and TSS were estimated from the predicted deposition, existing aquatic chemistry, and estimates of surface hydrology used in the 2012 Ekati AEMP (ERM Rescan 2013) (for details see Section 8.5.4.1).

The effects of aerial deposition from mining activities were assessed for various lakes around the Project that were included in the hydrology section of the 2012 AEMP report for the Ekati Mine (ERM Rescan 2013). The selected lakes included six small lakes in the ESAs for fish (e.g., Koala watershed and sub-basin B) and cover a range of distances and directions from the Project and surrounding developments. Therefore, results of the deposition analyses for these lakes provide an overview of regional deposition effects.

The potential deposition of acids, metals and dust were evaluated using Steady-State Water Chemistry (SSWC) modelling methods applied to Base Case and Application Case scenarios. Base Case emissions were representative of conditions from approximately 2014 to 2018, and emissions for the Application Case were representative of the worst-case conditions during mining operations (around 2030). Deposition was modelled at a monthly time step, with every year within the same assessment case assumed to have the same worst-case emissions.

Modelling results showed that the potential acid input (PAI) in the Application Case increased at most of the lakes, but decreased by 5 and 12% at Nema and Vulture lakes, respectively (Section 8.5.4.2). The decrease in deposition rates is likely due to an overall switch in the location of the main source of deposition, as mining at the Jay Pit will be the only planned active mine area. Largest increases in PAI for the Application Case were observed at Christine and Cujo lakes (100% increases). However, none of the lakes had critical load exceedances for acidity in either the Base or the Application cases. Less than one percent of total PAI in the deposition was from sulphate, and sulphate concentrations in the lakes appear to be primarily driven by non-depositional sources. Therefore, the effect of PAI from the Project to habitat quality in small lakes near the Project is predicted to be measureable but minor in magnitude and result in no residual effects for fish and other aquatic life.

Predicted metal deposition rates decreased at each of the lakes between the Base and Application cases (Section 8.5.4.2). As such, the concentrations of metals in each lake were also predicted to decrease, and the effect of air emissions from the Project on metal concentrations on habitat quality in small lakes is considered to be very minor in magnitude. In contrast to predicted metal deposition rates, concentrations of TSS from dust deposition were predicted to increase above baseline concentrations in small lakes, including Christine Lake. However, the maximum concentration (9.5 mg/L) is not above any regulatory guidelines, and the prediction did not account for settling and is likely overestimated. Therefore, the effect of dust deposition from the Project to habitat quality in small lakes near the Project is predicted to be minor in magnitude and have no residual effects for fish and other aquatic life.

Acidifying air emissions and the deposition of dust and metals from air emissions may result in small changes to habitat quality for fish and other aquatic life in waterbodies within the Lac du Sauvage and Lac de Gras watersheds. However, changes to habitat quality are expected to be minor, resulting in no residual effects to fish and aquatic life VCs. This pathway was classified as a secondary pathway.

Impingement and entrainment of fish in intake pumps during construction and operation activities (e.g., dewatering) may cause injury and mortality to fish in Lac du Sauvage

Impingement and entrainment of fish in intake pumps during back-flooding activities may cause injury and mortality to fish in source waterbodies including Lac du Sauvage

Water pumping from fish-bearing waterbodies will be required during construction of the dike around the Jay Pit area in Lac du Sauvage, during dewatering, and for operational needs. Pumping from waterbodies will also be required during back-flooding of the Jay Pit and dewatered area at closure, as well as back-flooding the Misery Pit and the Panda and Koala pits to create a freshwater cap. To minimize potential harm to fish, fish screens will be placed on all water intake pipes in fish-bearing waterbodies. Where water withdrawal occurs within a fish-bearing waterbody, fish will be at risk of entrainment or impingement from the intake pipe. Entrainment occurs when a fish is drawn into a water intake and cannot escape, and impingement occurs when a fish becomes entrapped on an intake screen and is unable to free itself.

As described in Section 9.3.2.1, measures recommended by DFO to avoid causing harm to fish at screened water intake pipes (DFO 1995, 2014b) will be implemented as necessary for mitigation to minimize entrainment and impingement of fish. DFO guidelines for fish screens on freshwater intake pipes (DFO 1995) will be followed in design, installation and maintenance of fish screens on intake pipes for the Project. Through discussion with DFO, the appropriate screen mesh size for the planned pumping rates will be determined to prevent fish from entering the intake during pumping.

Screening of intake pumps will reduce fish mortality resulting from impingement or entrainment. It is likely that a limited number of small fish will become impinged or entrained and die, but it is anticipated that this will be limited to localized areas around the pumps. Therefore, residual effects to Arctic Grayling, Lake Trout, and Lake Whitefish populations are predicted to be negligible.

The construction of the diversion channel will result in loss of habitat downstream of the diversion, potentially affecting Arctic Grayling, Lake Trout, and Lake Whitefish in the diverting sub-basins (i.e., ESA-B and ESA-Ac35)

The dewatered area within the horseshoe dike in Lac du Sauvage includes flows from small, ephemeral streams in adjacent sub-basins (Ac4, Ac35, and B). Two of the sub-basins, Ac35 and B, were identified as supporting resident populations of VC species (Lake Trout and Arctic Grayling) (Annex XIV). Because of the volume of water predicted to flow from sub-basins Ac35 and B during construction and operations, the environmental design of the Project includes a diversion channel (i.e., Sub-Basin B Diversion Channel) of approximately 1,275 m in length.

The diversion channel will divert water that originally flowed from sub-basin B (i.e., ESA-B) and Ac35 (i.e., ESA-Ac35) into the dewatered portion of Lac du Sauvage, away from the pit and into the area of Lac du Sauvage outside of the diked area. The diversion channel will convey water from two small, fish-bearing streams: Stream B0, downstream of Christine Lake; and, the lower section of Stream Ac35, a small ephemeral stream downstream of Lake Ac35.

The stream length lost because of the diversion includes the following:

- ESA-B – 355 m of Stream B0 (21.7% of Stream B0 and B1 combined, or 4.1% of total stream length in sub-basin B); and,
- ESA-Ac35 –112 m of Stream Ac35 (12.1% of the Stream Ac35, or 7.4% of total stream length in sub-basin Ac35).

It is expected that habitats in Stream B0 and Stream Ac35 may be used by both resident populations in the sub-basins and populations in Lac du Sauvage. The assessment of effects of the diversion channel for populations in Lac du Sauvage was considered a primary pathway, addressed in Section 9.4.2.2.

However, self-sustaining populations of VCs in the diverted sub-basins should remain unaffected by the Project. The populations may live out their life histories within these sub-basins and species residing in Lake B1 (Christine) and Lake Ac35 are unlikely to use Stream B0 and the lower reach of Stream Ac35, respectively (Annex XIV) where flows will be diverted. Although there may be a measurable change to stream habitat with the implementation of the Sub-Basin B Diversion Channel in ESA-B and ESA-Ac35, there will be either no measurable effects, or negligible effects, to self-sustaining populations of Arctic Grayling, Lake Trout, and Lake Whitefish in these sub-basins.

Altered site drainage and runoff from facilities and water transfers during operations may cause direct changes to water levels, flows, and channel/bank stability in Lac du Sauvage and the Narrows, affecting fish and other aquatic life

During the operations phase of the Project, dike seepage, local runoff, and minewater from the Jay Pit will be pumped to the Misery Pit. For the first five years of operations, this activity could cause a short-term reduction in water levels and discharge at downstream locations, including the Narrows. When the water level in the Misery Pit reaches the maximum operating water levels (anticipated five years into operations), the minewater in the Misery Pit will be pumped from the top of the Misery Pit to Lac du Sauvage through an engineered diffuser (2025 to 2029). This activity could cause a short-term increase water levels and discharge at downstream locations, including the Narrows.

Early operations will cause the median 30-day averaged low flows and the median 90-day averaged low flows for the Lac du Sauvage outlet to decrease by less 2% from the baseline value. Lac du Sauvage outlet water levels during early operations will be similar to baseline values. Monthly mean stages are expected to change by less than 0.02 m. Changes are not expected in March, April, May, June, July, September, October, and December. Monthly maximum and mean depths in the Narrows are not expected to change from baseline values.

During late operations, the 2-year peak daily flood discharge for Lac du Sauvage will increase by approximately 2% from the baseline value, and the 100-year peak daily flood discharge will increase by approximately 1% from the baseline value. Lac du Sauvage outlet water levels during late operations will be similar to baseline values. Monthly mean stages are expected to change by less than 0.01 m during the open water season (June to September).

The banks of the Lac du Sauvage Narrows are comprised of bedrock and given the small increase in flood magnitudes the potential for erosion is expected to be very low. No effects to adjacent riparian habitats are expected. Defined limits/pumping conditions for the operational discharge will remain within the capacity of the Narrows and channel banks at the Narrows will be monitored for evidence of erosion.

The small magnitude and short duration of flow changes is within the range of natural flow variability that would be expected within Lac du Sauvage and at the outlet of Lac du Sauvage. As a result, changes in water levels and flow from altered operations are not expected to alter fish habitat conditions, including riparian habitats, or affect populations of fish VCs. Therefore, this pathway was determined to be a secondary pathway, and effects to fish and other aquatic life are predicted to be negligible.

Indirect effects from dewatering and placement of the waste rock storage area may cause changes in water levels and surface discharges in nearby tributary lakes and streams (i.e., sub-basin C), affecting available habitat for fish and other aquatic life

The Project requires dewatering of the diked area of Lac du Sauvage to initiate mining and then for the duration of mining to remove groundwater inflows in the pit to safely access and mine the Jay kimberlite pipe (Mine Water Management Plan; Appendix 3A). Dewatering of the diked area may increase the hydraulic gradient in the surrounding active surface groundwater regime. The reduced groundwater pressures in the deep groundwater flow system in the dewatered diked area may cause groundwater to flow from Lake C1 toward the dewatered area. Lake C1 is located along the inferred enhanced permeability zone that is assumed to conservatively extend over the entire hydrology ESA. Changes in groundwater discharges to other lakes within the effects study area were predicted to be negligible (Section 8.4-2).

Additional Project activities that may affect the surface hydrology, and possibly habitat quantity for fish in sub-basin C include the Jay WRSA footprint. The WRSA footprint will reduce the watershed area of Stream C1 and Lake C17, a shallow tributary lake to Stream C1. The WRSA will be constructed to minimize runoff and encourage permafrost formation through placement sequence of materials. The intent is that any water infiltrating the waste rock will encounter permafrost conditions and freeze within the pile. This will limit leaching to the outer surface of the waste rock (i.e., the active layer).

The Project activities that may affect the surface hydrology, resulting in changes to available fish habitat in sub-basin C include the following:

- The operations phase will be expected to include increased groundwater losses from Lake C1 due to reduced groundwater pressures in the deep groundwater flow system caused by the dewatering of the diked area and from the Jay Pit development. Lake C1 is located along the inferred enhanced permeability zone that is assumed to conservatively extend over the entire ESA. Lake C1 is 163 ha in area with a maximum depth of approximately 24 m, supporting a resident fish community of Round Whitefish, Lake Trout, Slimy Sculpin, and Arctic Grayling (Annex XIV).
- The footprint of the WRSA will reduce the watershed area by 83 ha (7% of the total sub-basin area), potentially affecting water levels and flows at downstream locations. Downstream effects may extend to Stream C1, which drains east from Lake C1 for 2.1 km before entering Lac du Sauvage internal basin Ac, and provides habitat for Arctic Grayling and forage species, such as Slimy Sculpin (Annex XIV).

The increase in groundwater discharge from Lake C1 above baseline conditions due to dewatering is predicted to be less than 100 m^3/d at the start of pit development. Under average climate conditions, monthly mean stages of water levels during the open water season (June to September) are expected to change by less 0.04 m during the dewatering phase and less than 0.01 m during post-closure. The groundwater losses from Lake C1 will return to baseline conditions as the diked area is back-flooded.

The assumed extent of the enhanced permeability zone away from the Jay pipe, and in particular, the west direction, is highly speculative. Model sensitivity analysis showed that if this zone is of limited lateral or vertical extent, the predicted groundwater inflows to the Jay open pit and associated changes in discharge from Lake C1 will be much less than those rates provided (Appendix 8A). Thus, predictions may have overestimated effects to water levels and flows in Lake C1 and Stream C1.

Based on the above considerations, changes to localized groundwater flows towards the dewatered zone are expected to result in water levels and surface discharges that will be within the natural range of variability. Although the combined effects of groundwater losses from Lake C1 and the reduced watershed area in sub-basin C have the potential to affect water levels and flows in sub-basin C during operations, effects to fish habitat are expected to be negligible. Therefore, this pathway was determined to be a secondary pathway.

Discharges from the dewatering of the diked area of Lac du Sauvage may change flows, water levels, and channel/bank stability in Lac du Sauvage, the Lac de Gras-Lac du Sauvage Narrows, and Lac de Gras, affecting fish and other aquatic life

Discharges from dewatering the diked area directly to Lac du Sauvage have the potential to cause an increase in water levels in Lac du Sauvage and Lac de Gras and an increase in flow at the Lac du Sauvage Narrows as presented in the hydrology assessment (Section 8.5.3.3.1). The duration of increased flow due to pumping water directly to Lac du Sauvage is expected to be approximately three months from May through July and will not affect the seasonal timing of flow magnitude at the Lac du Sauvage Narrows or the seasonal water level fluctuations in Lac du Sauvage or Lac de Gras. A Dewatering Plan will be prepared for the Wek'èezhìi Land and Water Board (WLWB) as an anticipated condition of the water licence before dewatering. Limits on pumping conditions will be put in place as mitigation to ensure flows during dewatering will remain within the Lac du Sauvage outlet capacity and channel banks at the Lac du Sauvage outlet channel will be monitored for evidence of erosion. No outlet or bank stability effects are expected as a result of the small increases in discharge and water level.

Water level changes in Lac du Sauvage and Lac de Gras are expected to be minimal, with increases equal to or less than 0.05 m expected for both peak water levels and mean monthly water levels. No changes to shoreline stability are expected and the small increase in water level is within the range of natural variability and will not result in a measurable change in fish habitat.

Increased peak flows can result in channel erosion, which has the potential to change fish habitat conditions. The water balance results for the Lac du Sauvage Narrows show that during dewatering, monthly mean flows will increase compared to baseline. The 2-year peak daily flood discharge during dewatering will increase at the Lac du Sauvage outlet by approximately 10% from the baseline value, and the 100-year peak daily flood discharge will increase by approximately 4% from the baseline value. The expected changes in monthly flow are within 10% of baseline flow condition. Maintaining flows within 10% of the natural condition is thought to have a low probability of detectable impacts (DFO 2013b) and a departure from the natural flow conditions of less than or equal to 10% would result in a high level of ecological protection whereby the natural structure and function of the ecosystem would be maintained (Richter et al. 2012).

The small magnitude and short duration of flow increase is within the range of natural flow variability that would be expected within Lac du Sauvage, Lac de Gras, and at the outlet of Lac du Sauvage. As a result, changes in water levels and flow during dewatering are expected to result in minor effects to channel/bank stability, riparian conditions, and habitat for fish and other aquatic life. Therefore, this pathway was determined to be a secondary pathway for fish and other aquatic life, and effects to fish and other aquatic life are predicted to be negligible.

Discharges from the dewatering of the diked areas of Lac du Sauvage may change water quality (suspended sediments) in receiving waterbodies and affect fish and other aquatic life

To access and mine the Jay kimberlite pipe, a portion of Lac du Sauvage must be isolated and dewatered. A horseshoe-shaped dike will be constructed to isolate approximately 4.2 km^2 of Lac du Sauvage overlying the Jay kimberlite pipe. Dewatering the diked area is a pathway to potentially altered water quality in Lac du Sauvage which may affect fish and aquatic life.

It is expected that the chemistry of water in the diked area during Phase I of dewatering will be similar to the open basin of Lac du Sauvage. The concentration of TSS could vary between the diked and non-diked areas, but overall, water quality differences are expected to be within the range of natural variability and not affect fish and fish habitat. The pumped discharge of water from the diked area to Lac du Sauvage will be limited to water that meets water discharge criteria quality for TSS. If TSS concentrations exceed criteria for direct release to the receiving environment, source mitigations may be implemented or the water will be pumped to Lynx or Misery pits.

TSS can affect fish directly and settling of the sediment (i.e., sedimentation) can affect nearby habitats. The nature and extent of adverse effects of increased TSS is influenced by both the TSS concentration and the duration of exposure. Fish can tolerate low TSS concentrations for long periods and high concentrations for short periods without suffering adverse effects. The effects of sediment deposition can include infilling of interstitial spaces between substrate particles that provide habitat for rearing of fry or incubation of eggs, covering aquatic plants, which can provide habitat for juvenile rearing or incubation of eggs, and potential shifts to benthic communities. The severity of the effect depends on the type of habitat and its use by fish.

It is anticipated that water quality in the upper 5 m of the diked area of Lac du Sauvage during dewatering will be similar to the water quality in the main Lac du Sauvage basin. Therefore, the dewatering of the diked area and release of this water to Lac du Sauvage is not expected to cause a change in water quality. A Dewatering Plan will be prepared for the WLWB as an anticipated condition of the water licence before dewatering. During dewatering, water in the diked area and at the end of pipe will be monitored to confirm compliance with regulatory criteria for TSS.

Discharge of water from the diked area to Lac du Sauvage is expected to result in minor, localized changes to water quality in the immediate adjacent receiving environment of Lac du Sauvage compared to existing conditions. These changes are also expected to be limited to the end of the Phase I dewatering when water levels have reduced sufficiently for the shallow areas to be influenced by the lake bed sediment. When TSS levels are at the allowable threshold on an ongoing basis as per the response framework outlined in the Dewatering Plan, source mitigation will be implemented, or discharge to Lac du Sauvage will cease (i.e., pumping to Lynx and Misery pits). Consequently, this pathway was determined to have negligible effects to water quality, and also to fish and aquatic life VCs.

Release of sediment during construction of the horseshoe-shaped dike in Lac du Sauvage may cause changes in water quality, affecting fish and other aquatic life

Release of sediment from dike breaching/removal activities may cause changes in water quality, affecting fish and other aquatic life in Lac du Sauvage

To allow for dewatering within the dike and open-pit mining of the kimberlite pipe, a horseshoe-shaped dike will be constructed to isolate the portion of Lac du Sauvage overlying the Jay kimberlite pipe. Construction of the dike is expected to generate high levels of turbidity and TSS within the lake in close proximity to the construction area as a result of rockfill placement, trench excavation in shallow areas, and lake bed sediment removal from deeper areas.

Disturbance of lake bed sediment and deposition of mine rock material during dike construction will increase TSS concentrations in water and affect water quality in Lac du Sauvage. Additionally, increased levels of suspended particulate matter could settle out in the lake, which could potentially affect sediment quality through change in particle size. TSS can affect fish directly and settling of the sediment (i.e., sedimentation) can affect nearby habitats. The nature and extent of adverse effects of increased TSS is influenced by both the TSS concentration and the duration of exposure. Fish can tolerate low TSS concentrations for long periods and high concentrations for short periods without suffering adverse effects. The effects of sediment deposition can include infilling of interstitial spaces between substrate particles that provide habitat for rearing of fry or incubation of eggs, covering aquatic plants, which can provide habitat for juvenile rearing or incubation of eggs, and potential shifts to benthic communities. The severity of the effect depends on the type of habitat and its use by fish.

A detailed dike construction plan will be developed and implemented for dike construction, and will include information relevant to mitigation, inspection, monitoring, and corrective action if necessary. Construction of the Jay Dike is scheduled to begin during summer 2016 with the construction of the northern abutment of the dike. This will be followed along the entire length of the dike until dike construction is completed in approximately 2018. The majority of dike construction activities (central trench excavation, removal of lake bed sediment, and backfilling activities) will occur during the open water season.

Rockfill will be placed during both the winter and summer months. Erosion and sediment control measures will be implemented (e.g., installation of silt curtains) for turbidity control. During summer construction, turbidity curtains will be installed near the portion of the alignment where dike construction will occur, which is an approach demonstrated at other northern mining projects. Deployment of turbidity curtains will not be possible during the winter; however, it is expected that ice cover and a reduced rate of rock placement will limit the extent of suspended sediment transport, an approach that has been demonstrated at the Meadowbank Mine. Enhanced TSS settlement is anticipated under-ice in the areas in close proximity to dike construction.

Turbidity monitoring will be conducted at designated locations throughout open-water and under-ice conditions, within and outside of the zone of the turbidity curtains. In the event that TSS concentrations approach monitoring thresholds, a review of local conditions and activities will be conducted. Non-potentially acid generating, chemically inert material (i.e., granite) will be used to construct the dike to prevent leaching of metals into water (Section 3.3.2).

At closure, breaching and removal of sections of the dike will only occur when water quality within the diked area meets specifications. A closure plan will be developed which will include management of dike breaching and removal activities to limit the potential for effects to water quality and fish and fish habitat. The plan will include information relevant to mitigation, inspection, and monitoring of dike breaching and removal activities. Erosion and sediment control practices will be implemented where appropriate, such as the use of silt curtains.

Through the described mitigation, the release of sediment from dike construction and breaching of the dike is expected to result in short-term, localized, and minor changes to water quality in the adjacent environment of the dike, resulting in negligible effects to fish habitat and the health of fish VCs (Arctic Grayling, Lake Trout, and Lake Whitefish).

The dike isolating the Jay pipe may provide spawning habitat for fish where any potential contaminants within interstitial spaces may affect survival of eggs or fry in Lac du Sauvage

There is the potential for fish to use the area near the Jay Dike as spawning habitat. Based on the material used for the dike, there is a potential for effects to eggs or fry from any contaminants coming off or within the interstitial spaces of the dike. Lake Trout, and to a lesser extent Lake Whitefish, may use portions of the dike for spawning, depending on substrate size and shape, depth, and wave and current characteristics. As Arctic Grayling primarily spawn in streams, it is expected that Arctic Grayling will not use the dike for spawning or rearing.

The dike isolating the Jay pipe in Lac du Sauvage will be constructed using granite rockfill which is not potentially acid generating (non-PAG) rock (Section 8.2.2.2.3; Geochemistry Baseline Report, Annex VIII). Granite is considered relatively inert as a reef-building material (Wilding and Sayer 2002). Any sediments associated with the material or the placement during construction would be removed through wind and wave action along the dike. Bentonite and other materials used for dike construction will be isolated within the core of the dike. As a result, the water chemistry within the interstitial spaces of the dike is not expected to deviate substantially from ambient lake water, or from interstitial water at natural spawning habitat.

Potential use of the dike material by spawning Lake Trout and Lake Whitefish is another consideration in the assessment of exposure to water chemistry in the interstitial spaces. This would be a function of the suitability of the material for spawning (e.g., substrate size) and the availability of spawning shoals in the lakes (i.e., ESA-1). For example, a previous assessment of the Diavik mine dike in Lac de Gras did not detect Lake Trout spawning on the dike or adjacent habitats even though they were appropriate for spawning (Fitzsimmons 2013). This may be due to the large abundance of suitable spawning habitat throughout Lac de Gras and Lac du Sauvage, or it may be indicative of preferential spawning areas. An estimated 18 million square metres (m^2) of Lake Trout spawning habitat of good and fair quality was present in Lac du Sauvage, much as non-attached shoals and shoals extending from small islands. Lac de Gras may provide as much as 58 million m^2 of Lake Trout spawning habitat (Annex XIV).

Due to the inert nature of the granite used to construct the dike and that spawning activity on the dike may be low, the potential for fish eggs or fry to be affected by contaminants coming off or within the interstitial spaces of the dike was predicted to be negligible. As such, this pathway was determined to be secondary and have negligible residual effects to Lake Trout and Lake Whitefish.

Modification to Panda and Koala Pit closure may cause changes to flows, water levels, and channel/bank stability in downstream and source waterbodies which may affect fish and fish habitat

The Project will use the mined-out Panda and Koala pits and underground workings (in the Koala watershed) for fine processed kimberlite (FPK) deposition during the operations phase (2020 to 2029). Processing of the Jay kimberlite is expected to generate in the order of 25 to 30 million tonnes (Mt) of FPK. The Panda and Koala pits are the primary deposition locations for FPK resulting from the Project.

The deposition of FPK in Panda and Koala pits will begin during operations. Once filling with FPK and the processing plant discharge is complete, a 30 m deep freshwater cap will be created by pumping from Upper Exeter Lake. This pumping scenario is an improvement over the current Ekati Mine closure and reclamation plan, because substantially less freshwater is required (i.e., approximately 19 million m^3 versus the current volume of approximately 88 million m^3), which reduces freshwater requirements from source lakes. The infilling of the freshwater cap is expected to take approximately four years after the end of operations and the beginning of pumping, rather than 18 years.

The change to hydrology from the modification to the closure for the Panda and Koala pits was assessed in Section 8.4.2 as a secondary pathway. When FPK from the Project is used to fill the Panda and Koala pits and reclaim water is pumped from the LLCF, the Slipper Lake annual discharge is expected to increase 0.2% from existing Base Case conditions. During post-closure, when runoff coefficients are estimated to return to baseline values, the annual discharge in the Slipper watershed is expected to decrease 7% below Base Case conditions. The effects downstream of Slipper Lake, at Lac de Gras, would result in non-measureable effects to the surface hydrology and available fish habitat in Lac de Gras.

The effects to surface hydrology within Upper Exeter Lake (part of the Yamba Lake and larger Coppermine River watershed) were assessed as part of the 2011 Ekati ICRP. Withdrawals from Upper Exeter Lake during closure are estimated to be at a rate of 0.4 m^3/s during the open-water season (June to October), with an annual maximum withdrawal volume of 5 million m^3 and approximately four years of pumping. The scheduled pumping rate from Upper Exeter Lake, under average climate conditions, is expected to result in a reduction in lake surface elevation of 0.03 m and a reduction in annual lake outflows of approximately 18%. At the scheduled withdrawal rates, a minimum flow rate of 0.4 m^3/s is expected to be maintained in the Upper Exeter Lake outflow from June to September (BHP Billiton 2011). Scheduled withdrawals from Upper Exeter Lake will be also managed so that withdrawal rates and annual volumes withdrawn from source lakes do not cause negative impacts in the source lakes, as described in the Ekati ICRP.

The use of Panda and Koala pits for FPK deposition will modify the closure schedule, but it is expected to reduce the requirements for freshwater withdrawal from source lakes, compared to the existing Ekati Mine reclamation and closure plan (Dominion Diamond 2013). The changes in Slipper Lake, Upper Exeter Lake, and Lac de Gras water levels and discharges related to the closure of Koala and Panda pits are minor and temporary. Furthermore, post-closure conditions in the Koala watershed are expected to be similar to natural runoff and drainage conditions. Thus, this pathway was determined to be a secondary pathway with no or negligible residual effects expected for fish and other aquatic life.

Pumping water to back-flood the Jay Pit and dewatered diked area of Lac du Sauvage may affect flows, water levels, and channel integrity in the Coppermine River, affecting fish and other aquatic life

At the completion of mining the Jay pipe, the Misery Pit, the Jay Pit, and the diked area will be back-flooded with freshwater to create a freshwater cap on the pits, to re-establish natural water levels within the diked area, and to allow the Misery Pit to discharge to Lac de Gras. Water for back-flooding the Jay Pit and diked area and the Misery Pit will come from a combination of local runoff, direct precipitation, and pumping from Lac du Sauvage. The back-flooding period is expected to require approximately 3 years, 9 months of pumping (2030 to 2033) from Lac du Sauvage.

The water balance results for Lac de Gras in the hydrology assessment (Section 8.5.3.3.5) show that during closure (i.e., during back-flooding activities to fill the pits and the dewatered area), monthly mean flows will decrease compared to baseline. The 2-year peak daily flood discharge during closure will decrease by approximately 5% below the baseline value, and the 100-year peak daily flood discharge will decrease by approximately 6% below the baseline value. Closure will cause the 2-year 30-day averaged low flows to decrease by 6% below the baseline value and the 100-year 90-day averaged low flows to decrease by 10% below the baseline value. During anticipated low flow time periods, such as winter months, pumping rates out of Lac du Sauvage into the pits will be reduced and pumping rates will be managed to minimize downstream effects.

The duration of decreased flow due to back-flooding the Jay Pit and the dewatered area is expected to be less than 4 years and will not affect the seasonal timing of flows. Without additional mitigation in place, flows at the Lac de Gras outlet and further downstream in the Coppermine River are expected to be within 10% of baseline conditions. Maintaining flows within 10% of the natural condition is thought to have a low probability of detectable impacts (DFO 2013b) and a departure from the natural flow conditions of less than or equal to 10% would result in a high level of ecological protection whereby the natural structure and function of the ecosystem would be maintained (Richter et al. 2012). Due to the low magnitude of change predicted, and in consideration of mitigation that will be in place to reduce pumping during low flow periods, this pathway was determined to be a secondary pathway with negligible effects to fish and other aquatic life VCs.

9.3.2.2.3 Primary Pathways

The following primary pathways are assessed in detail in the effects analysis for fish and other aquatic life. The scale of the effects study area for the primary pathways is Lac du Sauvage, Lac de Gras and selected tributary streams (i.e., ESA-1).

- The construction of the horseshoe dike and Jay Pit within Lac du Sauvage will result in the direct loss or alteration of habitat, affecting fish and other aquatic life within Lac du Sauvage and Lac de Gras.
- The dewatering of the diked area will result in the direct loss or alteration of habitat in Lac du Sauvage, affecting fish and other aquatic life within Lac du Sauvage and Lac de Gras.
- Dewatering Lac du Sauvage within the diked area will require removal of fish from the area.

- The construction of the horseshoe dike and diversion channel may alter access to tributary stream habitats to Lac du Sauvage, resulting in habitat loss for Arctic Grayling, Lake Trout, and Lake Whitefish.
- Operational activities and discharge (e.g., discharge of treated domestic wastewater, altered drainage, runoff from facilities, including waste rock storage areas, pit inflows, dike seepage, release of nitrogen compounds from blasting residues, fine processed kimberlite management) may change surface water quality and affect fish and other aquatic life in Lac du Sauvage and Lac de Gras.
- Pumping water to back-flood the Jay Pit and diked area of Lac du Sauvage may affect water levels and riparian habitat in Lac du Sauvage and Lac de Gras, and water levels, flows, and riparian habitat in the Lac du Sauvage-Lac de Gras Narrows, affecting fish and other aquatic life.
- Reconnection of the back-flooded area of Lac du Sauvage to the remaining watershed and post-closure releases of water (e.g., Misery Pit overflow and seepage, waste rock storage area runoff, Long Lake Containment Facility discharge) may change long-term water quality in Lac du Sauvage and Lac de Gras and affect fish and other aquatic life.

9.4 Residual Effects Analysis

9.4.1 General Approach

The effects analysis considers all primary pathways that result in expected changes in assessment endpoints for fish, after implementing environmental design features and mitigation. Thus, the analysis is based on the residual effects from the proposed Project. Residual effects to VCs are analyzed using measurement indicators (Table 9.1-2). The objective of the effects analysis was to determine how Project activities would affect an individual measurement indicator or a given set of measurement indicators for the biophysical environment (e.g., direct loss or alteration of fish habitat, or changes to water quality during operations affecting fish and other aquatic life). The measurement indicators are, in turn, connected to the broader-scale assessment endpoints, which represents the ultimate properties of the system that are of interest or concern. The residual impact classification focuses on the assessment endpoint because that is a statement of what is most important to future generations.

The spatial scale of the analysis of potential effects to fish and fish habitat considers the area that Project activities could potentially have direct or cumulative effects on biological receptors or end-users. The spatial boundaries for each effects study area (ESA) were set so that all potential effects of the Project on populations of fish VCs would be captured. The proposed Project activities are located entirely in the Lac de Gras watershed, which includes the Lac du Sauvage watershed. The Project activities include mine infrastructure such as buildings, roads, open pits, dikes, diversion channels, processed kimberlite storage areas, and waste rock storage areas. The spatial scale for the analyses includes existing developments (i.e., the Ekati and Diavik diamond mines) which have the potential to overlap with the Project in all phases of the Project.

The temporal scale includes natural and development-related changes from reference conditions (i.e., before any regional development) through application of the Project, and reasonably foreseeable developments (where applicable). Base Case conditions represent a range of temporal values on the landscape from reference (little to no development) to 2014 (current or existing) baseline conditions. Environmental conditions on the landscape before industrial development (i.e., reference conditions) are considered part of the baseline conditions. This is because the baseline represents a range of conditions over time, and not just a single point in time. Comparison to a reference condition may allow for a further understanding of the cumulative effects of increases in development on the VCs.

The effects analyses determine the incremental and cumulative changes from the Project and other developments. Incremental effects represent the Project-specific changes relative to baseline condition values in 2014. Project-specific effects typically occur at the local scale and represent the predicted maximum spatial extent of effects.

Cumulative effects are the sum of all changes from reference conditions through application of the Project, and future developments, where applicable. In contrast to Project-specific (incremental) effects, cumulative effects may occur beyond the local scale. Cumulative effects represent the sum of all natural and human-induced influences through time and across space. The objective of the cumulative effects analysis is to predict the relative contribution of human-related influences on fish and other aquatic life in the Lac de Gras watershed in context of natural factors. The cumulative effects analysis for the fish and other aquatic life VCs also considers the cumulative effects related to surface hydrology and water quality (Section 8).

For fish and other aquatic life, cumulative effects are considered in all assessment cases. As the Ekati and Diavik mines are currently on the landscape as existing and approved projects, the 2014 baseline or existing conditions include the effects of these developments under the Base Case. Similarly, as the Application Case is the existing and approved projects plus the Jay Project, this case also includes the cumulative effects of these developments.

The magnitude, spatial extent, and duration of predicted changes in measurement indicators (e.g., habitat quantity and quality, status of lower trophic levels) from the proposed Project and other developments are expected to be similar to or greater than the actual effects to the abundance and distribution of populations. Where possible, the analyses considered conservative inputs and methods such that effects would be over-estimated as an approach to reduce uncertainty in predictions.

The analyses of residual effects from the proposed Project on fish were quantitative, where possible, and included data from field studies, scientific literature, monitoring programs at existing mines, government publications, and personal communications. Traditional knowledge and community information were incorporated where available. Due to the amount and type of data available, some analyses were qualitative and included professional judgement or experienced opinion.

The effects analysis for primary pathways related to direct loss of fish habitat are described in detail below. Analyses of primary pathways related to surface hydrology were based on methods and results described in detail in Section 8.5.3 and those related to water quality were based on methods and results described in detail in Section 8.5.4.

9.4.1.1 *Project Phases*

The Project phases include construction, operations, and closure. Many effects of the Project will end when operations cease or at closure.

The effects analysis encompasses the Project phases as follows:

- construction (2016 to 2019);
- operations (2019 to 2029); and,
- closure (2030 to 2033).

The surface hydrology and water quality assessments also had two snapshots during operations based on the operational discharge of minewater from the Misery Pit: early operations (before discharge from Misery Pit [2019 – 2024]); and late operations (during discharge from Misery Pit [2024 – 2029]).

The post-closure period describes the long-term effects of the Project following closure. The above timeframes are intended to be sufficiently flexible to capture the effects of the Project on fish and other aquatic life. Effects to fish VCs begin during the construction phase with construction of the diversion channel and roads, construction of the dike in Lac du Sauvage, and dewatering of the diked area, and continue through the operation and closure phases and into post-closure with portions of the dike remaining in Lac du Sauvage. Therefore, effects to fish were analyzed and assessed for significance from Project construction through post-closure. This approach generates the maximum potential spatial and temporal extent of effects on the fish and other aquatic life VCs, which provides confident and ecologically relevant effects predictions.

9.4.1.2 *Assessment Cases*

The residual effects analysis consists of three cases: Base Case, Application Case (the maximum point of development of the Project [includes construction, operation, and closure]), and the Reasonably Foreseeable Development (RFD) Case (if applicable; Table 9.4-1). Cumulative effects could occur in all three cases because of past, existing, and future mining and reclamation activities. The objective of the DAR is to assess cumulative effects for VCs where Project effects could contribute to a cumulative effect. Therefore, incremental and cumulative effects from the Project and other developments are analyzed and assessed together in this section of the DAR.

An RFD Case is not considered for fish and other aquatic life VCs because there are no potential RFD projects within the fish ESAs. The closest reasonably foreseeable development is the Courageous Lake project, located outside the Lac de Gras sub-basin and approximately 73 km to the southwest of the Project. The RFDs are defined as projects that:

- are currently under regulatory review or have officially entered a regulatory application process;
- have a reasonable likelihood of being initiated during the life of the Project, or may be induced by the Project; or,
- have the potential to change the Project or the effects predictions.

Table 9.4-1 Contents of Each Assessment Case

Base Case		Application Case	Reasonably Foreseeable Development Case
Reference Condition	**2014 Baseline Conditions**		
No or minimal human development	Conditions from all previous, existing, and approved developments before the Project	Base Case plus the Project	Application Case plus reasonably foreseeable developments Not considered for fish and other aquatic life because there are no other planned developments in the foreseeable future within the effects study areas

9.4.1.2.1 Base Case

The Base Case represents a range of conditions over time within the ESA before the application of the Project to provide an understanding of the current (2014) conditions that may be influenced by the Project. Environmental conditions on the landscape before human development, which represent reference conditions, were considered independently within the Base Case, where possible.

The Base Case describes the existing environment before the application of the Project to provide an understanding of the current conditions that may be influenced by the Project. Existing (2014 baseline) conditions include the cumulative effects from all previous and existing developments and activities that are approved (e.g., operations from the Ekati and Diavik mines, including the A154 and A418 dikes and pits in Lac de Gras at the Diavik Mine), and are either under construction or not yet initiated in the ESA (e.g., Lynx Project). Current (baseline studies) and future effects from ongoing projects that are approved (e.g., mining and reclamation at Ekati and Diavik mines) are also included in the 2014 baseline condition.

9.4.1.2.2 Application Case

The Application Case represents predictions of the cumulative effects of the developments in the Base Case combined with the effects from the Project. Physical disturbance to surface water and fish habitat is expected to occur at the beginning of construction and the effects from the Project on water quality are expected to be strongest during late operations because of discharge from the Misery Pit into Lac du Sauvage. The main components of the Project footprint that influence fish are the constructed Jay Dike, the construction of the diversion channel, the dewatering of the diked area, and the proposed mining activities and infrastructure (Jay WRSA, ore stockpile and transfer pad, Sub-Basin B Diversion Channel). The Application Case is also used to identify the incremental effects from the Project that are predicted to occur between the Base and Application cases.

9.4.2 Methods

9.4.2.1 *Assessing Direct Effects to Fish*

The development of the Project is expected to directly affect the availability of habitat through losses of fish habitat incurred by footprints in Lac du Sauvage and adjacent sub-basins (i.e., Ac4, Ac35, and B). The greatest changes will be a result of the construction of the Jay horseshoe dike and the dewatering of the diked area in Lac du Sauvage where the pit will be located. The assessment quantified habitat changes in a GIS platform by intersecting available spatial data on existing and proposed developments with surface waters (NTS 1:50,000) within the ESA. The direct loss of habitat will also result in direct fish mortalities incurred as part of the fish out activities during dewatering.

9.4.2.1.1 Habitat Calculations

Changes in available habitat may affect fisheries productivity (e.g., yield) when a loss of habitat area causes a reduction in carrying capacity, resulting in a reduction of fish production; where fish production reflect vital rates (e.g., growth, survival, reproduction) and life history characteristics (e.g., fecundity, age at maturity) (DFO 2014a). Key measurement indicators for the assessment of fisheries productivity were absolute (e.g., hectares, metres) and relative values (%) of lost or altered habitat for lakes and streams. Use of both absolute and relative values can provide complementary information in the assessment to habitat; for example, a prediction of high relative change may not necessarily mean that a large area is affected by the development.

The surface area of Lac du Sauvage (8,668 ha) used for calculation of relative habitat losses was derived from the shoreline delineation using georeferenced orthophoto and all relative changes to habitat are based on this area calculation. A total lake area for Lac du Sauvage and Lac de Gras of 65,758 ha was used for calculation of relative habitat change within both lakes (based on 1:50,000 NTS spatial data). The area of the Project footprint within aquatic habitats was calculated from the digitized layout of infrastructure overlaid on aquatic map features using GIS software. Within Lac du Sauvage, the Project footprint from the dike and dewatered area was quantified in terms of the area (ha) of aquatic habitat in the lake affected by the Project for different habitats. These habitats were also defined based on substrate type (fines, mixed, and coarse), as described by hydroacoustic surveys (Annex XIV; Section 9.2.2), falling into each of the four depth strata (0 to 2 m, 2 to 6 m, 6 to 10 m, and greater than 10 m). The objective of the assessment for substrate and areas at varying depths was to understand potential changes to habitat quality and to identify unique habitat types that may be affected by the Project.

The substrate categories were considered in the evaluation of Lac du Sauvage according to the key life history functions for fish VCs:

- Fines – consisted of sand, silt, and organics; generally considered the lowest habitat quality of the three categories for the VC species in terms of cover, but provides habitat for macroinvertebrate food items (e.g., chironomids) for species that are occasional benthic feeding, such as Lake Whitefish and Arctic Grayling, and primarily benthic feeding species, such as Round Whitefish (forage species);
- Mixed – considered a mix of fines and coarse substrates; mixed habitat may provide some of the functions described in both fines and coarse categories; and,
- Coarse – included all coarse substrates (i.e., gravel, cobble, and boulder); generally considered to be the highest habitat quality of the three categories because of the cover provided by coarse substrates, for example, for spawning, rearing, and foraging by Lake Trout and Lake Whitefish.

The total area of Lac du Sauvage and Lac de Gras was subdivided into four depth strata, which were defined by their potential life history habitat functions for species VCs:

- Shallow (less than 2 m) – expected to be productive foraging and rearing littoral areas during open water season because of warmer temperatures, light penetration, and substrates characterized by coarse substrate types or a mix of fines and coarse substrates; but includes areas that may have low oxygen during mid-summer when temperatures are warm, precluding use by large-bodied fish and includes areas most likely to freeze to bottom during winter;
- Moderate (2 m to 6 m) – potentially productive foraging and rearing areas for most species during open water season because of warmer temperatures, light penetration, and the occurrence of mixed substrates, and may include areas with higher levels of dissolved oxygen under-ice; likely preferred depths for spawning substrates for Lake Trout and Lake Whitefish (reviewed in Marsden et al. 1995); areas may have reduced or potentially inadequate dissolved oxygen levels to support use by large-bodied fish species during mid-summer when temperatures are warmest;
- Deep (6 m to 10 m) – areas likely to support most species and age-classes year-round; assumed to be less productive for VC species than shallower locations because of the dominance of fine substrates at this stratum and as depths may be below the range of effective light penetration; some locations may support spawning substrates for Lake Trout and Lake Whitefish depending on local wave action; and,
- Very Deep (greater than 10 m) – areas likely to support VC species and age-classes year-round, but can be the least productive stratum for foraging during summer because of the lack of coarse substrates and because depths are often below the range of effective light penetration; areas may be below the thermocline if present mid-summer, providing thermal refugia.

Shoreline substrate types were also examined for Lac du Sauvage using georeferenced orthophotos and ground-truthing methods for depths up to 5 m (Map 9.2-3A, B, C; see Annex XIV). Shoreline substrate types were mapped in detail as fines, gravel, cobble, boulder, and bedrock throughout shallow locations of Lac du Sauvage. The spatial data were summarized as area per substrate type for two depth strata: 0 to 2 m, and 2 to 5 m.

The construction of the dike will also eliminate fish access to tributary streams that flow into the diked area. These streams include Ac4, Ac35, and B0. Of these streams, Ac4 and Ac35 are characterized by ephemeral flows based on the small contributing drainage areas of their respective sub-basins (less than 300 ha in size). Furthermore, Rescan (2007) reported low flows and no fish in Stream Ac4 during sampling in summer 2006. The aquatic footprint of the Project also includes the Sub-Basin B Diversion Channel that will cross fish-bearing streams in sub-basin B (Christine) and sub-basin Ac35. Diverted streams fall within ESA-1 for Arctic Grayling, Lake Trout, and Lake Whitefish.

The overall Project footprint was quantified in terms of the area (ha) of lake and stream length (m) affected by the Project. Relative changes to fish habitat were examined on a population-level scale so that the assessment provided an ecologically relevant and confident assessment of the direct effects to fish habitat on VCs from the Project. Thus, the scale of the assessment for the fish and other aquatic life VCs included Lac du Sauvage, Lac de Gras, and supporting tributaries (i.e., ESA-1; Table 9.1-4). Supporting tributaries, including Stream Ac4, Ac35, and B0, were assumed to have potential to provide habitat for foraging and rearing for VC species and forage fish that reside in Lac du Sauvage and Lac de Gras.

The footprint statistics were determined according to the type of proposed activity for the Project within ESA-1:

- Placement of the dike;
- Dewatered area for isolating the Jay Pit;
- Proposed mining infrastructure within the dewatered area; and,
- Stream sections that will be diverted below the diversion channel.

9.4.2.1.2 Mortality Estimation

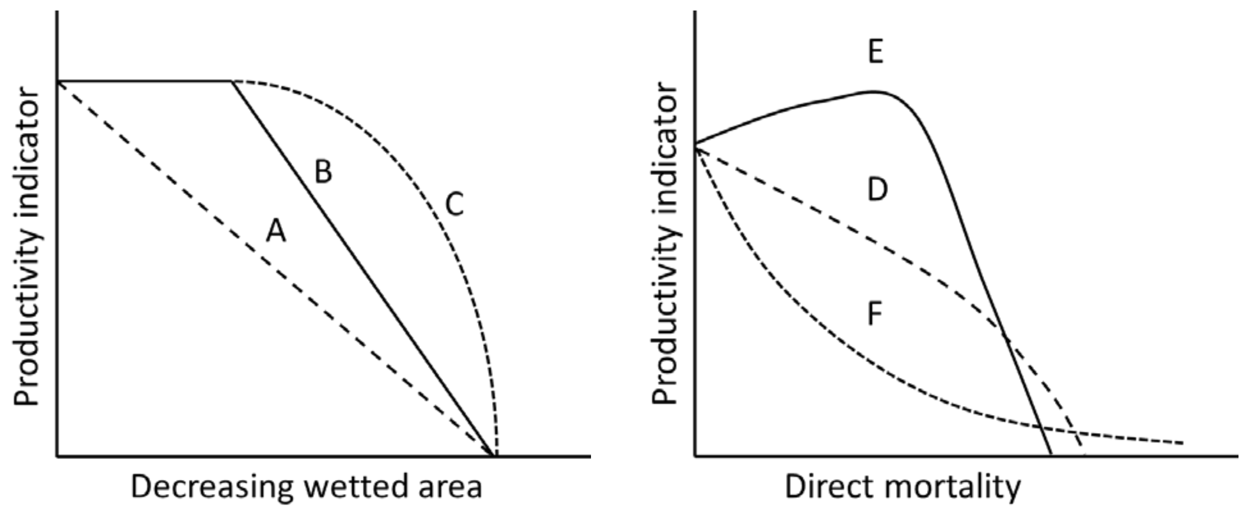
As part of the assessment of direct effects to habitat from the Project footprint, dewatering of the diked area of Lac du Sauvage is required to allow mining of the Jay kimberlite pipe located under the lake bed. The diked area will be isolated from Lac du Sauvage, and the fish remaining in the diked area will be targeted for removal before final dewatering. A fish-out will be conducted to remove fish from the diked area of Lac du Sauvage resulting in the direct mortality of fish (Appendix 9C). The assessment quantified the number of fish to be removed using volumetric densities reported from a hydroacoustic study of Lac du Sauvage (Annex XIV), combined with estimated water volumes within the diked area. Mortality or removal of fish in the diked area may affect fisheries productivity (e.g., yield) through a reduction in fish production; where fish production reflect vital rates (e.g., growth, survival, reproduction) and life history characteristics (e.g., fecundity, age at maturity) (DFO 2014a).

9.4.2.1.3 Evaluating Habitat Loss and Mortality

The development of the Project may affect fisheries productivity through losses of fish habitat incurred by the construction of the Jay horseshoe dike, dewatering the area behind the dike, and the removal of fish from the diked area in Lac du Sauvage where the pit will be located. The construction of the dike, dewatering the diked area, and the fish-out are related activities and these pathways were considered together as part of the assessment while recognizing that the responses of populations of fish VCs can vary depending on type of disturbance and the species life histories.

For the assessment of effects of habitat losses to fish VCs it was conservatively assumed that affected habitat was not abundant in the ESA and so the underlying assumption is that the population carrying capacity is proportional to the size of the habitat area (Figure 9.4-1) (DFO 2014a).

Figure 9.4-1 Conceptual Response of Fisheries Productivity to Habitat Loss and Direct Mortality (Modified from DFO 2014a)



A Linear relationship, considered a default or conservative relationship for assessments of habitat loss.

B A simplified curvilinear relationship with an upper plateau before a decline in productivity.

C Data from the literature strongly support the curvilinear relationship for habitat loss; wider plateau suggests habitat is abundant.

D The default relationship for assessing direct mortality; high levels trigger can increase rate in decline.

E If direct mortality occurs before key sources of density dependent mortality, compensatory effects can result in an increase in productivity followed by a steep decline; assumes strong density-dependent population regulation.

F If there are no opportunities for density-dependent compensatory responses after the direct mortality, then the direct mortality can reduce productivity below the default proportional line.

The effect of the fish-out was assessed using a relationship between direct mortality and fishery productivity, which was assumed to be proportional up to a point or threshold where large levels of mortality (e.g., more than 80% of the population is removed) will increase the rate of decline (DFO 2014a). The linear relationship was assumed for direct mortality because of expected response over the long-term. Although initial responses may follow an exponential decay trend (Figure 9.4-1) because the fish-out and footprint effects occur concurrently with the isolation of the diked area (i.e., removing fish from the diked area should not change the density of fish in remaining habitat within the ESA), a change in density at closure when the dike is breached may trigger an increase in rates of growth and survival through, for example, reduced competition for food resource. This phenomenon is described as a density-dependent effect, and can be a process that enhances recovery from a disturbance.

Although local population dynamics of fish VCs may conform to some level of density-dependent regulation during one or multiple life history stage (as is the case for many populations of fish; Rose et al. 2001), it is expected the population dynamics are also influenced by recruitment or production potential. The occasional exceptional recruitment year likely carries the self-sustaining population through poor years of recruitment given the life histories of the fish VCs (Johnson 1976; Rose et al. 2001). For example, production potential may be high for fish species in Arctic freshwater lakes because species typically delay maturation to attain a size sufficient for production of a large clutch and for surviving periods of suboptimal environmental conditions.

9.4.2.2 *Assessing Changes to Water Quality and Effects to Lake Ecosystem Productivity*

Changes to water quality in Lac du Sauvage and Lac de Gras are expected during operations and closure phases (Section 8.5.4). Concentrations of nutrients (such as phosphorus, nitrogen, and silica) and total dissolved solids (TDS) may increase due to Project activities. The predicted increases are expected to result from altered drainage, runoff from facilities including WRSAs, pit inflows, dike seepage, release of nitrogen compounds from blasting residues, and direct minewater discharge into Lac du Sauvage from the Misery Pit (Section 8.5.4). Predictions were based on quantitative models of water quality in Lac de Gras and considered cumulative changes resulting from activities at the Ekati and Diavik mines, in addition to the Project. There are no reasonably foreseeable developments in the ESA for fish and other aquatic life.

The analysis of potential effects related to predicted changes in water quality in Lac du Sauvage and Lac de Gras considered the following components of fish and other aquatic life:

- lower trophic communities, including phytoplankton, zooplankton, and benthic invertebrates;
- food base changes for fish production;
- changes to physical habitat, including the availability of spawning habitat; and,
- changes to fish health (summarized from Section 8.5.6)

Effects on lower trophic communities from changes in water quality were predicted using qualitative methods, including an assessment of trophic classification of aquatic ecosystems based on nutrient concentrations (CCME 2004; Environment Canada 2004; Wetzel 2001), experience from effects monitoring at operating northern diamond mines, and the scientific literature on the effects of nutrient enrichment in lakes. Quantitative relationships between the physical/chemical features of sub-Arctic lakes and lower trophic community characteristics are not available; however, the relationship between nutrient concentrations and aquatic productivity has been well studied (Wetzel 2001; Environment Canada 2004).

Lakes can be classified as oligotrophic, mesotrophic, or eutrophic based on low, moderate, and high levels of productivity. Evaluation of trophic status in Lac du Sauvage and Lac de Gras considered predicted concentrations of total phosphorus and nitrogen as well as phytoplankton biomass (as chlorophyll *a*). The general trophic classification of lakes in relation to these parameters based on CCME (2004; trigger values for phosphorus) and Wetzel (2001; trophic classification for nitrogen and chlorophyll *a*) is presented in Table 9.4-2.

Table 9.4-2 A General Trophic Classification of Lakes (CCME 2004; Wetzel 2001)

Trophic Classification	Total Phosphorous (TP; µg/L)	Total Nitrogen (TN; µg/L)	Chlorophyll *a* (µg/L)
Oligotrophic	4.0 - 10	307 – 1630	0.3 – 4.5
Mesotrophic	10 – 20	361 – 1387	3.0 – 11
Eutrophic	35 – 100	393 – 6100	3.0 – 78

µg/L = micrograms per litre

Numerous studies (commonly referred to as “fertilization” studies or experiments) have documented changes in plankton and benthic community structure in sub-Arctic and northern temperate lakes in response to nutrient additions (Morgan 1966; Smith 1969; Welch et al. 1988; Hershey 1992; Jorgenson et al. 1992; Clarke et al. 1997; Johnston et al. 1999). Aquatic effects monitoring programs at existing diamond mines in the NWT have also reported changes in lower trophic community characteristics with increasing levels of nutrients (De Beers 2010; Golder 2011), which is directly applicable to the assessment of potential effects to fish and other aquatic life in Lac du Sauvage and Lac de Gras.

9.4.2.3 *Assessing Downstream Changes During Back-Flooding*

The effects of the Project from change in downstream water quantity on fish and other aquatic life in Lac du Sauvage and Lac de Gras during the back-flooding period are evaluated and a brief description of the methods is provided below. Additional details are included in Section 8.5.3.1.

A regional water balance model was used for the assessment cases for surface water hydrology (Section 8.5.3.1; Appendix 8D). The baseline water balance model was used for the Base Case and then modified for the Application Case to represent changes to hydrology ESA watersheds for each phase of the Project. The model was set up using GoldSim™ software daily time step for the period of 1959 to 2013. This time period was selected to correspond with the long term climate data derived for the site.

The hydrology effects analyses emphasized Closure Year 3 (2032) because the Year 3 results show the largest effects of withdrawal of water from Lac du Sauvage (for back-flooding the Jay and Misery pits and the diked area) on the downstream watershed due to two years of antecedent pumping in addition to the Year 3 (2032) back-flooding volumes. Similar effects to surface hydrology during the entire back-flooding period are expected, but the Closure Year 3 analysis is provided as an assessment of the greatest effects to surface hydrology during back-flooding. Changes to fish habitat during back-flooding were considered based on absolute and relative changes to habitat based on changes in water levels, water depths, and wetted widths.

9.4.3 Results

9.4.3.1 *Direct Effects to Fish*

The following primary pathways are considered for the direct effects from the Jay Project footprint on fish and other aquatic life:

- The construction of the horseshoe dike and Jay Pit within Lac du Sauvage will result in the direct loss or alteration of habitat, affecting fish and other aquatic life within Lac du Sauvage and Lac de Gras.
- The dewatering of the diked area will result in the direct loss or alteration of habitat in Lac du Sauvage, affecting fish and other aquatic life within Lac du Sauvage and Lac de Gras.
- Dewatering Lac du Sauvage within the diked area will require removal of fish from the area.
- The construction of the horseshoe dike and diversion channel may alter access to tributary stream habitats to Lac du Sauvage, resulting in habitat loss for Arctic Grayling, Lake Trout, and Lake Whitefish.

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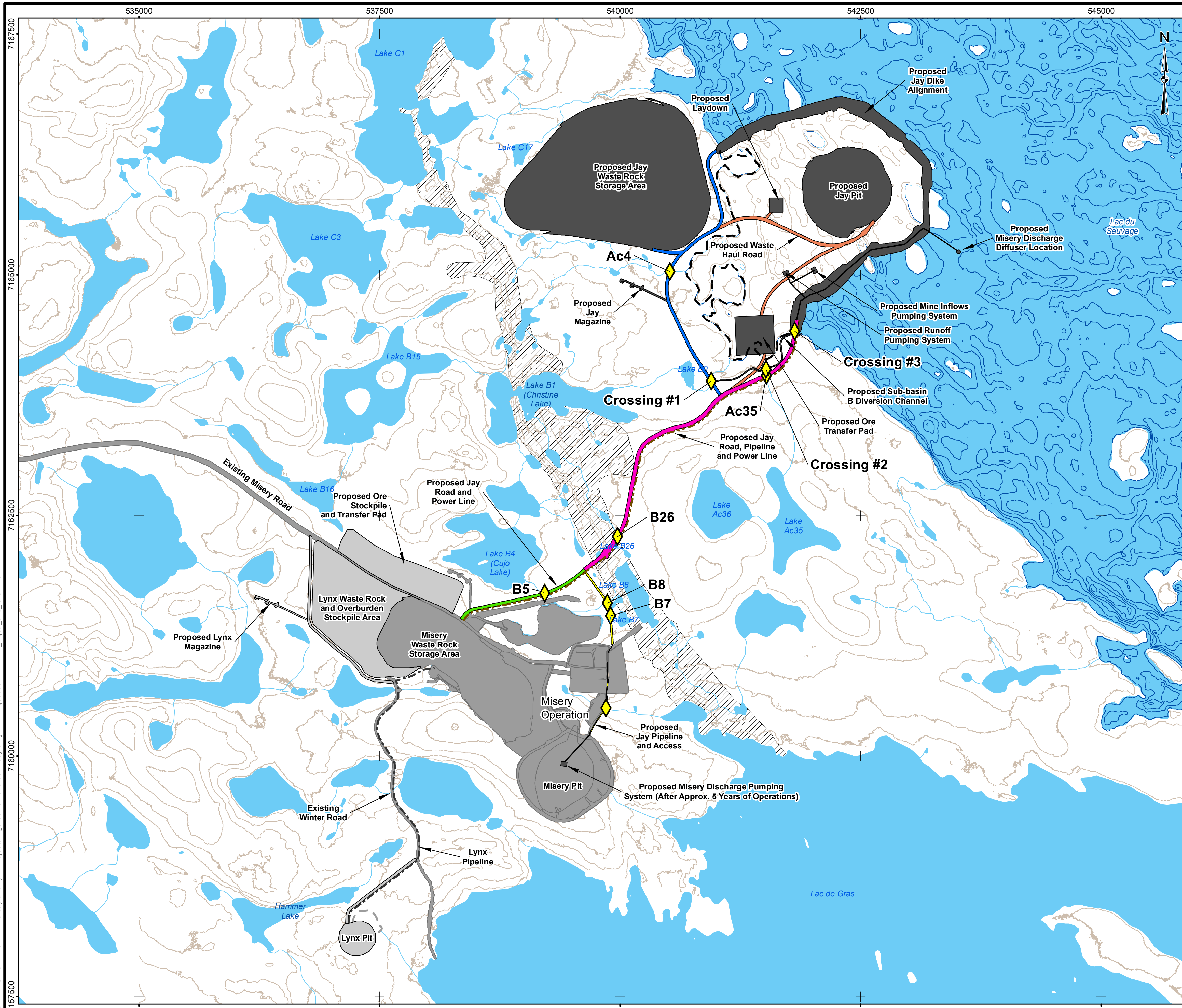
9.4.3.1.1 Dike-Dewatered Area Footprint

Historical reference conditions within the effects study area (ESA-1) for Arctic Grayling, Lake Trout, and Lake Whitefish includes 57,107 ha of available lake habitat in Lac de Gras and 8,651 ha of available lake habitat in Lac du Sauvage (or 65,758 ha combined) (based on NTS 1:50,000 map). Shoreline delineation using georeferenced orthophotos results in a calculated lake area of 8,668 ha for Lac du Sauvage, which was used for some of the habitat analysis calculations.

The loss of habitat associated with previous, existing, and proposed footprints (i.e., the Application Case) in Lac du Sauvage and/or Lac de Gras may cause a reduction in the overall carrying capacity in these lakes, resulting in a reduction of fish production for Arctic Grayling, Lake Trout, and Lake Whitefish. Although there are currently no developments in Lac du Sauvage, there are existing developments in Lac de Gras (A154 and A418 pits and dikes at the Diavik Mine) where the baseline footprint is approximately 196 ha (or 0.3% of lake habitat in the ESA for the 2014 Base Case). With the application of the Project, the in-lake footprint involves the construction of the Jay Dike and dewatering of the diked area in Lac du Sauvage (Map 9.4-1).

The total in-lake footprint of the Project in Lac du Sauvage during operations is estimated to be 54.3 ha from the dike and 335.7 ha from the dewatering of the diked area, resulting in a total loss of 390.0 ha, or 4.5% of the aquatic habitat in Lac du Sauvage (Table 9.4-3), and 0.6% within Lac du Sauvage and Lac de Gras combined (i.e., the ESA). The cumulative effect on lake habitat represents the existing footprint in Lac de Gras (196.0 ha) plus the operational footprint of the Project (390.0 ha). The total cumulative change in habitat for the Application Case will be 586.0 ha or 0.9% of lake habitat in the ESA; however, most of the altered habitat will be restored at closure when the dike is breached.

Of the four depth categories (0 to 2 m, 2 to 6 m, 6 to 10 m, and greater than 10 m), most of the affected habitat will be within the 2 to 6 m stratum, representing a 5.2% incremental change (135.0 ha loss) in Lac du Sauvage, and a 1.1% incremental change from Base Case in Lac du Sauvage and Lac de Gras combined (Table 9.4-3). The total cumulative change in habitat at 2 to 6 m depths is predicted to be 202.4 ha, or 1.7% of habitat with the application of the Project combined with effects from previous and existing developments in the ESA. This change represents effects to potentially productive foraging and rearing areas for species in the ESA, including Arctic Grayling, Lake Trout, Lake Whitefish, and forage species during the open water season. The predicted change also has implications for the availability of preferred substrates for spawning and egg incubation during fall and winter for Lake Trout and Lake Whitefish.



LEGEND

- EKATI MINE FOOTPRINT (MISERY OPERATION)
- BATHYMETRY CONTOUR (5 m INTERVAL)
- ELEVATION CONTOUR (10 m INTERVAL)
- ESKER
- WATERCOURSE
- WATERBODY
- WATERCOURSE CROSSING

JAY PROJECT FOOTPRINT

- EXISTING SHORELINE OF DEWATERED AREA
- POWER LINE
- PROPOSED JAY PROJECT INFRASTRUCTURE
- PROPOSED JAY ROAD NORTH (HAUL ROAD)
- PROPOSED JAY ROAD (HAUL ROAD AND POWER LINE)
- PROPOSED JAY ROAD (HAUL ROAD, PIPELINE AND POWER LINE)
- PROPOSED JAY PIPELINE ROAD (ACCESS ROAD AND PIPELINE)
- PROPOSED OPERATION ROADS

LYNX PROJECT FOOTPRINT

- EXISTING SHORELINE OF DEWATERED LYNX LAKE
- LYNX PIPELINE
- LYNX PROJECT INFRASTRUCTURE

NOTES

ROAD, PIPELINES, AND POWER LINE ARRANGEMENT TO BE DETAILED AS PART OF FURTHER PRE-FEASIBILITY DESIGN. APPROXIMATE CORRIDOR WIDTHS ARE SHOWN.

REFERENCE

JAY PROJECT CONCEPTUAL ENGINEERING REPORT, EKATI MINE, DOC#: 1313280041-E14037-R-REV0-4060, DATED: MAY 13, 2014
JAY PROJECT DESIGN BASIS MEMORANDUM FOR PRE-FEASIBILITY DESIGN OF PROJECT ROADS AND PIPELINE BENCHES, DOC#: 1313280041-E14031-TM-REVD-2020, DATED: AUGUST 1, 2014
LIDAR AND BATHYMETRIC DATA OBTAINED FROM AURORA, 2013
WATER OBTAINED FROM CANVEC © NATURAL RESOURCES CANADA, 2012
DATUM: NAD83 PROJECTION: UTM ZONE 12N

DOCUMENT

DEVELOPER'S ASSESSMENT REPORT

1 0 1
SCALE 1:40,000 KILOMETRES

PROJECT
DOMINION DIAMOND
JAY PROJECT
NORTHWEST TERRITORIES, CANADA

TITLE

AQUATIC FOOTPRINT FOR THE JAY PROJECT DURING OPERATIONS

Golder Associates

PROJECT	13-1328-0041		FILE No. DAR_Aqua_040_GIS	
DESIGN	CS	12/09/14	SCALE AS SHOWN	REV 0
GIS	ANK	20/10/14	MAP 9.4-1	
CHECK	CS	20/10/14		
REVIEW	KM	20/10/14		

G:\CLIENTS\DOMINION\DDEC Jay and Lynx Projects\Figures\13-1328-0041 Jay & Lynx EA\Aquatics\DAR\DAR_Aqua_040_GIS.mxd

The next most affected depth stratum (after 2 to 6 m) is the very deep water stratum where depths exceed 10 m. For the very deep stratum, the incremental change from Base Case in habitat will be 4.3% (108.2 ha affected) in Lac du Sauvage and 0.4% in Lac du Sauvage and Lac de Gras combined (Table 9.4-3). The total cumulative change in habitat at depths greater than 10 m is predicted to be 165.2 ha, or 0.6% of habitat with the application of the Project combined with effects from previous and existing developments in the ESA. This depth range includes areas that can support various age-classes year-round for Arctic Grayling, Lake Trout, and Lake Whitefish because the depths are well below ice cover during winter and also below the thermocline if present mid-summer (i.e., provide a thermal refugia).

Using the hydroacoustic data for substrate determination in Lac du Sauvage, habitat changes will occur in areas of primarily fines substrate (343.2 ha), resulting in a relative loss of 4.6% of the fines substrate areas in the lake (Table 9.4-3). The coarse substrate habitat losses will be primarily at shallow (0 to 2 m) and moderate depths (2 to 6 m) resulting in a relative overall loss of 5.9% of the coarse substrate areas in Lac du Sauvage (Table 9.4-3). The mixed substrate habitat losses will be primarily at the shallow depths (0 to 2 m), resulting in a relative overall loss of 0.9% of mixed substrate in the lake (Table 9.4-3). It is expected that relative changes in substrate types are considerably less when considering the spatial scale of the ESA, which includes Lac du Sauvage and Lac de Gras combined (i.e., relative effects are predicted to be approximately 1% or less).

An assessment of habitat losses along the shoreline was conducted using the more detailed habitat data derived from orthophotos and ground-truthed substrate delineations (Table 9.4-4). Losses of shallow and moderate depth (i.e., less than 5 m water depth) habitat types delineated using orthophotos will include fines (110.6 ha) and boulder/cobble (43.2 ha), resulting in a relative loss of 4.1% of the fines substrate, and 6.2% of the boulder/cobble substrate in the shallow and moderate depth habitats of Lac du Sauvage (Table 9.4-4). The other substrate types for which shallow and moderate depth habitat will be lost are boulder/fines and fines/boulder (2.1% and 0.3% for the boulder/fines and fines/boulder habitat, respectively).

A section of the shoreline in Lac du Sauvage will also be exposed in the diked area following dewatering and throughout operations, which may affect riparian habitat where present. The total length of affected riparian habitat was conservatively assumed to represent the entire length of shoreline to be exposed within the dewatered area (includes shorelines around islands) (see Map 9.4-1). Thus, the length of affected riparian habitat is predicted to be approximately 9.46 km from the dewatered area and 1.14 km from the diked area (10.60 km in total). The estimated incremental loss of riparian habitat with the application of the Project represents 0.9% of available riparian habitat in Lac du Sauvage and Lac de Gras. The amount of cumulative change to riparian habitat for the Application Case during operations is expected to result in no measurable effects to population abundance and distribution for fish VCs.

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Table 9.4-3 Relative Changes in the Aquatic Habitat of Lac du Sauvage by Substrate Type and Depth from the Dike and Dewatered Area Footprint from the Base Case (Reference and 2014) to Application Case

Depth of Habitat	Substrate Type	Base Case (ha)	Application Case					
			Dike Footprint (ha)	Dike Footprint Change (%) from Base Case to Application Case	Dewatered Area Footprint (ha)	Dewatered Area Footprint Change (%) from Base Case to Application Case	Total Footprint (ha)	Total Footprint Change (%) from Base Case to Application Case
0-2 m	Coarse	584.82	5.59	-0.95	29.76	-5.09	35.35	-6.04
	Fines	874.29	0.64	-0.07	17.48	-2.00	18.13	-2.07
	Mixed	260.84	-	0	3.10	-1.19	3.10	-1.19
	All	1,719.95	6.23	-0.36	50.35	-2.93	56.58	-3.29
2-6 m	Coarse	134.36	1.82	-1.36	6.03	-4.49	7.86	-5.85
	Fines	2,379.24	22.36	-0.94	104.57	-4.40	126.93	-5.33
	Mixed	96.40	0.05	-0.06	0.18	-0.18	0.23	-0.24
	All	2,609.99	24.23	-0.93	110.78	-4.24	135.01	-5.17
6-10 m	Coarse	11.99	-	0	0.01	-0.05	0.01	-0.05
	Fines	1,772.76	15.59	-0.88	74.28	-4.19	89.88	-5.07
	Mixed	31.82	0.11	-0.35	0.11	-0.34	0.22	-0.68
	All	1,816.57	15.70	-0.86	74.40	-4.10	90.10	-4.96
>10 m	Coarse	0	-	0	-	0	-	0
	Fines	2,521.32	8.08	-0.32	100.13	-3.97	108.21	-4.29
	Mixed	0.01	-	0	-	0	-	0
	All	2,521.34	8.08	-0.32	100.13	-3.97	108.21	-4.29
All depths	Coarse	731.17	7.41	-1.01	35.80	-4.90	43.21	-5.91
	Fines	7,547.61	46.68	-0.62	296.47	-3.93	343.15	-4.55
	Mixed	389.07	0.16	-0.04	3.39	-0.87	3.55	-0.91

% = percent, ha = hectares.

Table 9.4-4 Relative Changes in the Shallow (less than 5m) Aquatic Habitat of Lac du Sauvage by Substrate Type and Depth from the Dike and Dewatered Area Footprint from the Base Case (Reference and 2014) to Application Case

Depth of Habitat	Substrate Type	Base Case (ha)	Application Case					
			Dike Footprint (ha)	Dike Footprint Change (%) from Base Case to Application Case	Dewatered Area Footprint (ha)	Dewatered Area Footprint Change (%) from Base Case to Application Case	Total Footprint (ha)	Total Footprint Change (%) from Base Case to Application Case
0-2 m	Bo	0.55	-	0	-	0	-	0
	Bo/Co	570.25	5.59	-0.98	29.76	-5.22	35.35	-6.20
	Bo/Fi	106.98	-	0	2.43	-2.27	2.43	-2.27
	Br	7.55	-	0	-	0	-	0
	Co/Bo	6.55	-	0	-	0	-	0
	Co/Fi	1.62	-	0	-	0	-	0
	Fi	872.85	0.64	-0.07	17.48	-2.00	18.13	-2.08
	Fi/Bo	147.85	-	0	0.68	-0.46	0.68	-0.46
	Fi/Co	7.04	-	0	-	0	-	0
	All	1721.23	6.23	-0.36	50.35	-2.93	56.58	-3.29
2-5 m	Bo	0.01	-	0	-	0	-	0
	Bo/Co	128.39	1.82	-1.42	6.00	-4.68	7.83	-6.10
	Bo/Fi	19.29	-	0	0.16	-0.81	0.16	-0.81
	Br	1.41	-	0	-	0	-	0
	Co/Bo	0.08	-	0	-	0	-	0
	Co/Fi	1.55	-	0	-	0	-	0
	Fi	1839.48	14.68	-0.80	77.83	-4.23	92.51	-5.03
	Fi/Bo	58.87	-	0	-	0	-	0
	Fi/Co	0.79	-	0	-	0	-	0
	All	2049.86	16.50	-0.80	83.99	-4.10	99.68	-4.86

Table 9.4-4 Relative Changes in the Shallow (less than 5m) Aquatic Habitat of Lac du Sauvage by Substrate Type and Depth from the Dike and Dewatered Area Footprint from the Base Case (Reference and 2014) to Application Case

Depth of Habitat	Substrate Type	Base Case (ha)	Application Case					
			Dike Footprint (ha)	Dike Footprint Change (%) from Base Case to Application Case	Dewatered Area Footprint (ha)	Dewatered Area Footprint Change (%) from Base Case to Application Case	Total Footprint (ha)	Total Footprint Change (%) from Base Case to Application Case
0-5 m	Bo	0.56	-	0	-	0	-	0
	Bo/Co	698.64	7.41	-1.06	35.77	-5.12	43.18	-6.18
	Bo/Fi	126.27	-	0	2.58	-2.05	2.58	-2.05
	Br	8.96	-	0	-	0	-	0
	Co/Bo	6.63	-	0	-	0	-	0
	Co/Fi	3.16	-	0	-	0	-	0
	Fi	2712.33	15.32	-0.56	95.31	-3.51	110.63	-4.08
	Fi/Bo	206.71	-	0	0.68	-0.33	0.68	-0.33
	Fi/Co	7.82	-	0	-	0	-	0

% = percent, ha = hectares.

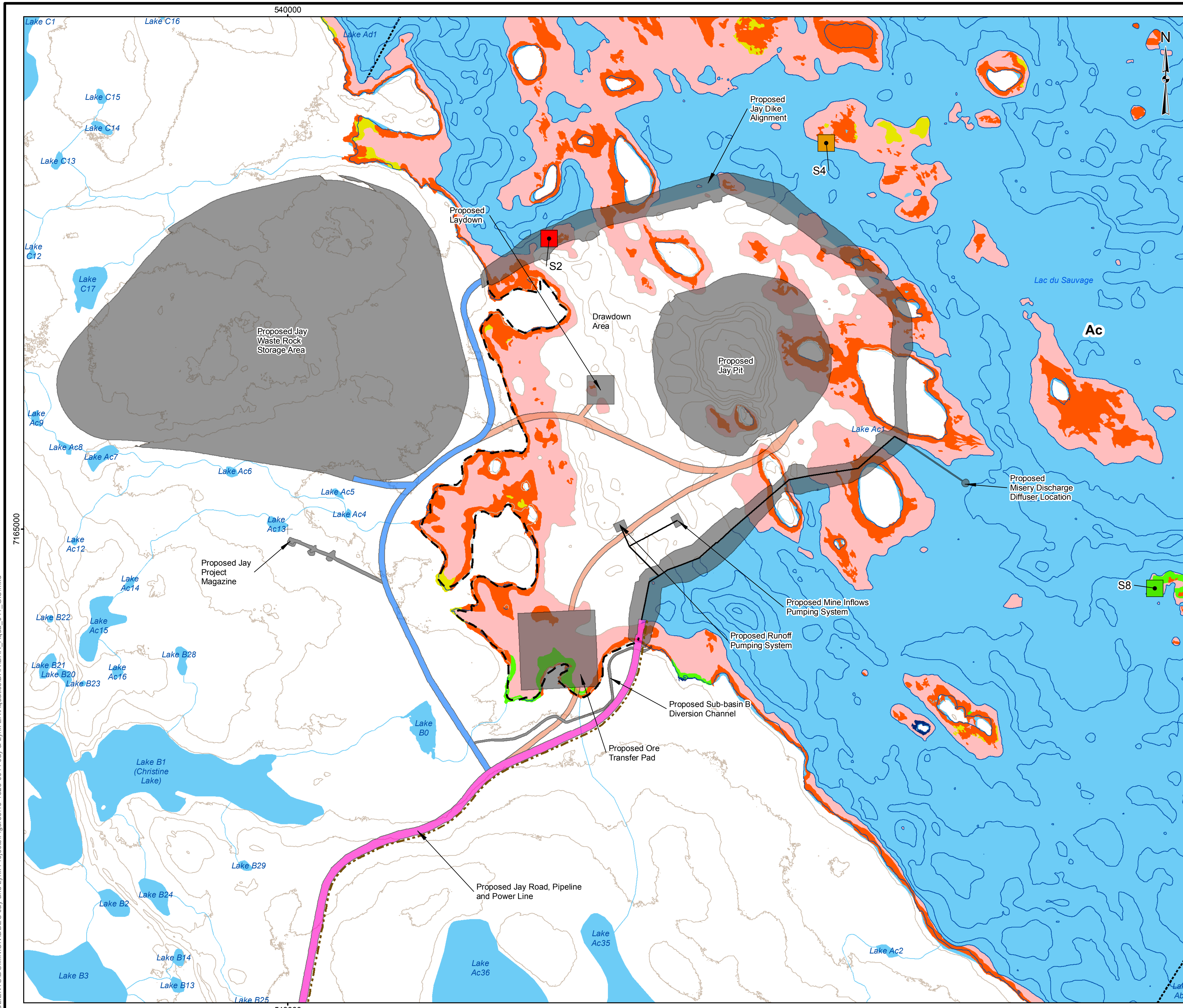
Effects to potential spawning shoals for Lake Trout and Lake Whitefish, and forage species, such as Cisco and Round Whitefish, were also assessed by comparing known shoal locations relative to the location of the dike and dewatered area (Annex XIV; Map 9.4-2). Baseline studies for the Diavik Mine showed an abundance of shoal habitats in the ESA (Golder 1997b,c,d,e). Up to 21 shoals were previously identified in Lac du Sauvage as potential habitat for spawning. All but one of the 21 previously identified shoals (S2) in Lac du Sauvage fall outside of the proposed diked area. S2 is located adjacent to the dike; however, S2 is classified as an unsuitable shoal for spawning (Annex XIV). This shoal may be that previously described by local Traditional Knowledge (Weledeh Yellowknives Dene 1997). The next closest spawning shoal in proximity to the dike is S4 (315 m northeast of the edge of the dike). S4 may be a fair-quality shoal for spawning Lake Trout, Lake Whitefish, and forage species. Other spawning shoals are well over 1,500 m from the edge of the dike location. Most of the high-quality shoal habitats in the effects study area are located in Lac de Gras (Golder 1997b,c,d,e). The amount of cumulative change to spawning shoal habitat for the Application Case is expected to result in no measurable effect to population abundance and distribution for fish VCs.

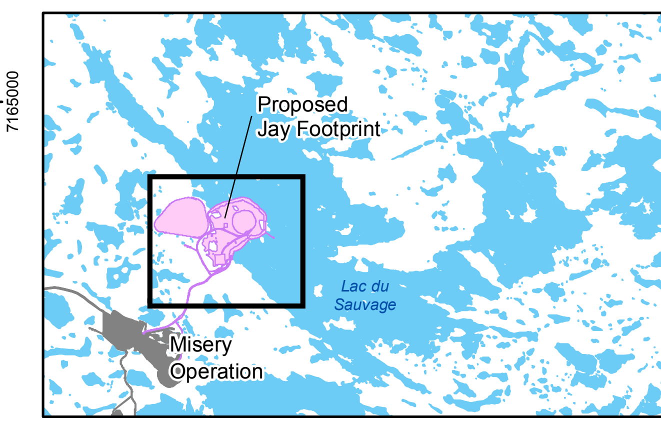
At closure, the dewatered area of Lac du Sauvage will be back-flooded and the 335.7 ha of aquatic habitat will be returned to Lac du Sauvage in an altered state (Map 9.4-3). The dike will be breached when water quality in the back-flooded area meets pre-determined acceptability criteria. The physical and chemical environment of the area will allow re-establishment of a healthy functioning aquatic ecosystem. Affected riparian habitat around the drawdown area will recover. Natural currents and fish in the water will be able to move in and out of the area.

The area of the Jay Pit within the dewatered area will be 64.9 ha. The Jay Pit represents a permanent loss of lake bottom substrate habitat for benthic feeding or bottom dwelling species such as Lake Whitefish and forage species such as Slimy Sculpin, but will include an extended water column as habitat for pelagic species such as Lake Trout and forage species such Cisco. The upper level of the Jay Pit may remain well-oxygenated through the winter due to its depth and may provide additional overwintering refugia for fish and thermal refugia for fish in summer.

The Jay Dike will be breached at multiple locations at closure; however, the Project will result in the permanent loss of approximately 54.3 ha or less of lake area (or less than 0.6% of area of Lac du Sauvage) from the remnant portions of the dike that will permanently remain in Lac du Sauvage post-closure. The remnant portions of the dike will remain as islands in Lac du Sauvage and are permanent habitat losses at areas that will remain above the normal high water level. The breached portions of the dike and areas of the dike below the normal high water level will result in permanently altered physical habitat for Lake Trout and Lake Whitefish, and forage species. The outer edges of the dike remnants will be available to fish and may provide fish habitat. Lake trout spawning habitat consists of cobble-rubble substrate with deep interstitial spaces, located near or on a steep drop-off (reviewed in Marsden et al. 1995).

The dike and pits in Lac de Gras for the Diavik mine will also be reclaimed (DDMI 2011b). Thus, the amount of permanent change to habitat (e.g., dike footprints) in the ESA for the Application Case is expected to result in less than a 1% loss in habitat area at post-closure and no measurable effects to population abundance and distribution for Arctic Grayling, Lake Trout, and Lake Whitefish.





LEGEND

- WATERCOURSE
- WATERBODY
- BATHYMETRY CONTOUR (5 M INTERVAL)
- ELEVATION CONTOUR (10 M INTERVAL)

SPAWNING HABITAT LAKE TROUT

- GOOD
- FAIR
- UNSUITABLE
- INTERNAL BASIN DIVIDE

JAY PROJECT FOOTPRINT

- EXISTING SHORELINE OF DEWATERED AREA
- POWER LINE
- PROPOSED JAY PROJECT INFRASTRUCTURE
- PROPOSED JAY ROAD NORTH (HAUL ROAD)
- PROPOSED JAY ROAD (HAUL ROAD, PIPELINE AND POWER LINE)
- PROPOSED OPERATION ROADS

SUBSTRATE TYPE (0-5 METRES)

- BO/CO - BOULDER/COBBLE
- BO/FI - BOULDER/FINES
- BR - BEDROCK
- FI - FINES
- FI/BO - FINES/BOULDER

REFERENCE

CANVEC © NATURAL RESOURCES CANADA, 2012
NATURAL RESOURCES CANADA, CENTRE FOR TOPOGRAPHIC INFORMATION, 2012
BATHYMETRIC DATA OBTAINED FROM AURORA, 2013
DATUM: NAD83 PROJECTION: UTM ZONE 12N

DOCUMENT

DEVELOPER'S ASSESSMENT REPORT

500 0 500
SCALE 1:20,000 METRES

PROJECT
DOMINION DIAMOND
JAY PROJECT
NORTHWEST TERRITORIES, CANADA

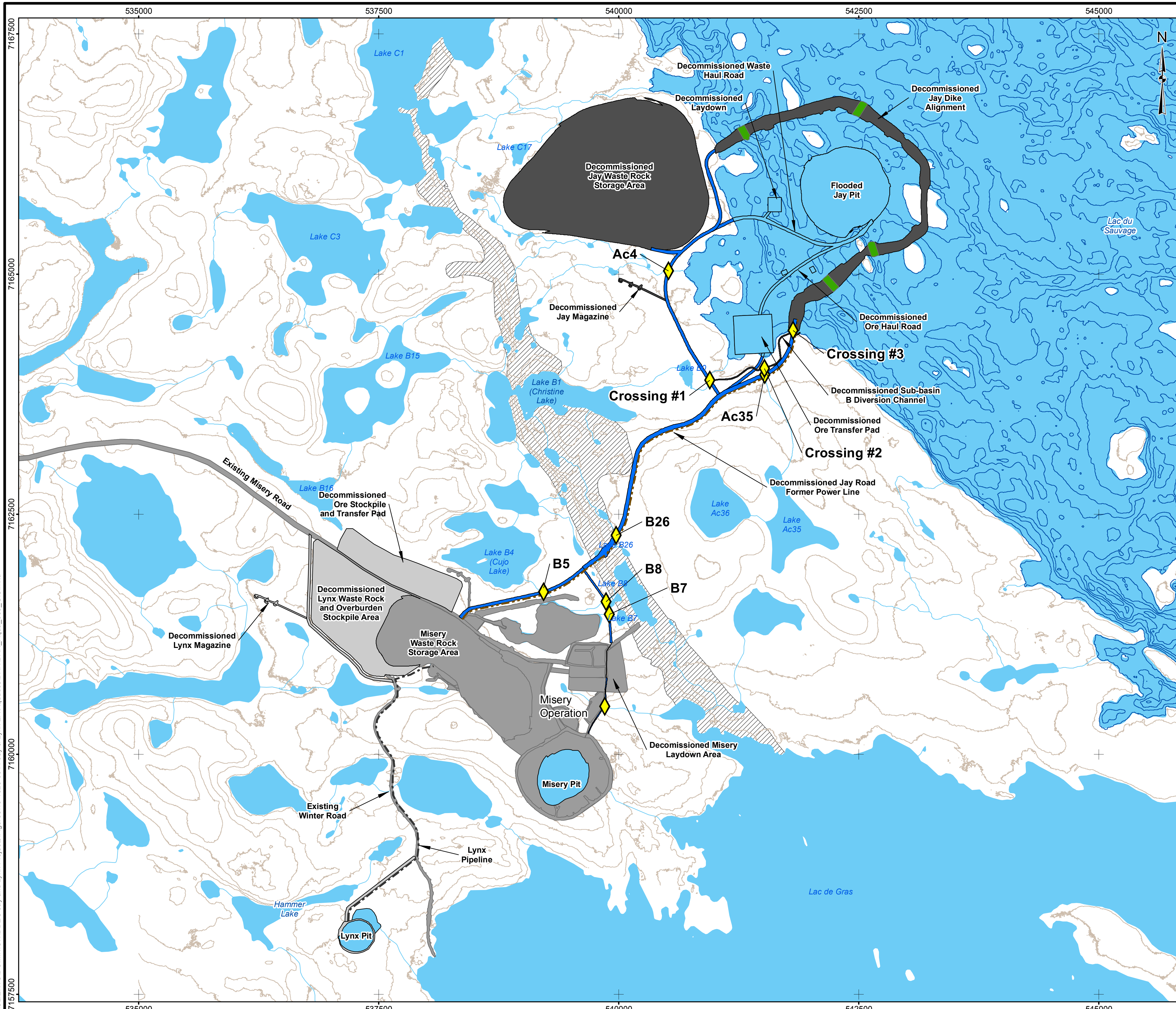
TITLE

SHORELINE HABITAT MAP NEAR THE PROPOSED JAY PROJECT IN LAC DU SAUVAGE

Golder Associates

PROJECT		13-1328-0041	FILE No. DAR_Aqua_041_GIS
DESIGN	CS	12/09/14	SCALE AS SHOWN REV 0
GIS	JE/ANK	21/10/14	
CHECK	CS	21/10/14	MAP 9.4-2
REVIEW	KM	21/10/14	

G:\CLIENTS\DOMINION\DDEC Jay and Lynx Projects\Figures\13-1328-0041 Jay & Lynx EA\Aquatics\DAR\DAR_Aqua_041_GIS.mxd



LEGEND

- EKATI MINE FOOTPRINT (MISERY OPERATION)
- BATHYMETRY CONTOUR (5 m INTERVAL)
- ELEVATION CONTOUR (10 m INTERVAL)
- ESKER
- WATERCOURSE
- WATERBODY
- WATERCOURSE CROSSING

JAY PROJECT FOOTPRINT

- FORMER POWER LINE
- DECOMMISSIONED JAY PROJECT INFRASTRUCTURE
- DECOMMISSIONED JAY ROADS
- PROPOSED DIKE BREACHING LOCATION

LYNX PROJECT FOOTPRINT

- LYNX PIPELINE
- LYNX PROJECT INFRASTRUCTURE

NOTES

ROAD, PIPELINES, AND POWER LINE ARRANGEMENT TO BE DETAILED AS PART OF FURTHER PRE-FEASIBILITY DESIGN. APPROXIMATE CORRIDOR WIDTHS ARE SHOWN.

REFERENCE

JAY PROJECT CONCEPTUAL ENGINEERING REPORT, EKATI MINE, DOC#: 1313280041-E14037-R-REV0-4060, DATED: MAY 13, 2014
JAY PROJECT DESIGN BASIS MEMORANDUM FOR PRE-FEASIBILITY DESIGN OF PROJECT ROADS AND PIPELINE BENCHES, DOC#: 1313280041-E14031-TM-REVD-2020, DATED: AUGUST 1, 2014
LIDAR AND BATHYMETRIC DATA OBTAINED FROM AURORA, 2013
WATER OBTAINED FROM CANVEC © NATURAL RESOURCES CANADA, 2012
DATUM: NAD83 PROJECTION: UTM ZONE 12N

DOCUMENT

DEVELOPER'S ASSESSMENT REPORT

1 0 1
SCALE 1:40,000 KILOMETRES

PROJECT
DOMINION DIAMOND
JAY PROJECT
NORTHWEST TERRITORIES, CANADA

TITLE
DECOMMISSIONED JAY PROJECT AQUATIC FOOTPRINT AT POST-CLOSURE

PROJECT		13-1328-0041	FILE No. DAR_Aqua_039_GIS	
DESIGN	CS	12/09/14	SCALE AS SHOWN	REV 0
GIS	JG	20/10/14	MAP 9.4-3	
CHECK	CS	20/10/14		
REVIEW	KM	20/10/14		

Golder Associates

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The recovery or reversibility of effects from habitat losses on fish VCs will begin following closure when the diked area is breached. Most habitat functions will be recovered at the completion of back-flooding and before opening the dike, allowing for a quick return of the abundance and distribution of fish within the back-flooded area. The back-flooded area will initially be populated by most species and life-stages from adjacent habitat areas in Lac du Sauvage. Full utilization of the habitat by fish VCs is expected to occur quickly and within a few years given the highly mobile behaviour of the species in the ESA. Density-dependent compensatory effects may result in small, initial increases in population growth (i.e., fish production) because of new access to habitat behind the dike (Rose et al. 2001). Access to previously unavailable habitat reduces overall population density, which can result in increases in vital rates, such as growth and reproduction, followed by increases in population size until densities are at carrying capacity. The maximum period for populations to approach densities of fish similar to other areas of Lac du Sauvage and Lac de Gras is likely within one generation time[1] of fish VCs. The short recovery period predicted for the back-flooded area after breaching also reflects that no, or minor measureable effects to fisheries productivity in the ESA are predicted during operations and closure.

An offsetting plan will be developed in discussion with Fisheries and Oceans Canada (DFO) and local Aboriginal communities, and ultimately, authorized by DFO to undertake offsetting measures to counterbalance the unavoidable residual serious harm to fish from the Project, with the goal of maintaining or improving the productivity of the commercial, recreational, or Aboriginal fisheries. The conceptual Offsetting Plan is in Appendix 9A. A final offsetting plan will be produced during the permitting phase of the Project and will be submitted as part of the Application for Authorization under the *Fisheries Act*.

9.4.3.1.2 Direct Mortality From Fish-Out

Eleven species of fish potentially occur within the diked area of Lac du Sauvage, including Lake Trout, Lake Whitefish, and Arctic Grayling. Dewatering the diked area will result in the temporary loss of fish production from the dewatered area of Lac du Sauvage. Before the dewatering, a fish-out will be conducted to remove fish from the dewatered area of Lac du Sauvage. It is expected that the direct removal of the fish from the diked area is proportional to the loss in fisheries productivity of Lac du Sauvage and Lac de Gras (DFO 2014a).

The fish-out is intended to minimize the waste of fish caused by the dewatering of the diked area. The conceptual fish-out plan is included in Appendix 9B. Because the dewatered area of Lac du Sauvage contains large-bodied and small-bodied fish species with a variety of habitat preferences, a combination of gear types will be used to maximize capture efficiency. These gear types could include gill nets, trap-nets, minnow traps, boat and backpack electrofishing, and angling. The final fish-out plan will be designed and implemented in discussion with DFO and local Aboriginal communities, and will follow the General Fish-out Protocol for Lakes and Impoundments in the Northwest Territories and Nunavut (Tyson et al. 2011), as appropriate. Project-specific protocols will be developed before initiating the fish-out.

[1] Generation time can be defined as the average length of time for a sexually mature fish to be replaced by offspring with the same spawning capacity.

The fish salvage from the A154 Dike in 2002 at the Diavik Diamond Mine (McEachern et al. 2003) showed a survival rate of approximately 50% of 5,049 fish captured during the salvage and fish-out operation. Therefore, the possibility exists that fish could be moved to other regions of Lac du Sauvage to reduce the potential for serious harm to the fishery. This option would depend on the approval of DFO and input from local Aboriginal communities. Based on the project-specific protocols developed, captured fish may be provided to local Aboriginal communities to avoid wasting of fish.

To estimate the number of fish to be removed the dewatered area, fish densities were calculated for yearling and older fish using hydroacoustic data (Section 9.2; Annex XIV). The predicted abundance in the dewatered area was estimated from a median statistic of fish density in the west internal basins of Lac du Sauvage (i.e., the Ac/d/e internal basins). The predicted abundance estimate in the dewatered area was approximately 7,100 fish using the median density statistic and 23,400 fish using the 75th percentile from the fish tracking analysis (Table 9.4-5). Assuming a mean weight of 0.1 kg for fish in the dewatered area, total biomass in the dewatered area may be as high as 2,340 kg (Annex XIV). For comparison, the predicted abundance estimated in La du Sauvage was approximately 197,400 fish using the median density statistic and 828,200 fish using the 75th percentile. Thus, up to 3.6% of the total number of fish in Lac du Sauvage will be targeted for removal from the dewatered area. Assuming the same density of fish in Lac du Sauvage applies to Lac de Gras, a much smaller percentage of the fish population will be affected at the scale of the ESA (i.e., less than 1%).

Based on fish sampling effort in Lac du Sauvage between 2006 and 2013, Lake Trout was the most abundant species (63%), followed by Lake Whitefish (18%), Round Whitefish (11%), Slimy Sculpin (4%), Cisco (3%), and Burbot (1%), with Arctic Grayling, Northern Pike, and Ninespine Stickleback captured least frequently (less than 1% each). Given the reported relative abundance of species and predicted densities of fish, there may be as many as 234 Arctic Grayling, 14,758 Lake Trout, 4,217 Lake Whitefish and 4,217 fish of other species, including forage fish, to be removed during the fish salvage in the dewatered area (Table 9.4-5).

The amount of direct mortality from the fish-out in the ESA for the Application Case is expected to result in minor measurable effects to population abundance and distribution for Arctic Grayling, Lake Trout, and Lake Whitefish. It is expected that fish from the fish-out will be distributed to local communities for consumption. The recovery or reversibility of mortality effects from removal of fish during the fish-out on Lac du Sauvage and Lac de Gras fish populations will begin during the operations phase, assuming environmental conditions are favourable for high recruitment. If the density of fish remains unchanged in unaffected areas outside the dike, density-dependent responses should initially be minor, and vital rates, such as growth, survival, and reproduction should not change relative to baseline. A recovery of the abundance of fish VCs from mortality incurred during the fish-out is predicted to occur within the operations phase.

Table 9.4-5 Percentile (Including Quartile) Statistics for the Abundance of Fish in the Dewatered Area

Analytical Method	Percentile Statistics	Predicted Abundance in Dewatered Area	Arctic Grayling	Lake Trout	Lake Whitefish	Other
			1% of catch	63% of catch	18% of catch	18% of catch
Echo Integration	10%	1,246	12	785	224	224
	25%	3,018	30	1,901	543	543
	50%	7,404	74	4,665	1,333	1,333
	75%	14,801	148	9,325	2,664	2,664
	90%	44,180	442	27,833	7,952	7,952
Fish Tracking	10%	468	5	295	84	84
	25%	2,315	23	1,458	417	417
	50%	7,111	71	4,480	1,280	1,280
	75%	23,426	234	14,758	4,217	4,217
	90%	55,622	556	35,042	10,012	10,012

Note: Abundance derived using a volume of 13,204,200 m^3 at depths >5m, and 13,833,105 m^3 at depths 0 to 5 m.

% = percent; m^3 = cubic metre; >= greater than; m = metre.

9.4.3.1.3 Diversion Footprint

Historical references conditions within the ESA for Arctic Grayling, Lake Trout and Lake Whitefish includes 43,349 m of available tributary stream habitat in Lac de Gras and 11,551 m of available tributary stream habitat in Lac du Sauvage (or 54,900 m combined). The scale of the assessment included tributaries in the ESA that may support spawning, foraging, and rearing habitat for fish in Lac du Sauvage and Lac de Gras. Total length of tributaries identified for the assessment included 43.3 fluvial km in Lac de Gras and 11.6 fluvial km in Lac du Sauvage. The tributaries included sections of small streams extending from Lac de Gras and Lac du Sauvage to the outlet of a first upstream lake of approximately 10 ha in area or larger. Tributary stream sections ranged in length from 23 m to 2,611 m (n = 75). There are no existing developments affecting the tributaries for Lac de Gras and Lac du Sauvage that were identified for the assessment, so the reference conditions and 2014 baseline conditions are considered equivalent for the Base Case at an assessment scale of the ESA.

There are no direct habitat losses within watercourses caused by direct overlap with the construction of the Jay Dike or associated Project infrastructure. However, loss of habitat quantity can also occur if habitat becomes isolated or inaccessible by blockage or passage issues due to the Project footprint. Isolation effects are most likely for fish species that are fluvial specialists, such as Arctic Grayling, which require flowing water to support key life history aspects of their life history (e.g., spawning and rearing). With the application of the Project, the residual stream footprint involves indirect effects from the isolation of the dewatered area, and direct effects from stream diversions related to the construction of the Sub-Basin B Diversion Channel.

The dewatered area within the horseshoe dike in Lac du Sauvage includes the stream inlets from small, ephemeral streams in adjacent sub-basins (Ac4, Ac35, and B). These streams may be used by Arctic Grayling in Lac du Sauvage for spawning, rearing, and foraging. Adult Arctic Grayling residing in Lac du Sauvage move into smaller streams to spawn in June and return to Lac du Sauvage to forage in late summer before freeze-up. Although Arctic Grayling are the primary users of the tributary streams, other users of the tributary streams include forage species, such Slimy Sculpin, Lake Chub, and Round Whitefish that reside in Lac du Sauvage, and to a lesser extent, Lake Trout, that may enter streams to feed during spring. Small-bodied fish may also use small tributary streams for refugia and foraging during the open water season. Maintaining habitat connectivity for all species will be important in minimizing changes to ongoing fisheries productivity in the Lac du Sauvage and Lac de Gras ESA.

Because of the volume of water predicted to flow from sub-basins Ac35 and B during operations, the environmental design of the Project includes a diversion channel (i.e., Sub-Basin B Diversion Channel) of approximately 1,275 m in length. The diversion channel will divert water that originally flowed from sub-basin B and Ac35 into the dewatered portion of Lac du Sauvage, away from the pit and into the area of Lac du Sauvage outside of the dewatered area. The diversion channel will convey water from two small, fish-bearing locations, Stream B0, downstream of Christine Lake and the lower section of Stream Ac35, a small ephemeral stream downstream of Lake Ac35. Stream Ac4 (410 m in length) will not be diverted since it is an ephemeral stream and is identified as non fish-bearing. However, upon isolation of the dewatered area, the lowermost stream section of Stream Ac4 (i.e., mouth of the creek), which may provide limited habitat at high flows in spring, will be inaccessible to fish in Lac du Sauvage.

The combined length of diverted stream habitat in ESA-1 is 467 m. Stream length to be diverted (i.e., lost) during operations includes the following:

- Within sub-basin B, 355 m of Stream B0 (21.7% of the length of Stream B0 and B1 combined); and,
- Within sub-basin Ac35, 112 m of Stream Ac35 (12.1% of the length of Stream Ac35).

To mitigate for potential changes in habitat connectivity between Lac du Sauvage and upstream habitats within the diverted watercourses (i.e., upper reaches of Stream Ac35, B0 and B1), the diversion channel will be designed to facilitate fish passage to upstream locations. Design features for the diversion channel will permit upstream passage of target species (i.e., adult Arctic Grayling, and to a lesser extent, Lake Trout), based on their swimming abilities (Section 9.3.2.1.3). For example, the proposed diversion channel site meanders across flat topography to provide suitable velocities for upstream passage. Estimated velocities in the channel for the 1 in 2 year design flow (1.37 m^3/s for both sub-basins combined) is 0.53 m/s along the minimum channel slope (0.1%) and 1.70 m/s along the 50 m section of the channel near the mouth at Lac du Sauvage (2.5%). The design specifications for the channel to facilitate upstream fish passage for target species will be discussed with DFO and communities during the detailed design phase of the Project.

There may be a delay (approximately one-year delay) in the response by fish in Lac du Sauvage and Lac de Gras as adults adapt, eventually selecting the new location where diverted flows enter the lake. The expectation is that adults are opportunistic and plastic in their movements and spawning behaviour because of the variable flow environments in which local populations have evolved. However, some adult Arctic Grayling return to the same streams for spawning and for feeding (i.e., the species displays a moderate degree of philopatry), and the mechanism for imprinting migration patterns for these individuals may begin when juvenile Arctic Grayling follow adults to spawning and feeding areas (Tack 1980). Thus, the effects to fish use of Stream B0 and B1 are expected to be minor and of a short-duration, as the individual fish that do not immediately find and use the diversion channel adapt to the new location. The outlet of the diversion into Lac du Sauvage is relatively close to the natural stream and is located as close to the natural stream outlet as practicable while diverting water outside of the diked area.

The total length of affected tributary stream habitat with the application of the Project is 877 m (if the calculation conservatively includes the entire length of Stream Ac4 which is likely non fish-bearing), representing a change of 7.6% for Lac du Sauvage tributaries and 1.6% for Lac du Sauvage and Lac de Gras tributaries combined. However, the addition of the 1,275 m diversion channel will provide connectivity for the duration of operations. The relationship between habitat quantity and productivity is assumed to be linear, but it is expected that effects will be reversible when the natural channels are reconnected (DFO 2014a; Figure 9.4-1). The natural channels will be reconnected to Lac du Sauvage at closure when the dike is breached.

9.4.3.2 *Changes to Water Quality and Effects to Lake Ecosystem Productivity*

Potential effects on fish and other aquatic life may occur from changes to water quality and lake ecosystem productivity during the early operations, closure, and closure phases. The following primary pathways are discussed in the sections below:

- Operational activities and discharge (e.g., discharge of treated domestic wastewater, altered drainage, runoff from facilities, including waste rock storage areas, pit inflows, dike seepage, release of nitrogen compounds from blasting residues, fine processed kimberlite management) may change surface water quality and affect fish and other aquatic life in Lac du Sauvage and Lac de Gras.
- Reconnection of the back-flooded area of Lac du Sauvage to the remaining watershed and post-closure releases of water (e.g., Misery Pit overflow and seepage, waste rock storage area runoff, Long Lake Containment Facility discharge) may change long-term water quality in Lac du Sauvage and Lac de Gras and affect fish and other aquatic life.

9.4.3.2.1 Summary of Water Quality Changes

Lac du Sauvage

Water quality predictions in Section 8 were developed using a conservative approach and assumptions, which are expected to result in projected concentrations that represent worst-case future concentrations. The evaluation of effects on aquatic life and productivity for the pathways assessed in this section follows directly from water quality predictions, and therefore, incorporate the same degree of conservatism. As a result, Project effects on aquatic life from changes in water quality represent worst-case potential effects, with a high level of confidence that actual Project effects from this stressor are not underestimated.

Time series plots are presented for key parameters including total phosphorus, total nitrogen, phytoplankton biomass (as chlorophyll *a*), silica, and total dissolved solids (TDS), to illustrate the expected changes to water quality parameters that are relevant to aquatic life. Predicted concentrations are presented as whole-lake averages based on depth-averaged model results for the main body of the lake, which includes water quality modelling nodes described in Section 8.5.4. Pre-mining, early operations, operations, closure, and post-closure periods are identified on the time-series plots.

The time series plots of key parameters indicate that increases in nutrient concentrations and salinity are expected to occur during operations (Figures 9.4-2 to 9.4-6), as also discussed in the water quality assessment (Section 8.5.4). Following the end of the operations, nutrient concentrations are predicted to decrease rapidly (i.e., within five years) during closure and are expected to return to values similar to baseline concentrations, with the exception of nitrogen parameters, which are predicted to remain elevated over the long-term (i.e., at approximately 0.3 mg/L, versus close to 0.2 mg/L during the baseline period; Figure 9.4-3). These trends are discussed in greater detail below.

Concentrations of phosphorus in Lac du Sauvage are expected to increase during operations and return to baseline levels by the end of the closure period (Figure 9.4-2). Under baseline conditions, concentrations of total phosphorus ranged from 0.0026 to 0.018 mg/L during the open-water period. The median total phosphorus concentration in Lac du Sauvage was 0.0064 mg/L under baseline conditions. Phosphorus concentrations are expected to increase up to approximately 0.011 mg/L in the main basin of the lake (Figure 9.4-2). The prediction of total phosphorus concentrations was based on conservative assumptions regarding sources, suggesting that actual concentrations may be lower than the predicted peak concentration of 0.011 mg/L for the main basin of Lac du Sauvage.

During operations, nitrogen concentrations in Lac du Sauvage are expected to increase four-fold compared to baseline conditions. Nitrogen concentrations will decrease during the closure period but remain slightly elevated above baseline in the main basin of the lake (Figure 9.4-3). The main basin of the lake is expected to exhibit the largest increase, with nitrogen concentrations up to approximately 0.8 mg/L.

Predicted chlorophyll *a* concentrations exhibit similar trends to those observed for nutrients over time. Under baseline conditions, chlorophyll *a* concentrations ranged from 0.65 µg/L during the summer to 3.24 µg/L during the fall, coinciding with peak phytoplankton biomass. Peak chlorophyll *a* concentrations are predicted to increase up to 14 µg/L near the end of operations and then decline to baseline levels during closure (Figure 9.4-4).

At the time of peak predicted nutrient concentrations (near the end of operations), total phosphorus is predicted to increase to just above the phosphorus trigger range (4 to 10 µg/L) for oligotrophic lakes (CCME 2004). Predicted increases in phytoplankton biomass (modelled as chlorophyll *a*) during operations suggest that the lake will exhibit a temporary shift in trophic status, as chlorophyll *a* values increase to mainly within the mesotrophic range (3 to 11 µg/L; Wetzel 2001). However, nutrient concentrations in Lac du Sauvage are expected to remain within the ranges characteristic of oligotrophic lakes (3.0 to 17.7 µg/L for phosphorus; 307 to 1,630 µg/L for nitrogen) described by Wetzel (2001). During the closure and post-closure period, phosphorus, nitrogen and chlorophyll *a* concentrations are expected to return to near baseline values, and Lac du Sauvage will return to an oligotrophic state.

Phosphorus is generally the limiting nutrient for primary production in most Canadian Shield lakes (Schindler 1974), because of its scarcity in bedrock and overburden in Shield watersheds, and efficient retention by upland forests and wetlands (Allan et al. 1993; Devito et al. 1989 cited in Steedman et al. 2004). Studies have shown that total phosphorus is usually the nutrient limiting primary productivity and also fish production in lakes (Dillon et al. 2004). Productivity is especially low in Arctic waters, as Arctic soils are shallow and frozen for most of the year, so the weathering rate and hence production of dissolved nutrients is slower than farther south.

Lakes with a nitrogen to phosphorus molar ratio (N:P ratio) of greater than 23 are expected to be phosphorus limited, whereas nitrogen is more likely to be the limited nutrient in lakes with an N:P ratio of less than 23 (Wetzel 2001). Under baseline conditions, the N:P ratio suggests that Lac du Sauvage is at the boundary between co-limitation by nitrogen and phosphorus, and nitrogen-limitation, as indicated by a ratio of approximately 13 during the open-water period (Hecky et al. 1993). Due to the predicted changes in total nitrogen and total phosphorus concentrations along different trajectories, the N:P ratio is predicted to increase (up to 92) during the operational period, indicating phosphorus limitation. The N:P ratio is predicted to remain high through closure and then decrease to approximately 43 during post-closure. Therefore, Lac du Sauvage is expected to remain phosphorus limited through post-closure and into the long-term.

Silica concentrations are expected to exhibit a similar trend to other nutrients, with increases (up to 0.25 mg/L) during operations followed by decreases during closure (Figure 9.4-5). Concentrations of silica under baseline conditions were less than 0.1 mg/L, which suggests that silica may be limiting diatom growth (Schelske and Stoermer 1971). Concentrations are expected to return to baseline conditions at the end of the closure period.

TDS concentrations are expected to increase in Lac du Sauvage from median baseline concentration of 11 mg/L to a maximum average whole-lake concentration of close to 80 mg/L (Figure 9.4-6). The increase in TDS concentrations in Lac du Sauvage is observed during the period of operations and decreases rapidly in the closure period to nearly background values during post-closure.

Although increased concentrations of some metals, major ions, and TDS in Lac du Sauvage are predicted as a result of the Project, these changes are not predicted to result in adverse effects to lower trophic communities or fish health through direct exposure in the water column (Section 8.5.6). All constituents will remain below federal, provincial (e.g., BC), and site-specific guidelines.

Figure 9.4-2 Total Phosphorus Concentrations Predicted to Occur in the Main Basin of Lac du Sauvage

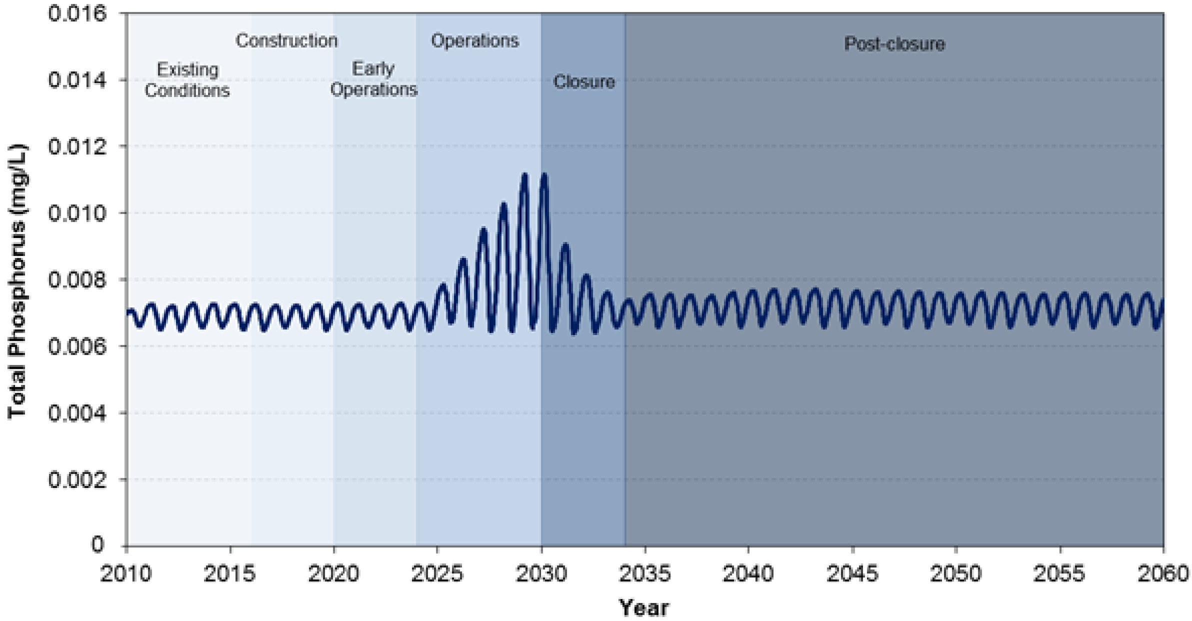


Figure 9.4-3 Total Nitrogen Concentrations Predicted to Occur in the Main Basin of Lac du Sauvage

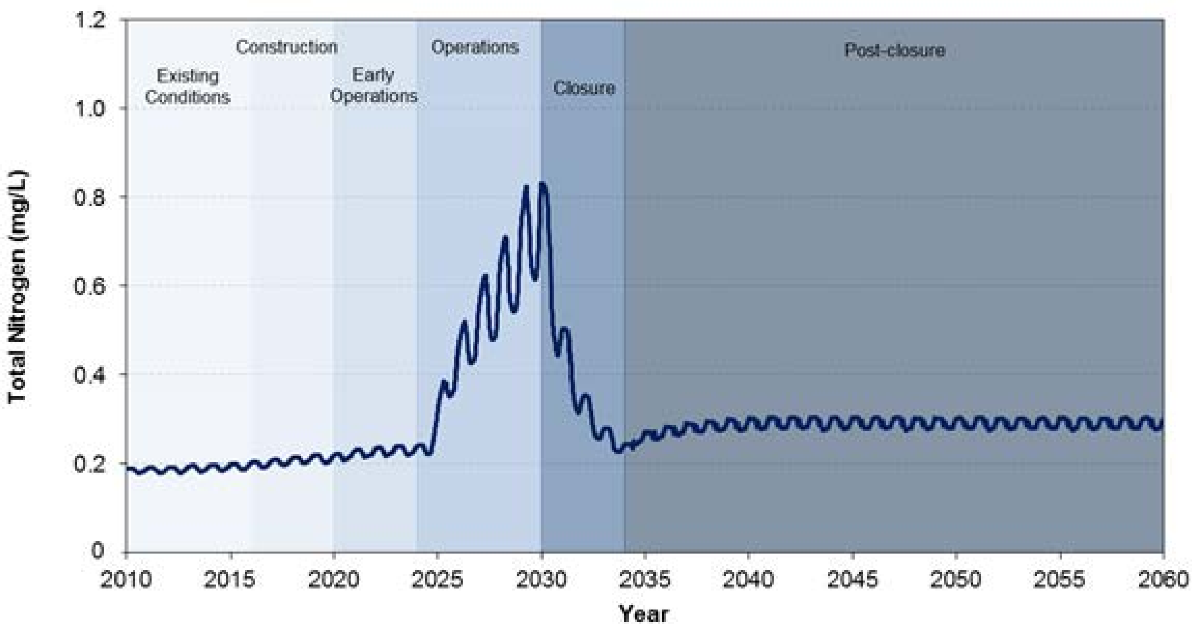


Figure 9.4-4 Phytoplankton Biomass (as chlorophyll *a*) Predicted to Occur in the Main Basin of Lac du Sauvage

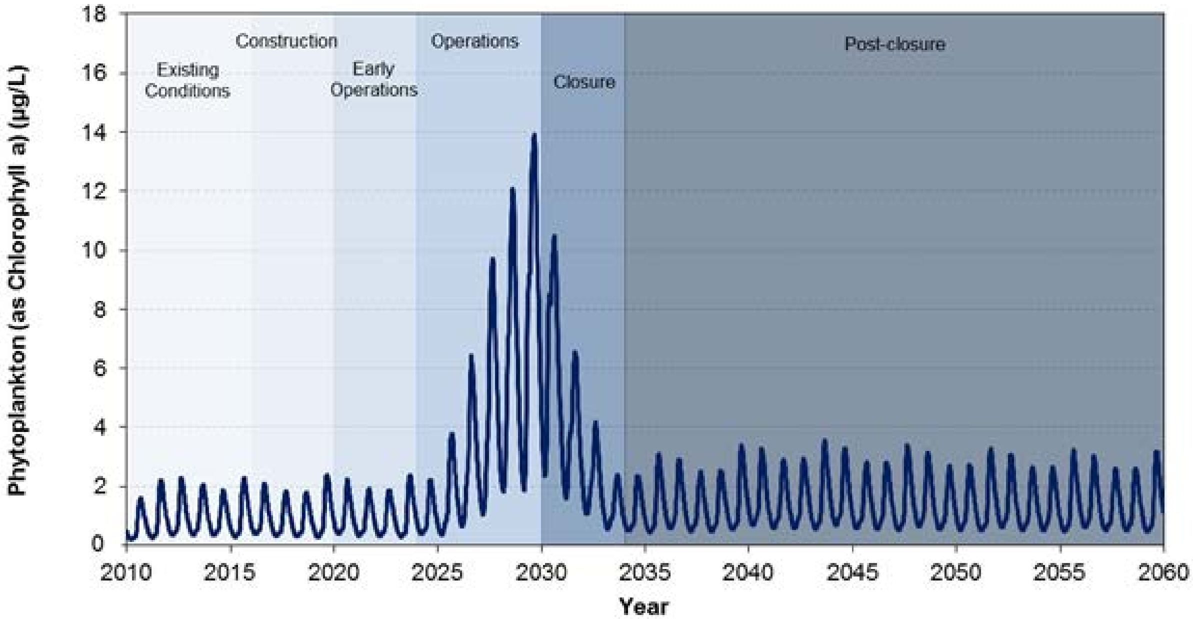


Figure 9.4-5 Silica Concentrations Predicted to Occur in the Main Basin of Lac du Sauvage

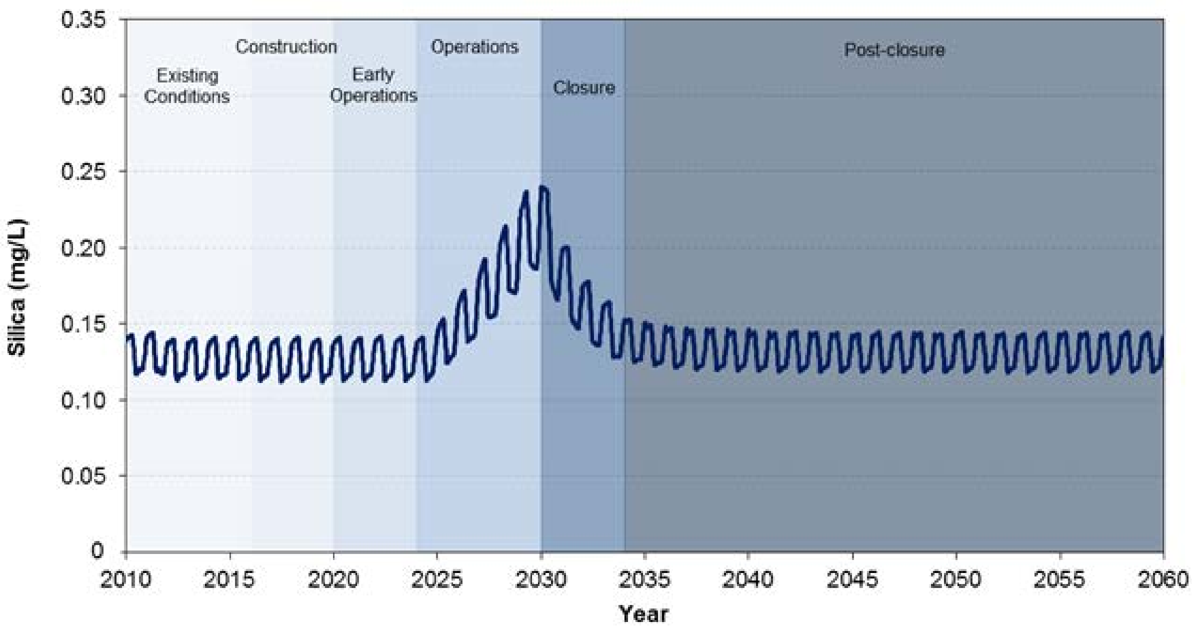
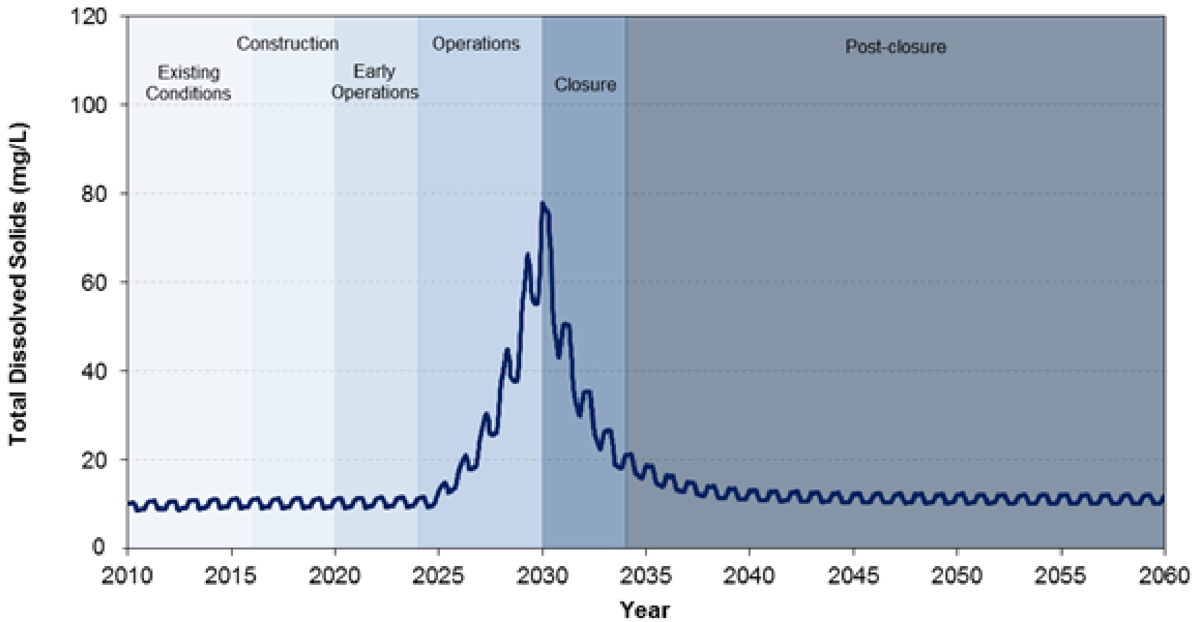


Figure 9.4-6 TDS Concentrations Predicted to Occur in the Main Basin of Lac du Sauvage



Lac de Gras

For the purposes of the lower trophic section, Lac de Gras was divided into three areas summarized below:

- Lac du Sauvage Inflow Area (Inflow);
- Slipper Bay Area (Slipper); and,
- Main body of Lac de Gras.

The predicted water quality in Lac de Gras reflects cumulative effects, resulting from inputs from the Diavik and Ekati mines and the Project. Depth averaged water quality predictions for these areas of Lac de Gras are presented in the time series plots below. Pre-mining, early operations, operations, closure, and post-closure periods are identified on these plots to illustrate the expected changes to water quality over time. Increases in nutrient concentrations are expected to start during pre-mining and increase to peak concentrations during early operations, as discussed in the water quality assessment (Section 8.5.4). Subsequent to closure of the Diavik Mine, most parameters are predicted to decrease and return to baseline conditions by post-closure. For some parameters (e.g., nitrogen and TDS), a slight increase is also observed during late operations and early closure, but will decrease again during the closure period. The results for the Slipper Bay area have peaks in concentrations of some parameters every freshet. These peaks are caused by increased flows during freshet included in the modelling, and may not reflect true values.

Mean concentrations of phosphorus in Lac de Gras are expected to increase during early operations to close to 0.0045 mg/L, largely reflecting inputs from sources other than the Project (Figure 9.4-7). A steady decline in phosphorus is expected through operations, and concentrations will return to baseline values by the end of the closure period. Under baseline conditions, concentrations of total phosphorus ranged from less than 0.001 to 0.01 mg/L during the open-water period. All areas of Lac de Gras are expected to follow a similar pattern.

Nitrogen concentrations in Lac de Gras are expected to increase starting during pre-mining through early operations. The area of the lake which has the inflow from Lac du Sauvage experiences the largest increase in nitrogen concentrations (Figure 9.4-8). Concentrations of nitrogen are expected to increase up to 0.35 mg/L in this area. A second increase in nitrogen is expected during operations but in general, nitrogen concentrations are below 0.30 mg/L during this period. Nitrogen concentrations decrease during the closure period and return to baseline concentrations by post-closure.

Chlorophyll *a* concentrations exhibit similar trends to those observed for phosphorus over time (Figure 9.4-9). Under baseline conditions, chlorophyll *a* concentrations in Lac de Gras varied among areas, ranging from 0.20 to 1.59 µg/L (Section 9.2). Peak chlorophyll *a* concentrations are predicted to increase up to 6 µg/L near the end of early operations. The largest increase is expected in the Slipper inflow area. Increases in other areas of Lac de Gras are mostly below 4 µg/L.

Based on nutrient concentrations (total phosphorus and total nitrogen), Lac de Gras is expected to remain oligotrophic. Predicted increases in phytoplankton biomass (as chlorophyll *a*) also remain mainly within the oligotrophic range (0.3 to 4.5 µg/L; Wetzel 2001). During the closure and post-closure period, phosphorus, nitrogen, and chlorophyll *a* concentrations are all expected to return to baseline values.

The N:P ratio in Lac de Gras is expected to increase slightly. Under baseline conditions, Lac de Gras may be co-limited by nitrogen and phosphorus, as indicated by an N:P ratio of approximately 20 during the open-water period. This value is close to the transitional zone between nitrogen and phosphorus limitation (Wetzel 2001; Hecky et al.1993). It is also possible that the shift to phosphorus limitation may occur at N:P ratios as low as 10 (Environment Canada 2004) whereby the current conditions in Lac de Gras may actually be phosphorus limited. Lac de Gras is expected to have an N:P ratio between 30 and 40 through operations, closure, and post-closure and will become more strongly phosphorus limited compared to baseline conditions.

Silica concentrations in Lac de Gras are not expected to exhibit increases due to the Project and concentrations remain largely unchanged during operations, closure, and post-closure (Figure 9.4-10).

TDS concentrations are expected to increase in Lac de Gras up to 25 mg/L from median baseline concentration of approximately 13 mg/L. Two small peaks in TDS concentrations are observed during the period of early operations and closure (Figure 9.4-11). A steady decline in TDS concentrations is expected during closure and will continue through the post-closure period.

Although increased concentrations of some metals, major ions, and TDS in Lac de Gras are predicted as a result of the Project, these changes are not predicted to result in adverse effects to lower trophic communities and fish health through direct exposure in the water column (Section 8.5.5). All constituents will remain below federal, provincial (e.g., BC), and site-specific guidelines.

Figure 9.4-7 Total Phosphorus Concentrations Predicted to Occur in the Area of Lac du Sauvage Inflow, Main Basin, and Slipper Bay Areas of Lac de Gras

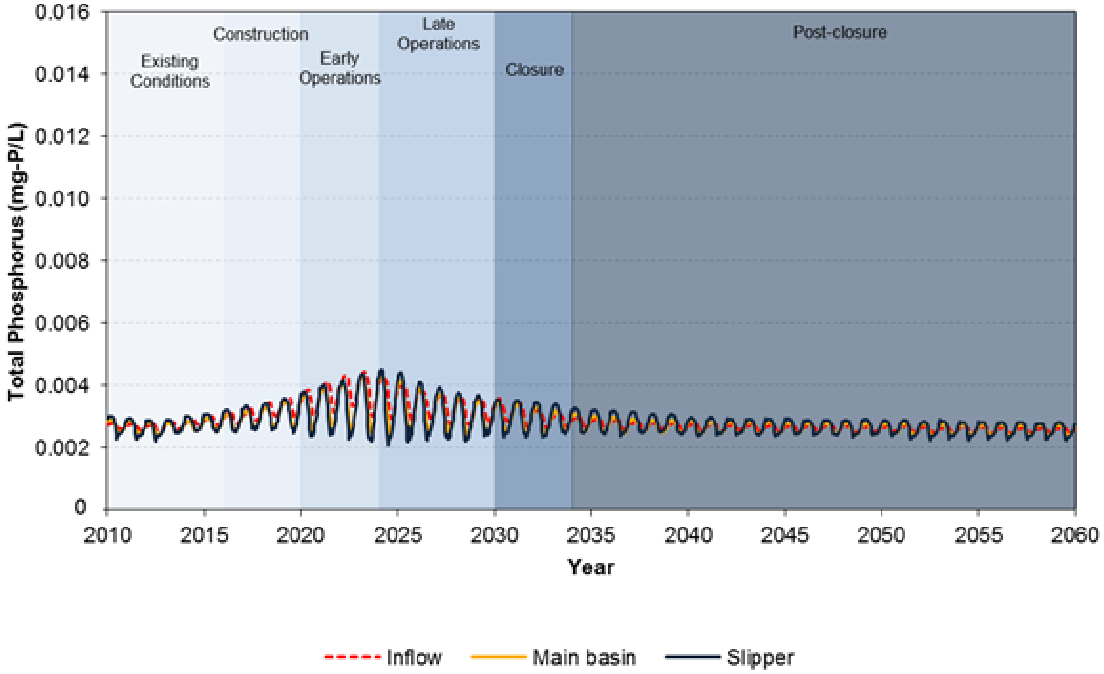


Figure 9.4-8 Total Nitrogen Concentrations Predicted to Occur in the Area of Lac du Sauvage Inflow, Main Basin, and Slipper Bay Areas of Lac de Gras

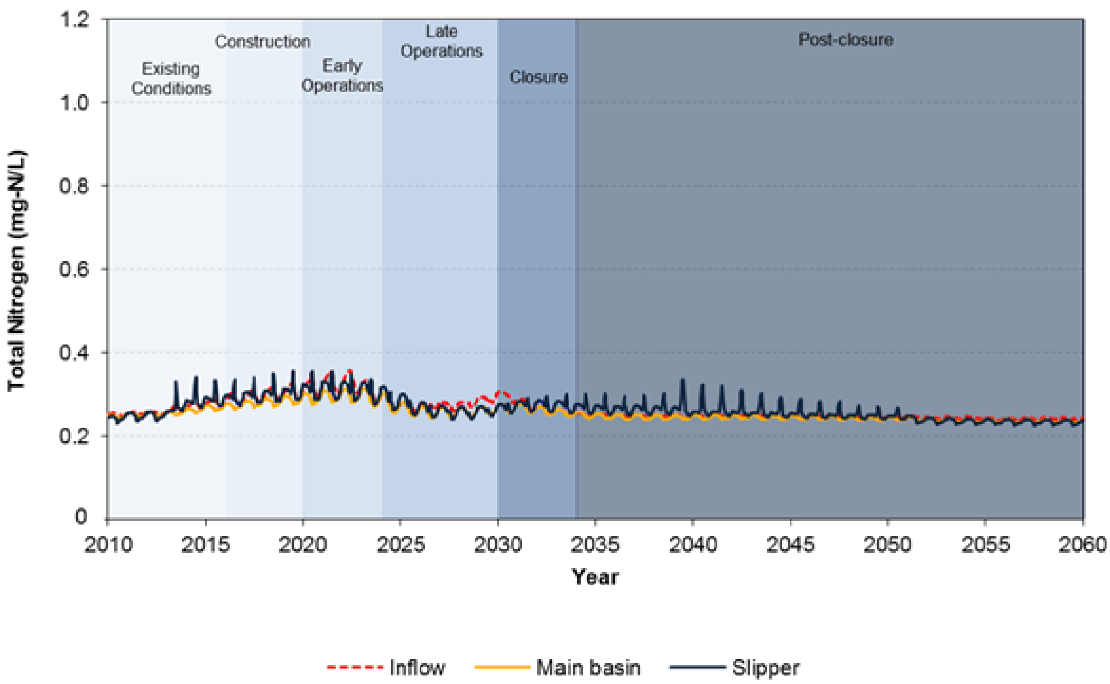


Figure 9.4-9 Phytoplankton Biomass (as chlorophyll *a*) Predicted to Occur in the Area of Lac du Sauvage Inflow, Main Basin, and Slipper Bay Areas of Lac de Gras

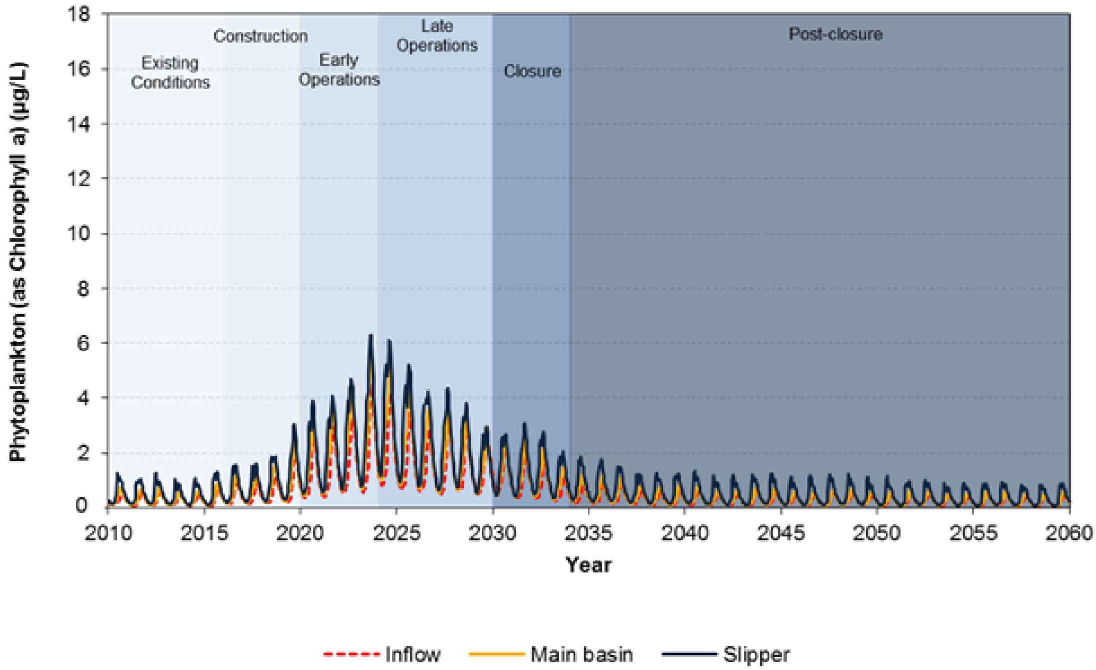


Figure 9.4-10 Silica Concentrations Predicted to Occur in the Area of Lac du Sauvage Inflow, Main Basin, and Slipper Bay Areas of Lac de Gras

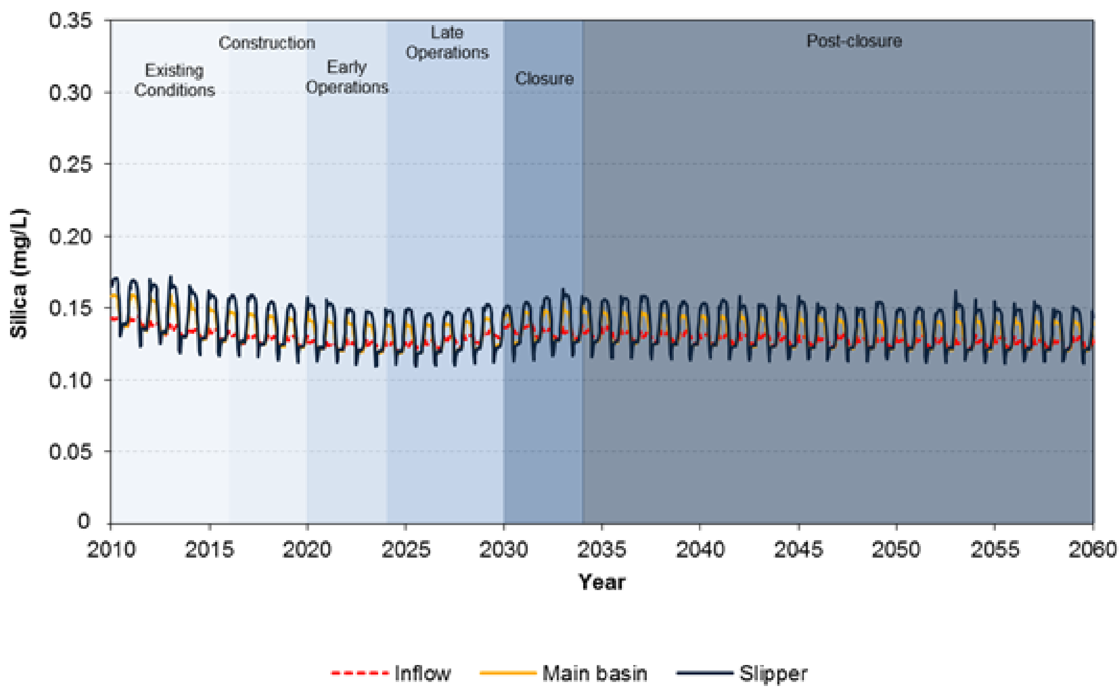
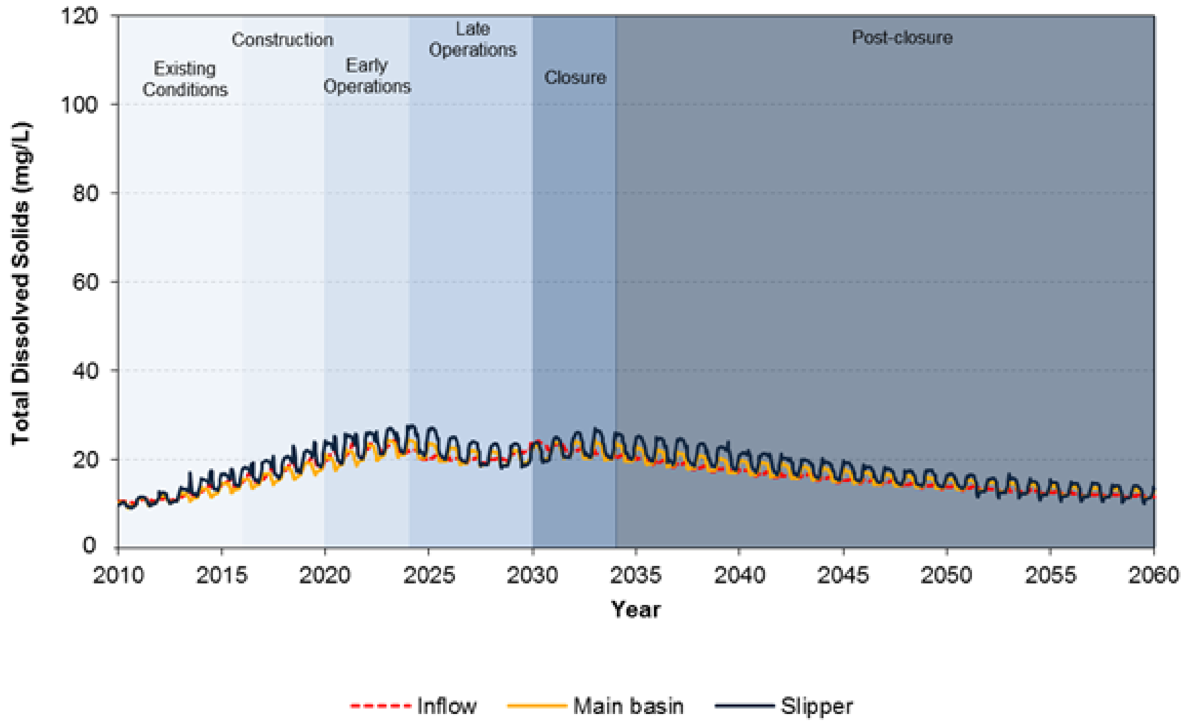


Figure 9.4-11 TDS Concentrations Predicted to Occur in the Area of Lac du Sauvage Inflow, Main Basin, and Slipper Bay Areas of Lac de Gras



9.4.3.2.2 Effects from Changes to Water Quality During Operations and Closure

Primary pathways for effects to ongoing fisheries productivity include indirect effects to fish and other aquatic life VCs through changes in water quality during early operations, late operations, and closure. The effects of the Project on fish and other aquatic life VCs in Lac du Sauvage and Lac de Gras during the operational period and closure are evaluated and described below. The following pathway is considered in this section:

- Operational activities and discharge (e.g., discharge of treated domestic wastewater, altered drainage, runoff from facilities, including waste rock storage areas, pit inflows, dike seepage, release of nitrogen compounds from blasting residues, fine processed kimberlite management) may change surface water quality and affect fish and other aquatic life in Lac du Sauvage and Lac de Gras.

The effect of increased nutrient concentrations during operations is expected to result in a general increase in productivity at lower trophic levels. Large shifts in composition of plankton and benthic invertebrate communities during operations and closure are not expected. However, biomass of phytoplankton, zooplankton, and benthic invertebrates will increase during operations, as these communities take advantage of the increased nutrient supply. In addition, shifts to overall community structure and dominant taxonomic groups may also result. The increased nutrient concentrations may also affect fish growth and production from the increase in the food base, as well as potentially causing habitat effects (e.g., changes to conditions of spawning habitat). A subsequent decrease in nutrient concentrations is expected during the closure period with concentrations returning to near baseline conditions by the end of closure. This is expected to result in a corresponding decrease in biomass of lower trophic organisms.

Potential changes to concentrations of some metals, major ions, and TDS in Lac du Sauvage and Lac de Gras also have the potential to affect aquatic health, and ultimately, self-sustaining and ecologically effective populations of fish VCs.

Potential residual effects to the lower trophic community and fish populations from changes in water quality are described further in the sections below.

Phytoplankton

The phytoplankton community in Lac du Sauvage has been observed to vary spatially within the lake and over time. During baseline sampling, phytoplankton biomass in Lac du Sauvage was dominated by chrysophytes (Section 9.2). Dominance by cyanobacteria was also frequently noted during some previous sampling events in Lac du Sauvage. Other major taxonomic groups that were present in Lac du Sauvage included chlorophytes and diatoms. Cyanobacteria, chlorophytes, chrysophytes, and diatoms were also the major phytoplankton taxa found in Lac de Gras.

Phytoplankton biomass is expected to increase in Lac du Sauvage and Lac de Gras due to predicted increases in nutrient concentrations during operations. In general, increased concentrations of the limiting nutrient results in increased primary productivity and phytoplankton biomass. Arctic lakes can be limited by nitrogen or phosphorus, or be co-limited by both nutrients (Ogbego et al. 2009). As such, the phytoplankton community will typically be more responsive to additions of both phosphorus and nitrogen (Ogbego et al. 2009; O'Brien et al. 2005). Lakes fertilized with both phosphorus and nitrogen have been found to respond with large increases in phytoplankton biomass (O'Brien et al. 2005). The addition of fertilizer in whole-lake experiments has been found to consistently increase lake primary production (LeBrasseur et al.1978; Hyatt and Stockner 1985; Jorgenson et al. 1992; Welch et al. 1988; Welch et al. 1989). Increases in summer phytoplankton biomass documented by some studies were several-fold relative to background biomass estimates.

A temporary shift from oligotrophic to the lower range of mesotrophic conditions could occur in Lac du Sauvage during operations, with subsequent return to oligotrophic conditions during closure. The increase in lake productivity may result in altered species composition and shifts in dominance at the level of major phytoplankton group (Reynolds 1998). The observed dominance by chrysophytes and cyanobacteria in Lac du Sauvage under baseline conditions may change to dominance by other groups, such as diatoms, chlorophytes, and dinoflagellates that usually dominate mesotrophic and eutrophic lakes (Wetzel 2001; Watson et al. 1997).

The functional size of algal species and the taxonomic division are known to be strongly correlated. Small algal species are generally more abundant in oligotrophic lakes, and the size of dominant algae often increases with trophic status (Wetzel 2001). However, both oligotrophic and mesotrophic lakes have been found to be dominated by similar average levels of small, edible algal species and it is not until the lake becomes eutrophic that an increasing dominance by inedible algal species is observed (Watson et al. 1997).

Under baseline conditions, Lac du Sauvage is at the boundary between nitrogen and phosphorus limitation during the open-water period (with an N:P ratio of 13). Predicted changes in concentrations of phosphorus and nitrogen are expected to alter the N:P ratio such that the lake becomes strongly phosphorus-limited (N:P ratio up to 92). Although an increase in the proportion of cyanobacteria may occur as a result of increased nutrient concentrations in Lac du Sauvage, a shift to strong cyanobacteria dominance is unlikely because of this shift to a phosphorus dominated system. Cyanobacteria are capable of directly fixing nitrogen, which can result in their dominance of the phytoplankton community in nitrogen limited environments (Environment Canada 2004). Given that Lac du Sauvage is expected to become increasingly phosphorus limited, cyanobacteria are not expected to become a dominant part of the phytoplankton community.

Changes in silica concentrations are frequently associated with changes in diatom populations. Strong correlations between the dominance of specific diatom taxa and silica availability have been observed (Kilham 1971). Increased phosphorus input can create an increased uptake of silica by diatoms, which in turn can eventually lead to silica depletion and a shift away from diatom dominance in the phytoplankton community (Schelske and Stoermer 1971; Shelske 1985; Shelske et al. 1986). The predicted increase in silica concentrations in Lac du Sauvage, along with increases in total phosphorus could be expected to lead to a temporary increase in relative abundance and biomass of diatoms in that lake.

Changes in TDS can also potentially affect the species composition of lake food webs if TDS is present in sufficiently elevated concentrations. However, phytoplankton appear to be tolerant to a wide range of TDS concentrations. Predicted TDS concentrations in Lac du Sauvage and Lac de Gras are less than the upper optima for relevant phytoplankton species (Wilson et al. 1994, 1996). Vyverman et al. (1996) found limited differences in phytoplankton assemblages attributable to increases in calcium concentrations (and correspondingly TDS concentrations). The predicted TDS concentrations in Lac du Sauvage and Lac de Gras are well below any potential thresholds for effects to aquatic health (Section 8.5.5) and also appear to be below concentrations that would be expected to result in shifts in community composition.

The magnitude of the increase in biomass and potential shift in community structure in Lac du Sauvage and Lac de Gras will depend on nutrient concentrations, as well as environmental factors, such as light, temperature, mixing regime, and predation, which interact to regulate spatial and seasonal growth and succession of phytoplankton populations (Wetzel 2001). These interactions introduce potential uncertainty but, as they are not expected to change substantially over time, would not contribute to an under-prediction of effects.

Phytoplankton biomass is expected to decrease during the closure period due to decreases in nutrient concentrations following the end of operations. Phytoplankton communities would likely begin returning to baseline conditions through the closure period. Further evaluation of the predicted response of phytoplankton communities following closure and through post-closure is provided in Section 9.4.3.2.4.

Zooplankton

Under baseline conditions in Lac du Sauvage and Lac de Gras, rotifers were generally present in the highest numbers followed by cladocerans, calanoid copepods, and cyclopoid copepods (Section 9.2). Seasonal trends were also observed in zooplankton community composition.

The predicted increase in primary productivity in Lac du Sauvage and Lac de Gras is expected to result in increased secondary productivity and biomass of the zooplankton community, reflecting the increased amount of available food for zooplankton. However, because energy transfer between trophic levels is inefficient (McCauley and Kalff 1981; Kalff 2002), the proportional increase in zooplankton biomass caused by increased nutrient concentrations will likely be lower than the increases in phytoplankton biomass. The coupling between zooplankton and phytoplankton interactions tend to be strongest in lakes of intermediate productivity (Elser and Goldman 1991) suggesting that a concomitant increase in zooplankton biomass may occur from the increase in total phosphorus concentrations (i.e., into the lower mesotrophic range) in Lac du Sauvage, but the increase in zooplankton biomass under oligotrophic conditions in Lac de Gras may be less pronounced.

Zooplankton biomass has been frequently found to be enhanced by nutrient enrichment of lakes. For example, LeBrasseur et al. (1978) found that whole-lake annual fertilizer treatment resulted in a five-fold increase in mean summer primary production and a nine fold increase in zooplankton standing stock. Other studies have also found that phosphorus enrichment can increase zooplankton biomass indirectly through enhanced food availability (Hanson and Peters 1984; Shortreed and Stockner 1986).

In addition to the potential for an increase in zooplankton biomass, changes in zooplankton community composition are also possible, although difficult to predict, because zooplankton species composition can be controlled by predation (i.e., top-down processes; McQueen et al. 1986; Carpenter 1989; Carpenter et al. 2001), resource availability (i.e., bottom-up processes; Clarke et al. 1997; O'Brien et al. 2005), or potentially a combination of these factors. An increase in productivity has the potential to alter size-dependent predatory interactions (Johnson et al. 1999). The potential for an increase in overall algal size could give larger zooplankton a competitive advantage. O'Brien et al. (2005) found that macro-zooplankton (*Daphnia*) were found to respond to enrichment in Arctic lakes with a two-fold increase in abundance, but micro-zooplankton (cyclopoid copepods) showed no response.

TDS and all major ions are predicted to be well below levels that would affect aquatic health (see Section 8.5.6). Maximum predicted concentrations of TDS are far below toxicity thresholds for zooplankton. A minor change in zooplankton community structure may result from an increase in TDS because of stimulated growth of calcium limited cladoceran species. The distribution of *Daphnia* species tends to be related to the calcium concentration of lakes, because calcium is an essential element for zooplankton growth and the development of their carapace (Waevagen et al. 2002). *Daphnia* have greater calcium requirements than copepods and other cladocerans, which may explain their low abundance in soft water lakes (Alstad et al. 1999; Waevagen et al. 2002).

Higher concentrations of TDS (in particular calcium) may stimulate growth of *Daphnia* species and potentially cause a shift in community structure towards larger-sized zooplankton. Calcium limitation may explain the observation that high TDS lakes are associated with higher zooplankton productivity (Shuter et al. 1998). Large zooplankton are more susceptible to predation by planktivorous fish (Kettle and O'Brien 1978). Fish predation may help control the abundance of *Daphnia* and prevent an observable shift in community structure. A minor shift to larger body size for cladocerans or higher zooplankton biomass would not be detrimental to the food supply for fish because *Daphnia* species are considered to be a preferential zooplankton prey (O'Brien et al. 1992).

As noted for phytoplankton, a decrease in zooplankton biomass will likely occur through the closure period, as nutrient concentrations and phytoplankton production decrease. Further evaluation of the predicted response of zooplankton communities following closure and through post-closure is provided in Section 9.4.3.2.4.

Benthic Invertebrates

The benthic invertebrate community in Lac du Sauvage consisted mostly of midges (Chironomidae) and fingernail clams (Pisidiidae) during baseline studies conducted in 2013 and during previous surveys from 2000 to 2012 (Section 9.2). The benthic invertebrate communities in Lac de Gras were dominated by Chironomidae, followed by Oligochaeta, Pisidiidae, and Acari. Invertebrate abundance was generally low, consistent with the oligotrophic status of Lac du Sauvage and Lac de Gras under baseline conditions.

The response of the benthic invertebrate community to increased concentrations of nutrients is less predictable than that of plankton. Nutrient enrichment has sometimes been found to result in increased benthic invertebrate biomass (Rasmussen and Kalff 1987; Jorgenson et al. 1992; Clarke et al. 1997), but in some cases, no response to enrichment has also been documented (Dinsmore et al. 1999).

It is likely that predicted increases in nutrient concentrations and primary productivity during the operational period result in an increase in benthic invertebrate abundance and biomass, reflecting the increased food supply. The response by invertebrates may be delayed by several years relative to the response by plankton, as observed by Hershey (1992) in an experimentally fertilized lake. The increase in biomass may also be less pronounced because invertebrates, such as chironomids, are also regulated by predation (Hershey 1992).

Differences in responses by different taxonomic groups could also lead to a potential shift in composition of the benthic invertebrate community related to increases in nutrients during operations. Taxonomic shifts in benthic invertebrate communities have been observed in studies of artificially fertilized lakes. For example, Jorgenson et al. (1992) observed varying responses by different invertebrate taxa to enrichment, ranging from two-fold increases in caddisfly biomass, to five to ten-fold increases in the biomass of amphipods. Some groups (e.g., snails) are able to take advantage of the increased food supply in fertilized lakes in the absence of predators, while abundances of others (e.g., chironomids) may be effectively controlled by predation (Hershey 1992). The timing and magnitude of benthic invertebrate response in whole-lake enrichment has been linked to life cycle duration and trophic role (Clarke et al. 1997). Clarke et al. (1997) found that short-lived herbivores such as chironomids, pisidiid clams, and gastropods exhibited faster and more pronounced responses to enrichment compared to longer-lived predatory taxa such as leeches and dragonflies. Studies have also shown that as lakes become increasingly eutrophic, there is a general reduction in the abundances of chironomids and other benthic animals, and a concomitant increase in oligochaete worm abundance (Wetzel 2001).

Effects in other unproductive sub-arctic lakes undergoing nutrient enrichment related to operating diamond mines also provide an indication of expected benthic community changes in Lac du Sauvage and Lac De Gras during operations. Snap Lake and Lac de Gras have been monitored extensively as part of the Snap Lake Mine and Diavik Mine AEMPs. In these lakes, total phosphorus has increased slightly (but remains less than 0.01 mg/L, on average) and total nitrogen has increased moderately during the first decade of operations (De Beers 2010; DDMI 2011a). This has resulted in increases in total invertebrate density and densities of fingernail clams (Pisidiidae), snails (*Valvata*) and a number of chironomid genera (Snap Lake: *Microtendipes*, *Corynocera*, *Procladius*; Lac de Gras: *Procladius*, *Heterotrissocladius*, *Micropsectra*) in affected areas of these lakes, without apparent changes in densities of other invertebrates, or in other benthic community variables (richness, diversity, dominance, evenness) (DDMI 2011a; De Beers 2010). The changes observed in these lakes could also be expected during the early stages of enrichment in Lac du Sauvage. In terms of total phosphorus concentrations, both Snap Lake and Lac de Gras have remained oligotrophic to date, whereas projected trophic status of Lac du Sauvage is expected to increase to the lower range of mesotrophic conditions for a period of less than five years.

Observational data from field studies indicate that effects on benthic invertebrates from salinity do not occur until TDS concentrations are much higher than the predicted 80 mg/L for Lac du Sauvage and 25 mg/L for Lac de Gras (Hynes 1990; Moore 1978; Leland and Fend 1997). Hynes (1990) describes no effects on the benthic invertebrate community of a lake in northern Saskatchewan receiving uranium mill effluent with elevated TDS up to 2,700 mg/L. The major ions primarily responsible for this increase were calcium, sodium, chloride, and sulphate. Species richness declined, with fewer oligochaetes, Hirudinea, and amphipods, but considerably more *Tanytarsus* (Chironomidae).

Chironomids, the dominant group of benthic invertebrates in Lac du Sauvage and Lac de Gras, inhabit freshwaters with varying concentrations of TDS. Moore (1978) found that the distribution of chironomids showed little relation to salinity in his examination of 22 saline lakes in Saskatchewan. Leland and Fend (1997) found that many chironomid species in rivers have high TDS optima between 130 and 1,300 mg/L. Therefore, predicted concentrations of TDS are not expected to adversely affect the benthic invertebrate community in Lac du Sauvage and Lac de Gras.

A decrease in benthic invertebrate biomass and a community shift back to near baseline conditions may accompany the closure period, as nutrient concentrations return to near baseline conditions. The accumulation of food resources in the benthic zone during the operations may lead to a time lag in the response of the benthic invertebrate community during closure and thereafter, behind the responses of zooplankton and phytoplankton communities. Further evaluation of predicted response of benthic invertebrate communities following closure and through post-closure is provided in Section 9.4.3.2.4

9.4.3.2.3 Fish Populations

Indirect effects to assessment endpoints for fish VCs include changes to the abundance and composition of plankton and benthic invertebrates (i.e., food base), and habitat through changes to trophic state and water quality. Potential changes to concentrations of some metals, major ions, and TDS in Lac du Sauvage and Lac de Gras also have the potential to affect fish health, and ultimately, self-sustaining and ecologically effective populations. Residual effects from changes to water quality to fish and other aquatic life measurement indicators during operations are described further in the sections below.

Food Base

The effect of increased primary and secondary production on fish in lakes is complex and is dependent on several factors. These factors include the physical and chemical conditions of the water and lake sediments (Schindler 1974), the complexity of the food web (Schindler 1974; Carpenter et al. 1985; Elser et al. 1990), the efficiency of energy transfers between trophic levels (McQueen et al. 1990; Micheli 1999), and the relative importance of “bottom-up” (i.e., resource availability) or “top-down” (i.e., predation) control of lake productivity (Power 1992; Carpenter et al. 1985; McQueen et al. 1986). Top-down and bottom-up controls both operate in aquatic ecosystems (McQueen et al. 1986; Power 1992) but the relative importance of top-down effects increases in oligotrophic systems (McQueen et al. 1986).

Studies have shown that nutrients, and in particular TP, control the rate of fish production in lakes (Colby et al. 1972; Plante and Downing 1993), including cold-water fish production (Dillon et al. 2004). For example, LeBrasseur et al. (1978) found that during annual fertilizer treatment in Great Central Lake, British Columbia, mean summer primary production increased five-fold, zooplankton standing stock increased nine-fold, the percentage survival from estimated potential egg deposition to juvenile Sockeye Salmon (*Oncorhynchus nerka*) increased 2.6 times, and the mean stock of adult Sockeye Salmon increased from less than 50,000 to greater than 360,000 fish. Hyatt and Stockner (1985) found that addition of fertilizer to several oligotrophic British Columbia coastal lakes, which approximately doubled total phosphorus concentrations, increased autotrophic (phytoplankton) and heterotrophic (bacteria) production and led to larger standing stocks of zooplankton and increased in-lake growth of juvenile Sockeye Salmon. The researchers suggested that this may also lead to increases in harvestable surplus sockeye adults and provided evidence to support predictions of gains in sockeye stock returns due to the application of lake fertilization as an enhancement technique (Hyatt and Stockner 1985). In fertilization experiments in Norway, Johannessen et al. (1984, cited in Dillon et al. 2004) found that the length and weight of Brown Trout (*Salmo trutta*) increased during the three seasons of fertilization (Johannessen et al. 1984 cited in Dillon et al. 2004). Johnston et al. (1990) found that whole-river fertilization of the Keough River, British Columbia, which increased total phosphorus concentration from less than 1 µg/L to 10-15 µg/L, increased the size of Steelhead Trout (*Oncrorhynchus mykiss*) and Coho Salmon (*Oncorhynchus kisutch*) fry. Nutrient additions to the North Arm of Kootenay Lake, BC, increased the biomass of phytoplankton, zooplankton, and Kokanee Salmon (*Oncorhynchus nerka*) in the lake (Ashley et al. 1997 cited in Dillon et al. 2004).

Whole lake fertilization experiments were also performed at small, oligotrophic lakes in Saqvaqjuac, in the Canadian central Arctic, from 1978 to 1983. During these studies, total phosphorus concentration was raised two to three-fold depending on lake, starting from 0.005 to 0.007 mg/L. The studies found increases in primary production and secondary production (i.e., macrobenthos) (Jorgenson et al. 1992; Welch et al. 1988, 1989). Fish populations increased in one of the experimental lakes as a result of the fertilization, but in keeping with their relatively long life cycles, had not stabilized at the time of the last sampling in 1983 (Jorgenson et al. 1992). O’Brien et al. (2005) found increased phytoplankton growth during nutrient addition, but mixed responses in macrozooplankton and benthic invertebrates, indicating that other factors (e.g., predation) also play a role in the Arctic food web. During whole-lake experimental fertilization of a small, oligotrophic Arctic lake in Alaska, the researchers found increased primary productivity, chlorophyll *a,* and snail density (Lienesch et al. 2005). Lake Trout density was not affected by the manipulation, but growth and average size increased. The increased growth during the period of fertilization was considered to be due to the increased food availability (Lienesch et al. 2005). Other researchers found increased fish growth and yield in lakes that underwent cultural eutrophication in the 1970s (e.g., from sewage, detergents, fertilizers, agricultural runoff) (Nümann 1972; Gascon and Leggett 1977; Hartmann and Nümann 1977; Näslund et al. 1993).

As a result of the increased nutrients in Lac du Sauvage during late operations, it is expected that there will be increases in the lower trophic food base for fish, potentially resulting in numerical increases in forage fish such as Cisco and Slimy Sculpin (through increases in growth and reproduction rates). Because of the increased food base (lower trophic levels and forage fish), there may also be a minor increase in growth and reproduction rates in the fish VCs. However, the increased food base will be spatially restricted to sections of Lac du Sauvage and effects, if any, to VC population sizes may be temporally limited to the late operations phase and potentially into closure. Furthermore, other environmental factors associated with the increased nutrients potential change in trophic status during operations will also play a role in the response of the fish VC populations in the ESA.

Spawning Habitat

Increased nutrients in lakes may lead to increased algal growth or hypoxia on spawning areas used by fish species, such as Lake Trout and Lake Whitefish. An increase in attached algae on spawning shoals can potentially affect recruitment, as reproduction relies upon the presence of suitable spawning shoal habitat for successful egg incubation and fry emergence. For example, researchers have been concerned with algal growth on Lake Trout spawning reefs, and increased deposition of detrital organic matter on reefs in early fall. Decay of these materials could increase ammonia and hydrogen sulphide levels and decrease dissolved oxygen if little water circulation occurs at the site (Sly 1988; Marsden et al. 1995). Oxygen depletion of interstitial water within the substrate, due to decomposition of organic material, is a concern where excessive nutrient inputs occur; dissolved oxygen concentrations less than 4.5 mg/L have been found to retard development, delay hatching, and to cause malformation of embryos (Evans et al. 1991).

During whole-lake fertilization experiments in an Arctic lake, hypoxic conditions that developed near the sediments were implicated in the loss of Lake Trout recruitment, through the mortality of overwintering embryos and decreased habitat availability (Lienesch et al. 2005). Similar concerns have also been raised for whitefish species. For example, Nümann (1972) suggested that the eggs of coregonines in the Bodensee suffered from oxygen deficiency due to eutrophication. Eutrophication and associated degradation of spawning habitat have been implicated in the decline of the Lake Whitefish and Lake Trout populations in Lake Simcoe, Ontario (Evans and Waring 1987; Evans et al. 1988; McMurtry et al. 1997).

However, habitat quality is only one of many factors that may affect reproduction rates. Marsden et al. (1995) indicated that Lake Ontario is meso-eutrophic and yet, under certain conditions, supports relatively high Lake Trout egg survival. In studies of interstitial water quality at Lake Trout spawning sites, Sly (1988) found that although some of the spawning habitats studied were degraded, the extent to which this affected reproductive success was uncertain. Lake Trout also were proven to be highly adaptable to spawning habitat disturbances and repeatedly selected new sites in lakes in northern Ontario when previous spawning sites were covered with opaque plastic sheeting. The new sites were also found to produce alevins (i.e., newly hatched fish with yolk sac) indicating that recruitment was not eliminated by the habitat disturbances (Gunn and Sein 2004).

Due to increased nutrient levels in Lac du Sauvage during late operations, there may be a minor increase in algae or sediment on spawning shoals in close proximity to the diked area in Lac du Sauvage. However, most of the high quality spawning habitat in Lac du Sauvage is in the 2 to 6 m depth range, which is kept clean of silt and fine organic debris by wave-generated currents. It is expected that the current and wave action will lessen the growth of algae on these exposed shoals. This wind and wave action would also minimize the accumulation of sediment and organic matter in the interstices of the shoals. Furthermore, although Lac du Sauvage has suitable Lake Trout and Lake Whitefish spawning habitat (Annex XIV) most of the known high-quality spawning shoals in the ESA are located in Lac de Gras where there will be only a very small increase in nutrients, and as such, no measureable changes to algae and sediment. The closest spawning shoal in proximity to the proposed diffuser location is 1.1 km to the southeast (Map 9.4-2; Annex XIV). Other spawning shoals are well over 1.5 km from the edge of the dike location.

Minor changes in shoal habitat in Lac du Sauvage may occur for Lake Trout, Lake Whitefish, and forage species, such as Cisco and Round Whitefish. Physical change will be in response to nutrient loading during late operations phases in Lac du Sauvage. However, affected spawning habitat may be limited to lower-quality shoals in close proximity to the diffuser. Higher-quality shoal habitats for spawning are located in Lac de Gras and will not be affected by nutrient loading. Thus, minor residual effects are predicted for the population in response to peak loading of nutrients at the end of the operation phase. Effects, if any, should be reversible before the end of the closure phase.

Fish Health

Although increased concentrations of some metals, major ions, and TDS in Lac du Sauvage and Lac de Gras are predicted as a result of Project operations, these changes are not predicted to result in adverse toxic effects to aquatic health through direct exposure to substances in the water column (Section 8.5.5.3). All constituents will remain below federal, provincial (e.g., BC), and site-specific guidelines.

Furthermore, simulated effluent testing suggests that maximum predicted effluent TDS concentrations produced during open-pit mining of the Jay Pit is not likely to be acutely toxic. Thus, acute localized effects to aquatic life at the point of discharge into Lac du Sauvage are not expected.

Potential indirect effects to fish related to accumulation of substances within fish tissue via uptake from both water and diet were identified for aluminum (during operations and into closure) and vanadium (during operations and into closure); however, adverse effects to the health of fish VCs are unlikely. The assessment methods included very conservative assumptions, and therefore, predicted concentrations in tissue are likely overestimated (Section 8.5.5.3.2). For example, for aluminum, a relatively high bioaccumulation factor was considered even though the current scientific understanding of aluminum is that it does not bioconcentrate, and that tissue concentrations are poor predictors of toxicity (Wilson 2012). For vanadium, the bioaccumulation factor used to predict tissue concentration was the maximum upper-bound estimate of the range of site-specific bioaccumulation factors (BAFs) developed for the Project. If the minimum upper-bound estimate was used, then the predicted tissue concentrations would have been four times lower, and below the tissue benchmark.

Adverse effects are unlikely for Arctic Grayling, Lake Trout, and Lake Whitefish health, and thus, no measurable effects or minor residual effects are predicted for self-sustaining and ecologically effective populations.

9.4.3.2.4 Effects During Post-Closure

The effects of the Project from changes in water quality on fish and other aquatic life in Lac du Sauvage and Lac de Gras during the post-closure period are evaluated and described below. The following primary pathway is considered:

- Reconnection of the back-flooded area of Lac du Sauvage to the remaining watershed and post-closure releases of water (e.g., Misery Pit overflow and seepage, waste rock storage area runoff, Long Lake Containment Facility discharge) may change long-term water quality in Lac du Sauvage and Lac de Gras and affect fish and other aquatic life.

The closure plan includes transferring water from the Misery Pit to the bottom of the Jay Pit, and back-flooding the Jay Pit and the dewatered area of Lac du Sauvage with freshwater from Lac du Sauvage. Breaching the dike will occur only when water quality in the dewatered area is suitable for mixing with the lake. The physical and chemical environment of the back-flooded area will allow re-establishment of a healthy functioning aquatic ecosystem, including habitat functions for foraging, spawning, rearing, and overwintering.

Under the closure plan, the majority of water quality parameters during post-closure are expected to return to near baseline values in both Lac du Sauvage and Lac de Gras. The exception is nitrogen in the main basin of Lac du Sauvage, which will remain elevated over the long-term, at approximately 0.3 mg/L, compared to 0.2 mg/L during the baseline period. Periodic increases in nitrogen are also predicted in the Slipper Bay area of Lac de Gras during post-closure. Trophic status and biomass of phytoplankton, zooplankton, and benthic invertebrates are expected to return to near baseline levels. However, there will be a time lag in recovery for some trophic levels following decreases in nutrient inputs and some minor shifts in overall community structure may result due to an altered N:P ratio. The potential shifts in community structure are not expected to alter overall lake productivity.

Potential residual effects to the lower trophic community and fish populations during post-closure are described further in the sections below.

Phytoplankton

Reduction of phosphorus loading has been demonstrated to be effective in reducing lake productivity (Wetzel 2001). The predicted rapid decrease (i.e., within 5 years) in nutrient concentrations to Lac du Sauvage and Lac de Gras during closure is expected to result in a return to phytoplankton biomass similar to baseline conditions. Phytoplankton biomass is expected to follow a similar trajectory to nutrient concentrations during the closure and post-closure periods. However, sometimes internal phosphorus loading can delay recovery of trophic state (Jeppesen et al. 1991; Sondergaard et al. 2001).

In general, new equilibria is expected to be reached in less than ten years for total phosphorus and in less than five years for total nitrogen (Jeppesen et al. 2007). Ecosystem resilience (a measure of the rate at which the system can recover from disturbances) is a function of the turnover time of limiting resources (Wetzel 2001). Depending on the lake size, mixing regime, and hydraulic retention time, phosphorus can continue to be released from the sediment (i.e., internal loading) for years following a reduction in external phosphorus loading (Jeppesen et al. 1991). Slower responses are typically observed in shallow lakes with high hydraulic retention times (Jeppesen et al. 2007; Wetzel 2001). In most lakes, the contribution of phosphorus through internal loading is relatively small compared to external sources so that phytoplankton productivity is typically reduced with a decrease in external loading of nutrients (Wetzel 2001).

The N:P ratio is expected to remain elevated during post-closure due to nitrogen concentrations remaining above baseline values. Phosphorus limitation is common among sub-arctic lakes; thus, it is expected that although the phytoplankton community may be different from the baseline community, it will be similar to those in other oligotrophic sub-arctic lakes.

Zooplankton

During closure and post-closure, zooplankton communities are expected to return to close to baseline conditions and be typical of communities found in other oligotrophic sub-arctic lakes. A decrease in zooplankton biomass will likely be observed through the closure period as nutrient concentrations and phytoplankton production decrease. In addition, a slight shift to smaller zooplankton species may occur if the size of algal species decreases. In oligotrophic lakes, the effects of top-down (predator-mediated) interactions are expected to have greater importance in determining biomass in pelagic systems (McQueen et al. 1986). However, zooplankton biomass is largely set by food resource availability (Wetzel 2001) and a decrease in zooplankton biomass is expected to follow subsequent to a decrease in phytoplankton biomass.

Benthic Invertebrates

During closure and post-closure, benthic invertebrate communities are expected to return to baseline conditions in Lac du Sauvage and Lac de Gras. Biomass will likely decrease and the community is expected to continue to be dominated by chironomids as is typical of sub-arctic lakes (Beaty et al. 2006; Northington et al. 2010). It is possible that food resources accumulate over time in the benthic zone of lakes (Hershey 1992), which could cause the response of the benthic invertebrate community to lag behind the response observed in phytoplankton and zooplankton, if benthic invertebrates are limited by food availability. Alternatively, if benthic invertebrates, such as chironomids, are more limited by predation, as observed by Hershey (1992), the response of the benthic invertebrate community to changes in nutrients may be less pronounced and difficult to detect. The collection of long-term monitoring data will be useful in assessing trends in trophic state and environmental condition.

Fish Populations

At closure, the dewatered area of Lac du Sauvage will be back-flooded and habitat will be returned to Lac du Sauvage in an altered state. The dike will be breached when water quality in the dewatered area meets acceptability criteria. The physical and chemical environment of the area will allow re-establishment of a healthy functioning aquatic ecosystem.

As described in Section 8.5.4, the majority of water quality parameters during post-closure are expected to return to near baseline values in both Lac du Sauvage and Lac de Gras. Trophic status and biomass of phytoplankton, zooplankton, and benthic invertebrates are expected to return to baseline levels. It is predicted that residual effects to fish VCs through changes to food resources and available spawning habitat will either not be measurable or will be measurable but minor in post-closure.

Although increased concentrations of some metals, major ions, and TDS in the ESA may persist beyond closure in Lac du Sauvage and Lac de Gras as a result of the Project, these changes are not predicted to result in adverse toxic effects to aquatic health through direct exposure to substances in the water column (Section 8.5.5). Furthermore, the majority of water quality parameters are expected to decrease during post-closure to steady-state concentrations within or slightly higher than the range of existing conditions. Adverse effects are unlikely for Arctic Grayling, Lake Trout, and Lake Whitefish health. Thus, predicted changes to fish health will result in no measurable effects to self-sustaining and ecologically effective populations.

9.4.3.3 *Downstream Changes to Habitat During Back-Flooding*

The effects of the Project from change in downstream water quantity on fish and other aquatic life in Lac du Sauvage and Lac de Gras during the back-flooding period are evaluated and described below. The following primary pathway is considered:

- Pumping water to back-flood the Jay Pit and diked area of Lac du Sauvage may affect water levels and riparian habitat in Lac du Sauvage and Lac de Gras, and water levels, flows, and riparian habitat in the Lac du Sauvage-Lac de Gras Narrows, affecting fish and other aquatic life.

9.4.3.3.1 Change in Lake Water Level

During closure, water will be pumped from Lac du Sauvage to back-flood the upper level of the Jay and Misery pits and the dewatered area of Lac du Sauvage. During back-flooding, water levels in Lac du Sauvage and Lac de Gras are expected to decrease as described in the hydrology assessment (Section 8.5.3.2.4). The magnitude of change will vary seasonally and water level decreases will range from 0.03 m to 0.05 m in Lac du Sauvage and from 0.01 m to 0.08 m in Lac de Gras. The predicted change in water levels fall within the natural range of variability observed. The seasonal timing and pattern of lake level fluctuation will be maintained during back-flooding. During anticipated low flow time periods, such as winter months, pumping rates out of Lac du Sauvage into the pits may be reduced and pumping rates will be managed to minimize downstream effects. The duration of the back-flooding period is expected to be less than 4 years, and the small changes predicted will occur during the back-flooding period only. Therefore, changes in water levels in Lac du Sauvage and Lac de Gras are expected to have a minor measurable effect on fish habitat, including riparian habitat.

9.4.3.3.2 Change in Lac du Sauvage Outlet Flow

The Lac du Sauvage outlet, or the Narrows, is a relatively wide (minimum bankfull width of approximately 45 m) and short (210 m in length) outlet stream with a low gradient (less than 0.1%). The Narrows was identified as a highly productive and important area for fish (Dillon 2002a; Fitzsimmons 2013). Open water remains in the Narrows year-round, and habitat conditions present provides for above average spawning, rearing, and forage habitats (Dillon 2002a). The Narrows is also expected to be an important year-round movement corridor for fish between Lac du Sauvage and Lac de Gras and Traditional Knowledge has identified the Narrows as an important fishing location, particularly during winter (Section 9.2.7).

Maintaining characteristics of the natural flow regime, in terms of timing, magnitude and frequency of flow, is generally accepted and supported by the scientific literature as an important consideration in sustaining the health of river ecosystems (Poff et al. 1997; Arthington et al. 2006; Richter et al. 2012). Changes in flow can alter fish habitat through loss of available habitat area from reductions in channel width, or changes in habitat characteristics and fish passage through changes to flow depth and velocity conditions.

The water balance results for Lac du Sauvage described in the hydrology assessment (Section 8.5.3.2.4) show that during closure, monthly mean flows in the Lac du Sauvage outlet will decrease from baseline values. The 2-year peak daily flood discharge will decrease by approximately 13% from the baseline value, and the 100-year peak daily flood discharge will decrease by approximately 18% from the baseline value. Pumping water for back-flooding will cause the 2-year 30-day averaged low flows in the Lac du Sauvage outlet to decrease by 22% from the baseline value and the 100-year 90-day averaged low flows to decrease by 30% from the baseline value. However, these model results do not consider the low flow pumping mitigation that is proposed to reduce pumping rates during low flow time periods to minimize downstream effects. Small changes in flow (i.e., less than 10%; DFO 2013b; Richter et al. 2012) are not expected to result in detectable effects to the aquatic ecosystem. Since the predicted flow changes during back-flooding are greater than 10%, an analysis of the potential effects of flow reductions on fish habitat characteristics (i.e., channel depth and width) was completed.

Based on the hydrology assessment (Section 8.5.3.2.4), no outlet or bank stability effects are expected because flood magnitudes will be reduced from baseline values. Therefore, changes in habitat conditions within the Lac du Sauvage outlet channel were assessed based on changes to the channel width and channel depth caused due to reduction in monthly flow for the duration of back-flooding. Channel widths in the Narrows are predicted to decrease by approximately 3.7 m during the 2-year peak flow conditions; however, this would still result in a channel width of approximately 40 m. Seasonal changes in mean monthly channel width are predicted for every month of the year, and range from as little as a 0.24 m to 0.37 m decreases in width during the lowest flow months (February through April), and from 1.02 m to 3.58 m decreases in width for the remainder of the year (May through January). The maximum depths within the Lac du Sauvage outlet channel are also predicted to change seasonally during back-flooding, and range from a decrease of 0.03 m to 0.05 m throughout the year.

The flow depth and channel widths will remain within the range of natural variability for the duration of back-flooding. The natural timing of peak flows and the relative seasonal magnitude of flow conditions will not be altered due to back-flooding activities. Maximum flow depth in the Lac du Sauvage outlet channel is only predicted to change by a small amount (maximum of 0.05 m), and flow depths in the channel will remain above 0.4 m throughout the winter and during low flow periods. During anticipated low flow time periods, such as winter months, pumping rates out of Lac du Sauvage into the pits and dewatered area will be reduced and pumping rates will be managed, which will further reduce the downstream effects. The habitat areas lost due to flow reductions would be shallow (i.e., 0.05 m total depth or less) and would occur along the stream margins. Areas of shallow habitats along the stream margins and riparian habitat would still remain in the Narrows during the back-flooding period and areas of deeper habitat that would support spawning and fish movements would not measurably change from the small change in flow depth.

Based on the small change in flow depth, the habitat suitability within the channel is not expected to change and fish passage will be maintained throughout the year. Changes in wetted width are only expected to affect very shallow habitat areas along the stream margins. The reduction in overall habitat area in the Lac du Sauvage-Lac de Gras Narrows is small since the channel is only 210 m in length. The changes to wetted width and riparian habitat will be temporary, as back-flooding is planned to be completed in less than four years. As a result, the changes in flows predicted during the back-flooding period are not expected to result in serious harm to fish in Lac du Sauvage or Lac de Gras and effects to fish and other aquatic life are predicted to be minor.

9.4.4 Residual Effects Summary

Residual effects to fish and other aquatic life from the Project will primarily occur from direct habitat losses (i.e., footprint changes) from the construction of the Jay horseshoe dike, the Jay open pit, and the dewatering of the diked area in Lac du Sauvage where the pit will be located. Habitat losses will also include diverted flows of tributary streams during the operation of the Sub-Basin B Diversion Channel. Existing habitat losses in the ESA include affected lake habitat in Lac de Gras from the Diavik Mine. There are no previous or existing mine footprints that overlap with tributary habitats for fish affected by the Project in Lac de Gras and Lac du Sauvage.

The total operations in-lake footprint of the Project in Lac du Sauvage is estimated to be approximately 54.3 ha from the dike and 335.7 ha from the dewatering of the diked area, resulting in a total loss of 390 ha, or 4.5% of the aquatic habitat in Lac du Sauvage and 0.6% within Lac du Sauvage and Lac de Gras combined (i.e., the ESA). The area of the cumulative changes from direct loss of lake habitat from the Project during operations plus previous and existing developments (i.e., the Application Case) will be less than 1% of the lake habitat in the ESA relative to the Base Case reference condition. Direct loss of stream habitat from the Project is estimated to be approximately 877 m or 1.6% of the selected tributary habitats in the ESA relative to the reference condition. There are no reasonably foreseeable developments in the ESA for fish and other aquatic life. The amount of cumulative change to habitat in the ESA is expected to result in no measurable effects, or minor residual effects, to population abundance and distribution for Arctic Grayling, Lake Trout, and Lake Whitefish.

At closure, the dewatered area of Lac du Sauvage will be back-flooded and the dike will be breached when water quality in the diked area is suitable for mixing with the lake (i.e., when most habitat functions are recovered). Affected riparian habitat around the dewatered area will recover (with the exception of habitat permanently affected by the placement of the dike). Importantly, fish from adjacent habitat areas in Lac du Sauvage are expected to immediately move into the area and fully exploit the restored habitat within a few years of closure. Density-dependent compensatory effects may result in small, initial increases in population growth (i.e., fish production) because of new access to habitat behind the dike (Rose et al. 2001). Thus, recovery may occur within a few years and should be no longer than one generation time of fish VCs for populations to approach densities in other regions of Lac du Sauvage and Lac de Gras. The short recovery period predicted for the back-flooded area after breaching also reflects that no, or minor, measureable effects to fisheries productivity in the ESA are predicted during operations and closure.

The remnant portions of the dike will remain in Lac du Sauvage post-closure, resulting in the permanent loss of less than 54.3 ha of lake area (or less than 1% of the area of Lac du Sauvage and Lac de Gras). Remaining dike material will remain as islands in Lac du Sauvage, potentially providing habitat functions for spawning, rearing, and foraging fish. At closure, the Jay Pit represents a permanent loss of approximately 65 ha of lake bottom substrate habitat for benthic feeding or bottom dwelling species such as Lake Whitefish and forage species such as Slimy Sculpin, but will include an extended water column as habitat for pelagic species such as Lake Trout and Cisco (forage species for Lake Trout). The upper level of the Jay Pit may remain well-oxygenated through the winter due to its depth and may provide additional overwintering refugia for fish in winter or thermal refugia in summer. Thus, the amount of permanent change to habitat in the ESA is expected to result in no measurable effects to population abundance and distribution for Arctic Grayling, Lake Trout, and Lake Whitefish.

Dominion Diamond will work with DFO and local Aboriginal communities on developing an offsetting plan to counterbalance for losses in fish habitat productivity expected during operations and at closure. The final offsetting plan will be developed during the permitting phase of the Project as a requirement of the *Fisheries Act* Authorization.

Before dewatering, a detailed fish-out plan will be developed in discussion with local Aboriginal groups and DFO. The objective of the fish-out is to minimize the waste of fish caused by the dewatering of the diked area, while following a scientific protocol for removing fish. Based on estimates from hydroacoustic sampling, up to 23,400 fish are predicted to be within the diked area that would be removed as part of a fish-out. Because the predicted number of fish to be removed is small compared to the entire population in Lac du Sauvage and Lac de Gras (i.e., less than 1%), this would not affect self-sustaining and ecologically effective populations of fish VCs.

Increased concentrations of some metals, major ions, and TDS in Lac du Sauvage and Lac de Gras are predicted as a result of the Project (Section 8.5.4). However, concentrations of all constituents in Lac du Sauvage and Lac de Gras are predicted to be less than guidelines and benchmarks at all assessment locations and during all phases, and thus, no constituents of concern were identified. Concentrations of these parameters peak in the operations phase, but decrease in post-closure to a steady state concentration that is predicted to be within or slightly higher than the range of existing conditions.

Based on the aquatic health assessment (Section 8.5.5), changes to concentrations of all substances considered are predicted to result in negligible effects to aquatic health in Lac du Sauvage and Lac de Gras. As a result, adverse effects to Arctic Grayling, Lake Trout, and Lake Whitefish health are unlikely, and thus, no effects would be expected to the self-sustaining and ecologically effective populations of these VCs.

The effect of increased nutrient concentrations from minewater discharge to Lac du Sauvage during operations is expected to result in a general increase in productivity at lower trophic levels in the main basin of Lac du Sauvage and a similar, but less pronounced, effect in the eastern part of Lac de Gras. A clear, defined change in composition of plankton and benthic invertebrate communities is not expected. However, biomass of phytoplankton, zooplankton, and benthic invertebrates will likely increase during operations, as these communities take advantage of the increased nutrient supply. In addition, minor shifts in overall community structure and dominant taxonomic groups may also result. Following closure, plankton and benthic invertebrate communities are expected to return to baseline conditions. Due to the increased food base (lower trophic levels and forage fish), there may also be a minor increase in growth and reproduction rates in the fish VCs. However, effects will be limited primarily to Lac du Sauvage during the late operations phase and potentially into closure.

During back-flooding at closure, effects to downstream habitat quantity and riparian conditions may persist for up to four years during the pumping of water from Lac du Sauvage to back-flood the Jay and Misery pits and the diked area. The flow depth, channel widths, and riparian conditions of the Narrows will remain within the range of natural variability for the duration of back-flooding. The natural timing of peak flows and the relative seasonal magnitude of flow conditions will not be altered due to back-flooding activities. Maximum flow depth in the Lac du Sauvage-Lac de Gras Narrows is only predicted to change by a small amount (maximum of 0.05 m), and flow depths in the channel will remain above 0.4 m throughout the winter and during low flow periods. During anticipated low flow time periods, such as winter months, pumping rates out of Lac du Sauvage into the pits and dewatered area may be reduced and pumping rates may be managed, which will further reduce the downstream effects. Areas of shallow habitats along the stream margins and riparian habitat would still remain in the Narrows during the back-flooding period and areas of deeper habitat that would support spawning and fish movements would not measurably change from the small change in flow depth.

As described in Section 8.5.4, the majority of water quality parameters during post-closure are expected to return to near baseline values in both Lac du Sauvage and Lac de Gras, providing a physical and chemical environment for the recovery or reversibility of effects on fish VCs following closure when the diked area is breached. Recolonization of the back-flooded area is expected to occur immediately from adjacent habitat areas and will likely be populated by fish of all species and life-stages. Upon recolonization of the back-flooded area, density-dependent compensatory effects may result in small, initial increases in population growth (i.e., fish production) because of new access to habitat behind the dike (Rose et al. 2001). Population recovery for fish VCs is expected to occur within a few years, in part, because measurable changes to populations within the ESA are expected to be minor and may not occur at all.

9.5 Prediction Confidence and Uncertainty

The purpose of this section is to identify the key sources of uncertainty and to discuss how uncertainty has been addressed to increase the level of confidence that impacts are not worse than predicted. Confidence in the assessment of environmental significance is related to the following elements:

- water balance modelling inputs and results;
- water quality modelling inputs and results;
- adequacy of baseline data for understanding current conditions and future changes unrelated to the Project (e.g., extent of future developments, climate change, catastrophic events);
- understanding of Project-related impacts on complex ecosystems that contain interactions across different scales of time and space (e.g., exactly how the Project will influence fish and other aquatic life); and,
- knowledge of the effectiveness of the environmental design features and mitigation for reducing or removing impacts (e.g., best management practices).

Prediction confidence and uncertainty with respect to predictions related to surface water hydrology, water quality, and aquatic health are described in Sections 8.6.2 to 8.6.5.

Sources of uncertainty for surface water hydrology predictions for the Project were third-party datasets (hydrometric, meteorological, and topographical data), model input data (datasets derived from meteorological and hydrological data, planned water transfers, and watershed physical characteristics), and model calibration parameters (runoff, snowmelt, and lake outlet freezing coefficients). The level of uncertainty in third party data was assessed as low. Uncertainty in model input data was mitigated using various methods (e.g., adjusting data for distance from the Project, modelling seasonal trends rather than exact values), or the data sets were verified against other existing data sets. The moderate level of uncertainty in planned water transfers was addressed by completing the effect analysis based on currently available and approved plans. Considering all model components and associated uncertainties, there is a high level of confidence in overall predicted changes to surface hydrology due to the Project.

Sources of uncertainty for surface water quality include adequacy of baseline data, uncertainties related to water quality modelling and air quality modelling, and uncertainties associated with external influences, such as forest fires. Baseline water quality data are considered adequate, but are subject to limitations related to the list of constituents and detection limits. Missing constituents were relatively few; non-detect data were handled consistently across the data set. The water quality modelling approaches used for the Project assessment are consistent with current modelling practices, and are considered to provide a reasonable approximation of future water quality within the context of the assumptions applied. The dispersion models used in the Air Quality assessment simplify the atmospheric processes associated with air mass movement and turbulence, and tend to be conservative, thereby over-estimating Project-related deposition. Coupled with the conservative assessment approach to predict changes in water quality, the confidence is high that effects from the aerial deposition pathway are not underestimated. For purposes of this assessment, forest fires did not affect the quality of the data included in the water quality baseline or that used in the modelling. Overall, there is high level of confidence in predicted water quality, but with the caveat that monitoring of source terms is required to verify the input assumptions and monitoring of the lakes is required to verify the movement and assimilation patterns in the lakes.

Uncertainty in the aquatic health assessment was managed by the compilation of representative data for the Project, adoption of a risk-based approach based on established practices, application of methods supported by published literature, consideration of established mitigation and best practices to minimize or eliminate effects, and use of a conservative approach, so that potential effects are expected to be overestimated. The level of certainty in various aspects of the aquatic health assessment varies from low to moderate; however, the overall level of confidence in the assessment results is high, and it is unlikely that changes to the environment as a result of Project activities were underestimated.

The procedure for addressing uncertainty in scientific study is the same procedure in environmental assessment. All scientific predictions must be tempered with uncertainty associated with the data and the current knowledge of the system while recognizing that ecosystems are inherently complex. Ecosystems, such as the Lac du Sauvage-Lac de Gras ecosystem, may be characterized by interactions across multiple scales, nonlinearity, self-organization, and emergent properties (Holling 1992; Levin 1998). These characteristics can create fluctuations in species abundance and distribution and confound our understanding of ecosystem functions and underlying processes, which limit our capacity to make predictions. Describing variation and understanding factors that underlie variation in the ecology of valued components through time can be a common challenge in environmental assessment, particularly when there is a lack of information. Factors underlying variation might include stochastic processes (e.g., sampling biases) or deterministic processes (e.g., climate change influences, overharvesting).

Variability in fish baseline information for the Project can be reviewed in Section 9.2 or Annex XIV (Fish and Fish Habitat Baseline). In brief, fisheries data were collected over approximately 20 years of sampling starting with baseline studies for the Ekati and Diavik mines. Baseline data collection was substantial at both spatial and temporal scales and includes information on fish relative abundance, species distributions, habitat, species life history, and metals in tissue for a region where there is very little historical and existing development. Additionally, sampling has been conducted throughout much of this time period for lower trophic levels (i.e., plankton and benthic invertebrates) that provide a food base for fish. Estimates of numbers of fish to be removed in the fish-out were conservatively estimated using a 75th percentile statistic (23,400 fish) versus the median statistic (7,100 fish) as an approach to address uncertainty underlying the hydroacoustics method for estimating fish densities. For example, hydroacoustic surveys can underestimate the number of fish occurring on the lake bottom where detection rates are low (e.g., for Burbot). Overall, there is a moderate to high level of confidence that the data collected in the BSA provide the necessary baseline knowledge of species biology and environmental conditions for an environmental assessment.

Also, the level of effort that was performed for the baseline study considered both “reliability” (i.e., confidence) in the data and the effect from sampling itself. It is important to minimize mortality that can result from the deployment of standard sampling methods, such as gill netting. Additional sampling efforts in the BSA, particularly invasive methods (e.g., gill netting), would have resulted in more mortality, potentially affecting the abundance and distribution of populations.

Knowledge of fish life history requirements and local species distributions were also used in characterizing fish assemblages for the assessment. This approach reduced uncertainty potentially underlying baseline descriptions and impact predictions. For example, in some cases where a fish VC was not recorded but potentially present and undetected during sampling, the waterbody under examination was deemed to support that species. Specifically, if a lake or stream upstream (e.g., Christine Lake) of given location supported Lake Trout, the downstream waterbodies (e.g., Stream B0) were all characterized as Lake Trout habitat even if the species was undetected during sampling at the downstream location. Traditional Knowledge information for fish species presence and distribution in the study area was also incorporated where available. Although limited, the species presence information agreed with fish sampling data from historical and recent studies.

It is understood that development activities will affect fish habitat, fish mortality, and fish behaviour and movement. However, direct disturbance to habitat from cumulative effects was calculated to be a small proportion of the ESA and the understanding of the success of mitigation policies and practices for limiting effects to fish populations and aquatic ecosystems has increased over the past decade. For example, designing the Sub-Basin B Diversion Channel to facilitate fish passage between Lac du Sauvage and upstream watercourses and waterbodies will be an effective, technically and economically feasible option to mitigate for lost habitat connectivity. There is relatively low uncertainty associated with the effectiveness of the proposed diversion channel as a migration corridor for adult Arctic Grayling because of the environmental design features of the diversion channel and the characteristics of the target species. Arctic Grayling may be resilient because the species is often exposed to highly variable flow conditions, and thus, has life history adaptations (e.g., behavioural plasticity in response to a disturbance, good dispersal ability, migration strategies), that prevents extirpation of local populations.

Habitat losses from the Project were estimated using GIS. There is a moderate level of confidence that the calculation represents a reasonable estimate of the aquatic footprint. The footprint area will be refined as the Project advances the detailed design and will be updated with the final offsetting plan. However, although the absolute numbers in terms of the footprint may change (e.g., in ha), the relative numbers in terms of percentage compared to the overall lake area within the ESA will remain similar. Furthermore, the permanent losses are small in comparison to the ESA; as such, the effects on the populations of fish VCs associated with habitat losses have not been underestimated. The final numbers will be included in the offsetting plan, which will be developed in the permitting phase of the Project.

Although there is a moderate to high level of certainty that the population of fish VCs will recover to the carrying capacity of the lake when the diked area is reconnected to Lac du Sauvage and fish are once again able to access the habitat, there is a level of uncertainty with respect to the duration of effects post-closure. Key factors to consider include the capacity of the population to recover (i.e., resiliency), potential functions of reclaimed habitat for fish, and future environmental conditions. It is expected that most species and life stages of fish from Lac du Sauvage will be able to move into and exploit the recovered habitat immediately after the dike has been breached initiating the population recovery. Furthermore, a compensatory density-dependent response may underlie the recovery of species (i.e., increasing growth and reproduction rates) beginning when the dike is breached (e.g., Rose et al. 2001). This is a typical response when population densities are reduced and new habitat becomes accessible, which in turn promotes a numerical increase in populations. The predicted recovery period also reflects predicted Project effects to fisheries productivity, which are expected to be minor or not occur at all. Thus, for fish VCs, it is expected that effects from the aquatic footprint may be reversible within a few years of closure, with the possibility of a recovery period extending to one generation time of fish VCs.

At closure, back-flooding of the Jay Pit will initially include water transferred from the Misery Pit. The top of the Jay Pit and the diked area will be back-flooded with natural, local, freshwater from Lac du Sauvage over a 3 to 4 year period. Portions of the Jay Dike will be breached and partially removed when water quality standards are met. Plankton and benthic invertebrates will recolonize during the back-flooding period; however, there may be some uncertainty associated with the timing of the response. It is also expected that fish will recolonize the dewatered area and remnant sections of the dike will remain at closure, potentially providing spawning and rearing habitat for Lake Trout and Lake Whitefish. However, there is some uncertainty as to whether fish will select the remaining sections of the dike for spawning and rearing given the abundance of spawning shoals at other locations in the effects study area (Fitzsimmons 2013). Most of the back-flooded areas should retain functions similar to those provided before dewatering. However, there are few, if any, observational studies examining fish populations or habitat suitability in back-flooded areas including open pits in Arctic ecosystems. For example, the extent of fish use of the pit edge and slopes of the pit is unknown, as well as the use of the upper level of the open pit for summer thermal refugia or overwintering habitat. To date, the only management plans proposing back-flooding of pits under large lakes in the Northwest Territories or Nunavut are those proposed for the Diavik Mine and the Meadowbank Gold Mine, as well as the De Beers Gahcho Kué Project.

Predicting the duration of effects is also a challenge when the future may be outside the range of observable baseline environmental conditions (e.g., because of climate change; Walther et al. 2002). In the DAR, quantifying changes to habitat provides a static assessment of a species' environment, ignoring change that may occur over time as a result of ecological succession and climate change. Thus, there is less certainty in long-term predictions (e.g., over periods of up to 10 to 20 years post-closure), compared to near-term predictions. There is a high level of confidence that the plankton, benthic invertebrate, and fish populations and communities in the study area will be different with or without the Project in future decades, mainly because of climate change.

Particular concerns for northern environments are climate change and the potential effects of climate on the ecology of the species that Aboriginal groups rely on for cultural values and subsistence harvests. Climate has the potential to affect populations of fish directly (e.g., drought events), and the distributions of individual components of ecosystems may shift in different ways under different climate scenarios, generating potentially new combinations of species and ecosystem types (reviewed in Mawdsley et al. 2009). However, changes, particularly those from indirect effects, will be difficult to predict (e.g., bottom-up versus top-down responses) (Krebs and Berteaux 2006).

Although there is uncertainty in the ability to forecast the course of climate change in coming decades and the ability to predict the biogeographic responses of fish species to climate change (Jackson et al. 2009), some research suggest that precipitation and climate changes have been, and will continue to be, key factors for changes in exposure to contaminant burdens for freshwater Arctic fish species (Carrie et al. 2010). However, uncertainty that underlies predictions of future conditions will be addressed with monitoring under the AEMP (Appendix 9C). The AEMP will be designed to address predicted effects to the aquatic environment related to changes in surface water quantity and quality, sediment quality, aquatic life other than fish, fish habitat, and fish health (including fish tissue chemistry).

Despite the uncertainties discussed above, the magnitude, duration, and geographic extent of effects from the Project on fisheries productivity are minor in magnitude relative to the temporal and spatial scales that are associated with climate change. The absolute magnitude of direct and indirect effects from the Project is also small and the long-term trajectory of fisheries productivity will not be significantly affected by the Project. The relative contribution to changes may increase when environmental conditions are poor, but such events will likely be infrequent within the duration of the Project and the absolute effect size from the Project would remain very low.

The effectiveness of mitigation measures related to the aquatic environment is discussed in Sections 8.4.2.1 and 9.3.2.1. The mine plan utilizes several environmental design features and mitigation to eliminate or reduce the potential for Project activities to result in adverse environmental effects on hydrology, water quality, and fish and fish habitat. This includes strategies and mine infrastructure associated with the water management plan, such as water recycling, containment of mine site water, dikes, diversion channels, explosives management, blasting practices, sediment and erosion controls, and fish screens. There is a moderate to high level of confidence in the use and effectiveness of these mitigation measures, as most are already in use at the Ekati Mine, or used at other northern mine sites. Monitoring and adaptive management will also be used to determine the effectiveness of a particular mitigation measure and where modifications may be required.

9.6 Residual Impact Classification and Significance

9.6.1 Methods

9.6.1.1 *Residual Impact Classification*

The purpose of the residual impact classification is to describe the incremental and cumulative adverse effects from previous and existing developments and the Project (Application Case) on fish and other aquatic life VCs using a scale of common words rather than numbers and units. The use of common words or criteria is accepted practice in environmental assessment.

Other developments that may overlap with the Project under the Base and Application cases include existing and approved developments at the Ekati and Diavik mines. As discussed in Section 9.4-1, there is no RFD Case for the fish and other aquatic life VCs, as there are no reasonably foreseeable developments located within the ESA.

The classification of residual impacts from associated primary pathways and the determination of environmental significance are only completed for those VCs that have assessment endpoints. This is because assessment endpoints represent the key properties of the VC that should be protected for their use by future human generations (i.e., assessment endpoints consider sustainability; Section 6.2.2).

Results from the residual impact classification are then used to determine the environmental significance from the Project and other developments on the assessment endpoint for fish and other aquatic life VCs. Effects are described using the criteria defined in Table 9.6-1, and reflect the impact descriptors provided in the TOR (MVRB 2014). Together, these criteria are used to describe the nature (e.g., severity or intensity of change, and the area and amount of time over which the change occurs) and type (e.g., direction of the change) of an effect on fish and other aquatic life VCs. The main focus of the DAR is to predict if the Project is likely to cause a significant adverse (i.e., negative) effect on the environment or to cause public concern. Therefore, positive effects are not assessed for significance.

Table 9.6-1 Effects Criteria Used in the Determination of Significance for Fish and Other Aquatic Life Valued Components

Criteria	Rating	Definition
Magnitude	Low	Amount of change to measurement indicator results in no measurable effect to population abundance and distribution, or results in a minor measurable residual effect to the population
	Moderate	Amount of change to measurement indicator results in a clearly defined change to population abundance and distribution, but the residual effects are well within the predicted resilience limits and adaptive capacity of the VC
	High	Amount of change to the measurement indicator is sufficiently large that the resulting ranges of residual effects are near or exceeding the predicted resilience limits and adaptive capacity of the VC
Geographic Extent	Local	Predicted maximum spatial extent of direct and indirect effects from changes to measurement indicators due to a project or activity
	Regional	Residual effects from changes to measurement indicator due to a project or activity exceed the local scale and/or can include cumulative effects from other developments in the effects study area
	Beyond Regional	Residual cumulative effects from changes to measurement indicator due to a number of developments extend beyond the effects study area
Duration	Short-term	Residual effect from change to measurement indicator is reversible at end of construction of a project or a specific phase of a project or only occurs for a short time in any other phase
	Medium-term	Residual effect from change to measurement indicator is reversible at end of operations of a project or at end of closure (if effect started in closure).
	Long-Term	Residual effect from change to measurement indicator is reversible within a defined length of time past closure of a project
	Permanent	Residual effect from change to measurement indicator is irreversible
Frequency	Infrequent	Residual effect from change to measurement indicator is confined to a specific discrete event
	Frequent	Residual effect from change to measurement indicator occurs intermittently
	Continuous	Residual effect from change to measurement indicator occurs continuously
Reversibility	Reversible	Residual effect from change to measurement indicator is reversible within a time period that can be identified when a development or activity no longer influences the population
	Irreversible	Residual effect from change to measurement indicator is predicted to influence the population indefinitely (duration is permanent or unknown)
Likelihood	Unlikely	Residual effect from change to measurement indicator is possible but unlikely (<10% chance of occurrence)
	Likely	Residual effect from change to measurement indicator may occur, but is not certain (10% to 80% chance of occurrence)
	Highly Likely	Residual effect from change to measurement indicator is likely to occur or is certain (80% to 100% chance of occurrence)

Magnitude – Magnitude is a measure of the intensity of a residual effect on a VC. For example, magnitude can represent the degree of change caused by the Project relative to baseline conditions (i.e., effect size). Magnitude is VC-specific and is classified into three scales: low, moderate, and high. For fish VCs, magnitude is a function of the numerical and qualitative changes in measurement indicators and the associated influence on the abundance and distribution of the population. Project-specific (incremental) and cumulative changes in physical (e.g., habitat quantity, quality, and fragmentation) and biological (e.g., survival, reproduction, movement, and behaviour) measurement indicators result in effects on the abundance and distribution of populations. Because the assessment endpoint for fish and other aquatic life VCs is self-sustaining and ecologically effective populations (i.e., ongoing fisheries productivity), the magnitude of residual effects is assessed at the population level. By definition, self-sustaining populations are not populations at the brink of extirpation; they are healthy, robust populations capable of withstanding environmental change and accommodating random population processes (Reed et al. 2003). For VCs that have strong effects on ecosystem structure and function (i.e., highly interactive species), the concept of ecologically effective populations also is used (Soulè et al. 2003). An ecologically effective population of a highly interactive species maintains ecosystem function(s).

To provide an ecologically relevant classification of effect sizes of changes in measurement indicators for a particular VC, the assessment of magnitude included the known or inferred ability of the VC to absorb or otherwise accommodate disturbance. The evaluation and classification of magnitude considers the adaptive capacity and resilience of VCs to absorb effects from the Project and other disturbances and continue as self-sustaining and ecologically effective populations. Adaptable VCs can change their behaviour, physiology, or demographic characteristics (e.g., change in location of spawning habitat, change in birth rate) in response to a disturbance such that there is little change in abundance and distribution. For example, migration strategies and behavioural plasticity allows for adaptation to disturbance, high birth rates allow for replacement of harvested individuals (i.e., density-dependent compensatory response), and good dispersal ability allow for connection of fragmented populations (Weaver et al. 1996). Less adaptable VCs will be more strongly influenced by human and natural disturbance than VCs with greater adaptive capacity.

A concept closely related to ecological adaptability is ecological resilience. Ecosystems and populations often have inertia and will continue to function after disturbance up to the point where the disturbance becomes severe enough that the system or population changes. Ecological resilience is the capacity of the system to absorb disturbance, and reorganize and retain the same structure, function, and feedback responses (Holling 1973; Gunderson 2000; Curtin and Parker 2014). Population resilience can be considered to share similar features as ecological resilience with adaptability influencing the ability of the population to absorb or recover from change. Highly resilient VCs have the potential to recover quickly after reclamation (i.e., they are also adaptable), whereas VCs with narrower resilience limits will recover more slowly or may not recover at all.

Ideally, effect threshold values for adaptability and resilience limits of a VC would be known, and changes in measurement indicators can be quantified with a high degree of confidence to evaluate whether thresholds are expected to be exceeded. However, critical thresholds such as amount of quality habitat required to maintain ongoing fisheries productivity or the specific number of individuals required for an ecologically effective population size are not available for fish VCs in this assessment. Moreover, ecological thresholds vary by species, watershed type, and spatial scale (Fahrig 1997; Swift and Hannon 2010). Consequently, a detailed and transparent account of the predicted effects associated with incremental and cumulative changes to each measurement indicator are provided for each VC using available scientific literature, logical reasoning, and experience of the practitioners completing the assessment (reasoned narrative approach). Because of the uncertainty regarding the effects of development on VCs, magnitude classification was applied conservatively to avoid underestimating effects.

Geographic Extent – Geographic (spatial) extent refers to the area (or distance covered or range) of the effect, and is different from the spatial boundary (i.e., effects study area) for the effects analysis. The study area for the effects analysis represents the maximum area used for the assessment and is related to the spatial distribution and movement of VCs (Section 6.3.1). However, the geographic extent of effects can occur on a number of scales within the spatial boundary of the assessment, and is VC-specific. Geographic extent is categorized into three scales of local, regional, and beyond regional.

Effects at the local scale are largely associated with the predicted maximum spatial extent of combined direct and indirect changes from a specific development or activity (e.g., cumulative effects that are specific to the Project). Effects at the regional scale occur within the ESA, and are associated with incremental and cumulative changes from the Project and other developments (i.e., the existing Ekati and Diavik mines). The beyond regional scale includes cumulative residual effects from the Project and other developments that extend beyond the ESA. The principle applied when using geographic extent to understand magnitude is that local effects from the Project are less severe than effects that extend to the regional or beyond regional scales, all other factors being equal.

Duration – Duration is defined as the amount of time (usually in years) from the beginning of a residual effect to when the residual effect on species populations is reversed. Typically, duration is expressed relative to development phases; however, for effects that start later in the Project (i.e., not at construction) the duration of effects may still occur for a short or medium duration within the phase (e.g., back-flooding during closure).

Both the duration of individual events and the overall time frame during which the residual effect may occur are considered. Some residual effects may be reversible soon after the effect has ceased, while other residual effects may take longer to be reversed. By definition, residual effects that are short-term, medium-term, or long-term in duration are reversible.

In some cases, available scientific information and professional judgment may predict that the residual effect is irreversible. Alternately, the duration of the residual effect may not be known, except that it is expected to be extremely long and well beyond the temporal boundary of the assessment. As such, any number of factors could cause species populations to never return to a state that is unaffected by the Project.

The definition of irreversibility for the impact classification for fish VCs is similar to DFO's definition included in the Fisheries Productivity Investment Policy (DFO 2013a). In this document, DFO defines permanent alteration as a change to fish habitat of a spatial scale, duration, or intensity that limits or diminishes the ability of fish to use such habitat(s) to carry out one or more of life processes. The issue is whether there is a permanent change to the self-sustaining population, regardless of the duration of the change in the measurement indicator. A high magnitude classification confined to a specific discrete event could results in irreversible residual effects, whereas a low magnitude effect caused by a permanent change in habitat may be completely reversible.

9.6.1.2 *Determination of Significance*

The classification of primary pathways and the associated predicted changes in measurement indicators provide the foundation for determining the significance of incremental and cumulative effects from the Project and other existing, and approved developments on the assessment endpoint for fish and other aquatic life. The significance of the contribution of incremental effects from the Project on VCs is provided, but the evaluation is focused on determining the significance of cumulative effects on fish and other aquatic life VCs.

Magnitude is the primary criterion used to determine environmental significance, while other criteria are used as modifiers and to provide context when assigning magnitude. Geographic extent and duration provide important ecological context for classifying the magnitude of effects to VC assessment endpoints. For example, determining the magnitude of an effect from changes in habitat availability and connectivity on a fish VC depends on the spatial extent (amount of area or proportion of the population) and duration of the changes in habitat (how long the population is adversely affected). Duration includes reversibility, and a reversible effect from development is one that does not result in a permanent adverse effect on population processes (e.g., survival and reproduction) and properties (e.g., stability and resilience). Frequency and likelihood are also considered as modifiers when determining significance, where applicable.

Duration is also a function of resilience, which is the ability of the population to recover or bounce back from a disturbance (e.g., rate and degree of fluctuation in population abundance and distribution after a disturbance). Resilience is largely a function of demographic and behavioural life history traits such as size and number of eggs and survival of fry, age at reproduction, inter-birth interval, age-specific survival rates, lifespan of individuals, habitat selection, and effective dispersal (probability of leaving the natal range and successfully establishing a breeding range and reproducing). The capacity or ability of individuals in a population to change and accommodate disturbance is also related to resilience. For example, some species that avoid human features in relatively undisturbed habitats can change their behaviour to accommodate disturbance where it is more prevalent (Martin et al. 2010; Knopff 2011). Other populations may be able to increase reproduction to compensate for harvest mortality (Rose et al. 2001; Winemiller 2005). The ability of a population to regulate itself is an important mechanism that allows populations to respond to declines with either rapid or time-lagged recoveries. Fish species, such as Lake Trout, have been shown to actively seek out alternate spawning sites when their traditional habitat is lost (McAughey and Gunn 1995; Gunn and Sein 2000).

Resilience can vary with population size, stability, and the likelihood of demographic rescue from neighbouring populations. During periods of low abundance, animal and plant populations can become less resilient to natural environmental and human-related disturbances, which may reduce stability (i.e., trajectory of the population). Stable populations exhibit no long-term increasing or declining trend in abundance outside of natural fluctuations and cycles (e.g., predator-prey cycles). The model of an Arctic fish population in a steady or stable state is one with the ability to absorb annual fluctuations in year-class strength; if the juvenile population is depleted through several years of poor hatching, it is quickly restored with the advent of a good year (e.g., Johnson 1976). Resilience and stability are properties of a population that influence the amount of risk to VCs from development (Weaver et al. 1996). The duration of development-related effects may be shorter for VCs that are highly resilient and stable.

As much as possible, effects are classified and significance determined using established guidelines, thresholds or screening values, and scientific principles. In accordance with the TOR (MVRB 2014), for those environmental effects that are determined to be not significant, a reasoned narrative is given that provides a potential significance threshold level. For some VCs, such as water quality, guideline or threshold values are known, which provides confidence in effects predictions and determining environmental significance. For other VCs of the biophysical and human environments, social and ecological benchmarks or effects thresholds are not known and challenging to define, which creates uncertainty in determining the significance of predicted effects. For example, critical thresholds and screening levels for measurement indicators such as habitat quality, quantity, and connectivity, and ecologically effective population size are frequently not available for plant, fish, and wildlife species. Moreover, thresholds vary by species, landscape type, and spatial scale (Fahrig 2001; Swift and Hannon 2010). Because of the uncertainty regarding the effects of development on VCs, magnitude classification was applied conservatively to increase the level of confidence that effects will not be worse than predicted (Section 6.6). Furthermore, the determination of significance considers the key sources of uncertainty in the effects analysis, the management of uncertainties, and the correspondent level of confidence in effects predictions.

The evaluation of significance for fish and other aquatic life considers the entire set of primary pathways that influence the assessment endpoint; thus, significance is not explicitly assigned to each pathway. Rather, the relative contribution of each pathway is used to determine the significance of the Project and other developments on the assessment endpoint of self-sustaining populations (ongoing fisheries productivity), which represents a weight of evidence approach (i.e., evaluating the persuasiveness of evidence indicating that an effect is significant or not significant). For example, a pathway with a high magnitude, a large geographic extent, and a long-term duration is given more weight in determining significance relative to pathways with smaller scale effects. The relative effect from each pathway is discussed; however, pathways that are predicted to have the greatest influence on changes to the assessment endpoint are assumed to contribute the most to the determination of environmental significance.

The following is a summary of some of the key factors considered in the determination of environmental significance on fish and other aquatic life:

- results from the residual impact classification of primary pathways and associated predicted changes in measurement indicators;
- magnitude is the primary criterion used to determine significance with geographic extent and duration providing important context for assigning magnitude. Frequency and likelihood act as modifiers for determining significance, where applicable; and,
- the level of confidence in predicted effects, established benchmarks and thresholds, scientific principles (e.g., resilience and stability) and experienced opinion are also included in the evaluation of determining environmental significance.

This method is used to identify predicted residual adverse effects that have sufficient magnitude, duration, and geographic extent to cause fundamental changes to fish and other aquatic life, and therefore, result in significant impacts. The following definitions are used for predicting the significance of effects to compliance with regulatory air emission guidelines and standards.

Not significant – impacts are measurable at the individual level, and strong enough to be detectable at the population level, but are not likely to decrease resilience and increase the risk to self-sustaining and ecologically effective fish populations (i.e., ongoing fisheries productivity).

Significant – impacts are measurable at the population level and likely to decrease resilience and increase the risk to a self-sustaining and ecologically effective fish populations. Loss of habitat that causes permanent adverse changes to survival or reproduction at a population level would likely be significant. A significant effect may also result from habitat loss that affects fish movement and restricts population connectivity, disrupting the potential for demographic rescue between adjacent waterbodies, such that it causes permanent adverse changes to survival or reproduction at a population level.

9.6.2 Results

The incremental and cumulative effects from the Project and previous and existing developments are expected to not have a significant adverse effect on fish and other aquatic life VCs. Primary pathways influencing measurement indicators of ongoing fisheries productivity (i.e., self-sustaining and ecologically effective populations of Arctic Grayling, Lake Trout, and Lake Whitefish) and ongoing support for fisheries productivity were determined to be of low magnitude in the Application Case (Table 9.6-2). The geographic extent of the effects are local to regional (i.e., measurable in Lac du Sauvage and Lac de Gras, and possibly for a short distance past the outlet of Lac de Gras).

It is expected that effects will primarily be a result of direct habitat losses (i.e., footprint effects) from the construction of the Jay Dike and the dewatering of the diked area in Lac du Sauvage where the mine pit will be located. Effects related to the direct losses of lake habitat from the dike (sections remaining at post-closure) and Jay open pit development are expected to be low in magnitude, permanent, and occur at the local scale. Direct losses of lake habitat in the dewatered area are expected to be low magnitude, long-term effects, but will be reversible following flooding and reconnection. The geographic extent is considered regional.

The removal of fish before dewatering (i.e., the fish-out) is considered to be a low magnitude impact, occurring at the regional scale. The numbers of fish being removed are small in comparison to the overall population; as such, the residual effects to population abundance or distribution in Lac du Sauvage-Lac de Gras would not be measurable. Recovery from the effects of the fish-out may occur during the operations phase.

Effects to stream habitat from the dike and diversion channel are expected to be low magnitude, medium-term duration effects, occurring at the local scale. The effects would be reversible when the diversion channel is decommissioned at closure.

Changes to water quality during operations and post-closure are expected to be low magnitude, long duration effects, occurring on the regional scale for fish and other aquatic life VCs. Changes are considered reversible, as the concentrations of water quality parameters are expected to return to near baseline conditions, such that any effects on fish or aquatic life other than fish would not be measurable.

The effects to habitat (including riparian habitat) related to pumping water from Lac du Sauvage to back-flood the Jay Pit and diked area are expected to be low in magnitude, short-term (i.e., less than four years), and regional in geographic extent. The effects would be reversible upon the cessation of back-flooding activities.

The duration for a complete recovery of populations following dike breaching and reconnection will depend, in part, on the strength of density-dependent compensatory effects, demographic resilience, post-closure environmental conditions and life histories (e.g., Rose et al. 2001). For the assessment, it was conservatively assumed that effects from density-dependent processes would be minimal at post-closure, such that the recovery potential of resident populations may be underestimated (Rose et al. 2001; Vincenzi et al. 2012). The general trajectory of recovery for species will be quicker the more resilient the population (Section 9.4.2.1.3). For example, populations with individuals that mature the fastest and have the shortest lifespan will have shorter recovery times (e.g., Arctic Grayling versus Lake Trout and Lake Whitefish). Fish VCs with high reproductive potential may also recover quickly assuming there are optimal environmental conditions for recruitment during post-closure.

The incremental and cumulative changes from the Project and previous and existing developments are expected to have no significant adverse effect on ongoing fisheries productivity. There is a low degree of uncertainty associated with this prediction. Confidence in the prediction is based on the consistent low effect sizes (i.e., magnitudes of change) that were determined from the incremental and cumulative changes from the Project and other developments for habitat quantity and habitat quality. However, there is moderate uncertainty for the duration of effects, and the variability inherent in making long-term predictions in ecological systems. Some uncertainty may also underlie the classification of magnitude for individual pathways. For example, there is some uncertainty of the behavioral response of Arctic Grayling to the diversion channel during operations, and there is some uncertainty in habitat functions of features of the Jay Pit or remnants of the dike at post-closure. However, the classification of magnitude may remain the same or be no higher than moderate for the related pathways even if the diversion channel failed to provide fish passage, and if fish completely avoided the Jay Pit or dike.

The cumulative direct loss of lake habitat for the Application Case (there are no reasonably foreseeable developments for the assessment of fish and other aquatic life) is expected to be less than 1% for the ESA of Lac du Sauvage and Lac de Gras. The effects of habitat loss on Arctic Grayling, Lake Trout and Lake Whitefish populations in Lac du Sauvage and Lac de Gras are expected to be low despite the conservative approach to the assessment. For example, the relationship between habitat quantity and productivity is assumed to be linear, but it is expected that the relationship is curvilinear starting with an upper plateau followed by a sharp decline in productivity beyond a certain threshold (DFO 2014; Section 9.4.2.1.3). The expected threshold of habitat loss where the upper plateau breaks may be in the range of 20 to 30% for fish VCs because abundant habitat remains for Arctic Grayling, Lake Trout, and Lake Whitefish in Lac du Sauvage and Lac de Gras.

Of the four depth categories (0 to 2 m, 2 to 6 m, 6 to 10 m, and greater than 10 m), the most affected depth category will be within the 2 to 6 m stratum (135.0 ha), representing a 1.1% incremental relative change in Lac du Sauvage and Lac de Gras combined (Table 9.4-2). The total cumulative change in habitat at 2 to 6 m depths is predicted to be 202.4 ha, or 1.7% of habitat with the application of the Project combined with effects from previous and existing developments in the ESA. This change represents effects to potentially productive foraging areas during the open water season for most fish species (e.g., within the extent of light penetration, and coarse and fines substrates present). The predicted change also has implications for the availability of preferred substrates for spawning during fall for Lake Trout and Lake Whitefish and the availability of under-ice cover during winter for all fish species. Thus, an offsetting plan will be developed during the permitting phase of the Project to undertake offsetting measures to counterbalance the unavoidable residual serious harm to fish from the Project, with the goal of maintaining or improving the productivity of the commercial, recreational, or Aboriginal fisheries.

The Base Case is characterized by an abundance of shoal habitats in the ESA. Up to 21 shoals were previously identified in Lac du Sauvage as potential habitat for spawning (Section 9.2.4; Annex XIV). Although one shoal will be located within the proposed diked area, the affected shoal is classified as an unsuitable shoal for spawning. Most spawning shoals are well over 1,500 m from the edge of the dike location. Furthermore, most of the high-quality shoal habitats in the ESA are located in Lac de Gras. Thus, the amount of change to spawning shoal habitat for the Application Case, including previous, current and proposed developments, is expected to result in no measurable effect to self-sustaining populations of Lake Trout, Lake Whitefish, and forage species.

The effect of fragmentation on loss of habitat for Arctic Grayling, Lake Trout, and Lake Whitefish populations in Lac du Sauvage and Lac de Gras is also expected to be low despite the conservative approach to the analyses that included overestimated footprint areas. Of the three species selected as VCs, effects are expected to be largest for Arctic Grayling, a fluvial specialist that requires flowing water to support key life history aspects of their life history (e.g., spawning and rearing). However, to mitigate for potential changes in habitat connectivity between Lac du Sauvage and upstream watercourses (e.g., upper reaches of Stream Ac35, B0 and B1), the Sub-Basin B Diversion Channel will be designed to facilitate fish passage to upstream locations. The design specifications for the channel to facilitate upstream fish passage for target species will be discussed with DFO during the detailed design phase of the Project.

Stream length to be diverted (i.e., lost) during operations is approximately 467 m. The total length of affected tributary stream habitat with the application of the Project is 877 m (if the calculation conservatively includes the entire length of Stream Ac4), representing a change of 7.6% for Lac du Sauvage tributaries and 1.6% for Lac du Sauvage and Lac de Gras tributaries combined. Although these changes may affect the population of Arctic Grayling (low magnitude), the population may be characterized by individuals with a range of adaptations that allow them to maintain positive fitness over the long term. The species may be resilient because it is often exposed to highly variable flow conditions, and thus, without adaptations (e.g., behavioural plasticity in response to a disturbance, good dispersal ability), resident populations would have been extirpated long ago.

Before the water is pumped from the diked area, up to 23,400 fish will be removed (fished-out). Because the area to be fished-out is small compared to the entire area of Lac du Sauvage (approximately 86 km^2) and Lac de Gras (approximately 570 km^2), this would have low effects on self-sustaining populations in the effects study area. Dominion Diamond will work with DFO and local Aboriginal communities on developing a fish-out plan so that no captured fish is inadvertently wasted. It is assumed that the direct removal of the fish from the diked area is proportional to the loss in fisheries productivity of Lac du Sauvage and Lac de Gras (DFO 2014a). However, the possibility exists that some fish could be moved to other regions outside the diked area of Lac du Sauvage (i.e., salvaged) during the removal of fish, which would reduce overall impacts to fisheries productivity in the ESA. Some mortality will occur regardless of the approach, and the recovery or reversibility of mortality effects on fish VCs from the fish-out will occur during operations and the speed of the recovery will depend on environmental conditions (e.g., effects from local weather).

The Project also considered a suite of environmental design features and mitigations that will reduce effects to fish and other aquatic life from changes to water quality. Adverse effects are unlikely to occur for Arctic Grayling, Lake Trout, and Lake Whitefish health. However, the effect of increased nutrient concentrations from minewater discharge to Lac du Sauvage during operations is expected to result in a general increase in productivity at lower trophic levels in the main basin of Lac du Sauvage and a similar, but less pronounced effect in the eastern part of Lac de Gras. Although large shifts in composition of plankton and benthic invertebrate communities are not expected, biomass of phytoplankton, zooplankton, and benthic invertebrates will likely increase during operations, as these communities take advantage of the increased nutrient supply. Due to the increased food base, there may also be some effects on the growth and production of fish. As such, operational discharge may change water quality in Lac du Sauvage and Lac de Gras, but effects to supporting ongoing fisheries will be very low in magnitude (possibly neutral) and reversible at closure.

Climate change can also influence fish and other aquatic life in Arctic ecosystems. Climate has the potential to affect populations of fish directly (e.g., drought events), and the distributions of individual components of ecosystems may shift in different ways under different climate scenarios, generating potentially new combinations of species communities (reviewed in Mawdsley et al. 2009). Temperature changes can also be key factors underlying changes in fish health (Carrie et al. 2010). However, the key point is that the magnitude, duration, and geographic extent of effects from the Project on the physical environment and demography of VC populations are very low when compared to effects associated with the temporal and spatial scales of climate change processes. The absolute magnitude of direct and indirect effects from the Project is also low and the long-term trajectory of ongoing fisheries productivity will not be significantly affected by the Project.

In conclusion, cumulative effects from development are predicted to not have a significant adverse impact on the ability of Arctic Grayling, Lake Trout, and Lake Whitefish populations to be self-sustaining and ecologically effective, where self-sustaining and ecologically effective populations of fish VCs are the foundation for ongoing fisheries productivity. Cumulative effects from development on aquatic life other than fish are also predicted to not have a significant adverse impact on the ongoing support of fisheries productivity.

Table 9.6-2 Summary of Residual Impact Classification of Primary Pathways and Predicted Significance of Cumulative Effects on Fish and Other Aquatic Life Valued Components

Pathway	Magnitude	Geographic Extent	Duration	Frequency	Reversibility	Likelihood	Significance for Assessment Endpoint[a]
The construction of the horseshoe dike and Jay Pit within Lac du Sauvage will result in the direct loss or alteration of habitat, affecting fish and other aquatic life within Lac du Sauvage and Lac de Gras	Low	Local	Permanent	Continuous	Irreversible	Likely	*Not Significant*
The dewatering of the diked area will result in the direct loss or alteration of habitat in Lac du Sauvage, affecting fish and other aquatic life within Lac du Sauvage and Lac de Gras	Low	Regional	Long-Term	Continuous	Reversible	Likely	
Dewatering Lac du Sauvage within the diked area will require removal of fish from the area	Low	Regional	Medium-Term	Infrequent	Reversible	Highly Likely	
The construction of the horseshoe dike and diversion channel may alter access to tributary stream habitats to Lac du Sauvage, resulting in habitat loss for Arctic Grayling, Lake Trout, and Lake Whitefish	Low	Local	Medium-Term	Continuous	Reversible	Likely	
Operational activities and discharge (e.g., discharge of treated domestic wastewater, altered drainage, runoff from facilities, including waste rock storage areas, pit inflows, dike seepage, release of nitrogen compounds from blasting residues, fine processed kimberlite management) may change surface water quality and affect fish and other aquatic life in Lac du Sauvage and Lac de Gras	Low	Regional	Long-Term	Frequent	Reversible	Likely	
Pumping water to back-flood the Jay Pit and diked area of Lac du Sauvage may affect water levels and riparian habitat in Lac du Sauvage and Lac de Gras, and water levels, flows, and riparian habitat in the Lac du Sauvage-Lac de Gras Narrows, affecting fish and other aquatic life	Low	Regional	Short-Term	Continuous	Reversible	Likely	
Reconnection of the back-flooded area of Lac du Sauvage to the remaining watershed and post-closure releases of water (e.g., Misery Pit overflow and seepage, waste rock storage area runoff, Long Lake Containment Facility discharge) may change long-term water quality in Lac du Sauvage and Lac de Gras and affect fish and other aquatic life	Low	Regional	Long-Term	Continuous	Reversible	Likely	

a) Self-sustaining and ecologically effective fish populations (ongoing fishery productivity).

9.7 Follow-up and Monitoring

9.7.1 General Overview

Monitoring programs are proposed to address the uncertainties associated with the effect predictions and the performance of environmental design features and mitigation related to the Project. In general, monitoring is used to verify the effects predictions. Monitoring is used to identify any unanticipated effects and provide for the implementation of adaptive management to limit these effects. Monitoring programs can be divided into two categories, which may be applicable during the development of the Project:

Compliance monitoring – monitoring activities, procedures, and programs undertaken to confirm the implementation of approved design standards, mitigation, and conditions of approval and company commitments. Examples of compliance monitoring include inspection of silt fences and other mitigation during construction and the Surveillance Network Program (SNP).

Follow-up monitoring – monitoring programs designed to assess the accuracy of the predictions in the DAR and the effectiveness of mitigation measures, evaluating the short-term and long-term effects on the physical, chemical, and biological components of the aquatic ecosystems affected by the Project, estimating the spatial extent of effects, and providing the necessary input for implementation of adaptive management throughout the developmental lifespan of the Project. Examples of follow up monitoring include aquatic effects monitoring program (AEMP), wildlife effects monitoring program (WEMP), and fisheries offsetting monitoring. Results from these programs can be used to increase the certainty of effect predictions in future environmental assessments.

These monitoring programs form part of the environmental management system for the Project. If monitoring results indicate effects that are different from predicted effects, or the need for improved or modified design features and mitigation, then adaptive management will be implemented. Adaptive management may include increased monitoring, changes in monitoring plans, or additional mitigation. In addition, special studies, which are studies proposed with the intent to supplement the primary monitoring programs, address potential data gaps, and support future monitoring, may be considered.

9.7.2 Monitoring for Fish and Aquatic Life other than Fish

Substantial monitoring of the Project site and receiving environment is anticipated; the existing Ekati Mine monitoring programs and management plans are outlined in Section 1.2.3.2. Monitoring related to fish and other aquatic life includes an AEMP, an evaluation of offsetting measures developed for the Project, and construction monitoring as appropriate. Monitoring program design will incorporate traditional knowledge gathered through engagement with communities, where appropriate. The program design will also consider previously collected data.

Plankton, benthic invertebrate, and fish and fish habitat data have been collected from Lac du Sauvage, and Lac de Gras, as well as other lakes and connecting streams in the watershed, as described in the Plankton Baseline Report (Annex XII), Benthic Invertebrate Baseline Report (Annex XIII), and Fish and Fish Habitat Baseline Report (Annex XIV). In additional to the historical data, additional data were collected in 2013 and 2014 in the Lac du Sauvage watershed.

An AEMP will be required of the Project through the Project's Water Licence and will involve aquatic components focused on the receiving environment. Given the Project is an extension of the existing Ekati Mine, it is anticipated that the AEMP for the Project will be an expansion of the existing AEMP under the current Water Licence #W2012L2-0001 (WLWB 2014). A conceptual overview of the scope of the expanded AEMP is outlined in Appendix 9C (Conceptual AEMP); however, the detailed AEMP design will be developed during the permitting phase of the Project. The AEMP for the Project will build upon the existing AEMP for the Ekati Mine (e.g., ERM Rescan 2014).

Monitoring for fish and lower trophic levels, both at the Project site and in the receiving environment, will be implemented. The AEMP will be the basis of environmental effects monitoring and will be implemented during all Project phases, including post-closure. Monitoring will include data collection at locations within the Project footprint, and at locations within the Lac du Sauvage and Lac de Gras watersheds.

The AEMP is intended to track any effects in the aquatic environment during the phases of the Project, and to support verifying the effects predictions in the DAR for fish and aquatic life other than fish, as well as identify additional unanticipated effects and provide information for the implementation of adaptive management plans.

It is anticipated that components of the AEMP specific to this KLOI will include: plankton, benthic invertebrates, and fish (i.e., sampling for fish tissue and fish health); and various biological monitoring in reference lakes. Monitoring will be multi-phased, occurring during construction, operations, closure, and post-closure and occur on a seasonal basis as appropriate for the component. Monitoring will be complex in terms of sampling locations and sampling frequencies, with efficient alignment between programs (including hydrology and water quality), such that linkages can be made between activities at the mine and changes or responses in the aquatic environment.

It is expected that monitoring of the Sub-Basin B Diversion Channel will also be conducted during operations to confirm design specifications are met for flows and fish passage, and similarly that the reconnected channel in post-closure is functioning as anticipated.

Monitoring details for sampling locations, sampling frequency, and the list of measurement indicators for the plankton, benthic invertebrate, and fish components for the AEMP will be developed through careful consideration and reference to guidance documentation that may include AEMP designs from other northern mines (i.e., Ekati and Diavik mines) and resources such as *Guidelines for Designing and Implementing Aquatic Effects Monitoring Programs for Development Projects in the NWT* (Government of Canada 2009). The final design plan for the Project AEMP will be determined through the permitting process and detailed planning, which will include consultation and engagement with regulatory agencies and Aboriginal parties.

Specific objectives of the AEMP include:

- providing information to validate impact predictions from the DAR, and reduce uncertainty in predictions;
- incorporating local traditional and ecological knowledge, where applicable and available;

- through the associated Aquatic Response Framework, proposing action levels or adaptive management triggers that can be used as early warning signs for reviewing and implementing mitigation practices and policies;
- designing and implementing special studies for Project-specific issues or requirements, and data collection protocols that are consistent with other programs in the region; and,
- considering existing regional and collaborative programs, if necessary.

It is anticipated that the objectives of the AEMP will also include links to management responses, as follows:

- evaluate the short-term and long-term predicted effects of the Project on the physical, chemical, and biological components of the aquatic ecosystem of Lac du Sauvage and Lac de Gras;
- estimate the spatial extent of predicted effects;
- compare monitoring results to effects predictions, and where applicable and necessary, update effects predictions;
- provide the necessary input for monitoring responses to potential unacceptable effects on the aquatic ecosystem; and,
- evaluate the effectiveness of monitoring responses.

Monitoring and sampling techniques and analysis procedures will be consistent with methods used during the baseline survey period to the maximum extent possible. The field and laboratory processes will include the implementation of quality assurance/quality control measures for data acquisition, water and biota sampling, and analysis and reporting.

Monitoring will also be conducted to evaluate the effectiveness of offsetting measures, and will include evaluation of both physical and biological characteristics, as appropriate. This monitoring will be critical to confirming that the objective of counterbalancing serious to harm fish has been achieved (DFO 2013a). Monitoring will be undertaken for a period of sufficient time to allow for the following (DFO 2013a):

- biological or physical changes to be reflected in the data collected;
- possible adjustments to the monitoring to better estimate changes in fishery productivity; and,
- restored habitat to reach full ecological functionality.

The Conceptual Offsetting Plan is included as Appendix 9A; the detailed monitoring plan will be included in the final offsetting plan which will be developed in discussion with DFO and with input from local Aboriginal communities during the permitting phase of the Project.

During some construction activities (e.g., dike construction in Lac du Sauvage), turbidity monitoring will be conducted to prevent adverse effects on fish and fish habitat from the entrainment and deposition of sediments.

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9.9 Glossary

Term	Definition
Alkalinity	A measurement (expressed in milligrams per litre of calcium carbonate) of the capacity of water to neutralize acids. The concentration is measured based on the presence of naturally available bicarbonate, carbonate, and hydroxide ions.
Aquatic Effects Monitoring Program	A monitoring program designed to determine the short- and long-term effects in the aquatic receiving environment resulting from the mine operations, to evaluate the accuracy of predictions, to evaluate the effectiveness of planned impact mitigation measures, and to identify additional mitigation measures to reduce or eliminate environmental effects.
Application Case	The Environmental Assessment case that includes the Project and existing and approved developments or activities.
Assessment endpoints	Qualitative expressions used to assess the significance of effects on the fish and aquatic life VCs, and represent the key properties of these VCs that should be protected for future human generations (i.e., incorporate sustainability). Key properties of the VCs, such as ongoing fisheries productivity and self-sustaining and ecologically effective populations, are assessment endpoints that should be protected for their use by future generations.
Babiche	A type of cord or lacing made from rawhide.
Base Case	The assessment case that includes existing environmental conditions as well as existing and approved projects or activities, before the construction of the Project in question, acts as reference against which data from construction and operational phases of development will be compared.
Baseline	Background or reference; conditions before Project development.
Baseline study area	The area where direct effects and small-scale indirect effects from the Project are expected to occur.
Basin	A geographic area in which all water running off the land drains into a single point at lower elevation, such as a river or lake.
Bathymetry	Measurement of water depths in a lake.
Bedrock substrate	Substrate defined by unbroken, solid rock.
Benthic invertebrates	Animals without backbones that live on river and lake bottoms. Benthic refers to the bottom.
Biomass	The weight of living matter in a given area or sample.
Body condition	A measurement of overall health of a fish by comparing its weight to the typical weight of another fish of the same length.
Boulder substrate	Substrates with a particle size greater than 256 mm in diameter.
Boulder garden	An area of a stream with exposed, large boulders providing instream cover, and potentially a barrier to upstream passage of fish at low flows.
Braided	Flowing in an interconnected network of channels that divide and reunite.
Canadian Water Quality Guidelines (CWQG)	Guidelines established by the Canadian Council of Ministers of the Environment and used to evaluate the potential effects of the concentration of different water quality parameters upon aquatic life (i.e., fish, aquatic plants [macrophytes], and benthic invertebrates).
Canadian Shield	Large area of exposed Precambrian igneous and high-grade metamorphic rocks (geological shield) that forms the ancient geological core of the North American continent (North American or Laurentia craton), covered by a thin layer of soil. It is an area mostly composed of igneous rock which relates to its long volcanic history. It has a deep, common, joined bedrock region in Eastern and central Canada and stretches north from the Great Lakes to the Arctic Ocean, covering over half of Canada.
Cascade habitat	A succession of steep, small falls where water falls over a vertical drop.
Catch-per-unit effort	The total catch divided by the total amount of effort used to capture the fish.
Catchment	An area of land where water from precipitation drains into a body of water.
Chlorophyll *a*	A photosynthetic pigment found in plants responsible for the conversion of inorganic carbon and water into organic carbon. The concentration of chlorophyll *a* is an indicator of algal concentration.

Term	Definition
Cobble substrate	Substrates with a particle size between 64 and 256 mm in diameter.
Composite sample	A sample taken by combining several fractions of water from different depths within the water column of a lake into a common vessel that is used to collect the water sample destined for the laboratory. A composite sample can also be obtained as a combination of samples taken from different parts of a waterbody laterally.
Conductivity	A measure of the resistance of a solution to electrical flow; an indirect measure of the salinity of the water.
Demersal	Fish or other aquatic organisms found or living near the lake bottom.
Dewatering	Removal of water from a natural waterbody by pumping or draining.
Discharge	The volumetric rate of flow of water in a watercourse at a specified point, expressed in units of cubic metres per second or equivalent.
Dissolved Oxygen	Oxygen dissolved within the water column.
Drainage basin	The area drained by a river or stream; see also watershed.
Drumlins	A long narrow hill, made up of till, which points in the direction of the glacier movement.
Ecosystem	An integrated and stable association of living and non-living resources functioning within a defined physical location. A community of organisms and its environment functioning as an ecological unit. For the purposes of evaluation, the ecosystem must be defined according to a particular unit and scale.
Echo Integration	The processing technique that determines the average squared echosounder output voltage for selected range intervals and average times. The integrator output is proportional to fish density or biomass.
Ephemeral	Lasting for a short time or part of a complete cycle. In reference to water, typically describes a stream that flows for only part of the open-water period.
Eskers	Linear structures of loose sand and gravel, formed by glacial rivers. They Eskers provide critical habitat for carnivores and ungulates in the Arctic.
Evenness	A measure of how evenly the total invertebrate abundance is distributed among the different types of organisms present at a site.
Fin ray	Splintlike supporting structures to the fin membranes, includes both soft-rays and spines.
Fine/organic substrate	Substrates with a particle size less than 2 mm in diameter.
Fish community	A group or assemblage of fish species inhabiting the same location at the same point in time.
Fork length	Fork length (FL) refers to the length of a fish measured from the tip of the snout to the end of the middle caudal fin rays and is used in fishes in which it is difficult to tell where the vertebral column ends.
Fish tracking	Raw acoustic tag echoes which have been selected and assigned a tag ID through an auto-tracking method. Also referred as auto-tracked.
Flat habitat	An area of stream where the water velocity is slow, channel depth is uniform and lacks direct riffle/run association.
Freshet	The period of increased stream flow in spring caused by the melting snow pack.
Geographic Information System	Computer system designed to capture, store, manipulate, analyze, manage, and present all types of geographical data.
Global Positioning System	A space-based satellite navigation system that provides location and time information in all weather conditions, anywhere on or near the Earth where there is an unobstructed line of sight to four or more GPS satellites.
Gradient	The slope of a stream channel or lake shoreline.
Gravel substrate	Substrates with a particle size between 2 and 4 mm in diameter.
Habitat	The physical space within which an organism lives, and the abiotic and biotic entities (e.g., resources) it uses and selects in that space.
Habitat fragmentation	A process by which habitats are increasingly subdivided into smaller units, resulting in their increased restriction as well as an overall loss of habitat area and biodiversity.

Term	Definition
Hardness	A characteristic of water caused by the presence of positively charged ions (cations) such as calcium, magnesium, iron, and manganese. This parameter is measured in mg/L of calcium carbonate.
Headwater	The source of water at the top of a watershed, typically a lake or marsh.
Hydroacoustics	The study or use of sound in water to remotely obtain information related to the physical characteristics of the waterbody, its bathymetry, or biotic populations.
Hydrology	The study of flowing water and effects of flowing water on the Earth's surface, in the soil and underlying rocks, and in the atmosphere.
Infrastructure	Basic facilities, such as transportation, communications, power supplies and buildings, which enable an organization, project or community to function.
Invertebrates	Animals without backbones.
Kettle lakes	A steep-sided bowl or basin-shaped hole or depression in glacial drift deposits, especially outwash or kame, and believed to have formed by the melting of a large, detached block of stagnant ice (left behind by a retreating glacier) that had been wholly or partly buried in the glacial drift. Kettles commonly lack surface drainage and some may contain a lake or swamp.
Key Line of Inquiry	Areas of the greatest concern that require the most attention during the environmental impact review and the most rigorous analysis and detail in the Developer's Assessment Report. Their purpose is to ensure a comprehensive analysis of the issues that resulted in significant public concern about the proposed development.
Kimberlite	Igneous rocks that originate deep in the Earth's mantle and intrude the Earth's crust. These rocks typically form narrow pipe-like deposits that sometimes contain diamonds.
Kimberlite pipe	Vertical structures on which kimberlites occur in the Earth's crust.
Length-Weight Equation	A regression model that describes patterns of growth and can be used to calculate relative weights.
Lichens	Any complex organism of the group Lichenes, composed of a fungus in symbiotic union with an alga and having a greenish, grey, yellow, brown, or blackish thallus that grows in leaflike, crustlike, or branching forms on rocks, trees and other surfaces.
Life history	The full range of changes, habits, and behaviors of an individual over the course of its life.
Littoral	The shallow, shoreline area of a lake.
Macrophyte	Aquatic plants that are large enough to be seen by the naked eye. May include submergent (grow underwater) or emergent (grow above the waterline) varieties.
Mean	Arithmetic average value in a distribution.
Median	A single statistical value used to characterize a series of data values. Half of the data values are larger than the median value, and half of the data values are less than the median value.
Meandering	Following a winding or intricate course.
Nutrients	Elements or chemicals essential to growth or repair of organic bodies, including carbon, oxygen, nitrogen, phosphorus, and silica.
Oligotrophic	Designation for peatlands that are poor to extremely poor in nutrients and with low biological activity.
Open-water period	Summer season when lakes, rivers and streams are free of ice (generally June or July to October).
Otolith	A calcium carbonate structure found in the chambers (sacculus, utriculus, and lagena) of the inner ear of fishes. Usually the one in the sacculus is the largest and it can often be used to tell the age or identity of the fish.
Outflow	Water flowing out of a lake.
Parameter	A particular physical, chemical, or biological property that is being measured in a groundwater system; whatever it is you measure in a groundwater system.
Pelagic	Relating to fish or other aquatic organisms that live offshore in the middle or lower part of the water column.

Term	Definition
pH	The negative log of the concentration of the hydronium ion. The pH is a measure of the acidity or alkalinity of all materials dissolved in water, expressed on a scale from 0 to 14, where 7 is neutral, values below 7 are acidic, and values over 7 are alkaline.
Phytoplankton	Small, usually microscopic, plants that live in the water column of lakes and make their food through primary production.
Plankton	Microscopic aquatic organisms (tiny plants [phytoplankton] and animals [zooplankton]) free-floating and suspended in the water column.
Population	A group of individuals of one species in one area; it often means the group of organisms that is convenient and practical to count. A population is also defined as individuals of a species that are close enough to each other for there to be at least occasional mating between them.
pH	A measure of the acidity or alkalinity of water.
Pool habitat	An area of stream where the water velocity is slow and stream depths are relatively deep.
Processed kimberlite	The residual material left behind when the processing of kimberlite has been completed to extract the diamonds.
Processing plant	A facility where the kimberlite is physically processed. The process involves size reduction (crushing); washing (also referred to as scrubbing); screening (filtering the material by size); and primary and secondary concentration (separating the material by density).
Riffle habitat	An area of stream where the water velocity is fast and stream depths are relatively shallow causing broken water.
Riparian	Relating to the banks or shoreline area of a stream or lake often referring to nearshore vegetation.
Run habitat	An area of stream where the water velocity is moderate, depths are greater than a riffle and most of the surface is not broken.
Sedges	A grass-like plant with a triangular stem often growing in wet areas. Sedge wetland habitats are typically wet sedge meadows and other sedge associations of non-tussock plant species. Sedge species such as *Carex aquatilis* and *C. bigelowii*, and cotton grass (*Eriophorum angustifolium*) are the dominant vegetation types. Plant species occupy wet, low lying sites where standing water is present throughout much of the growing season.
Sediment	Solid material that is transported by, suspended in, or deposited from water. It originates mostly from disintegrated rocks; it also includes chemical and biochemical precipitates and decomposed organic material, such as humus. The quantity, characteristics and cause of the occurrence of sediment in streams are influenced by environmental factors. Some major factors are degree of slope, length of slope soil characteristics, land usage and quantity and intensity of precipitation.
Secchi depth	A parameter used to inform the clarity of surface waters, typically in lake environments. The measurement is made with a "Secchi" disk, a black and white disk approximately 20 cm in diameter, which that is lowered into the water column. The Secchi depth is the depth at which the disk is no longer visible. A Secchi depth recording of 2 m indicates that the disk was last visible at 2 m below the surface. High Secchi depth readings indicate clearer water that allows sunlight to penetrate to greater depths. Low readings indicate turbid water, which can reduce the passage of sunlight through the water column. Limited light penetration can be a factor in diminished aquatic plant growth beneath the surface, thus reducing the biological re-aeration at lower depths.
Shoal	A shallow, offshore reef in a lake.
Silt	As a particle size term: a size fraction between 0.002 and 0.05 mm equivalent diameter, or some other limit (geology or engineering).
Simpson's diversity index	An index used to measure diversity, to quantify the biodiversity of a habitat. It takes into account the number of species present, as well as the relative abundance of each species. It represents the probability that two randomly selected individuals in the habitat will not belong to the same species.
Sonar	Commonly referred to as the transmission of sound waves and measuring the time it takes for their echo to return after reaching an object.

Term	Definition
Species	A group of organisms that actually or potentially interbreed and are reproductively isolated from all other such groups; a taxonomic grouping of genetically and morphologically similar individuals; the category below genus.
Specific conductivity	(See also Conductivity). A conductivity reading normalized to a temperature of 25ºC.
Sub-basin	A smaller scale basin within a larger basin. The sub-basin contributes runoff to the drainage system of the larger basin.
Substrate	The bottom of a waterbody, usually consisting of sediments of various particle sizes (e.g., sand, silt, clay, gravel, cobble, boulder) and organic material (e.g., living or dead plant material).
Surface area	The area of the lake water surface, excluding islands.
Taxon	A group of organisms at the same level of the standard biological classification system; the plural of taxon is taxa.
Terms of Reference (TOR)	The Terms of Reference identify the information required by government agencies for an Environmental Assessment.
Thermal stratification	Horizontal layers of differing densities produced in a lake by temperature changes at different depths.
Thermocline	The depth in a lake where temperatures most sharply decline causing a separation of higher density water below the thermocline (hypolimnion) and lower density water above the thermocline (epilimnion).
Total alkalinity	A measure of the ability of water to resist changes in pH caused by the addition of acids or bases and therefore, the main indicator of susceptibility to acid rain; in natural waters it is due primarily to the presence of bicarbonates, carbonates and to a much lesser extent occasionally borates, silicates and phosphates; it is expressed in units of milligrams per litre (mg/L) of $CaCO_3$ (calcium carbonate). Alkalinity is determined from a discernable inflection point in the measured titration curve.
Total dissolved solids	The dissolved matter found in water comprised of mineral salts and small amounts of other inorganic and organic substances.
Total Kjeldahl nitrogen	The sum of organic nitrogen and ammonia concentrations measured in a water sample.
Total length	Total length refers to the length of a fish measured from the tip of the snout to the tip of the longer lobe of the caudal fin, usually measured with the lobes compressed along the midline. It is a straight-line measure, not measured over the curve of the body.
Total organic carbon	A measure of the concentration of organic carbon in water, determined by the oxidation of the organic matter into carbon dioxide (CO_2). Also referred to as TOC.
Total richness	The total number of different taxa occupying a given area.
Total suspended solids	The amount of suspended substances in a water sample. Solids, found in wastewater or in a stream, which can be removed by filtration. The origin of suspended matter may be artificial or anthropogenic wastes or natural sources such as silt.
Traditional Knowledge	Knowledge systems embedded in the cultural traditions of regional, indigenous, or local communities. It includes types of knowledge a traditional technologies, the environment and ecology.
Tributary	A stream that flows into a larger stream or lake.
Trophic level	A functional classification of organisms in an ecosystem according to feeding relationships, from primary producers through herbivores (primary consumers) and carnivores (secondary and tertiary consumers).
Tundra	A vast, mostly flat, treeless Arctic region of Europe, Asia, and North America in which the subsoil is permanently frozen. The dominant vegetation is low-growing stunted shrubs, mosses, lichens.
Turbidity	A measure of light penetration dependent on the concentration of suspended solids.

Term	Definition
Upland	Forested or non-forested areas of the landscape with non-saturated and non-peat-forming soils. Excludes bogs, fens, swamps and marshes. See terrestrial vegetation. Areas where the soil is not saturated for extended periods as indicated by vegetation and soils.
Valued component (VC)	Valued components represent biophysical, economic, social, heritage and health properties of the environment that are considered to be important by society.
von Bertalanffy growth	A widely used growth curve used in fisheries studies to predict and calculate length-at-age.
Waterbody	An area of water such as a river, stream, lake or sea.
Watercourse	A flowing body of water, such as a stream or river.
Watershed	The upstream land area drained by a river network.
Wetland	Land having the water table at, near, or above the land surface or which is saturated for a long enough period to promote wetlands or aquatic processes as indicated by hydric soils, hydrophytic vegetation and various kinds of biological activity which are adapted to the wet environment.
Wetted width	The width of the water surface measured at right angles to the direction of flow. Multiple channel widths are summed to obtain total wetted width.
Yearling	An animal in its second year.
Young-of-the-year	Fish at age 0, within the first year after hatching.
Zooplankton	Small (often microscopic) aquatic animals suspended or weakly swimming in water.