## Supplemental Information Request 5

*Impacts of PSMF Discharge to Hare Lake*

**Original IRs:**

IR 12.1.1 Baseline Conditions in Hare Lake

IR 12.1.2 Effluent Discharge Location in Hare Lake

IR 12.11 Conclusions on Effects to Surface Water Quality

IR 12.2.2 Baseline Hydrology of Hare Creek

IR 12.6.1 Surface Water Temperature

**References:**

SID #1 Aquatic Resources Baseline Report

SID #3 Baseline Water Quality

SID #6 Water Quality and COPC Fate Modelling

SID #20 Baseline Hydrologic Conditions

**Related Comments:**

CEAR #544 (Ontario Ministry of Natural Resources)

CEAR #547 (Environment Canada)

CEAR #557 (Ontario Ministry of the Environment)

**Rationale:**

Hare Lake is currently a productive biological aquatic ecosystem. It will be receiving discharge from the PSMF and has the potential to be negatively impacted by the project. It is important that the baseline conditions and function of Hare Lake are adequately understood and described, and the potential impacts of effluent discharge to Hare Lake are fully assessed and presented. It is also important to understand any long term impacts which may occur over the length of the project, particularly with respect to variation in primary productivity and the consequences to the overall biological integrity of Hare Lake.

The response to original IR's 12.1.1 and 12.1.2 stated that work needed to complete the final modelling of effluent discharge to Hare Lake is ongoing. SCI stated its intention to complete the modelling exercise prior to provincial permitting. However, this information is needed during the EA process in order to gain a better understanding of the potential impacts of PSMF discharge to Hare Lake.

In addition, Environment Canada recommended that information be provided to support the conclusion that the revised water balance approach presented in response to IR 12.2.2 and applied to the Hare Creek watershed will not change the water quality predictions for Hare Lake and Hare Creek.

Ministry of Natural Resources questioned the validity of SCIs suggestion in the response to IR 12.6.1 that the discharge from the PSMF will not be "warm". Ministry of Natural Resources contends that the PSMF will be warmed by solar radiation and this should be taken into consideration when modelling effects of PSMF discharge on lake biota that are dependent upon a stratified environment. .Ministry of Natural Resources also recommended that SCI assess potential effects of the mitigation proposed in the response to IR 12.11 for a possible meromictic condition in Hare Lake, i.e. to proactively mix the lake.

Ministry of Natural Resources was concerned that this would ultimately remove the stratified condition of the lake.

**Information Request:**

1. Provide a comprehensive summary of baseline conditions and function for Hare Lake pulling together data and information collected as part of the EIS and additional data and information collected in 2013 as described in the response to IR 12.1.1. This should include the following information:

   a. hydrologic regime, quantity and quality of water to the lake including seasonal variation;

   b. chemical and nutrient influx to the lake;

   c. seasonal temperature profile of the lake and delineation of the lake thermal profile;

   d. primary productivity, including phytoplankton and zooplankton population diversity and structure;

   e. diversity and density of benthic invertebrate populations;

   f. identification of key indicator species;

   g. identification of fish species and their population dynamics (e.g. age structure);

   h. metal levels in fish tissue; and

   i. structure of the food chain, i.e. the energy pyramid

If information is not currently available, provide a study plan and timelines to obtain the information.

2. Provide a report that predicts and describes the impacts of the effluent from the PSMF on the aquatic ecosystem of Hare Lake and Hare Creek. This should include new modelling that incorporates the latest data collected and also a consideration/ rationalization of:

- any new estimates of COPC from the PSMF – see SIR 4;
- modelled temperature of discharge from PSMF addressing Ministry of Natural Resources concerns related to IR response 12.6.1;
- the proposed location of the diffuser; and
- updated hydrologic data for the Hare Creek watershed mentioned in the response to IR12.2.2.

The report is to include modelling results to predict:

- the boundaries of a mixing zone;
- predicted concentrations of contaminants in the mixing zone;
- the effects of lake stratification and hydrology on plume dispersion;
- the effects of a non-buoyant plume and final effluent mixing within the lake; and
- lake retention time and its influence on contaminant retention/release downstream.

3. Using the results of the modelling exercise the report should present an evaluation of the potential impacts to the following:

- primary productivity and effects on food chain;
- phytoplankton and zooplankton species diversity and abundance;
- fish communities in Hare Lake and Hare Creek, such as lake trout hypolimnetic habitat and salmonid habitat downstream of the outflow of Hare Lake;
- bioaccumulation of metals or other contaminants;
- changes to hydrologic regime (increase or reduction of flow annual variations);
- variation to the thermal regime of the lake;
- chemical and physical composition of effluent discharge to the Lake (quantity over length of project);
- overview of deposition on the sediment for the duration of the project;

- impacts on the sediment from effluent deposition. Information should be provided on the potential impacts on the annual nutrient transfer to the lake during the spring and fall turnover; and

- assess possible impacts on benthic species and provide an overview of the impacts on the existing food chain.

If impacts are identified, the analysis report should also identify mitigation measures that would be undertaken to minimize impacts on the biological functions of Hare Lake and Hare Creek. Identify the criteria that are used to make this judgement, and contingency measures that could be undertaken if such mitigation is not effective.

For the mitigation proposed in the event of a meromictic condition in Hare Lake, i.e. artificial mixing of the lake, provide a description of the effects of the mitigation, including any changes to Hare Creek.

**SCI Response:**

The response to this supplemental information request has been provided as a stand-alone report and is attached.

# Supplemental Information Request for the Marathon PGM-Cu Project Environmental Assessment – Impacts of PSMF Discharge to Hare Lake

Report prepared for:

Stillwater Canada Inc.
1127 Barton Street
Thunder Bay, Ontario
P7B 5N3

Report prepared by:

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Ref. 13-2029
November 2013

**Supplemental Information Request for the Marathon PGM-Cu Project Environmental Assessment – Impacts of PSMF Discharge to Hare Lake**

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# EXECUTIVE SUMMARY

Stillwater Canada Inc. (SCI) submitted the Main Environmental Impact Statement (EIS) and a number of Supporting Information Documents in June 2012. The Joint Review Panel (JRP) responded to this submission with a series of Information Requests (IRs) on 26 November 2012, which SCI responded to over the period March to July 2013. The JRP issued a series of Supplemental Information Requests (SIRs) on 30 August 2013. This report has been prepared in response to SIR No. 5 – *Impacts of PSMF[1] Discharge to Hare Lake* – and contains: a comprehensive summary of baseline conditions in Hare Lake; a description of the conditions under which excess water from the PSMF will be released to Hare Lake; an analysis of the dispersion of PSMF discharge in Hare Lake; and, an analysis of the potential effects on the abiotic and biotic conditions in Hare Lake and Hare Creek and their significance in consideration of contemplated mitigation measures.

## Existing Conditions in Hare Lake

Hare Lake is situated in the Stream 5 subwatershed to the northwest of the main part of the proposed mine site. Hare Lake receives inflows from Bamoos Creek, as well as a couple of other small tributaries and discharges to Hare Creek at the western end, which outlets to Lake Superior approximately 3 km downstream at Port Munroe.

The surface area of the lake is about 57 ha and the total lake volume is approximately 8.5 M $m^3$. The maximum depth of Hare Lake is approximately 30 m. Mean lake depth is approximately 15 m. Lake retention time, based on annual average flows, is in the order of 6 to 7 months. Relatively long stretches of both the north and south sides of the lake shelve steeply and afford little in the way of littoral habitat. The majority of littoral zone habitat is isolated to the main inlet and outlet areas of the lake, as well as a couple of small embayments on both the north and south sides of the lake. Hare Lake supports a resident coolwater fish community, composed primarily of Spottail Shiner, a forage fish, and the large-bodied fish species Yellow Perch and Northern Pike.

The baseline environment program at Hare Lake included the assessment of water quality (inter- and intra-annual); sediment quality; benthic invertebrates; plankton communities and primary productivity; fish; and, fish usability.

## Hare Lake PSMF Discharge Modelling and Predictions

Projected monthly rates of excess water release from the PSMF to Hare Lake have been determined based on the most current mine plan. The following points are noted in this regard:

[1] Process Solids Management Facility

- discharge is not planned to begin until Year 5 of the project;
- excess water discharged from the PSMF will be derived from Cell 1 of the PSMF;
- in years when excess water is discharged, the discharge would occur during the ice free period, typically between April through November;
- discharge volumes would vary monthly with more discharge during the spring and fall periods to mimic the natural hydrograph of the Stream 5 subwatershed;
- the total discharge in Year 5 is estimated to be 428,000 cubic meters under normal meteorological conditions;
- the total discharge is expected to be similar for years 6 through 10 and is estimated to be 778,000 cubic meters under normal meteorological conditions;
- discharge is expected to decrease after Year 10, with re-location of the operating reclaim pond to the pit(s) and will cease upon conclusion of mining activities; and,
- a minimum ratio of Hare Lake outflow to PSMF discharge of 20:1 will be maintained during periods of discharge – that is the Hare Lake outflow (and subsequently flow in Hare Creek) will not increase incrementally by more than 5% under normal operating conditions.

Excess water from the PSMF will be pumped from the PSMF in a pipe to Hare Lake at ground level. The discharge structure in Hare Lake will be located along the south side of the lake in 3 to 5 m of water depth. The conceptual minimum design provides for a 30:1 mixing (ratio of lake water to PSMF water) within 50 m of the discharge – the so-called mixing zone. Based on achieving this ratio, the conceptual design of the discharge structure includes provision for an offshore, multiport diffuser aligned parallel to shore with ports oriented horizontally, perpendicular to shore. In this conceptual configuration the diffuser has ten, two inch (0.0051 m) diameter ports spaced at one meter intervals.

The discharge scenario and conditions described above were used to predict potential changes to the hydrology of the Stream 5 subwatershed, water quality in Hare Lake in terms of constituents of potential concern (COPCs), water temperature and PSMF discharge buoyancy, sediment quality in Hare Lake and the potential effects of COPCs bioaccumulation.

### Effects of the PSMF Discharge on Hare Lake and Hare Creek

The analysis of potential effects associated with the PSMF discharge on Hare Lake considered the following:

- the hydrology of the Stream 5 subwatershed;

- the thermal regime of Hare Lake and Hare Creek
- water chemistry in Hare Lake and Hare Creek;
- sediment quality in Hare Lake;
- nutrient cycling between Hare Lake Sediments and the overlying water column;
- primary productivity in Hare Lake and Hare Creek;
- phytoplankton and zooplankton density and diversity in Hare Lake and Hare Creek;
- benthic invertebrates in Hare Lake;
- benthic invertebrates in Hare Creek;
- fish in Hare Lake;
- fish in Hare Creek; and,
- potential bioaccumulation of COCPs in biota in Hare Lake and Hare Creek.

No effects on the hydrology of Hare Lake and Hare Creek as the result of the small incremental increase in flow as the result of the PSMF discharge are predicted. The release of excess water from the PSMF will not affect water levels in Hare Lake, nor will it cause shoreline erosion. No changes in stream flow regime will occur as the release of water from the PSMF will mimic the natural hydrograph of the subwatershed. No erosion or stream morphology effects are predicted for Hare Creek, which has low to moderate susceptibility. No issues with water conveyance at the Hwy 17 and CP rail line crossings are predicted as in both cases crossing capacity exceeds the predicted peak flows for the 100-year return period during mine operations.

Minor potential differences in temperature and/or density of the PSMF discharge water as compared to Hare Lake water will be rapidly dissipated in the mixing zone to the point of being practically indistinguishable from ambient water. No effects on surface water temperatures and the dimictic temperature regime of the lake are predicted. Under these conditions (i.e., rapid mixing via the diffuser in the mixing zone), and given the predicted total dissolved solids levels in the discharge, it is physically impossible for the lake to become meromictic as the result of the discharge of excess water from the PSMF to Hare Lake.

COPC levels in Hare Lake associated with the release of excess water from the PSMF to Hare Lake are predicted to be below surface water quality benchmarks. The benchmarks used in the assessment are the lower of the OMOE Provincial Water Quality Objectives (PWQOs) and the Canadian Council of Ministers of the Environment (CCME) surface water quality objectives, or background water quality in Hare Lake where a particular COPC is greater than the lower of the PWQO or CCME objectives. These benchmarks are protective of the existing biological/aquatic communities in Hark Lake and Hare Creek.

On average sediment quality is predicted to remain within existing natural variability and therefore will not be adversely affected by the release of excess water from the PSMF.

Nutrient cycling between the lake sediments and the water column during spring and fall turnover will be unaffected by the release of excess water from the PSMF. As indicated above, any differences in temperature and/or density of the PSMF water relative to the ambient conditions in Hare Lake will be rapidly dissipated and therefore the discharge will not affect the dimictic nature of the lake.

No effects on primary productivity and phytoplankton or zooplankton density are predicted. The release of excess water from the PSMF is not predicted to affect the thermal regime of the lake, nor nutrient cycling, and phosphorus levels and COPC levels will in the lake are predicted to remain below surface water quality benchmarks.

Benthic invertebrates in Hare Lake and Hare Creek will not be adversely affected by the PSMF discharge. As indicated above, water quality will be protected in Hare Lake and Hare Creek and on average sediment quality in Hare Lake are expected to remain within the range of existing background levels.

No effects on fish in Hare Lake or Hare Creek as the result of the release of excess water from the PSMF are predicted. A small amount of disruption of fish habitat (25 to 30 $m^2$) will however likely be associated with the commissioning and decommissioning of the PSMF discharge structure at Hare Lake. This effect will be mitigated by implementing best management practices and following and conforming to appropriate Department of Fisheries and Oceans and Ministry of Natural Resources operational statements, guidance and protocols for working around water, including but not limited to: scheduling the construction and decommissioning work to coincide with times of the year that minimize risk to resident fish species as necessary; avoiding where possible or maintaining setbacks from sensitive features where necessary; isolating access and work and access areas with temporary sediment control features such as berms and providing for the collection of drainage from disturbed areas; and, the restoration of disturbed areas as soon as is practical following disturbance.

The potential effects of bioaccumulation of COPCs on biota considered representative valued ecosystem components (VECs), including northern pike, mallard duck, mink and moose, which reside within Hare Lake and/or its watershed including Hare Creek. Hazard quotients were less than 1.0 for all COPCs and all animals included in the assessment, indicating no risk to the VECs as the result of COPC exposure.

In conclusion, based on the analysis provided herein no residual adverse effects on the biological functions of Hare Lake or Hare Creek are therefore are predicted.

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# 1.0 INTRODUCTION

## 1.1 Environmental Assessment Framework

Stillwater Canada Inc. (SCI) proposes to develop a platinum group metals (PGMs) and copper (Cu) open-pit mine and milling operation near Marathon, Ontario (Figure 1.1-1). A Notice of Commencement (NoC) of an environmental assessment (EA) in relation to the proposed Marathon PGM-Cu Project (the “Project”) was filed by the Canadian Environmental Assessment Agency (CEA Agency) under Section 5 of the Canadian Environmental Assessment Act on April 29, 2010 (updated July 19, 2010).

The EA was referred to an independent Review Panel by the Federal Minister of the Environment on October 7, 2010. On March 23, 2011 SCI entered into a Voluntary Agreement (VA) with the Province of Ontario to have the Project subject to the Ontario Environmental Assessment Act (OEA Act). This agreement was the instrument that permitted the provincial government to issue a Harmonization Order (HO) under Section 18(2) of the Canada-Ontario Agreement on Environmental Assessment Cooperation to establish a Joint Review Panel for the Project between the Minister of the Environment, Canada and the Minister of the Environment, Ontario.

The HO was issued on March 25, 2011. The Terms of Reference (ToR) for the Project Environmental Impact Statement (EIS) and the agreement establishing the Joint Review Panel (JRP) were issued on August 8, 2011.


**Figure 1.1-1: Location of the proposed Marathon PGM-Cu Project near Marathon, Ontario**

## 1.2 Marathon PGM-Cu Project

The Project is based on the development of an open pit mining and milling operation. Existing conditions on and around the site and the conceptual general layout of the components of the mine site, the transmission line corridor and access road are provided in Figures 1.2-1 and 1.2-2, respectively.

One primary pit and satellite pits to the south are proposed to be mined. Ore will be processed (crushed, ground, concentrated) at an on-site processing facility. Final concentrates containing copper and platinum group metals will be transported off-site via road and/or rail directly or via ship to a smelter and refinery for subsequent metal extraction and separation. The total mineral reserve (proven and probable) is estimated to be approximately 120 million tonnes.

During the operations phase of the Project, ore will be fed to the mill at an average rate of approximately 25,000 to 28,000 tonnes per day. The operating life of the mine is estimated to be approximately 10 to 12 years.

Approximately 192 to 288 million tonnes of mine rock[2] will be excavated. Non-potentially acid generating (non-PAG) mine rock will be permanently stored in a purposefully built Mine Rock Storage Area (MRSA) located east of the primary pit. The non-PAG or so-called Type 1 mine rock will also be used in the construction of access roads, dams and other site infrastructure as needed. Drainage from the MRSA will be collected, stored, treated (as necessary) and discharged to the Pic River. As part of the strategy to manage potentially acid generating (PAG) mine rock, or Type 2 Mine Rock, that may be excavated from the pits, contingency for the management of approximately 20 million tonnes of mine rock has been accounted for in the mine design. The Type 2 mine rock will be managed on surface during mine operations in temporary stock piles with drainage directed into the open pits. This material will be relocated to the bottom of the primary and satellite pits and covered with water to prevent potential acid generation and covered with Type 1 materials.

Process solids[3] will be managed in the Process Solids Management Facility (PSMF), as well as in the open pit(s). The PSMF will be designed to hold approximately 108 million tonnes of material, and its creation will require the construction of dams. Two streams of process solids will be generated. An estimated 85 to 90% of the total amount of process solids produced will be non-acid generating, or so-called Type 1 process solids. The remaining ten to fifteen percent of the process solids could be potentially acid generating and referred to as Type 2 process solids. The Type 2 process solids will be stored below the water table in the PSMF or below water in the pits to mitigate potential acid generation and covered with Type 1 materials. Water collected within the PSMF, as well as water collected around the mine will be managed in the PSMF for eventual reclamation in the milling process. Excess water not needed in the mill will be discharged, following treatment as is necessary, to Hare Lake.

Access to the Project site is currently provided by the Camp 19 Road, opposite Peninsula Road at Hwy 17. The existing road runs east towards the Pic River before turning north along the river to the Project site (approximately 8 km). The existing road will be upgraded and utilized from its junction with Hwy 17 for approximately 2.0 km. At this point a new road running north will be constructed to the future plant site. The primary rationale for

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[2] Mine rock is rock that has been excavated from active mining areas but does not have sufficient ore grades to process for mineral extraction.
[3] Process solids are solids generated during the ore milling process following extraction of the ore (minerals) from the host material.

developing the new road is to move traffic away from the Pic River. The new section of road will link two sections of forest access roads located on the site.

Power to the Project site will be provided via a new 115 kV transmission line that will be constructed from a junction point on the Terrace Bay-Manitouwadge transmission line (M2W Line) located to the northwest of the primary pit. The new transmission line will run approximately 4.1 km to a substation at the mill site. The width of the transmission corridor will be approximately 30 m. A pole line will follow the main Camp #19 access corridor to provide supplemental power, or approximately 25kV, at start up and for communications to site.

Reasonable steps will be taken to reclaim some disturbed areas of the Project footprint in a progressive manner. Natural drainage patterns will be restored as much as possible. The ultimate goal of mine decommissioning will be to reclaim land within the Project footprint to permit future use by resident biota, as determined through consultation with the public, Aboriginal peoples and government. A certified Closure Plan for the Project will be prepared as required by Ontario Regulation (O.Reg.) 240/00 as amended by O.Reg.194/06 “Mine Development and Closure under Part VII of the Mining Act” and “Mine Rehabilitation Code of Ontario”.

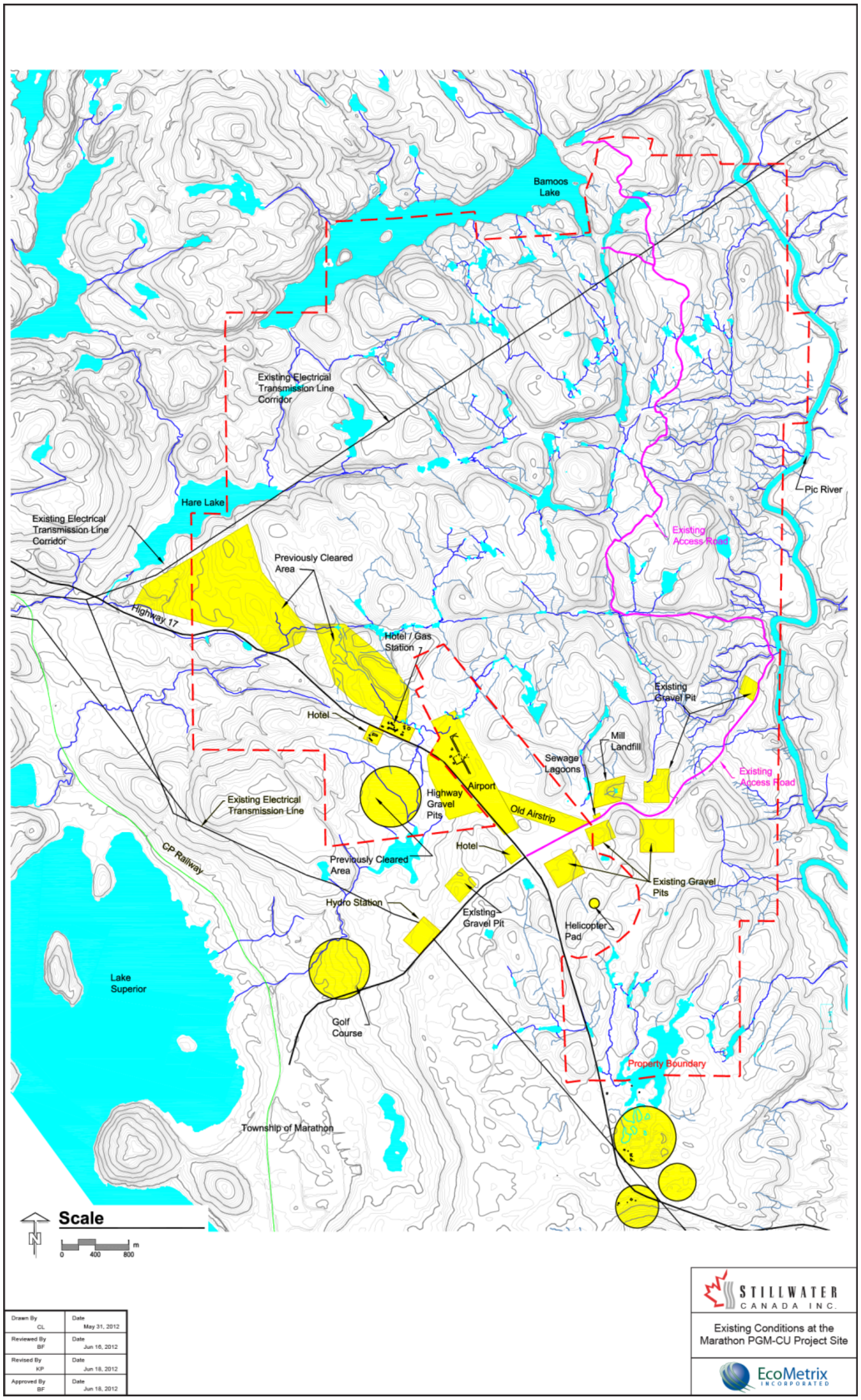


**Figure 1.2-1: Existing Conditions at the proposed Marathon PGM-Cu Project near Marathon, Ontario**

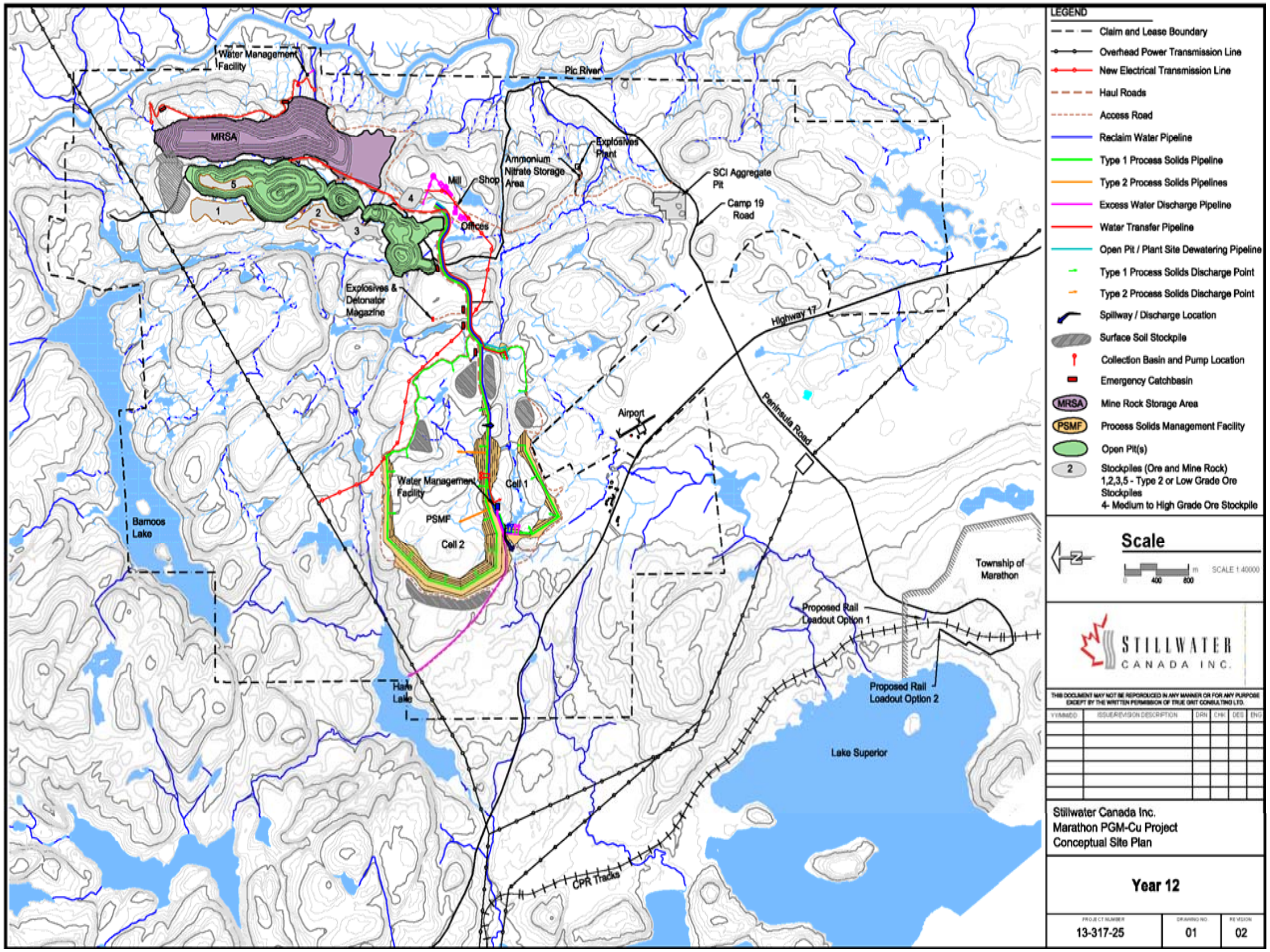


**Figure 1.2-2: Conceptual site layout of the proposed Marathon PGM-Cu Project near Marathon, Ontario**

## 1.3 Environmental Impact Statement Submission and Requests for Additional Information

SCI submitted the Main Environmental Impact Statement (EIS) and a number of Supporting Information Documents (SIDs) in June 2012. The Joint Review Panel (JRP) responded to this submission with a series of Information Requests (IRs) on 26 November 2012, which SCI responded to over the period March to June 2013. The JRP issued a series of Supplemental Information Requests (SIRs) on 30 August 2013. This report has been prepared in response to SIR No. 5 – *Impacts of PSMF Discharge to Hare Lake* - and includes: a comprehensive summary of baseline conditions in Hare Lake; a description of the conditions under which excess water from the PSMF will be discharged to Hare Lake and predictions related to the mixing of PSMF discharge in Hare Lake; and, an analysis of the potential effects on the abiotic and biotic conditions in Hare Lake and Hare Creek and their significance in consideration of contemplated mitigation measures.

This report brings together information that was previously provided as part of several SIDs[4] and a number of responses to IRs and SIRs, as well as new data collected in 2013 that are being reported for the first time.

## 1.4 Objectives

The specific objectives of this report are as follows:

- to provide a comprehensive summary of baseline conditions in Hare Lake;
- to provide a description of the conditions under which excess water from the PSMF will be released to Hare Lake and an analysis of the dispersion of PSMF discharge in Hare Lake; and,
- to provide an analysis of the potential effects on the biological functions of Hare Lake and Hare Creek as a result of the release of excess water from the PSMF to Hare Lake.

[4] The information provided herein has been sourced from the following SIDs:
SID 1 – Aquatic Baseline Program (EcoMetrix, 2012a)
SID 2 - Baseline Water Quality (EcoMetrix, 2012b)
SID 3 – Geochemistry of Mine Components (EcoMetrix, 2012c)
SID 6 – Water Quality and COPC Fate Modelling (EcoMetrix, 2012d)
SID 11 – PSMF/MRSA Alternatives Analysis (KPI, 2012)
SID 20 – Baseline Hydrology (Calder, 2012a)
SID 21 – Baseline Hydrology (Calder, 2012b)

## 1.5 Report Format

Following this introductory section the remainder of the report is organized as follows:

- Section 2.0 provides a description of the existing conditions within Hare Lake;
- Section 3.0 describes the conditions under which excess water from the PSMF will be released to Hare Lake and the dispersion of this discharge within the lake;
- Section 4.0 provides an assessment of potential effects of the PSMF discharge on abiotic and biotic conditions in Hare Lake and Hare Creek during the operating phase of mine life, including a description of contemplated mitigation measures used to minimize the potential effects, describes the predicted residual effects and provides an analysis of the significance of the potential residual effects;
- Section 5.0 provides and summary and the primary conclusions of the report; and,
- Section 6.0 provides the references cited in the preparation of this report.

A photographic appendix of the fish species collected in Hare Lake and Hare Creek is provided in Appendix A.

# 2.0 BASELINE INFORMATION FOR HARE LAKE

## 2.1 Hare Lake – General Description

### 2.1.1 Setting

Hare Lake is oriented northeast to southwest (upstream to downstream) and is approximately 2 km long by on average about 400 to 500 m wide. It is situated in the Stream 5 subwatershed. The subwatershed occupies an area of 4,833 ha. Hare Lake receives inflows from Bamoos Creek and Stream 5, at the eastern end of the lake, as well as an unnamed creek originating from a group of lakes approximately 2 km to the north, discharging mid lake. Hare Lake discharges to Hare Creek at the western end, which outlets to Lake Superior approximately 3 km downstream at Port Munroe.

### 2.1.2 Hare Lake Bathymetry, Surface Area and Volume

Hare Lake bathymetry is shown in Figure 2.1-1 and is derived from a bathymetric survey on Hare Lake in July 2013. The survey followed a standard method using an integrated recording depth sounder and global positioning system (GPS) with WAAS enabled receiver (Lowrance LC X-17 M). A boat was operated along systematic transects to simultaneously collect depth and position data. The Lowrance unit recorded GPS coordinates at the location of each depth measurement. Absolute positioning was accurate to within 2 to 3 m laterally, although relative positioning (i.e., the distance between point to point measurements) was accurate to within about 1 m. Processing of the bathymetry data was completed using contouring and 3D surface mapping software (Surfer 8; Golden Software Inc., 2002) employing a kriging geostatistical technique to create bathymetric contours and to provide surface area and volume estimates.

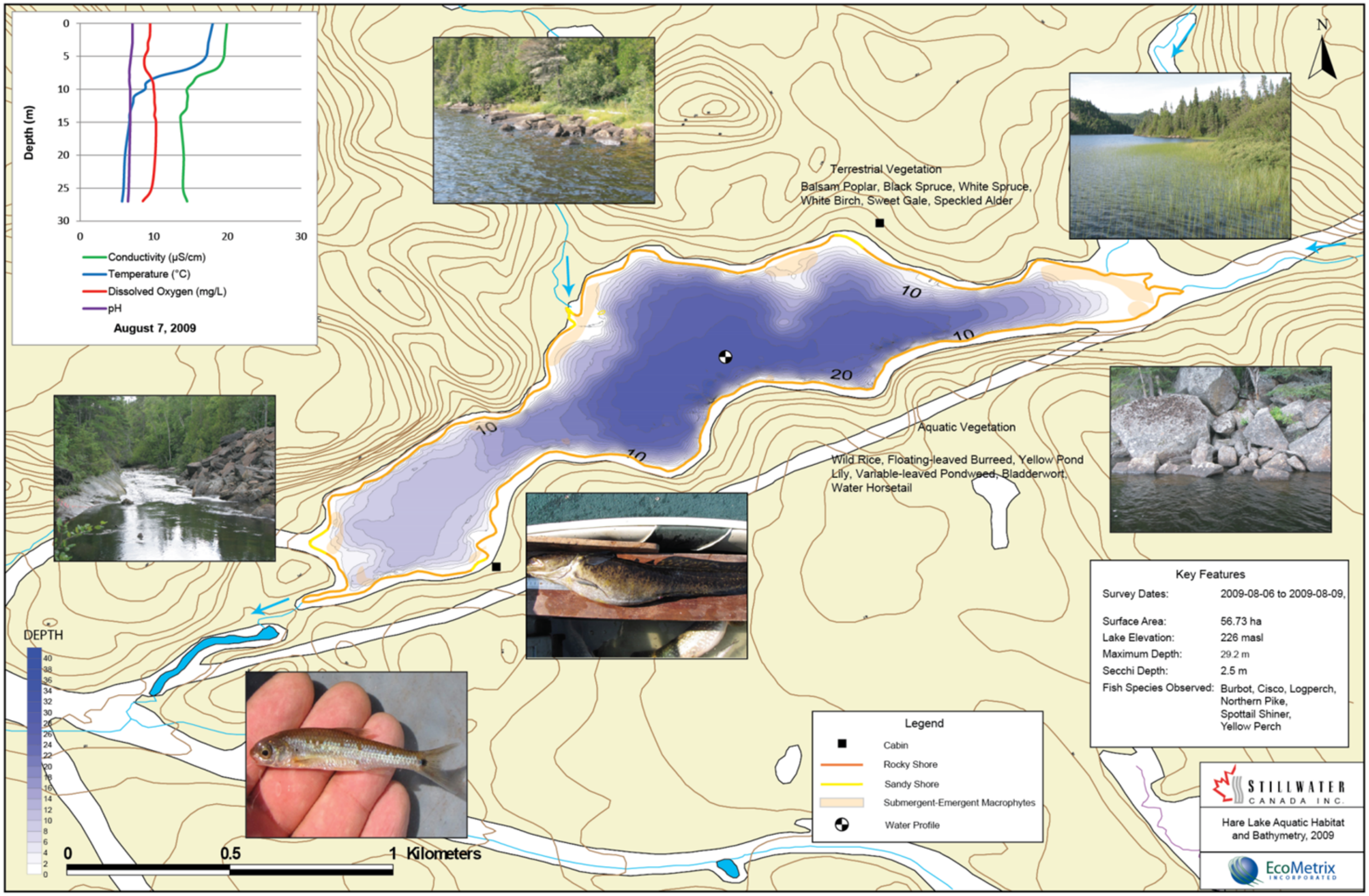


**Figure 2.1-1: Bathymetry of Hare Lake**

### 2.1.3 Habitat Features

Bottom substrates in Hare Lake are primarily fine-grained organic silt (muck), with lesser amounts of boulder, bedrock, cobble, gravel, sand and detritus typically in nearshore areas.

Aquatic plant beds are limited to nearshore embayments and in particular at the main inlet and outlet areas of the lake. Observed aquatic macrophytes included wild rice (*Zizania palustris*), floating-leaved burreed, yellow pond lily, variable-leaved pondweed, bladderwort (*Ulticulaire* sp.) and water horsetail (*Equisetum fluviatile*).

The terrain surrounding the lake is quite steep along the northwestern and southeastern shores. The adjacent upland forest community is comprised of white spruce, black spruce, white birch, balsam poplar, sweet gale and speckled alder.

Hare Lake is characterized by a single basin which is situated mid-lake. Relatively long stretches of both the north and south sides of the lake shelve steeply and afford little in the way of littoral habitat. The majority of littoral zone habitat is isolated to the main inlet and outlet areas of the lake, as well as a couple of small embayments on both the north and south sides of the lake.

The surface area of the lake is about 57 ha and the total lake volume is approximately 8.5 M $m^3$. The maximum depth of Hare Lake is approximately 30 m. Mean lake depth is approximately 15 m. Lake retention time, based on annual average flows is in the order of 6 to 7 months.

## 2.2 Hydraulic Regime in the Stream 5 Subwatershed

The Stream 5 subwatershed (also identified as sub-basin 105) drains approximately 4,833 hectares and discharges to Lake Superior. Of this area, approximately 4,454 hectares drains to Hare Lake. A detailed description of baseline hydrology for the Stream 5 subwatershed is provided in SID 20 and IR 12.2.2.

### 2.2.1 Flow Characteristics in the Stream 5 Subwatershed

<u>Baseline Flow Monitoring Program</u>

Local streamflow data are available for the Stream 5 subwatershed from both continuous streamflow monitoring and manual flow measurements at various locations. The streamflow monitoring locations are shown on Figure 2.3-1 (see Section 2.3). Data have been collected since 2007 and streamflow monitoring is on-going.

Continuous streamflow monitoring has been undertaken at four sites in the Stream 5 subwatershed: S10 (2009), S11 (2009-2012), S22 (2008) and S41 (2009–2010). Currently (2013), continuous streamflow monitoring is on-going for Hare Creek at the outlet of Hare Lake. Available streamflow data have been summarized in SID 20 and IR 12.2.2. Manual streamflow measurements have been undertaken since 2007 and are summarized in SID 20. In 2013, winter streamflow measurements were made at three locations in the Stream 5 subwatershed. These winter streamflow measurements are summarized in Table 2.2-1.

**Table 2.2-1: Winter streamflow measurements in the Stream 5 subwatershed**

| Location | February 27/28, 2013 | | March 21, 2013 | |
|---|---|---|---|---|
| | Max Depth (m) | Flow (cms) | Max Depth (m) | Flow (cms) |
| S5a | 0.10 | 0.004 | 0.24 | 0.030 |
| S5 | 0.23 | 0.101 | 0.21 | 0.064 |
| S11 | 0.25 | 0.049 | 0.30 | 0.026 |

Note: 1- Units: m =meters, cms = cubic meters per second; 2-Refer to Figure 2.4-1 for station locations

Baseline Hydrology Assessment

Baseline hydrology for the Stream 5 subwatershed has been summarized in SID 20 and IR 12.2.2. Information has been provided on mean, low, and peak flows. In addition to this information, a water balance model has been developed for the Stream 5 subwatershed. The water balance model has been applied to make predictions of flow conditions under various climatic scenarios and provide input to the Hare Lake/Hare Creek water quality impact assessment.

The water balance model was calibrated using available local streamflow data and compared to both local and regional streamflow information. A comparison of the runoff coefficients used in the water balance model and those calculated for the local study area (i.e., all continuous streamflow stations in local study area) and select regional stations is provided in Figure 2.2-1., Figure 2.2-2 and Figure 2.2-3. A comparison of the water balance predicted mean monthly flows to streamflow monitoring records and prorated streamflow at the Cedar Creek near Hemlo regional station (02BB004) at S11 is provided in Figure 2.2-4. Cedar Creek near Hemlo was selected since its basin size is more similar to those in the local study area than the other regional stations. The flows for Cedar Creek were scaled based on drainage area.

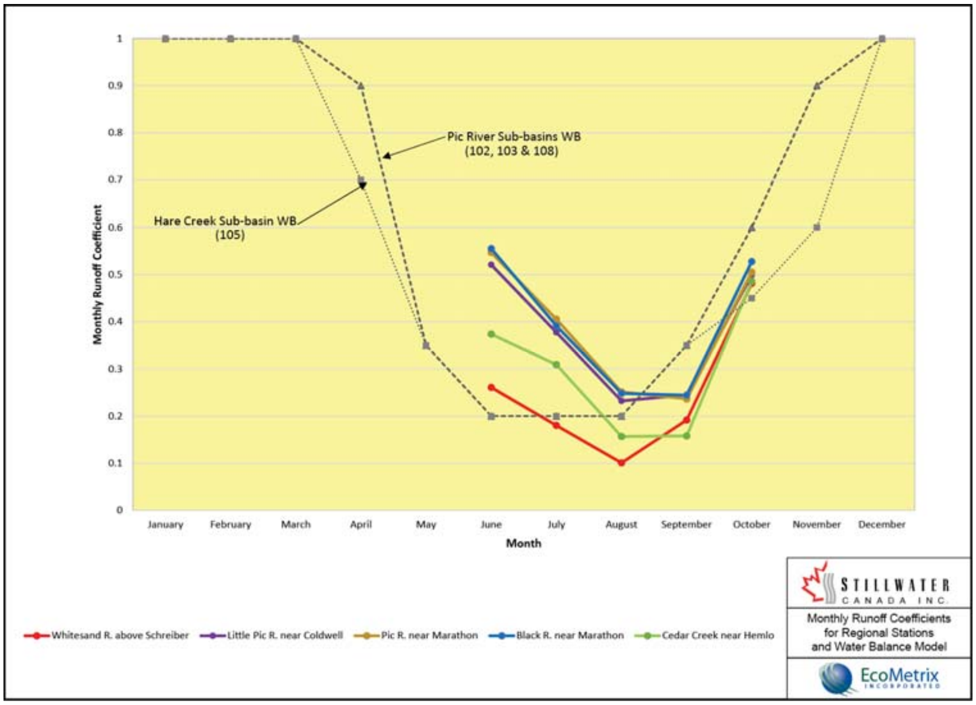


**Figure 2.2-1: Monthly runoff coefficients for regional stations and water balance model**

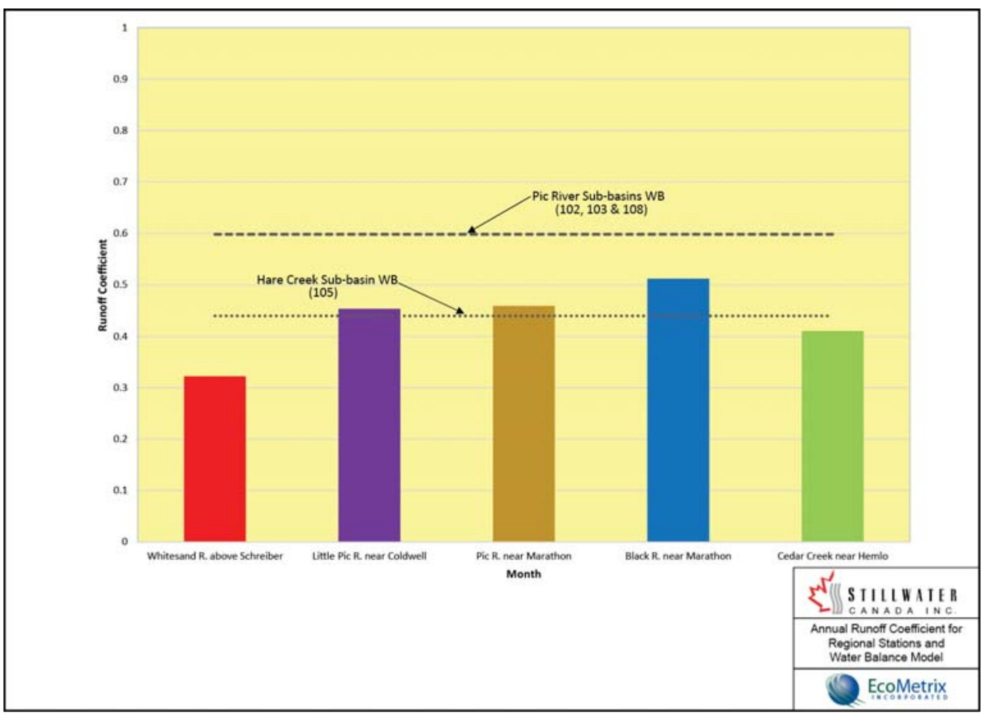


**Figure 2.2-2: Annual runoff coefficient for regional stations and water balance model**

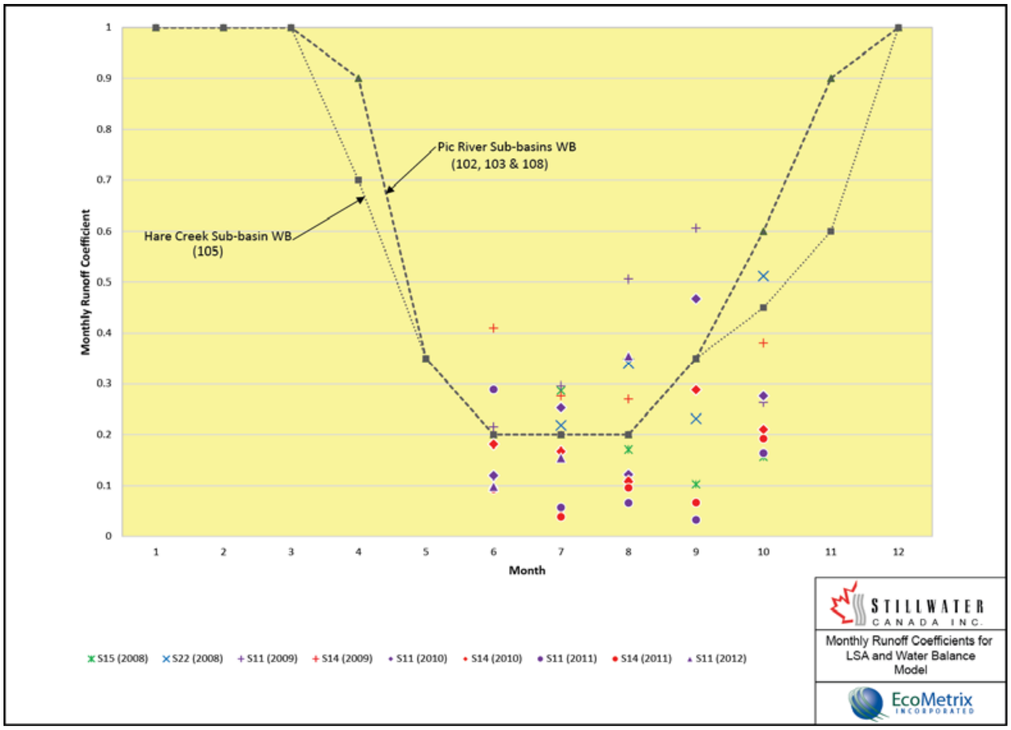


**Figure 2.2-3: Monthly runoff coefficients for the Local Study Area and water balance model**

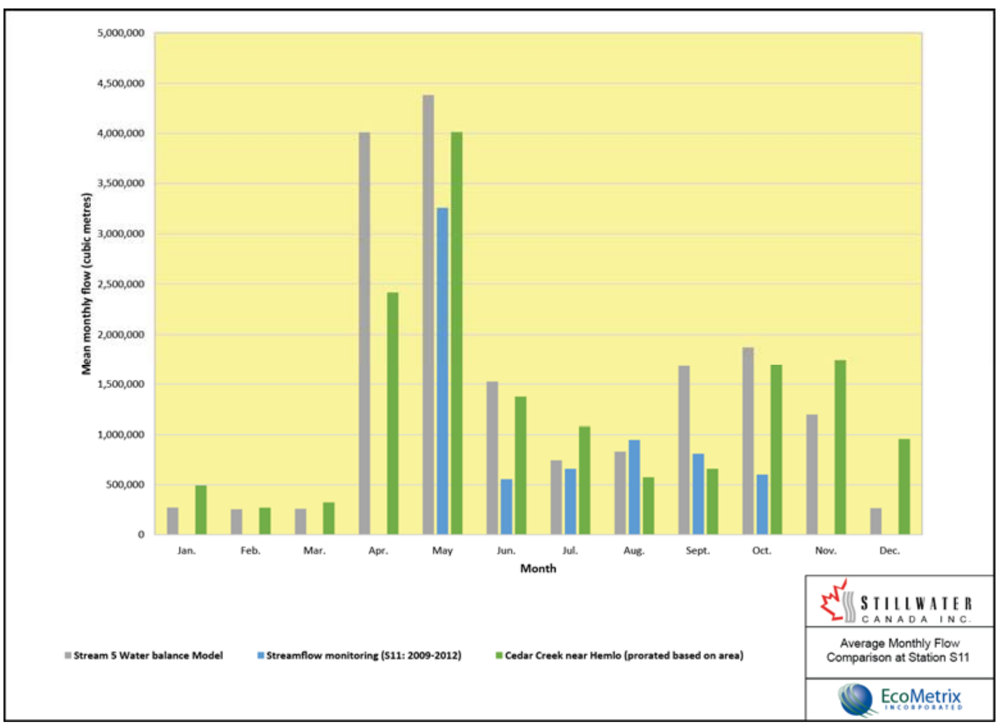


**Figure 2.2-4: Average monthly flow comparison at Station S11**

### 2.2.2 Hare Lake Retention Time

As indicated above, the retention time of Hare Lake, based on annual average flows, is in the order of 6 to 7 months.

## 2.3 Water Quality in Hare Lake

### 2.3.1 Sampling Program Overview

An extensive network of water quality monitoring stations has been established including headwater and downstream areas of all of the watersheds (and subwatersheds) that traverse the Project area. In total, the network comprises 58 stations including; 13 lake stations, four Pic River stations and 41 stream stations. Sampling of this network began in the spring of 2008 and is ongoing. Sampling was conducted on a monthly basis through the ice-free season (roughly May through November). Samples have also been collected in the winter under ice from the lakes within the Project area by Golder Associates in 2007 and True Grit Consulting Ltd. (TGCL) in 2009.

The sampling program includes QA/QC components that assess the integrity of field collection activities (trip blanks, field blanks, field duplicates), laboratory analyses (laboratory blanks, laboratory duplicates, concentration standards) and data management (manual checks of database values with laboratory reports). All samples were submitted to and analyzed by Canadian Association for Laboratory Accreditation Inc. (CALA) accredited laboratories. The range of parameters for which analyses (or measurements) were completed is provided in Table 2.3.-1.

**Table 2.3-1: Parameters Analyzed as part of Routine Surface Water Quality Sampling on the Project Site**

| Parameter Category | Analytes |
|---|---|
| Physical Tests | Colour, Conductivity, pH, TSS, TDS, Turbidity, DO, Temperature |
| Anions and Nutrients | Alkalinity, Total (as $CaCO_3$), Ammonia-N, Total Bicarbonate, Carbonate, Chloride, Fluoride, Hydroxide, Nitrate-N, Nitrite-N, TKN, Phosphorus (total), Sulphate |
| Carbon | DOC |
| Metals | Total Metals (full ICP-MS scan), Dissolved Metals (full ICP-MS scan), Mercury, Hexavalent Chromium |
| Aggregate Organics | BOD, Tannin and Lignins |
| Radionuclides | Radium-226 |

| | |
|---|---|
| Others | Chlorophyll *a* |

Routine water quality sampling has been undertaken since 2008 by TGCL. Sampling has been conducted according to standardized protocols based on the Metal Mining Environmental Effect Monitoring Technical Guidance Document (Environment Canada, 2008; 2011) Chapter 5, Section 7: Water Quality Monitoring, as summarized briefly below.

Water quality data were generated by both in-field measurements and laboratory analyses. In-field measurements (pH, conductivity, dissolved oxygen (DO), temperature) were made with appropriate water quality meters. Meters were calibrated according to manufacturer's instructions prior to each sampling effort and calibration checks were performed prior to each days sampling. In instances where the calibration check indicated a potential measurement error, the meter was re-calibrated prior to use in the field. Meter measurements were taken in-situ and meters were held in-situ until readings had stabilized before a water quality measurement was recorded. All in-field measurements were recorded manually on data sheets and inputted into spreadsheets for subsequent database storage. All data transferred into the master database was double checked for quality control immediately after field activities were completed.

Samples that were collected for subsequent laboratory analysis were collected as discrete grab samples in sterile, appropriately sized containers provided by the analytical laboratory. Samples which required preservatives (e.g., nitric acid for metal samples) were preserved in the field immediately after collection. Sample containers were pre-labeled by the laboratory, including a station name and project-specific reference number. The date and time of each sample collected was labeled on the containers by the field sampling crew at the time of collection. Dedicated nitrile gloves were worn during all sampling activities. Following collection, the samples were stored at 4ºC until they were received by the laboratory. Samples were transported in sealed coolers in accordance with prescribed hold times and were at all times accompanied by appropriately completed chain-of-custody forms. Following reception at the lab, the sample confirmation forms that were provided by the lab were cross referenced with the chain-of-custody forms to ensure all samples had been received and the correct sample analyses were ordered. This same process was completed when sample analyses results were obtained from the lab to ensure that all sample results were provided as ordered. Data from the lab reports were transferred from laboratory spreadsheets into the master database and double checked for accuracy shortly after receiving the data from the laboratory.

### 2.3.2 Water Sampling in the Stream 5 Watershed

Water sampling locations within the Stream 5 watershed are shown in Figure 2.3-1. Water quality in Hare Lake is represented by a sampling location near the Bamoos Creek inlet at the northeast end of the lake (station L-Hare).

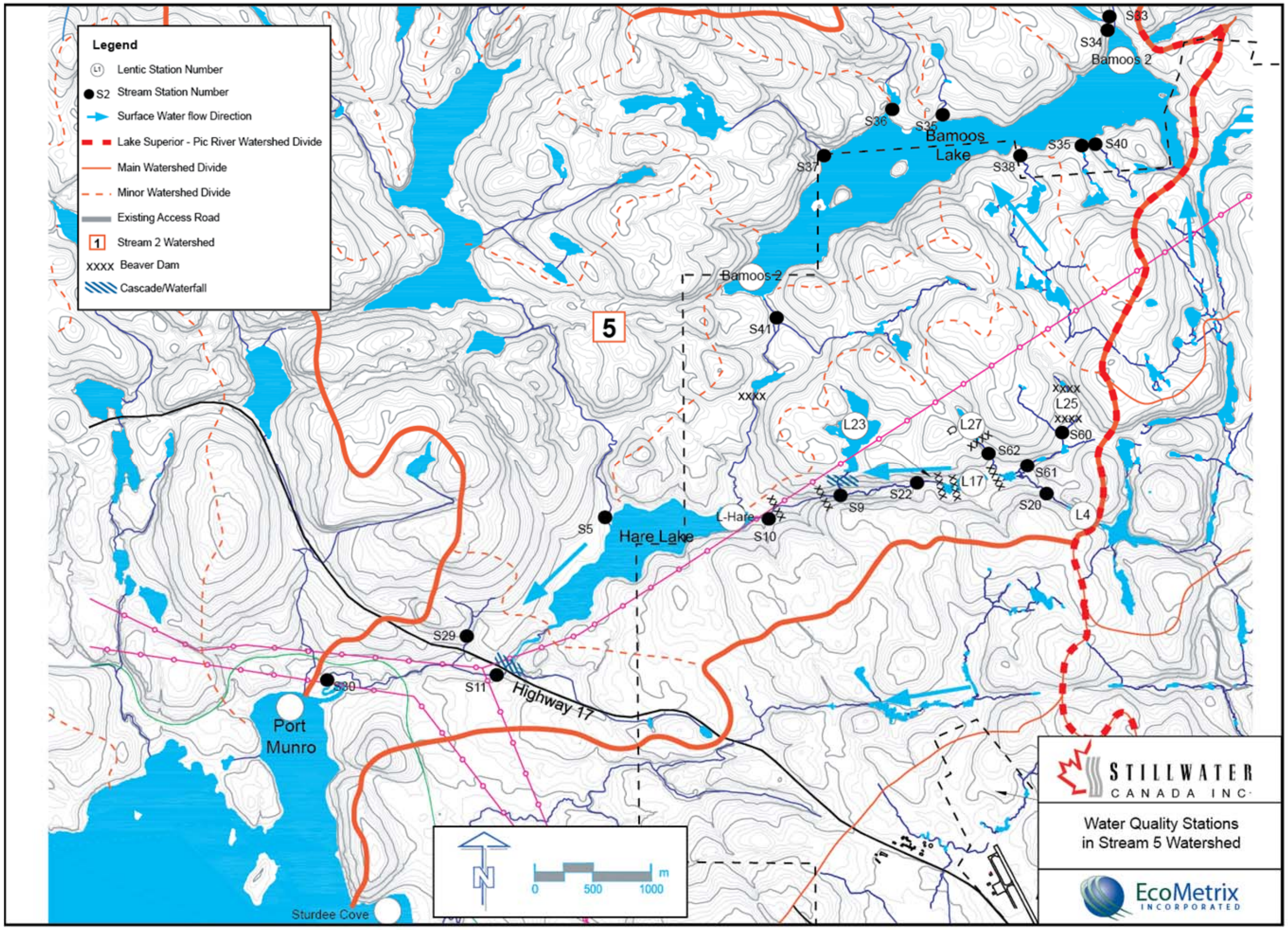


**Figure 2.3-1: Water Quality Stations in the Stream 5 Watershed**

### 2.3.3 Water Quality

General water quality based on data collected at the Hare Lake monitoring station (L-Hare) is summarized in Table 2.3-2. The data are provided along with the Provincial Water Quality Objectives (PWQOs) (OMOEE, 1994).

The water in Hare Lake is circumneutral with pH on average about 7.5. Over the period of record pH ranged from 5.8 to 10.3. Sulphate concentrations averaged 3.4 mg/L and had a minimum concentration of 2.5 mg/L and a maximum concentration of 4.2 mg/L. TSS levels in Hare Lake were on average about 3.3 mg/L, though most measurements were in fact generally below the MDL of 2 mg/L.

DOC averaged 6.4 mg/L, with minimum and maximum concentration of 4 mg/L and 9.7 mg/L, respectively.

Approximately two-thirds of the samples had phosphorus concentrations below the MDL (0.005 mg/L). For the remaining third the range was between 0.005 and 0.01 mg/L.

Nitrate (as N) averaged 0.12 mg/L, had a minimum concentration of 0.034 mg/L and a maximum concentration of 0.19 mg/L. TKN levels ranged from about 0.2 to 0.4 mg/L and were on average 0.26 mg/L. Ammonia concentrations ranged from below the MDL (i.e., 0.02 mg/L) to 0.04 mg/L.

Several analytes including arsenic, cadmium, cobalt, copper, lead, mercury, molybdenum, nickel and selenium were generally below their respective MDL.

Dissolved aluminum concentration ranged from 0.039 to 0.23 mg/L, with a mean of 0.088 mg/L exceeding the PWQO of 0.075 mg/L. Iron concentrations averaged 0.23 mg/L and ranged from 0.07 to 0.42 mg/L. Iron concentrations exceeded the PWQO of 0.3 mg/L on three occasions over the period of record. No other metals exceeded their respective PWQOs.

**Table 2.3-2: Water Chemistry at Station L-Hare**

| | PWQO (mg/L) | Maximum (mg/L) | Average (mg/L) |
|---|---|---|---|
| Alkalinity (as $CaCO_3$) | - | 10.1 | 7.3 |
| Dissolved Aluminum | 0.075 | 0.18 | 0.11 |
| Ammonia (as N) | 1.4 | 0.04 | 0.03 |
| Arsenic | 0.1 or 0.005 (Interim) | < 0.001 | < 0.001 |
| Cadmium | 0.0002 or 0.0001 (Interim) | 0.0052 | < 0.00009 |
| Cobalt | 0.0009 | < 0.0005 | < 0.0005 |
| Copper | 0.005 or 0.001 (Interim) | < 0.001 | < 0.001 |

| | | | |
|---|---|---|---|
| Dissolved Organic Carbon | - | 7.5 | 4.8 |
| Iron | 0.3 | 0.42 | 0.23 |
| Lead | 0.005 or 0.001 (Interim) | < 0.001 | < 0.001 |
| Mercury | 0.0002 | < 0.0001 | < 0.0001 |
| Molybdenum | 0.04 | < 0.0001 | < 0.0001 |
| Nickel | 0.025 | < 0.002 | < 0.002 |
| Nitrate (as N) | - | 0.19 | 0.12 |
| pH | 6.5-8.5 | 10.3 | 7.5 |
| Phosphorus | 0.03 | 0.0062 | 0.0055 |
| Selenium | 0.1 | < 0.005 | < 0.0004 |
| Sulphate | - | 4.2 | 3.4 |
| Total Kjeldahl Nitrogen | - | 0.42 | 0.26 |
| Total Suspended Solids | - | 4.2 | 3.3 |
| Zinc | 0.03 or 0.02 (Interim) | 0.007 | 0.004 |

## 2.4 Seasonal Temperature Variation and Thermal Profile in Hare Lake

### 2.4.1 Data Collection

Lake water temperature data, both spot measurements of surface temperatures and depth profiles, have been collected on an *ad hoc* basis coincident with other field programs (benthic and fish sampling) and through installations of temperature probes across the depth of Hare Lake to measure seasonal water temperature trends. Temperature probes were installed in the late fall of 2012 and have been in place more or less continuously from that time. The probes were set in the deepest part of the central lake basin at 2 m intervals from the surface to the bottom of the water column, with water temperatures measured on an hourly basis.

### 2.4.2 Temperature Regime

The temperature regime of Hare Lake fits the general conceptual model of a dimictic lake, as do many lakes in northern temperate areas. Hare Lake circulates freely twice per year in the spring and fall and is directly stratified in the summer and inversely stratified in the winter (Wetzel, 2001). The general conceptual model of a dimictic lake, as it concerns water temperatures, is described briefly below, beginning the cycle in the summer months.

In the summer, relatively high solar radiation input and warm air temperatures contribute to the warming of surface waters and the development of the thermal stratification of the water column. Winds tend to keep the surface water well-mixed, and this upper mixed region of the lake is called the epilimnion. Below the mixing action of the wind and the penetration depth of the solar radiation, a strong temperature and accompanying density gradient develops. This region of strong gradients is called the thermocline. Below the thermocline a weaker temperature gradient is observed and the water is cool and comparatively quiescent. The bottom region of the lake is called the hypolimnion and the bottom water will have a temperature near 4°C, the temperature of maximum density of water. The strong density gradients in the thermocline inhibit exchange between the epilimnion and the hypolimnion. Thus, bottom water in a stratified lake does not actively interact with the atmosphere and can easily become deprived of important dissolved gases.

As the air temperature gets cooler and the solar radiation input decreases in the fall, the surface water begins to cool. Eventually, the surface water and thermocline cool down to the temperature of the hypolimnion and the lake is no-longer stratified. In this state the lake can easily be mixed, even by a light wind; thus, the lake mixes, or in other words experience a turnover event. This gives the bottom water an opportunity to aerate with the atmosphere.

If the air temperature in the winter goes below 4°C so that the surface water can cool below this temperature, then the surface water becomes lighter than the bottom water and a so-called winter inverse stratification develops. The term inverse refers to the fact that the surface water is colder than the bottom water; however, the surface water remains less dense. When ice forms at the water surface, wind mixing is not possible and the winter density profile may not exhibit a well-defined thermocline. As the surface water heats up again in the spring, the lake will again reach a state of thermal homogeneity and in the presence of a light wind will turn over. As the surface waters become warmer, stratification sets in and the summer stratification state returns.

### 2.4.3 Temperature Monitoring Data

Water temperature profiles representative of different seasons and times of the year are shown in Figure 2.4-1. An example of the continuous lake temperature monitoring data for the period late February 2013 to late March 2013, the time when the lake is inversely stratified, is shown in Figure 2.4-2.

During the summer stratification period the following general observations can be made:

- maximum water temperatures in the epilimnion reach about 18 to 20°C and the epilimnion occupies about the top 5 to 6 m of the water column;
- the thermocline occupies the area below the epilimnion and extends to water depths of 9 to 12 m; and,
- the hypolimnion extends to the bottom of the lake where water temperatures are consistent and in the range of 4 to 5°C.

The timing of fall turnover is variably and dependent on local air temperatures wind conditions but is expected to occur sometime around mid-October. Figure 2.4-1 shows temperature depth profiles taken in mid-September 2012 and late October 2012. The lake was stratified on the former date but stratification had broken down and the lake had turned-over by the latter date.

Lake freeze-up typically occurs in December with the winter inverse stratification period setting up shortly thereafter. During winter 2013 water temperatures in the epilimnion were about 1.5°C. A small thermocline was evident in the top couple of meters in the water column and water temperature in the hypolimnion were in the range if 2.5 to 3.5°C.

Ice out occurs between April and early June followed shortly thereafter by spring turn over.

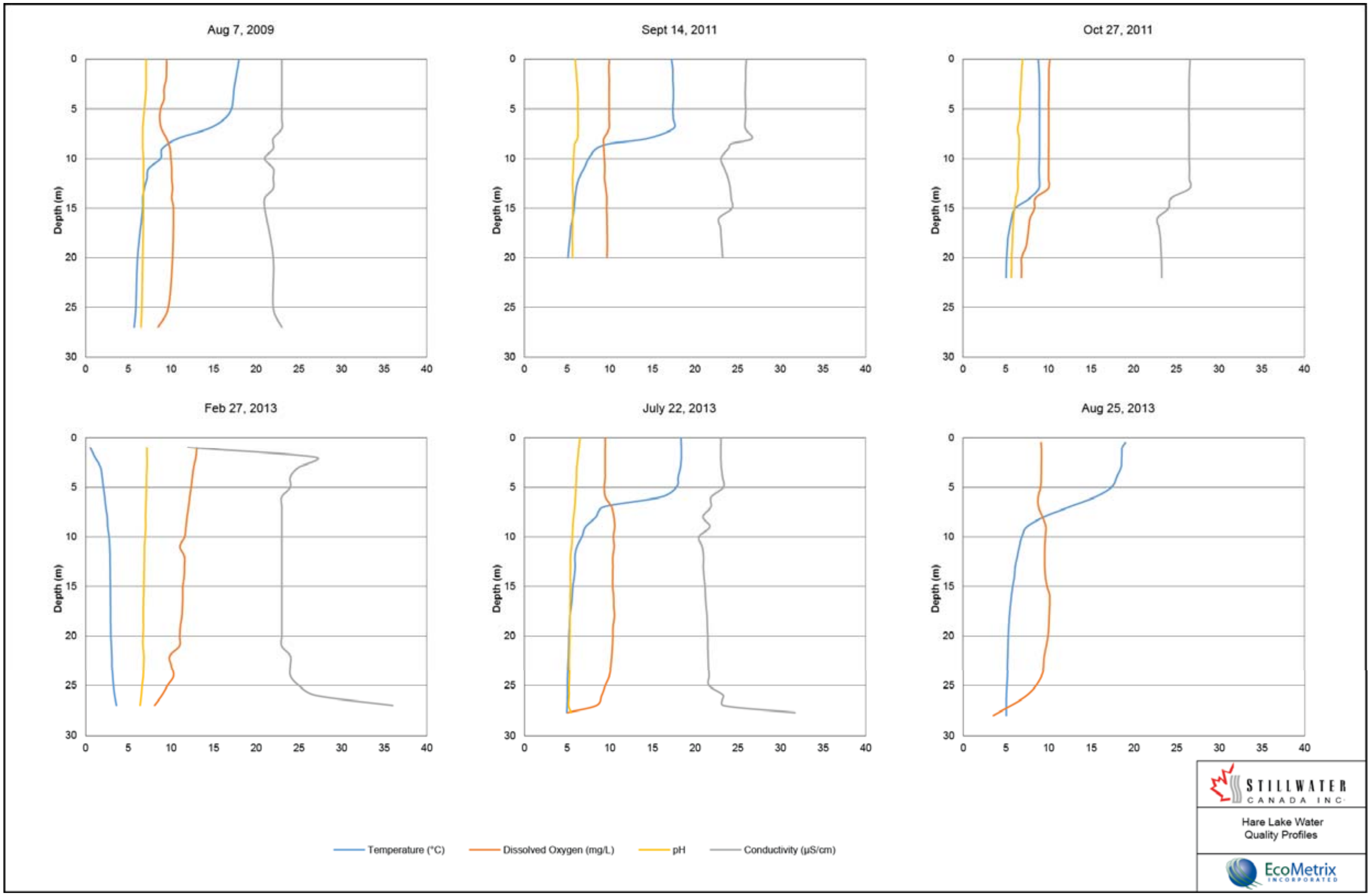


**Figure 2.4-1: Temperature-depth profiles for Hare Lake**

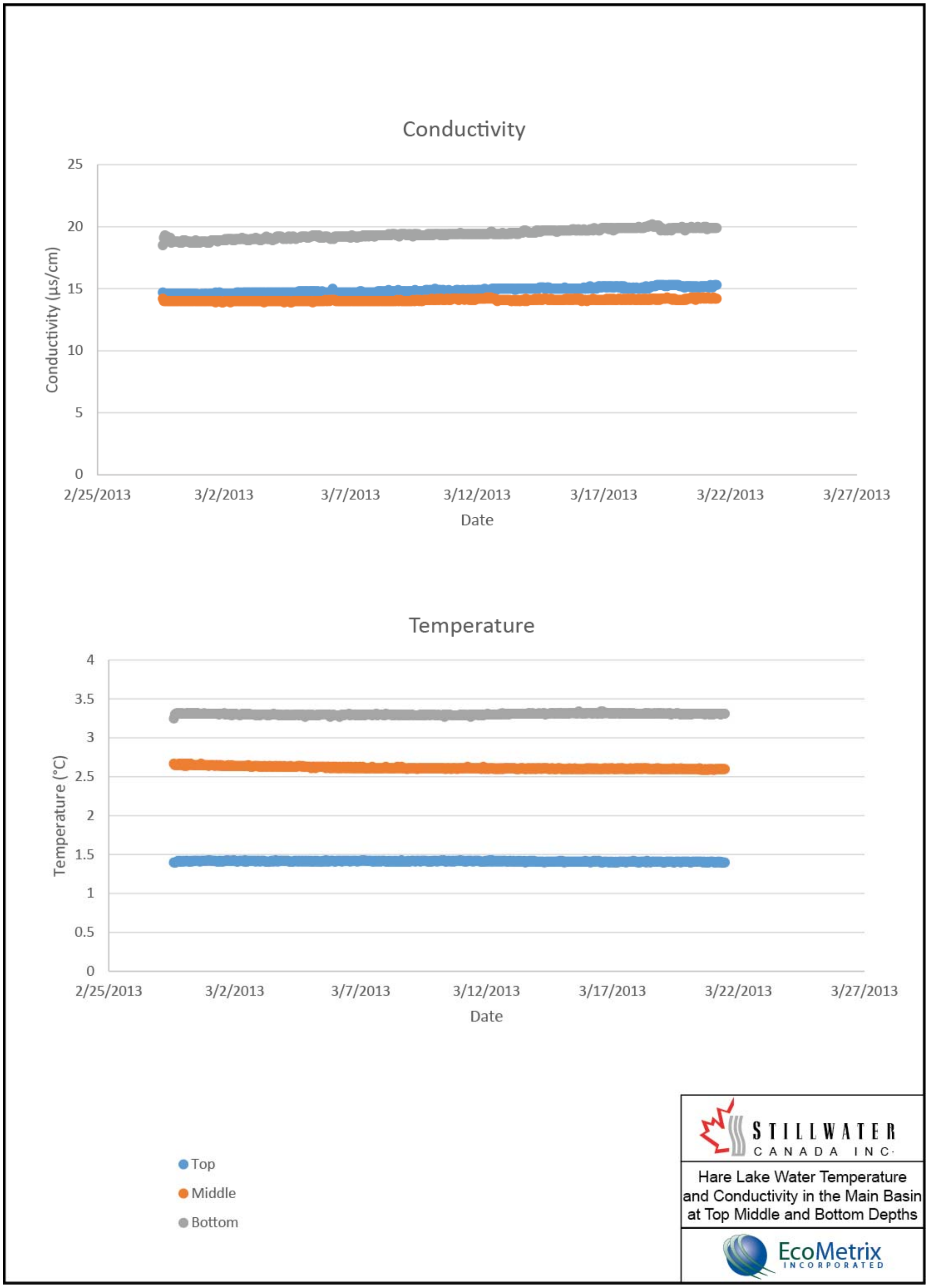


**Figure 2.4-2: Water temperature in Hare Lake February through March 2013**

## 2.5 Sediment Quality in Hare Lake

### 2.5.1 Sampling Program

Sediment samples for chemical and physical characterization were collected from profundal and littoral habitats In Hare Lake. Samples were collected using a bottom grab sampler (petite Ponar) and consisted of the top 5 cm or so of sediment. Sediment samples were placed in appropriately labeled glass jars and kept cool (< 10 °C) until submission for analysis. Sediment samples were submitted for analysis to ALS Laboratories, which is a Canadian Association for Laboratory Accreditation Inc. (CALA) accredited facility. Samples were analyzed with method detection limits (MDL) at or below the Provincial Sediment Quality Guidelines (PSQG) (Persaud et al., 1993).

Sediment analyses are provided relative to 'lowest effect' and 'severe effect' levels listed in the PSQG. These levels are defined as follows:

- Lowest effect level (LEL): A level of contamination which has no effect on the majority of sediment dwelling organisms; and,
- Severe effect level (SEL): A level of contamination considered detrimental to sediment dwelling organisms.

### 2.5.2 Sediment Quality

The substrate in the littoral and profundal zones were similar and was primarily comprised organic silt (muck) (Table 2.5-1).

For littoral zone samples, the mean of five parameters exceeded the LEL and one parameter's mean exceeded the SEL. TP (786 mg/kg), TOC (6.2%), Cd (1.4 mg/kg), Cu (21 mg/kg) and Zn (208 mg/kg) all exceeded the LEL criteria of 600 mg/kg, 1%, 0.6 mg/kg, 16 mg/kg and 120 mg/kg, respectively. TKN (5,622 mg/kg) exceeded the SEL of 4,800 mg/kg (Table 2.5-1). In addition there were two samples at which Fe and Ni also exceeded the LEL criteria.

The profundal sediment samples had a larger number of mean values that exceeded PSQG criteria. TP, As, Cd, Cu, Pb, Ni and Zn all exceeded the LEL criteria with mean values of 1,256 mg/kg, 14 mg/kg, 3.5 mg/kg, 32 mg/kg, 65 mg/kg, 17 mg/kg and 338 mg/kg, respectively. TKN (10,686 mg/kg), TOC (12%), and Fe (47,500 mg/kg) all exceeded the SEL criteria of 4,800 mg/kg, 10% and 40,000 mg/kg, respectively (Table 2.5-1).

**Table 2.5-1: Sediment Chemistry in Hare Lake**

| | Units | LEL | SEL | Hare Littoral | Hare Profundal |
|---|---|---|---|---|---|
| Physical Tests | | | | | |
| Total Phosphorus | (mg/kg) | 600 | 2,000 | 786 | 1,256 |
| Total Kjeldahl Nitrogen | (mg/kg) | 550 | 4,800 | 5,622 | 10,686 |
| Organic / Inorganic Carbon | | | | | |
| Total Organic Carbon | % | 1 | 10 | 6.19 | 11.94 |
| Total Metals | | | | | |
| Aluminum | (mg/kg) | - | - | 14,320 | 21,860 |
| Arsenic | (mg/kg) | 6 | 33 | 3.9 | 13.7 |
| Cadmium | (mg/kg) | 0.6 | 10 | 1.36 | 3.49 |
| Cobalt | (mg/kg) | 50 | | 9.82 | 18.88 |
| Copper | (mg/kg) | 16 | 110 | 20.88 | 31.56 |
| Iron | (mg/kg) | 20,000 | 40,000 | 19,940 | 47,500 |
| Lead | (mg/kg) | 31 | 250 | 18.2 | 65.2 |
| Molybdenum | (mg/kg) | - | - | 0.74 | 1.72 |
| Nickel | (mg/kg) | 16 | 75 | 15.12 | 17.16 |
| Selenium | (mg/kg) | - | - | 1.02 | 2.48 |
| Zinc | (mg/kg) | 120 | 820 | 208.0 | 338.4 |

## 2.6 Chemical and Nutrient Influx to the Lake

Aquatic ecosystems are open systems with energy and nutrients (both inorganic and organic) continuously entering and leaving the system (Wetzel, 2001). These nutrients are transported to aquatic ecosystems such as lakes in various forms and amounts. This can be from allochthonous or external sources that are transported to the lake from the watershed (e.g., river/stream inflows or groundwater) or through autochthonous or internal sources such as organic matter (e.g., phytoplankton or algae) produced within the lake (Forsberg, 1989). Hare Lake has a relatively small watershed and thus external sources of nutrients likely would be relatively small. Nutrients once in the system are transported through the water column to the sediments that make up the lake bottom through the process of sedimentation. Through various physical, biological, and chemical processes these nutrients can then be cycled back into the water column (Forsberg, 1989).

Internal nutrient cycling processes are very complex and vary with lake type and bottom conditions. Figure 2.6-1 illustrates a simplified nutrient cycle in a stratified lake. The rate at which nutrients cycle between the sediment and water is influenced by a number of factors including hydrological conditions, lake morphology, water residency, temperature, and the size and density of the particles (Forsberg, 1989). The rate of sedimentation and resuspension is strongly influenced by lakes that turn over twice per year or more (i.e., dimictic or polymictic lakes) and the trophic level (e.g., oligotrophic or eutrophic), which creates different conditions for lake metabolism. The organisms that live on or in the upper sediments are also an important part of the nutrient cycling process (Forsberg, 1989). In Hare Lake a portion of the nutrients that are held in the sediment pool are re-circulated into the water column twice per year, during spring and fall turnover.

The main biogeochemical cycles describe the movement of carbon, nitrogen and phosphorus within the lake system. Inorganic carbon, mainly in the form of dissolved carbon dioxide and bicarbonate, is the primary source of carbon for generating organic matter through photosynthesis. However, photosynthesis is more often limited by nitrogen and phosphorous than inorganic carbon as nitrogen and phosphorous both occur in lower amounts (Wetzel, 2001).

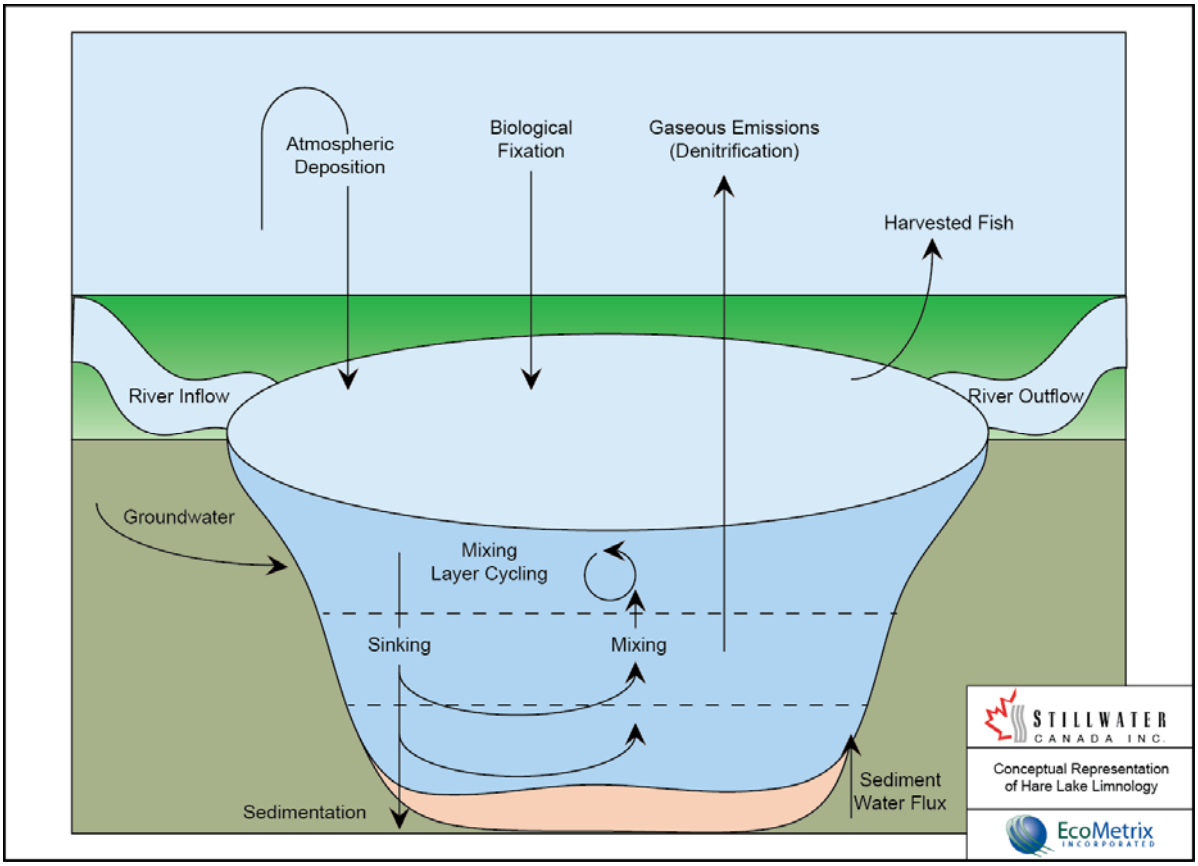


**Figure 2.6-1: Simplified Nutrient Cycle in a Stratified Lake (Source: Bootsma and Hecky, 1999.)**

## 2.7 Primary Productivity in Hare Lake

### 2.7.1 Chlorophyll *a*

Chlorophyll *a* has been measured on several occasions within Hare Lake. In each instance, depth-integrated water samples were collected in the epilimnion when Hare Lake was stratified. Chlorophyll *a* values have ranged from 1.4 to 1.8 µg/L indicating that Hare Lake is oligotrophic (Wetzel, 2001).

### 2.7.2 Phytoplankton

Initial samples were collected for phytoplankton analysis at three locations (east end, mid-lake and west end) in Hare Lake in September 2013. The samples were collected as depth-integrated samples[5] throughout the depth of the epilimnion when Hare Lake was stratified. These data have not yet been reported to SCI but will be made available at the earliest possible time. The data will be reported in terms of community composition (species), as well as measures of abundance and diversity.

Further baseline sampling is planned for 2014. Samples will be collected monthly in the epilimnion from June through September as described above. Samples for the analysis of chlorophyll *a* will be collected coincident with the phytoplankton samples.

### 2.7.3 Zooplankton

Baseline zooplankton samples were collected for analysis at three locations (east end, mid-lake and west end) in Hare Lake in September 2013. The samples were collected throughout the depth of the epilimnion when Hare Lake was stratified via a vertical plankton two net fitted with 63 micron mesh.

These data have not yet been reported to SCI but will be made available at the earliest possible time. The data will be reported in terms of community composition (species), as well as measures of abundance and diversity.

Further baseline sampling is planned for 2014. Samples will be collected monthly in the epilimnion from June through September as described above.

## 2.8 Benthic Invertebrates in Hare Lake

### 2.8.1 Sampling Program

A quantitative benthic invertebrate survey, consistent with Metal Mining Environmental Effects Monitoring (EEM) Program requirements, was conducted on Hare Lake in August 2009. This survey consisted of five littoral and five profundal samples collected throughout the lake where suitable habitat existed. Each sample consisted of three subsamples (grabs) collected using a petite Ponar. Grabs were sieved in the field using a 500 µm mesh collection net. Once all three grabs were composited they were placed in properly labeled

[5] Equal aliquots of water were collected at one meter intervals throughout the epilimnion and combined to represent the algal community in the lake.

containers (internally and externally) and the contents were preserved to a level of 10% buffered formalin. All benthic samples were collected following the EcoMetrix SOPs.

### 2.8.2 Benthic Invertebrate Community

Hare Lake benthic invertebrate data are summarized in Table 2.8-1.

The mean invertebrate density of the littoral and profundal stations were 5,516 and 1,140 organisms/m$^2$, respectively, with a range of 1,043 to 9,960 and 314 to 1,715 organisms/m$^2$, respectively. A total of 37 taxa were identified from the littoral zone samples with a mean per sample of 14 taxa and a range of 11 to 22. The profundal samples contained 12 discrete taxa with a mean of six and a range of four to eight. Simpson's Diversity values for the littoral and profundal samples had means of 0.84 and 0.68 with ranges of 0.76 to 0.90 and 0.55 to 0.76, respectively. The mean value of the littoral zone was relatively high with a mean maximum diversity value of 0.93. The profundal maximum attainable D value was 0.82 indicating the mean value was moderate. The mean Simpsons' Evenness values for the littoral and profundal zones were 0.52 and 0.57, respectively. The range of Evenness values for the littoral and profundal samples was 0.32 to 0.77 and 0.46 to 0.68, respectively. Both mean values were moderate as the Evenness scale ranges from 0 to 1 with 1 indicating a balanced community and 0 being indicative of a community dominated by large numbers of a relatively few taxa.

The benthic invertebrate communities in both littoral and profundal habitats were dominated by chironomids and sphaeriids. These two families comprised over 65% and 86% in the littoral and profundal zones, respectively. Three other taxa present in the profundal samples comprised more that 1% of the community (i.e., nemertean roundworms, mites, and ostracods). One family of amphipods and Tipulidae (crane flies) accounted for the remainder of the community. The littoral zone was more diverse than the profundal zone with additional taxa accounting for 1% of more of the community including, annelid worms, amphipods, mayflies, caddisflies and snails. Taxa present but not highly abundant (i.e., <1% relative abundance) included dragonflies, caddisflies, biting midges, midges and clams.

**Table 2.8-1: Benthos in Hare Lake**

| | Hare Lake | |
|---|---|---|
| | Profundal | Littoral |
| TOTAL NUMBER OF ORGANISMS | 80 | 386 |
| DENSITY (No./m$^2$) | 1140 | 5516 |
| TOTAL NUMBER OF TAXA | 12 | 37 |
| MEAN NUMBER OF TAXA | 6 | 14 |
| SIMPSON'S DIVERSITY | 0.68 | 0.84 |
| SIMPSON'S EVENNESS | 0.57 | 0.52 |

| | | |
|---|---|---|
| TOTAL EPT INDEX | 0 | 3 |
| MEAN EPT INDEX | 0.0 | 1.0 |
| HILSENOFF INDEX | 7.45 | 6.17 |
| EPT/CHIRONOMIDAE | 0.00 | 0.10 |
| | | |
| MAYFLIES | 0% | 2% |
| STONEFLIES | 0% | 0% |
| CADDISFLIES | 0% | 2% |
| EPT | 0% | 3% |
| CHIRONOMIDS | 47% | 39% |
| ANNELID WORMS | 0% | 4% |
| SPHAERIID CLAMS | 39% | 27% |

## 2.9 Fish Community

### 2.9.1 Sampling Program

Fish community surveys of Hare Lake were conducted over a five-year period during three surveys; August 2009, September 2011 and August 2013.

The 2009 survey included fish habitat characterization and fish community sampling using a variety of gear types as appropriate for habitat characteristics within the lake. Baited (i.e., dog kibble) minnow traps, small-mesh experimental gillnets measuring 75 ft x 6 ft with 25 ft panels of 1½", 2" and 2½" mesh, 225 ft x 6 ft experimental gillnets with mesh sizes of 1½", 2" 2½", 3", 4", 5" and 6", and trapnets with 3/8" mesh, 100 ft lead and a 4 ft house were set over a 4-day period. Gillnets were set within representative habitats and at a variety of depth strata. A 400 $m^2$ section of sand beach at the western end of the lake near the road access was also fished using a seine net (3/8" mesh 54 ft length). Passive gear (i.e., gillnets, trapnets, minnow traps) were set overnight for between 18 and 20 hours.

During September 2011, a Broad-scale Fish Community Monitoring (BsM) program was undertaken following Ontario Ministry of Natural Resources (OMNR) protocol (Sandstrom et al., 2009). In August 2013, the BsM program was again undertaken following revised OMNR protocols (Sandstrom et al., 2013) in consultation with Ontario Ministry of Natural Resources staff. For both the 2011 and 2013 surveys, large mesh nets consisted of two gangs each with 8 non-sequential single series panels (38, 51, 64, 76, 89 102, 114 and 127 mm mesh) for a total length of 49.6 m and height of 1.8 m. Small mesh nets consisted of two gangs each with 5 non-sequential single series panels (13, 19, 25, 32 and 38 mm mesh) for a total length of 25.0 m and height of 1.8 m. For both the large and small-mesh nets, different size mesh panels were at the ends where the two gangs were joined together and the end of the gang or net that was set closest to shore was randomly assigned.

The recommended minimum sample size by lake area: 20 to 100 ha for 2011 and 50 to 100 ha for 2013, and maximum depth: 20 to 35 m for both surveys (Sandstrom et al., 2009; Sandstrom et al., 2013) is described in Table 2.9-1. For the 2013 survey the recommended minimum strata sample size was based on Lake Trout (*Salvelinus namaycush)* since Lake Trout was the only BsM target species historically known to be native to Hare Lake (Sandstrom et al., 2013).

**Table 2.9-1: Minimum Stratum Sample Size for Large and Small Mesh Nets**

| Sampling Stratum | BsM 2011 (Sandstrom et al., 2009) | | BsM 2013 (Sandstrom et al., 2013) | |
|---|---|---|---|---|
| | Small Mesh | Large Mesh | Small Mesh | Large Mesh |
| 1-3 m | 2 | 2 | 3 | 2 |
| 3-6 m | 2 | 2 | 3 | 2 |
| 6-12 m | 2 | 2 | 2 | 4 |
| 12-20 m | 2 | 2 | 2 | 2 |
| 20-35 m | - | 2 | 2 | 2 |

Notes: m = metres; BsM = Broad-scale Fish Community Monitoring

All collected fish, regardless of the collection method, were identified, enumerated and released at the point of capture with the exception of mortalities, fish sacrificed for mandatory detailed sampling and tissue chemistry. Length and weight data were recorded for fish collected in gillnets during the 2009 and 2011 survey, and only for fish collected in large nets for the 2013 survey. For fish collected from small-mesh nets in 2013, only length data were recorded. In 2011 and 2013, fish collected in large-mesh nets were recorded for the entire net whereas fish collected in small-mesh nets were recorded by gang with gang 1 always being the closest to shore. For the 2013 survey, sex was recorded and aging structures were collected for primary (e.g., Northern Pike [*Esox Lucius*]) and secondary (e.g., Yellow Perch [*Perca flavescens]*) species collected in large mesh nets. Scales and otoliths were collected from Yellow Perch, and scales and cleithra were retained from Northern Pike.

Water quality data were collected in-situ concurrent with all surveys using a YSI 600 QS Sonde and YSI 650 MDS display-datalogger. During 2009 and 2011, pH, conductivity, dissolved oxygen and water temperature profiles were measured. Water temperature and dissolved oxygen profiles were recorded concurrent with 2013 survey. At each profile location, Secchi depth was recorded as the depth mid-way between where the Secchi disc first disappears on decent and then reappears with recovery.

All fish and water quality data were recorded manually on data sheets and entered into spreadsheets for subsequent data analysis and storage. All data transferred into the master database was double checked for quality control by EcoMetrix after field activities were completed.

### 2.9.2 Fish Species

During the 1960s and 1970s, Hare Lake supported coldwater fish species such as Lake Trout and Cisco (*Coregonus artedi*) (ODLF, 1960). In 1991 it was recommended that Splake (Brook Trout [*Salvelinus fontinalis*] x Lake Trout hybrid) be stocked and if successful, that Lake Trout be stocked (OMNR, 1991). Currently, Hare Lake supports a predominantly coolwater fish community with Yellow Perch and Northern Pike the most abundant large-bodied fish species. Limited coldwater species remain (i.e., Cisco, Burbot [*Lota lota*]); however these species are not nearly as abundant as the coolwater species.

During August 2009, five gear types (baited minnow traps, trapnet, small-mesh experimental gillnet, full experimental gillnet, seine net) were used to assess the Hare Lake fish community. The combination of these efforts resulted in the capture of six species including 303 Yellow Perch, 100 Spottail Shiner (*Notropis hudsonius*) 60 Logperch (*Perca caprodes*), 19 Northern Pike, 2 Cisco and one Burbot (Table 2.9.2). Both Ciscoes captured were sexually mature adults ~ 12 cm in total length (i.e., “dwarf” form).

The combined effort of the BsM netting program conducted in September 2011 resulted in the capture of nine fish species. Five of the species were captured previously (2009) including Yellow Perch, Spottail Shiner, Northern Pike, “dwarf” form Cisco and Logperch. Additional species included Longnose Sucker (*Catostomus catostomus*), Trout-Perch (*Percopsis omiscomaycus*), and Spoonhead Sculpin (*Cottus ricei*). Yellow Perch and Northern Pike and remained the most common large-bodied fish with catches of 513 and 67, respectively. Catch totals for the other species were 29 Cisco, 21 Logperch, 5 Longnose Sucker, 3 Trout-perch, 1 Spoonhead Sculpin and 1 Lake Trout (Table 2.9.2). The catch in Hare Lake in 2011 also included a single Lake Trout specimen, which was fin-clipped indicating that it was a stocked fish.

The 2013 BsM program yielded a total of eight fish species, one of which had not been previously reported (Slimy Sculpin). Yellow Perch (498) and Spottail Shiner (212) were most abundant, followed by “dwarf” form Cisco (21) and Northern Pike (12). Longnose Sucker (3), Trout-perch (2), Spoonhead Sculpin (2) and Slimy Sculpin (*Cottus cognatus*) (1) were relatively scarce (Table 2.9.2).

**Table 2.9-2: Fish Catch Summary for Hare Lake, 2009 to 2013**

| Date | Method | Sets | Effort (hrs) | Lake Trout | Cisco | Northern Pike | Spottail Shiner | Longnose Sucker | Trout-perch | Burbot | Slimy Sculpin | Spoonhead Sculpin | Yellow Perch | Logperch |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Aug-09 | seine net | 1 | 400 | - | - | - | 12 | - | - | - | - | - | 3 | 60 |
| Aug-09 | baited minnow trap | 8 | 20 | - | - | - | 1 | - | - | - | - | - | - | - |
| Aug-09 | trap net | 2 | 18 | - | - | 2 | 87 | - | - | - | - | - | 293 | - |
| Aug-09 | exp gillnet | 6 | 20 | - | 2 | 8 | - | - | - | 1 | - | - | 4 | - |
| Aug-09 | sm exp gillnet | 3 | 20 | - | - | 9 | - | - | - | - | - | - | 3 | - |
| Sep-11 | lg BsM | 20 | 20 | 1 | - | 43 | - | 2 | - | - | - | - | 51 | - |
| Sep-11 | sm BsM | 16 | 20 | - | 29 | 24 | 156 | 3 | 3 | - | - | 1 | 462 | 21 |
| Aug-13 | lg BsM | 13 | 18 | - | 4 | 9 | - | 3 | - | - | - | - | 7 | - |
| Aug-13 | sm BsM | 12 | 18 | - | 17 | 3 | 215 | - | 2 | - | 1 | 2 | 488 | - |

**Notes:** Aug = August; Sep = September; exp = experimental, sm = small; lg = large; hrs = hours; BSM = Broad-scale Fish Community Monitoring.
Effort for seine net is square metres.

Since 2009, eleven species have been documented for Hare Lake. Yellow Perch and Spottail Shiner have been the most abundant species inhabiting the lake. Northern Pike and Cisco were common, while the Longnose Sucker, Trout-perch, Logperch and Spoonhead Sculpin were uncommon. Burbot and Slimy Sculpin were rare. Two additional species, Walleye and Fathead Minnow (*Pimephales promelas*) have been reported (ODLF, 1960; OMNR 1975, 1991) but have not been captured recently. Walleye were stocked in the 1950s but likely no longer inhabit the lake. As indicated above, single Lake Trout specimen has been collected, which was fin-clipped indicating that it was a stocked fish.

### 2.9.3 Fish Community Age Structure

The age structure of the fish community in Hare Lake has been inferred from length distribution data. It is assumed that Hare Lake supports all age classes (young-of-the-year, juvenile, adult) of each of the resident fish species[6] that were captured between 2009 and 2013 during the baseline program, though not all age classes of each individual species have been collected. For example, although all Cisco collected were “dwarf” form, they were also representative of more than one age class as fish ranged in size from 81 mm (juvenile) to 193 mm (adult) with the largest fish captured during the 2013 survey. In the 2011 survey both juvenile and adult Northern Pike were collected and they ranged in size from 86 to 733 mm fork length. Only adult Northern Pike were collected during the 2013 survey ranging from 538 to 680 mm fork length.

There is no evidence of a Lake Trout population in Hare Lake; rather the single specimen that was collected in 2011 was a stocked fish.

Length distribution data for the two most populous fish species in Hare Lake, Yellow Perch and Spottail Shiner, were plotted to provide more insight into the age structure of these species on a year-by-year basis. The length frequency distribution plots are provided in Figure 2.9-1 (2011) and 2.9-2 (2013) for Yellow Perch and Figures 2.9-3 (2011) and 2.9-4 (2013) for Spottail Shiner.

The length frequency plots for Yellow Perch based on collections made in 2011 and 2013 provide similar results. It is inferred from the data that Yellow Perch in Hare Lake range in age from 0+ years (young-of-the-year) to 7+ years. It appears that 1+ fish range in length from about 75 mm to 88 mm and are the most numerous year class. A second peak in the plot appears between about 90 mm to 100 mm in length corresponding to 2+ fish. A broad peak between about 102 mm to 130 mm in length may represent 3+ fish or a combined age cohort of 3+ and 4+ fish. These cohorts are easier to discern based on the 2013 data in contrast to the 2011 data. Fish greater in length than approximately 135 mm are less

[6] Excluding Lake Trout – The single Laker Trout specimen that was collected was a stocked fish and does not represent a population in the lake.

abundant but fish up to about 260 mm have been collected and the fish in this size range likely represent the age classes 5+ to 8+.

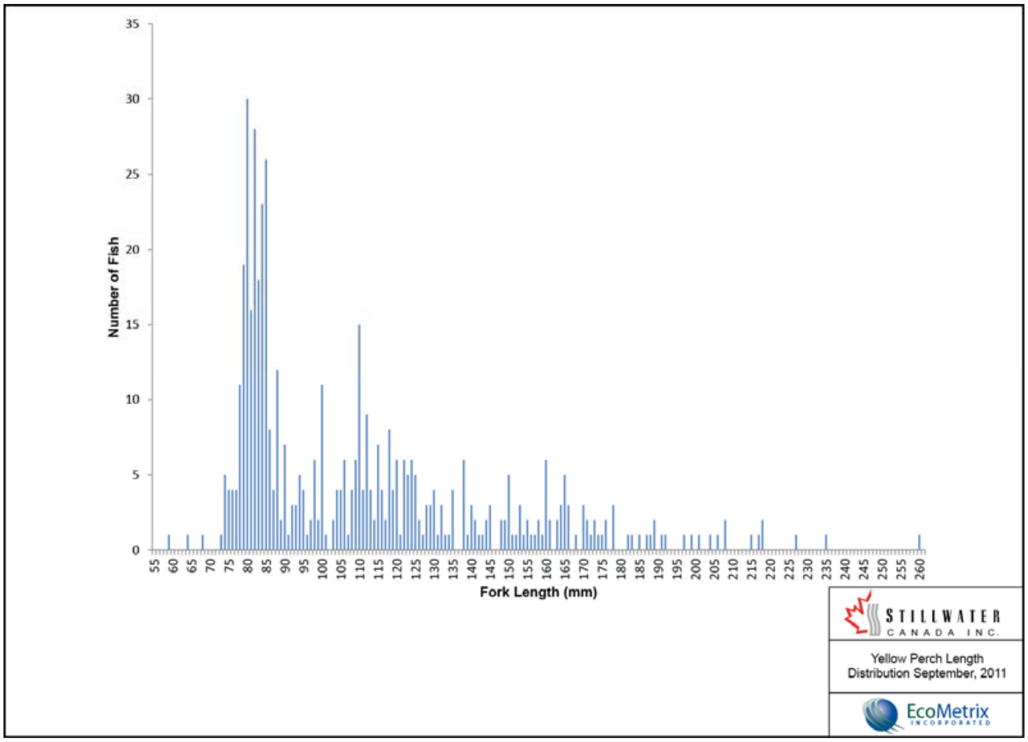


**Figure 2.9-1: Yellow Perch Length Distribution September, 2011**

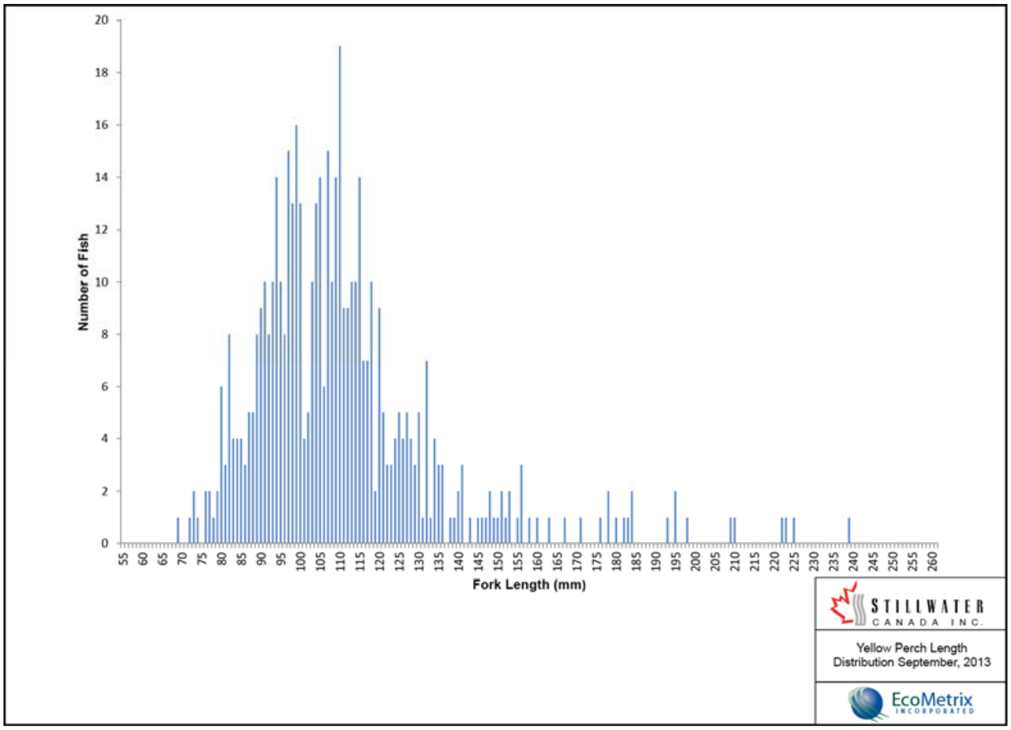


**Figure 2.9-2: Yellow Perch Length Distribution August, 2013**

The length frequency plots for Spottail Shiner based on collections made in 2011 and 2013 also provide similar results. It is inferred from the data that Spottail Shiner in Hare Lake range in age from 0+ years (young-of-the-year) to 2+ years. In 2011 the 1+ age cohort was more abundant than the 0+ cohort, whereas in 2013 the 0+ age cohort was the most abundant followed by the 1+ fish and 2+ fish.

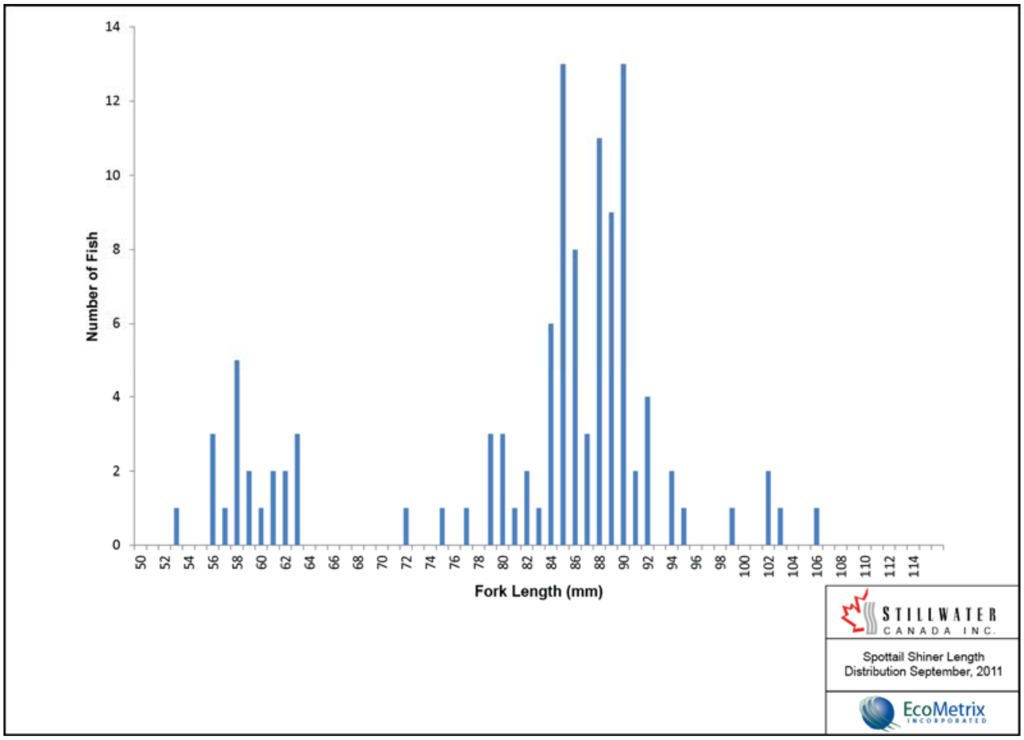


**Figure 2.9-3: Spottail Shiner Length Distribution September, 2011**

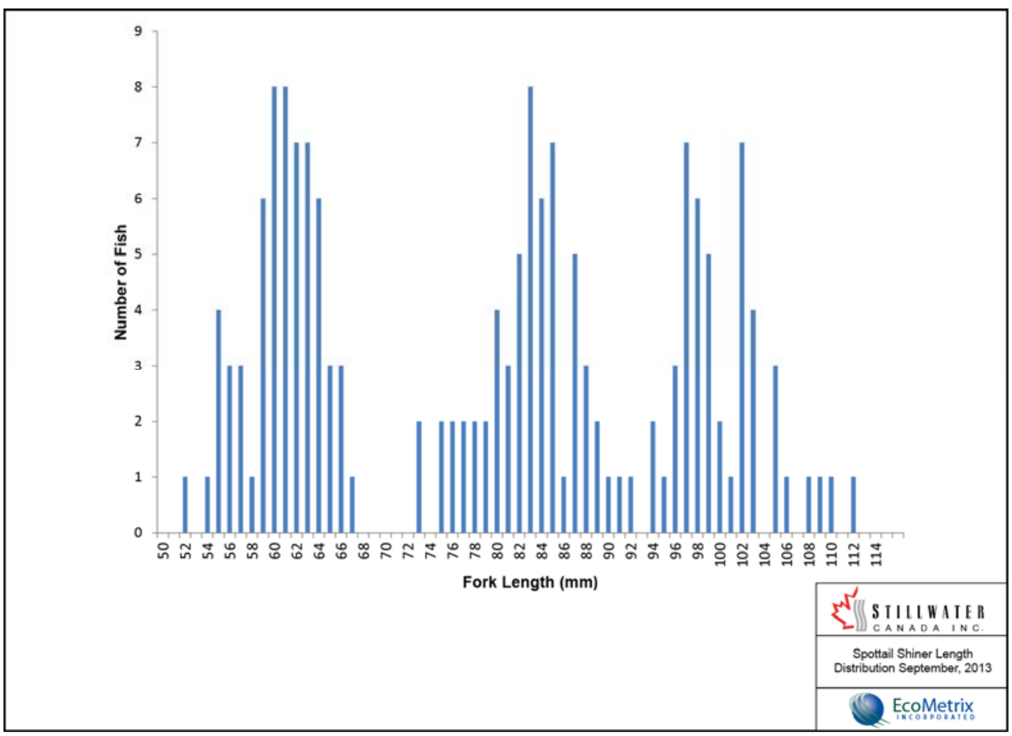


**Figure 2.9-4: Spottail Shiner Length Distribution August, 2013**

### 2.9.4 Hare Lake Broad-scale Netting Program Results

A total of 20 large and 16 small mesh nets were set in Hare Lake during the September, 2011 survey (Figure 2.9-5). All nets were set between 13:00 and 17:00 hours. Nets were pulled between approximately 08:00 and 11:00 hours with a few exceptions. Only three nets exceeded the maximum set time of 22 hours (efforts 31, 35 and 36). Set durations generally ranged between 18.8 and 22 hours (Table 2.9-3). Nets were set in locations to cover all required depth strata and to ensure even distribution around the lake. Nets were confined to a single depth stratum except when the stratum was too narrow for the entire net. In this circumstance nets were assigned to the stratum in which the majority of the net was set.

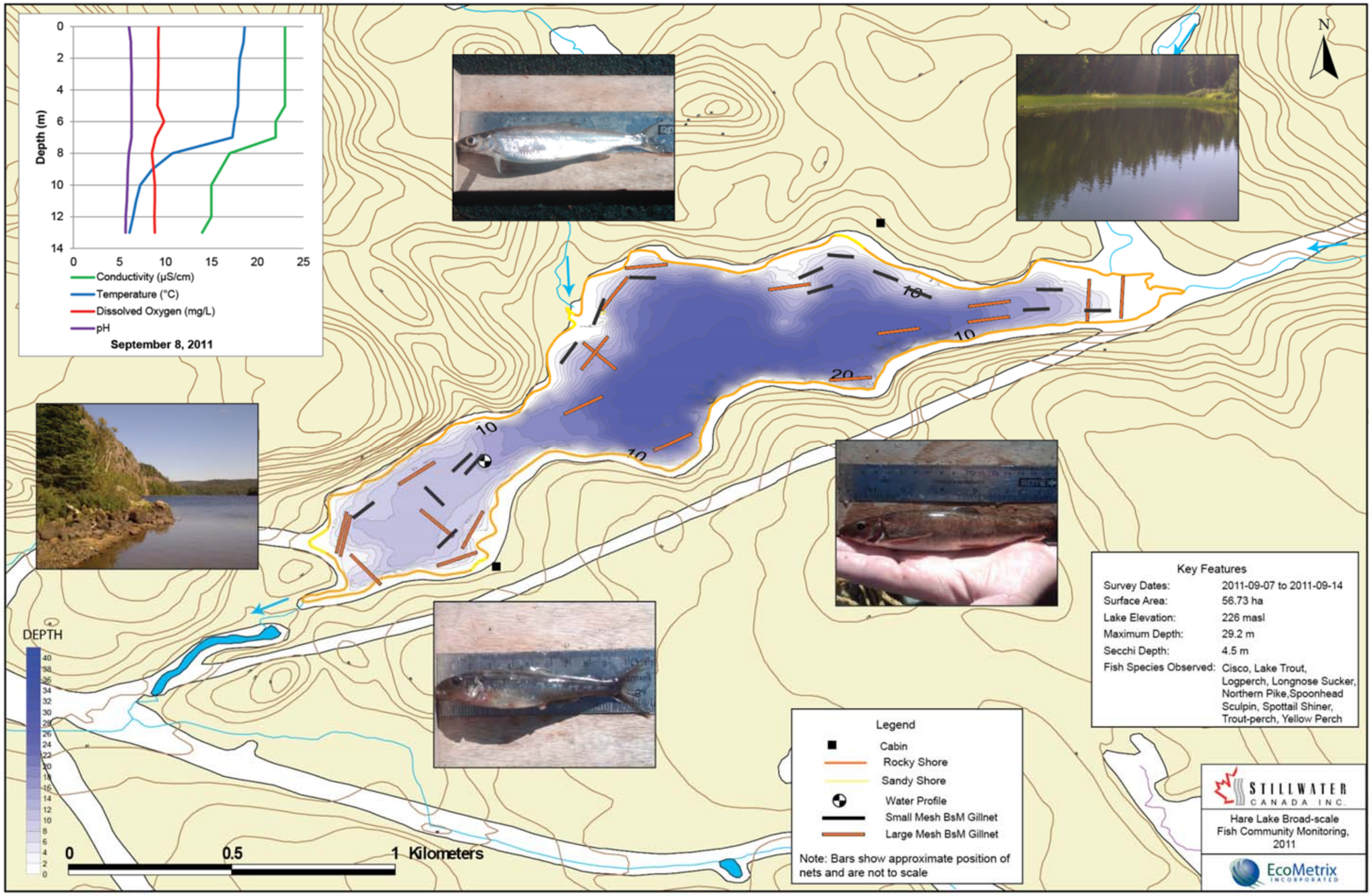


**Figure 2.9-5: Hare Lake Broad-scale fish community monitoring 2011**

## Table 2.9-3: Summary of the Broad-scale Fish Community Monitoring Survey in Hare Lake, September, 2011

| Effort | Stratum Depth (m) | Net Depth (m) | | | Set Duration (hr) | Total Catch | Catch per Unit Effort (fish/hr) | |
|---|---|---|---|---|---|---|---|---|
| | | Start | Mid | End | | | | |
| *Small Mesh* | | | | | | | | |
| 3 | 1-3 | 1.2 | 1.2 | 1.0 | 19.47 | 59 | 3.03 | 3.32 |
| 12 | | 1.5 | 1.8 | 1.8 | 19.83 | 64 | 3.23 | |
| 22 | | 1.5 | 2.1 | 2.7 | 20.30 | 87 | 4.29 | |
| 30 | | 2.1 | 1.5 | 3.0 | 20.33 | 55 | 2.70 | |
| 10 | 3-6 | 3.0 | 4.6 | 5.5 | 20.35 | 64 | 3.14 | 2.78 |
| 19 | | 6.0 | 5.8 | 5.5 | 19.55 | 51 | 2.61 | |
| 29 | | 3.7 | 4.3 | 4.9 | 20.82 | 34 | 1.68 | |
| 33 | | 3.7 | 4.9 | 6.4 | 21.35 | 79 | 3.70 | |
| 4 | 6-12 | 8.0 | 8.5 | 9.1 | 20.62 | 77 | 3.73 | 1.56 |
| 9 | | 11.0 | 11.3 | 11.0 | 20.17 | 10 | 0.50 | |
| 11 | | 8.8 | 9.1 | 9.1 | 19.57 | 17 | 0.87 | |
| 20 | | 12.0 | 11.8 | 11.3 | 20.32 | 12 | 0.59 | |
| 21 | | 9.4 | 9.6 | 10.0 | 19.95 | 26 | 1.30 | |
| 34 | | 7.6 | 7.0 | 6.7 | 21.60 | 49 | 2.27 | |
| 31 | 12-20 | 13.7 | 12.8 | 12.8 | 22.02 | 11 | 0.55 | 0.36 |
| 32 | | 15.0 | 14.0 | 12.2 | 19.43 | 4 | 0.21 | |
| | | | | Total | 325.68 | 699 | 2.15 | |
| *Large Mesh* | | | | | | | | |
| 14 | 1-3 | 1.8 | 1.5 | 2.1 | 21.42 | 26 | 1.21 | 0.56 |
| 18 | | 1.0 | 3.4 | 1.0 | 18.83 | 14 | 0.74 | |
| 27 | | 2.4 | 3.4 | 2.1 | 20.63 | 4 | 0.19 | |
| 36 | | 1.0 | 3.6 | 1.8 | 22.55 | 3 | 0.13 | |
| 2 | 3-6 | 3.7 | 5.2 | 6.0 | 19.15 | 11 | 0.57 | 0.31 |
| 15 | | 4.5 | 6.0 | 6.4 | 21.83 | 11 | 0.50 | |
| 17 | | 3.4 | 5.5 | 4.3 | 19.00 | 0 | 0.00 | |
| 26 | | 3.0 | 4.3 | 3.6 | 20.25 | 3 | 0.15 | |
| 1 | 6-12 | 8.8 | 9.1 | 9.4 | 19.00 | 1 | 0.05 | 0.2 |
| 7 | | 10.7 | 8.8 | 7.0 | 19.92 | 2 | 0.10 | |
| 8 | | 5.8 | 6.0 | 6.4 | 19.88 | 15 | 0.75 | |
| 25 | | 11.0 | 11.0 | 9.1 | 22.00 | 2 | 0.09 | |
| 28 | | 9.4 | 9.8 | 10.4 | 21.17 | 0 | 0.00 | |
| 13 | 12-20 | 17.0 | 18.6 | 21.0 | 21.17 | 1 | 0.05 | 0.05 |
| 16 | | 11.6 | 13.7 | 15.2 | 19.00 | 0 | 0.00 | |
| 24 | | 11.0 | 18.0 | 12.8 | 21.63 | 2 | 0.09 | |
| 35 | | 12.0 | 13.7 | 14.6 | 22.25 | 1 | 0.04 | |
| 5 | 20-35 | 20.1 | 22.5 | 23.5 | 21.00 | 1 | 0.05 | 0.02 |
| 6 | | 26.2 | 26.2 | 24.7 | 19.90 | 0 | 0.00 | |
| 23 | | 20.7 | 24.0 | 25.0 | 21.50 | 0 | 0.00 | |
| | | | | Total | 412.08 | 97 | 0.24 | |

Notes: All nets had two gangs 1.8 m in height; m = metres; hr = hours.

Nine species of fish were captured during the 2011 BsM survey: Spottail Shiner (156), Longnose Sucker (5), Northern Pike (67), "dwarf" form Cisco (29), Lake Trout (1), Trout-perch (3), Spoonhead Sculpin (1), Yellow Perch (513), and Logperch (21). A total of 796 fish were captured; 699 fish in the small mesh nets and 97 fish in the large mesh nets (Table 2.9-4). One Northern Pike fell out of net 29, gang 2 but it was not included in the results as per the BsM protocol (Sandstrom et al., 2009). Northern Pike and Yellow Perch were the most common large-bodied fish, whereas Spoonhead Sculpin were relatively scarce. As noted above, the single Lake Trout collected had its left pectoral fin clipped indicating it was a stocked fish.

The 6-12 m stratum included representative fish from the most species (8) while the 20-35 m stratum had the fewest species (1) (Table 2.9-4). Catches varied greatly between the two different net sizes, with only pike, perch, sucker and trout being captured in large mesh nets while small mesh nets collected all species with the exception of Lake Trout.

Catch-per-unit-effort (CPUE) was 0.24 fish/hr for large-mesh nets and 2.15 fish/hr for the small-mesh nets (Table 2.9-3). CPUE decreased with increased depth ranging from 0.56 to 0.02 fish/hr for large-mesh and 3.32 to 0.36 fish/hr for small-mesh sets. When the two gear types were combined, CPUE decreased from 1.90 fish/hr in the shallowest depth strata (i.e., 1 to 3 m) to 0.15 fish/hr in the fourth depth strata (i.e., 12 to 20 m). The overall CPUE for all gear combined was 1.08 fish/hr.

Mean fork length for Northern Pike was 461 ± 198 mm with 43 caught in the large mesh nets and 24 caught in the small mesh nets. Mean weight of the Northern Pike was 1,017 ± 793 g with the heaviest fish caught in the 1-3 m stratum (3,250 g). The average fork length of the Yellow Perch captured during the survey was 181 ± 25 mm for the large nets and 102 ± 25 mm for the small nets (104 ± 30 mm for gang 1 and 100 ± 23 mm for gang 2). The perch from the large nets had a mean weight of 70 ± 32 g and from the small mesh nets had an average weight of 14 ± 12 g.

Biomass per unit effort for large mesh nets was 151.88 g/hr, for small mesh nets was 60.05 g/hr and all gear combined was 111.34 g/hr. To establish a baseline, the total biomass (i.e., g/net) was calculated by net size (i.e., large and small) and for the small mesh nets by gang (i.e., gang 1 and gang 2). Large mesh nets had a mean biomass of 3,129 g and the small mesh nets had a combined gang mean biomass of 611 g (gang 1 mean, 733 g; gang 2 mean, 490 g).

To gauge the species diversity in Hare Lake, the Shannon diversity index and Berger-Parker dominance index were calculated. The Shannon diversity index was 1.10 and the Berger-Parker dominance index was 1.55.

## Table 2.9-4: Summary of Fish Collected by Stratum and Net Size for Broad-scale Fish Community Monitoring in Hare Lake, September, 2011

| Stratum | Effort | Gear* | Gang | Species and Code | | | | | | | | | Total Catch |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | SH (201) | LS (162) | NP (131) | Cisco* (093) | LT (081) | TP (291) | SC (383) | YP (331) | LP (342) | |
| 1-3 m | 3 | 2 | 1 | 9 | - | 1 | - | - | - | - | 19 | 4 | 33 |
| | | | 2 | 10 | - | - | - | - | - | - | 11 | 5 | 26 |
| | 12 | 2 | 1 | 18 | - | - | - | - | - | - | 19 | 1 | 38 |
| | | | 2 | 6 | - | - | - | - | - | - | 20 | - | 26 |
| | 14 | 1 | 0 | - | - | 11 | - | - | - | - | 15 | - | 26 |
| | 18 | 1 | 0 | - | - | 10 | - | - | - | - | 4 | - | 14 |
| | 22 | 2 | 1 | 12 | - | - | - | - | - | - | 23 | - | 35 |
| | | | 2 | 13 | - | - | - | - | - | - | 39 | - | 52 |
| | 27 | 1 | 0 | - | - | 1 | - | - | - | - | 3 | - | 4 |
| | 30 | 2 | 1 | 8 | - | 1 | - | - | - | - | 8 | 3 | 20 |
| | | | 2 | 17 | - | | - | - | - | - | 18 | - | 35 |
| | 36 | 1 | 0 | - | - | 3 | - | - | - | - | | - | 3 |
| 3-6 m | 2 | 1 | 0 | - | - | 4 | - | - | - | - | 7 | - | 11 |
| | 10 | 2 | 1 | 8 | - | 1 | - | - | - | - | 26 | - | 35 |
| | | | 2 | 5 | - | | - | - | - | - | 24 | - | 29 |
| | 15 | 1 | 0 | - | - | 5 | - | - | - | - | 6 | - | 11 |
| | 17 | 1 | 0 | No fish | | | | | | | | | 0 |
| | 19 | 2 | 1 | 1 | - | - | - | - | - | - | 11 | - | 12 |
| | | | 2 | 6 | - | - | - | - | - | - | 32 | 1 | 39 |
| | 26 | 1 | 0 | | - | 2 | - | - | - | - | 1 | - | 3 |
| | 29 | 2 | 1 | 6 | - | 1 | - | - | - | - | 7 | 3 | 17 |
| | | | 2 | 3 | - | - | - | - | - | - | 14 | - | 17 |
| | 33 | 2 | 1 | 8 | - | 16 | - | - | - | - | 27 | - | 51 |
| | | | 2 | 10 | - | - | - | - | - | - | 17 | 1 | 28 |
| 6-12 m | 1 | 1 | 0 | - | - | 1 | - | - | - | - | - | - | 1 |
| | 4 | 2 | 1 | - | - | - | | - | - | - | 53 | - | 53 |
| | | | 2 | 1 | - | 1 | - | - | - | - | 22 | - | 24 |
| | 7 | 1 | 0 | - | - | 2 | - | - | - | - | - | - | 2 |
| | 8 | 1 | 0 | - | - | - | - | - | - | - | 15 | - | 15 |
| | 9 | 2 | 1 | - | - | - | 2 | - | 1 | - | - | - | 3 |
| | | | 2 | - | 2 | - | 3 | - | - | - | 2 | - | 7 |
| | 11 | 2 | 1 | 1 | - | - | 2 | - | - | - | 2 | - | 5 |
| | | | 2 | 2 | - | - | - | - | - | - | 10 | - | 12 |
| | 20 | 2 | 1 | - | - | - | 1 | - | - | 1 | 1 | - | 3 |
| | | | 2 | 1 | - | - | 2 | - | 1 | - | 5 | - | 9 |
| | 21 | 2 | 1 | - | - | - | 3 | - | - | - | 3 | - | 6 |
| | | | 2 | - | - | - | 3 | - | - | - | 17 | - | 20 |

**2.9-4 (cont.): Summary of Fish Collected by Stratum and Gear for Broad-scale Fish Community Monitoring in Hare Lake, September, 2011**

| Stratum | Effort | Gear* | Gang | Species and Code | | | | | | | | | Total Catch |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | SH (201) | LS (162) | NP (131) | Cisco* (093) | LT (081) | TP (291) | SC (383) | YP (331) | LP (342) | |
| 6-12 m | 25 | 1 | 0 | - | - | 2 | - | - | - | - | - | - | 2 |
| | 28 | 1 | 0 | No fish | | | | | | | | | 0 |
| | 34 | 2 | 1 | 5 | - | 2 | - | - | - | - | 12 | - | 19 |
| | | | 2 | 6 | - | 1 | - | - | - | - | 20 | 3 | 30 |
| 12-20 m | 13 | 1 | 0 | - | - | 1 | - | - | - | - | - | - | 1 |
| | 16 | 1 | 0 | No fish | | | | | | | | | 0 |
| | 24 | 1 | 0 | - | 1 | 1 | - | - | - | - | - | - | 2 |
| | 31 | 2 | 1 | - | 1 | - | 2 | - | - | - | - | - | 3 |
| | | | 2 | - | - | - | 8 | - | - | - | - | - | 8 |
| | 32 | 2 | 1 | - | - | - | 3 | - | 1 | - | - | - | 4 |
| | | | 2 | No Fish | | | | | | | | | 0 |
| | 35 | 1 | 0 | - | - | - | - | 1 | - | - | - | - | 1 |
| 20-35 m | 5 | 1 | 0 | - | 1 | - | - | - | - | - | - | - | 1 |
| | 6 | 1 | 0 | No fish | | | | | | | | | 0 |
| | 23 | 1 | 0 | No fish | | | | | | | | | 0 |
| Total | | | | 156 | 5 | 67 | 29 | 1 | 3 | 1 | 513 | 21 | 796 |

Notes: All nets had two gangs 1.8 m in height; Gear 1 = large mesh; Gear 2 = small mesh; SH = Spottail Shiner; LN = Longnose Sucker; NP = Northern Pike; LT = Lake Trout; TP = Trout-perch; SC = Spoonhead Sculpin; YP = Yellow Perch; LP = Logperch
* = Cisco were drawf form

A water profile was collected during the survey mid-lake near where it is deepest (on September 8, 2011). The surface water temperature was 18.6 °C. A thermocline was observed between approximately 6 and 10 m, with temperatures above between 17 and 18°C and temperatures below approximately 6°C. Dissolved oxygen levels in the water column ranged from 9.8 to 8.8 mg/L with all measurements above 6.5 mg/L (minimum guideline for fresh water cold water ecosystem; Canadian Council of Ministers of the Environment [CCME], 1999). Secchi depth was recorded as 4.5 m.

A total of 13 large and 12 small mesh nets were set in Hare Lake during the August, 2013 survey (Figure 2.9-6). All nets were set between 13:00 and 17:00 hours and all nets were pulled between 08:00 and 11:00 hours with the exception of effort 003 which exceeded the maximum set duration of 22 hours. Set durations ranged between 16.5 and 19.8 hours (excluding effort 003) (Table 2.9-5). Nets were set in locations to cover all required depth strata and to ensure even distribution around the lake. All nets were set perpendicular or oblique to shore except where a narrow depth stratum required the net to be set parallel to shore to ensure that the net remained within the desired depth stratum.

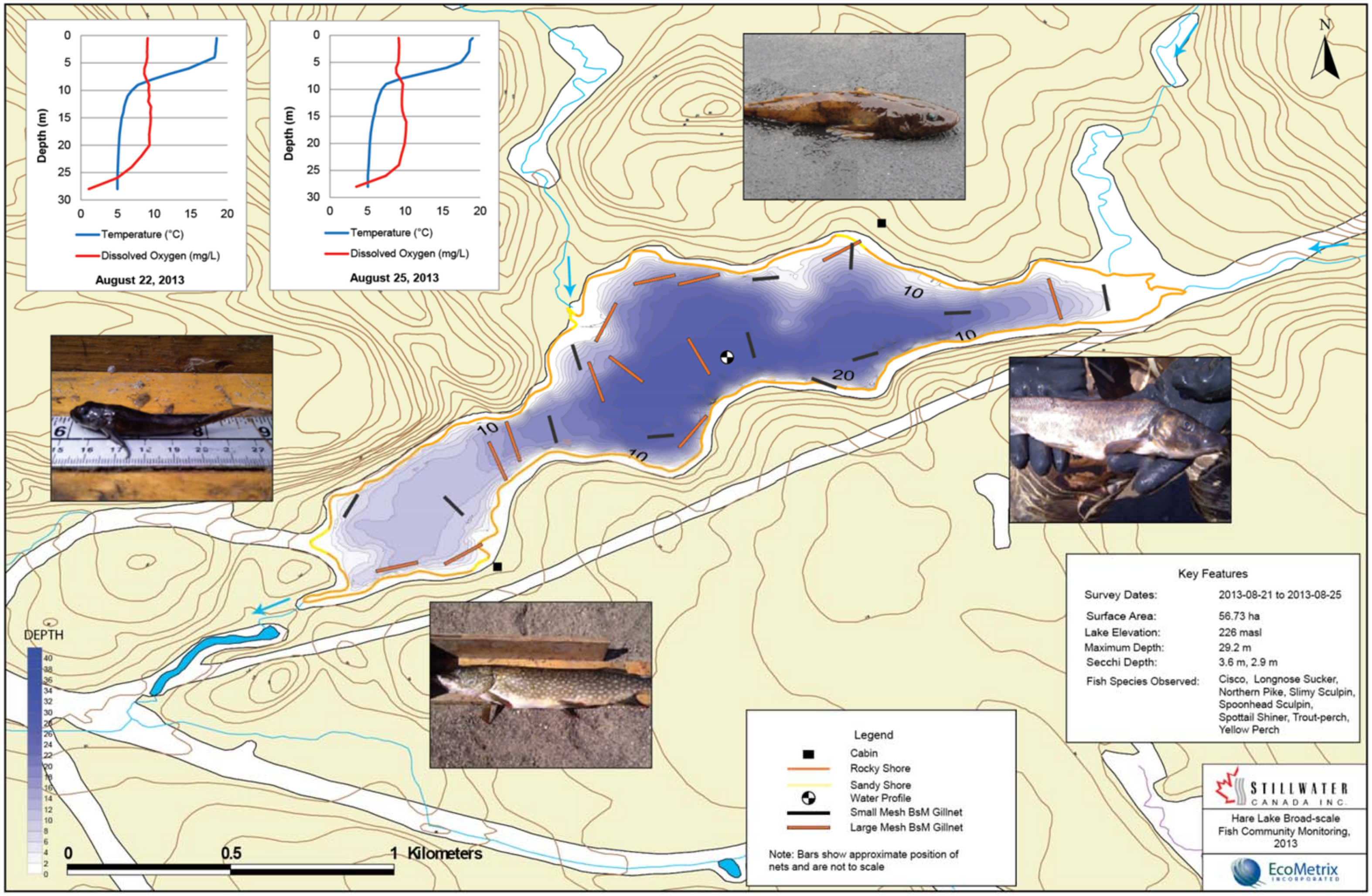


**Figure 2.9-6: Hare Lake Broad-scale fish community monitoring 2013**

## Table 2.9-5: Summary of the Broad-scale Fish Community Monitoring in Hare Lake, August, 2013

| Effort* | Stratum Depth (m) | Net Depth (m) | | | Set Duration (hr) | Total Catch | Catch per Unit Effort (Fish/hr) | |
|---|---|---|---|---|---|---|---|---|
| | | Start | Mid | End | | | | |
| *Small Mesh* | | | | | | | | |
| 010 | 1 - 3 | 1.2 | 1.5 | 2.4 | 16.47 | 88 | 5.40 | 9.8 |
| 013 | | 1.0 | 1.0 | 1.0 | 17.75 | 89 | 5.01 | |
| 021 | | 1.0 | 2.4 | 1.5 | 18.83 | 139 | 7.38 | |
| 004 | 3 - 6 | 3.0 | 4.6 | 4.3 | 17.42 | 102 | 5.86 | 7.43 |
| 020 | | 3.0 | 4.3 | 3.7 | 17.18 | 172 | 10.01 | |
| 022 | | 3.0 | 4.3 | 3.0 | 17.50 | 113 | 6.46 | |
| 019 | 6 - 12 | 9.1 | 9.4 | 9.8 | 18.17 | 10 | 0.55 | 0.30 |
| 024 | | 9.1 | 10.7 | 11.9 | 18.42 | 1 | 0.05 | |
| 007 | 12 - 20 | 11.9 | 13.4 | 14.9 | 19.05 | 1 | 0.05 | 0.08 |
| 014 | | 14.3 | 18.9 | 17.3 | 19.03 | 2 | 0.16 | |
| 005 | 20-35 | 25.3 | 28.3 | 28.3 | 17.48 | 6 | 0.34 | 0.29 |
| 023 | | 19.8 | 21.3 | 21.9 | 17.00 | 4 | 0.24 | |
| | | | | Total | 214.30 | 728 | 3.40 | |
| *Large Mesh* | | | | | | | | |
| 009 | 1 - 3 | 1.8 | 1.8 | 1.8 | 17.90 | 0 | 0 | 0.25 |
| 015 | | 1.2 | 1.8 | 1.0 | 18.62 | 9 | 0.48 | |
| 006 | 3 - 6 | 6.1 | 4.6 | 4.3 | 19.82 | 1 | 0.05 | 0.08 |
| 017 | | 3.7 | 4.3 | 4.6 | 18.55 | 2 | 0.11 | |
| 002 | 6 - 12 | 6.7 | 7.0 | 6.1 | 19.18 | 0 | 0 | 0.04 |
| 003 | | 10.6 | 11.9 | 11.3 | 22.95 | 2 | 0.08 | |
| 008 | | 6.1 | 7.6 | 7.6 | 17.95 | 1 | 0.06 | |
| 016 | | 10.6 | 8.8 | 10.4 | 18.80 | 0 | 0 | |
| 025 | | 9.1 | 9.8 | 10.7 | 17.83 | 1 | 0.06 | |
| 011 | 12 - 20 | 11.9 | 15.2 | 152 | 17.75 | 3 | 0.17 | 0.08 |
| 018 | | 11.9 | 14.6 | 19.8 | 18.52 | 0 | 0 | |
| 001 | 20-35 | 27.4 | 27.7 | 27.7 | 18.85 | 3 | 0.16 | 0.11 |
| 012 | | 19.8 | 22.9 | 25.9 | 18.18 | 1 | 0.05 | |
| | | | | Total | 245.90 | 23 | 0.09 | |

Note: * = All nets had two gangs 1.8 m in height; m = metres; hr = hours

Eight species of fish were captured during the 2013 BsM program: Spottail Shiner (212), Longnose Sucker (3), Northern Pike (12), Cisco (21), Trout-perch (2), Slimy Sculpin (1), Spoonhead Sculpin (2) and Yellow Perch (498). A total of 751 fish were captured; 728 fish in the small mesh nets and 23 fish in the large mesh nets (Table 2.9-5). Northern Pike and Yellow Perch were again the most common sport fish while Trout-perch, Spoonhead Sculpin and Slimy Sculpin were relatively scarce. All captured Cisco were "dwarf" form based on size and sexual maturity.

The number of fish species captured from the different depth strata sampled varied with the shallower depth strata (1-3, 3-6 and 6-12 m) including fish from 4 species, the deepest depth strata (12-20 and 20-35 m) included fish from 3 species, and the 12-20 m depth strata including fish from 2 species (Table 2.9-6). Although the number of fish captured in the 1-3 and 3-6 m depth strata (326 and 390 respectively) was much higher than any of the deeper strata (15, 6 and 14).

The data from the 2013 survey yielded a CPUE of 0.09 fish/hr for the large mesh nets, 3.40 fish/hr for the small mesh nets and 1.63 fish/hr when both mesh sizes are combined. Large mesh CPUE was greatest for the 1-3 m stratum (0.25 fish/hr) followed by the 20-35 m (0.11 fish/hr), 3-6 m and 12-20 m (0.08 fish/hr), and 6-12 m (0.04 fish/hr). The combined small mesh CPUE was greatest for the 3-6 m stratum (7.43 fish/hr) followed by the 1-3 m (5.98 fish/hr), 6-12 m (0.30 fish/hr), 20-35 m (0.29 fish/hr), and 12-20 m (0.08 fish/hr). Catch by gang (the first value being gang 1 and always closest to shore) showed little or no difference for the 1-3 m (54.9% to 45.1%), 3-6 m (49.1% to 50.9%) depth strata. The 6-12 m stratum had a larger percentage capture from gang 1 at 72.7% verses gang 2 at 27.3%, whereas the 20-35 m stratum had a lower percentage captive from gang 1 at 40% versus gang 2 at 60%. At the 2-20 m depth stratum all fish were captioned in gang 2.

Biomass per unit of effort for large mesh nets was 56.68 g/hr. To establish a baseline, the total biomass (i.e., g/net) was calculated for large mesh nets. Large mesh nets had a mean biomass of 1072 g. To gauge the overall species diversity in Hare Lake, the Shannon diversity index and Berger-Parker dominance index were calculated using the 2013 data. The Shannon diversity index was 0.86 and the Berger-Parker dominance index was 1.52. By stratum the Shannon diversity index and Berger-Parker dominance index were highest in the 6-12 m (1.25, 2.5) and 1-3 m (0.76, 1.73) strata. In decreasing order the Shannon diversity and Berger-Parker dominance values for the other strata were: 12-20 m (0.69, 2.0); 3-6 m (0.458, 1.27); and 20-35 m (0.51, 1.17).

The Northern Pike captured had a mean fork length of 592 ± 39 mm with 9 caught in the large mesh nets and 3 caught in the small mesh nets (gang 2). Mean weight of the Northern Pike was 1,409 ± 256 g with the heaviest fish caught in the 20-35 m stratum (1,840 g). The average fork length of the Yellow Perch captured during the survey was 197 ± 32 mm for the large nets and 110 ± 22 mm for the small nets (111 ± 22 mm for gang 1 and 108 ± 22 mm for gang 2). Following the BsM protocol (Sandstrom et al., 2013), only the perch from the large mesh nets were weighed and they had a mean weight of 90 ± 38 g.

**Table 2.9-6: Summary of Fish Captured by Stratum and Gear for Broad-scale Fish Community Monitoring in Hare Lake, August, 2013**

| Stratum | Effort | Gear* | Gang | Species Name and Code | | | | | | | | Total Catch |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Yellow Perch (331) | Spottail Shiner (201) | Trout-perch (291) | Cisco* (093) | Northern Pike (131) | Longnose Sucker (162) | Slimy Sculpin (382) | Spoonhead Sculpin (383) | |
| 1 – 3 m | 009 | 1 | 0 | No fish | | | | | | | | 0 |
| | 015 | 1 | 0 | 7 | - | - | - | 2 | - | - | - | 9 |
| | 010 | 2 | 1 | 25 | 20 | - | - | - | - | - | - | 45 |
| | | | 2 | 20 | 23 | - | - | - | - | - | - | 43 |
| | 013 | 2 | 1 | 30 | 17 | 1 | - | - | - | - | - | 48 |
| | | | 2 | 26 | 13 | - | - | 2 | - | - | - | 41 |
| | 021 | 2 | 1 | 38 | 43 | - | - | - | - | - | - | 81 |
| | | | 2 | 42 | 16 | - | - | - | - | - | - | 58 |
| 3 – 6 m | 006 | 1 | 0 | - | - | - | - | 1 | - | - | - | 1 |
| | 017 | 1 | 0 | - | - | - | - | 2 | - | - | - | 2 |
| | 004 | 2 | 1 | 39 | 13 | - | - | - | - | - | - | 52 |
| | | | 2 | 40 | 9 | - | - | 1 | - | - | - | 50 |
| | 020 | 2 | 1 | 51 | 18 | 1 | - | - | - | - | - | 70 |
| | | | 2 | 69 | 33 | - | - | - | - | - | - | 102 |
| | 022 | 2 | 1 | 61 | 7 | - | - | - | - | - | - | 68 |
| | | | 2 | 43 | 2 | - | - | - | - | - | - | 45 |
| 6 – 12 m | 002 | 1 | 0 | No fish | | | | | | | | 0 |
| | 003 | 1 | 0 | - | - | - | - | 2 | - | - | - | 2 |
| | 008 | 1 | 0 | - | - | - | - | 1 | - | - | - | 1 |
| | 016 | 1 | 0 | No fish | | | | | | | | 0 |
| | 025 | 1 | 0 | - | - | - | - | 1 | - | - | - | 1 |
| | 019 | 2 | 1 | 4 | - | - | 4 | - | - | - | - | 8 |
| | | | 2 | - | - | - | 2 | - | - | - | - | 2 |
| | 024 | 2 | 1 | No fish | | | | | | | | 0 |
| | | | 2 | - | - | - | - | - | - | - | 1 | 1 |
| 12 – 20 m | 011 | 1 | 0 | - | - | - | - | - | 3 | - | - | 3 |
| | 018 | 1 | 0 | No fish | | | | | | | | 0 |
| | 007 | 2 | 1 | No fish | | | | | | | | 0 |
| | | | 2 | - | - | - | 1 | - | - | - | - | 1 |
| | 014 | 2 | 1 | No fish | | | | | | | | 0 |
| | | | 2 | - | 1 | - | 2 | - | - | - | - | 3 |
| 20 -35 m | 001 | 1 | 0 | - | - | - | 3 | - | - | - | - | 3 |
| | 012 | 1 | 0 | - | - | - | 1 | - | - | - | - | 1 |
| | 005 | 2 | 1 | - | - | - | 1 | - | - | 1 | - | 2 |
| | | | 2 | - | - | - | 4 | - | - | - | - | 4 |
| | 023 | 2 | 1 | - | - | - | 2 | - | - | - | - | 2 |
| | | | 2 | - | - | - | 1 | - | - | - | 1 | 2 |
| | | | Total | 495 | 215 | 2 | 21 | 12 | 3 | 1 | 2 | 751 |

Notes: All nets had two gangs 1.8 m in height; Gear 1 = large mesh; Gear 2 = small mesh

* = All Cisco were dwarf form

Surface water temperature during the 2013 BsM program increased from 18.4°C on August 21, 2013 to 19.0°C on August 25, 2013. Two water profiles were undertaken within the deepest basin, on August 22 and on August 25, 2013. Surface water temperatures were 18.55 and 19.03°C respectively. A thermocline was observed between approximately 6 and 10 m with temperatures above ranging from 16 to 19°C and temperatures below ranging from approximately 5 to 6.5°C. Dissolved oxygen levels in the water column ranged from 10.10 to 3.51 mg/L with all measurements above 26 m over 6.5 mg/L (minimum guideline for fresh water cold water ecosystem, CCME, 1999). The maximum depth observed was 28 m. Two Secchi depths were taken concurrent with the water profiles. August 22 was sunny with less than 15% cloud cover and a Secchi depth reading of 3.6 m was recorded, whereas August 25 was overcast and a Secchi depth reading of 2.9 m was recorded.

## 2.10 Metal Levels in Fish Tissues in Hare Lake

Fish were sacrificed during the baseline program to establish existing levels of metals in fish from Hare Lake. Boneless, skinless fillets and liver samples from Northern Pike and composite whole-body samples of Spottail Shiner were collected and analyzed for metals. A summary of mean metal concentrations for each of these fish species is presented in Table 2.10-1. Mercury levels in Northern Pike are above the level at which consumption restrictions begin (OMOE, 2013), typical for lakes in the region (EcoMetrix, 2012a; OMOE, 2013).

**Table 2.10-1: Mean metal concentrations in fish collected in Hare Lake**

| | | | | Spottail Shiner | Northern Pike | |
|---|---|---|---|---|---|---|
| Parameter | n | Units | MDL | whole | muscle | liver |
| | | | | | | |
| Aluminum | 5 | mg/kg | 2 | <2 | <2 | 2 |
| Arsenic | 5 | mg/kg | 0.01 | 0.07 | 0.24 | 0.07 |
| Cadmium | 5 | mg/kg | 0.1 | <0.1 | <0.1 | 0.3 |
| Cobalt | 5 | mg/kg | 0.1 | <0.1 | <0.1 | <0.1 |
| Copper | 5 | mg/kg | 0.1 | 0.8 | 0.2 | 11.8 |
| Iron | 5 | mg/kg | 1 | 16 | 3 | 168 |
| Lead | 5 | mg/kg | 0.02 | 0.04 | <0.02 | <0.02 |
| Mercury | 5 | mg/kg | 0.002 | 0.182 | 2.084 | 1.510 |
| Molybdenum | 5 | mg/kg | 0.01 | 0.04 | 0.02 | 0.13 |
| Nickel | 5 | mg/kg | 0.1 | 0.3 | 0.1 | 0.1 |
| Selenium | 5 | mg/kg | 0.2 | 0.9 | 0.9 | 3.1 |
| Zinc | 5 | mg/kg | 0.1 | 54.8 | 3.7 | 41.6 |

## 2.11 Structure of the Food Web in Hare Lake

A conceptual representation of the Hare Lake food web is depicted in Figure 2.11-1. The representation includes the main species, or species groups (e.g., "benthic invertebrates), and describes how energy and nutrients flow in the lake through the different trophic levels from primary producers (e.g., phytoplankton), to first level consumers such as zooplankton which graze the phytoplankton, to secondary consumers such as Spottail Shiner and Yellow Perch and finally the top level aquatic predator resident in the lake, Northern Pike. Figure 2.11-1 also shows potential linkages between the aquatic environment of Hare Lake and terrestrial biota such as moose (which graze on aquatic vegetation), ducks (which graze benthic fauna) and mink (which eat lake fish).

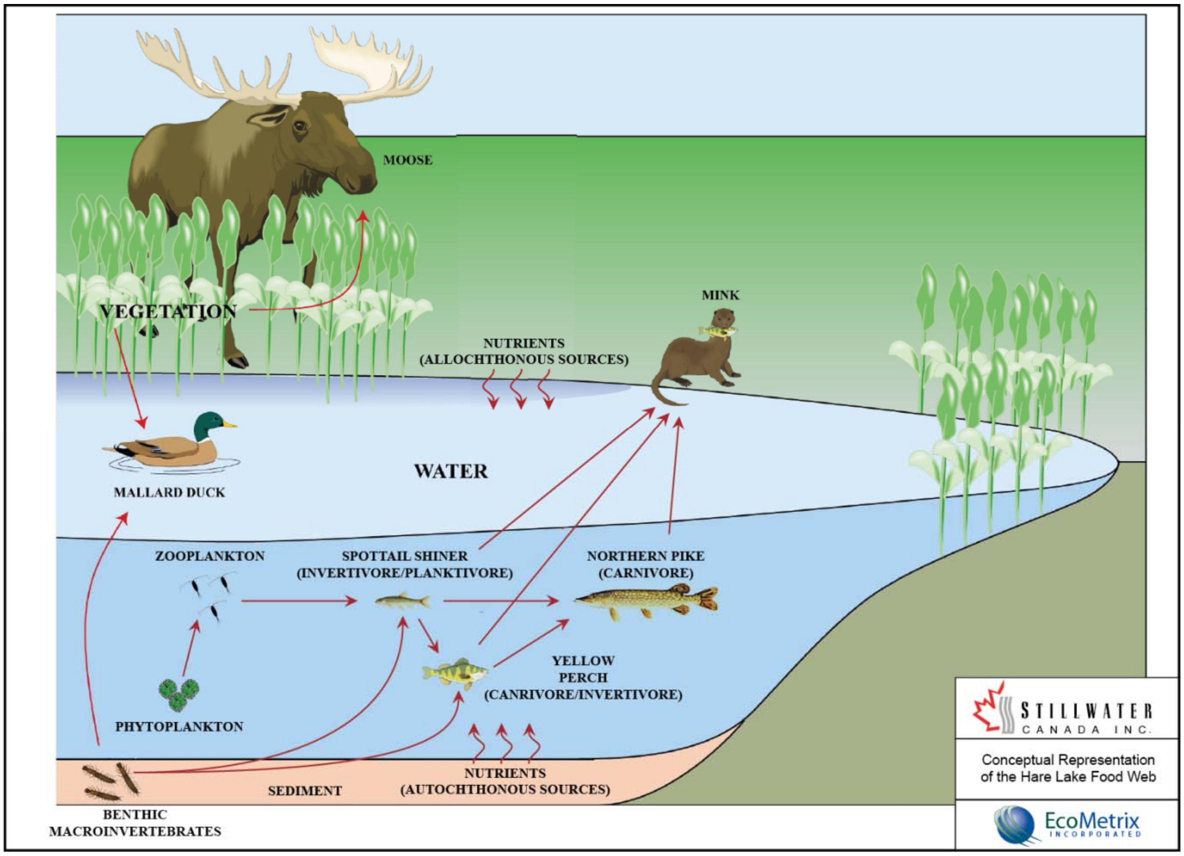


**Figure 2.11-1: Conceptual representation of the Hare Lake food web**

## 2.12 Key Indicator Species

Based on the above description of the existing conditions in Hare Lake the following table lists the key indicator species and summarizes the rationale for their designation as such. The list includes representative aquatic species that occupy different trophic levels.

**Table 2.12-1: Key indicator species in Hare Lake**

| Species | Rationale |
|---|---|
| Phytoplankton | Phytoplankton are primary producers and form the base of the food chain. Phytoplankton communities are very seasonally dynamic and therefore chlorophyll a levels are proposed as a surrogate measure of primary productivity. Chlorophyll a levels are commonly used in this fashion. |
| Zooplankton | Zooplankton are grazers of phytoplankton and as such convert primary production into a resource for consumers on higher trophic levels. |
| Benthic Invertebrates | Benthic invertebrates represent the larger organisms that inhabit lake substrates. They play a “middleman” role in aquatic food webs and therefore play an important role in nutrient and energy flow. They are considered good monitoring tools because, amongst other reasons, they are relatively immobile and their abundance and distribution provides a reflection of overall environmental conditions. |
| Spottail Shiners | Spottail shiners are the most abundant forage fish species in Hare Lake. |
| Yellow Perch | Yellow Perch are abundant in the lake and are omnivores. |
| Northern Pike | Northern Pike are the top level aquatic carnivore in Hare Lake. |

# 3.0 PREDICTION OF IMPACTS TO WATER QUALITY AND HYDROLOGY IN HARE LAKE AS THE RESULT OF PSMF DISCHARGE

## 3.1 PSMF Water Management and Discharge Volumes

A detailed water/solids balance analysis was completed for the updated conceptual mine plan for the Project by Knight Piesold Inc. (KPI) (2013). The water/solids balance is summarized below.

The water balance analysis was developed for a pre-production period followed by the projected mine life and ending with a 3 year post-closure period. The water balance model estimates the water volumes for each subwatershed on a monthly basis, using various inputs including catchment areas, runoff coefficients, and precipitation and evaporation data. The volumes of water reporting to Cells 1 and 2 and discharge volumes to Hare Lake were also calculated monthly.

The water balance model incorporates elevation versus storage capacity data for each of the subwatersheds, derived from the topography of the site. The elevation versus capacity relationship allows the required operating elevations for the individual basins to be estimated for the mine life. A deterministic analysis was completed using average precipitation and evaporation data to estimate the expected water reporting to each basin.

Figure 3.1-1 shows existing monthly Hare Lake outflows (average conditions), projected monthly discharge rates from the PSMF to Hare Lake and the outflows from Hare Lake during the period of mine operations.

The following points are noted in this regard:

- discharge is not planned to begin until approximately Year 5 of the Project;
- excess water discharged from the PSMF will be derived from Cell 1 of the PSMF;
- in years when excess water is discharged, the discharge would occur during the ice free period, typically between April through November;
- discharge volumes would vary monthly with more discharge during the spring and fall periods to mimic the natural hydrograph of the Stream 5 subwatershed;
- the total discharge in Year 5 is estimated to be 428,000 cubic meters under normal meteorological conditions;
- the total discharge is expected to be similar for years 6 through 10 and is estimated to be 778,000 cubic meters under normal meteorological conditions;

- discharge is expected to decrease after Year 10, with re-location of the operating reclaim pond to the pit(s) and will cease upon conclusion of mining activities; and,
- a minimum ratio of Hare Lake outflow to PSMF discharge of 20:1 during periods of discharge will be maintained – that is Hare Lake the outflow (and subsequently flow in Hare Creek) will not increase incrementally by more than 5% under normal operating conditions.

Therefore, of the approximate 10 to 12 year mine life, PSMF discharge, under normal conditions, is projected for the last 5 to 7 years of operation. During this period, effluent discharge to Hare will not however be continuous. Annually, effluent discharge would occur only during the ice free period, typically from April through November. In addition, effluent discharge volumes would vary monthly with more discharge during the spring and fall periods in conjunction with higher flow in the watershed – that is the discharge regime will mimic the natural hydrograph of the watershed.

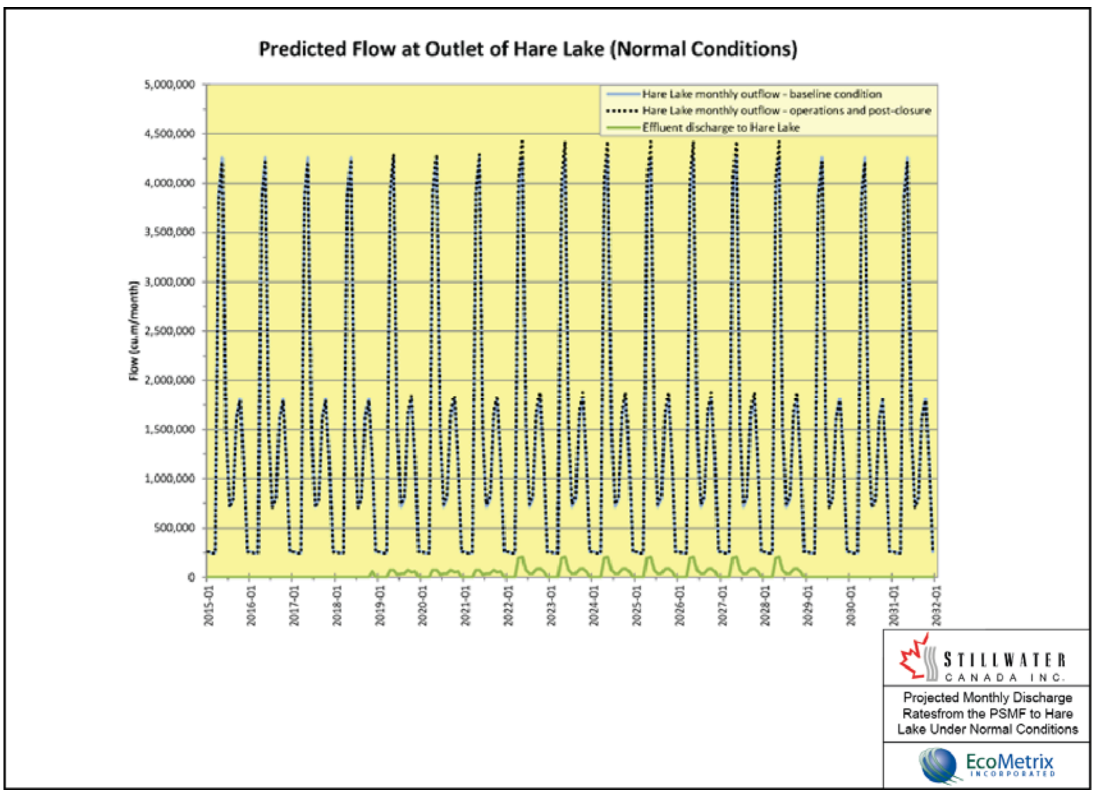


**Figure 3.1-1: Projected monthly discharge rates from the PSMF to Hare Lake under normal conditions**

## 3.2 COPC Levels in the PSMF Discharge

EcoMetrix (2012c) evaluated the geochemical characteristics of mine materials and components to quantify constituent loadings from mine materials and components. This evaluation included mineralogical and chemical characterization of the various rock types, static acid-base accounting (ABA and short term leach tests), as well as kinetic studies that involved column tests with submerged materials and humidity cell tests on mine rock and process solids. The water that goes to the PSMF will have inputs from several sources as depicted conceptually in Figure 3.2-1. These potential sources and interactions were considered in the prediction of water quality in the PSMF.

The geochemical assessment (EcoMetrix, 2012c) included loading rates for the various potential sources of COPCs on site, including;

- temporary stockpiles of Type 2 rock that will drain into the pits during operations;
- water from the pits;
- process water from the mill;
- water draining from the process solids beaches; and,
- the Type 2 process solids that will be under water in the Cell 1 of the PSMF.

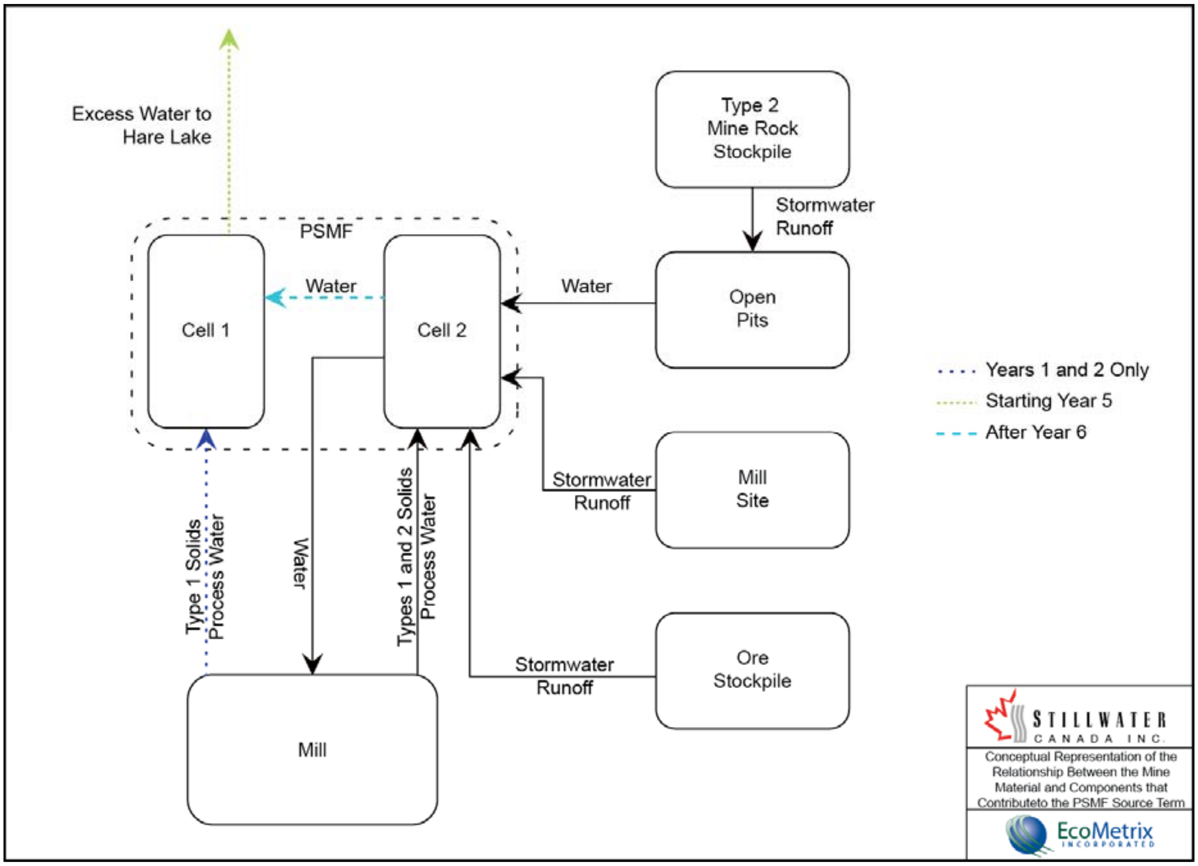


**Figure 3.2-1: Conceptual representation of the relationship between the mine material and components that contribute to the PSMF source term**

The source term loading rates for waters going to the PSMF were presented in EcoMetrix (2012c). The unit loading rates that have been updated are provided in Table 3.2.1. These updated unit loading rates were derived using the methodology described by EcoMetrix (2012c) and reflect the current conceptual mine plan, as well as the most recent data available from both ongoing geochemical testing and recent metallurgical testing. The updated unit loading rates include the following:

- updated chemistry of the process water for the mill, taken as the decant water from the 2013 pilot plant metallurgical test;
- updated loading rates from the 2012 humidity cells on Type 1 process solids;
- the assumed design capacity of 20 M tonnes of temporary Type 2 mine rock stockpiles;
- the assumed design capacity of 10 M tonnes of ore stockpiled at the mill during operations;

- the conceptual design for the PSMF, with updated areas of beaches and ponds; and,
- the updated water balance for the PSMF including the mill output and reclaim water.

Cell 1 of the PSMF will be constructed before Cell 2. Therefore, all waters will be managed in Cell 1 for the first 2 years of operation. Water will accumulate in Cell 1 during years 1 and 2 while process solids are deposited underwater in that cell. Site water from the pits, ore stockpile and mill site areas will be collected and sent to Cell 1 during that time as well. At the end of year 2, process solids deposition will be transferred from Cell 1 to Cell 2 and all site water will be directed to Cell 2. The water that is in Cell 2 will be used as reclaim water in the mill where it will undergo pH adjustment and be effectively “treated” in the mill. Cell 1 will then only receive natural runoff water until the end of year 5, after which some excess water in Cell 2 will be transferred to Cell 1 annually. Excess water from Cell 1 will be discharged to Hare Lake and it is anticipated that this will begin only in the early part of year 6 of the operation. The water quality predictions for the discharge to Hare Lake considered these water balance details.

The water quality predictions included four scenarios, a base case and 3 sensitivity cases. The base case is the prediction of water quality based on reasonable assumptions that were provided in EcoMetrix (2012c). One sensitivity case considered an alternate temperature adjustment factor to predict loading rates for COPCs from mine materials in the field from the measured values in the laboratory. In effect, the adjustment factor was 2 times the value used for the base case as suggested by NRCan and discussed in the response to SIR 4. A second case considered and alternated the adjustment factor for particle size differences between the laboratory samples tested and the anticipated blast rock that will result from mining. The sensitivity case for particle size used an adjustment factor that was 3 times greater than that in the base case. The third sensitivity case included the use of the alternate temperature factor and the particle size factor together which effectively resulted in combined adjustment factors that were six times that used in the base case. This is referred to as the upper bound case. Because the predicted effects of the changes between the base case and the upper bound are quite small for the PSMF water quality predictions, the other sensitivity cases are not shown. The results of the sensitivity cases with a temperature adjustment factor increase alone and a particle size adjustment factor alone are intermediate between the concentrations shown here for the base case and the upper bound.

**Table 3.2-1: Updated unit loading rates and process water concentration associated with the PSMF sources**

| COPC | Base Case Type 1 Process Solids Unit Loading Rate (mg/kg/wk)[1] | Upper Bound Type 1 Process Solids Unit Loading Rate (mg/kg/wk)[1] | Decant Water Chemistry (mg/L)[2] |
|---|---|---|---|
| Al | 0.00861 | 0.0152 | 0.0612 |
| As | 0.0000223 | 0.0000394 | 0.000450 |
| Cd | 0.00000147 | 0.00000259 | 0.0000100 |
| Co | 0.0000136 | 0.0000240 | 0.000120 |
| Cu | 0.0000877 | 0.000155 | 0.00124 |
| Fe | 0.00179 | 0.00316 | 0.0100 |
| Mo | 0.000175 | 0.000309 | 0.0179 |
| Ni | 0.000106 | 0.000187 | 0.00238 |
| Pb | 0.00000782 | 0.0000138 | 0.0000500 |
| Se | 0.0000196 | 0.0000346 | 0.000300 |
| U | 0.00000973 | 0.0000172 | 0.000101 |
| V | 0.000137 | 0.000241 | 0.00140 |
| Zn | 0.000257 | 0.000454 | 0.00100 |

[1] Based on 2012 humidity cells on Type 1 process solids

[2] Based on 2013 pilot plant metallurgical test

EcoMetrix used MINEmod™ to derive the "end-of-pipe" concentration for COPCs from the updated unit loading rates from Table 3.2-1 and with the updated water balance for the mine provided by KPI (2013). MINEmod™ is a flow and mass balance model that is GIS based for spatial referencing with a graphical interface to provide visualization of a site with all potential mine component sources and pathways to the aquatic environment. The model includes options for time varying source terms such as loading rates or concentrations and time varying flows for site components as well as natural surface and subsurface waters. The model can predict receiving water concentrations for a variety of temporal and spatial scales for time varying or average input conditions. Table 3.2-2 presents these results. Loading rates representing Type 2 mine rock, ore, pit rubble, pit walls and under water Type 2 process solids were those presented in EcoMetrix (2012c). The predicted end-of-pipe concentrations reflect the chemistry of the excess water from the PSMF that will be discharged to Hare Lake. The concentrations are provided for both the base case and upper bound scenarios.

**Table 3.2-2: Updated end-of-pipe base case and upper bound PSMF discharge concentrations**

| COPC | Base Case end-of-pipe concentration (mg/L) | Upper Bound end-of-pipe concentration (mg/L) |
|---|---|---|
| Al | 0.067 | 0.067 |
| As | 0.0045 | 0.0056 |
| Cd | 0.000047 | 0.000058 |
| Co | 0.00044 | 0.00167 |
| Cu | 0.0028 | 0.0103 |

| | | |
|---|---|---|
| **Fe** | 0.49 | 0.49 |
| **Mo** | 0.15 | 0.15 |
| **Ni** | 0.0030 | 0.0075 |
| **Pb** | 0.00051 | 0.00054 |
| **Se** | 0.0029 | 0.0035 |
| **U** | 0.0030 | 0.0034 |
| **V** | 0.0124 | 0.0127 |
| **Zn** | 0.0032 | 0.0041 |

## 3.3 Temperature of the PSMF Discharge

As explained in the response to IR 12.6.1, the temperature of the PSMF discharge will not be affected by anthropogenic activities associated with ore extraction, milling process or any other activity relating to the Project. The temperature of water in the PSMF will be subject to the same natural warming and cooling processes to which natural water bodies, including Hare Lake and the other small lakes and ponds on the project, are subject.

The surface area and water depth of Cell 1, the source of the PSMF discharge water, are comparable to that of Hare Lake and the other small lakes. The surface area will range from 650,000 to 750,000 $m^2$ during the discharge period as compared to 570,000 $m^2$ for Hare Lake, and water depth will be approximately 6 m during periods of discharge as compared to the 5 m depth of the epilimnion in Hare Lake. Given the similarity in size and depth, it is expected that Cell 1 will experience similar warming and cooling processes as water in Hare Lake, resulting in similar temperatures between the two water bodies, and thus of the discharge as well.

## 3.4 PSMF Discharge Location and Diffuser Configuration

### 3.4.1 Discharge Location

The proposed discharge location for excess water from the PSMF is shown in Figure 3.4-1.

Excess water from the PSMF will be pumped from the PSMF in a pipe to Hare Lake at ground level. The discharge structure in Hare Lake will be located along the south side of the lake in 3 to 5 m of water depth. This water depth corresponds to the upper water layer (epilimnion) when the lake is thermally stratified.

The 3 to 5 m depth interval situated about 10 to 15 m from the shoreline. Riparian zone vegetation includes spruce, with sedge and grasses intermixed with boulders at the water's edge. Near-shore substrates in the proposed location comprise rock and boulder. There is little to no submergent or emergent aquatic vegetation in the embayment.

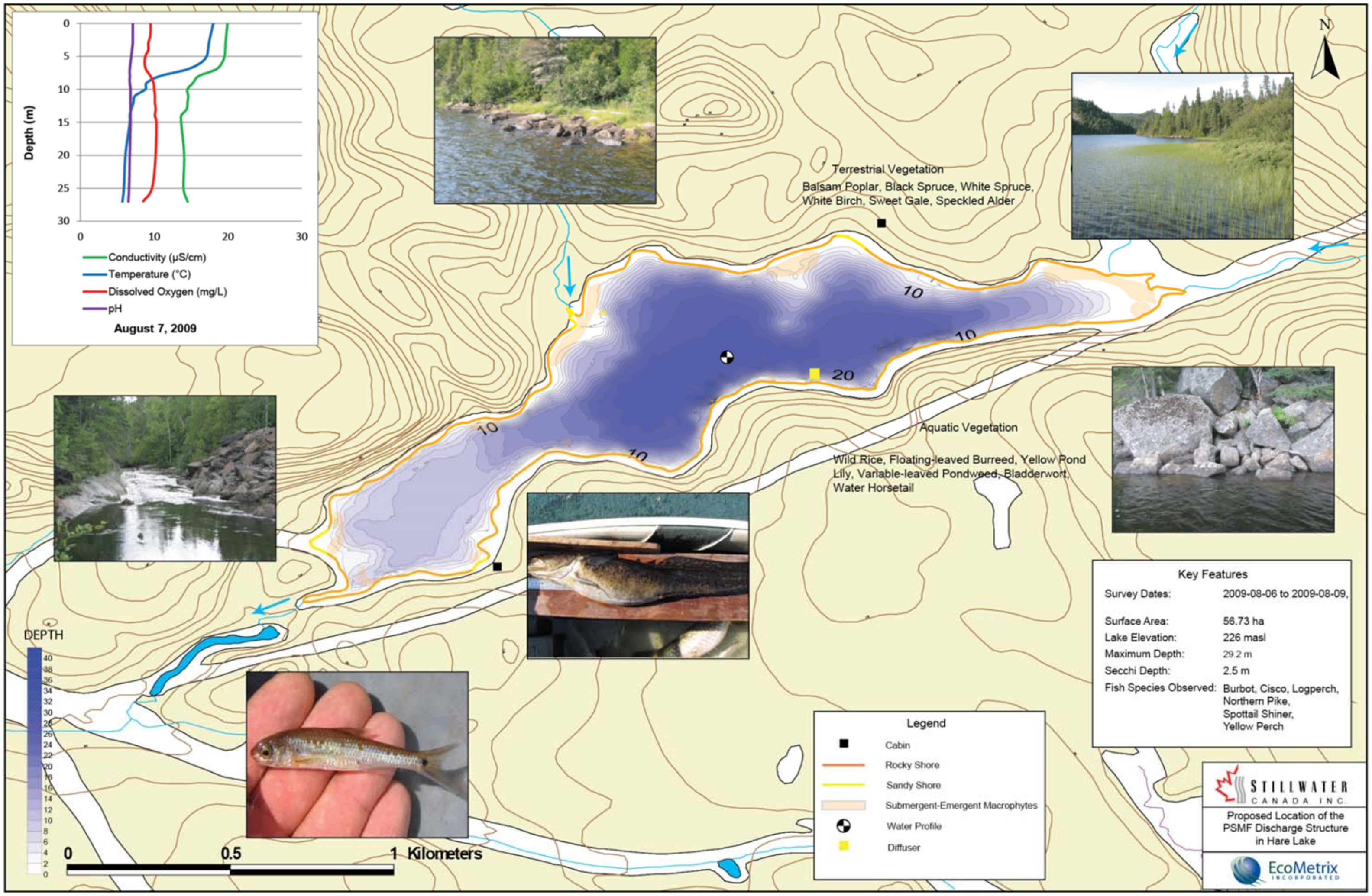


**Figure 3.4-1: Proposed location of the PSMF discharge structure in Hare Lake**

### 3.4.2 Diffuser Configuration

As indicated above, excess water from the PSMF will be pumped to Hare Lake in a pipe at ground level. The pipeline will extend from the shoreline into the lake on the lake bottom to a location where the water depth is 3 to 5 m.

The conceptual minimum design configuration for the proposed diffuser is summarized in Table 3.4-1. This conceptual design provides for a 30:1 mixing (ratio of lake water to PSMF water) within 50 m of the discharge – the so-called mixing zone. The conceptual design contemplates that the discharge structure would comprise an offshore, multiport diffuser aligned parallel to shore with ports oriented horizontally, perpendicular to shore is proposed. In this conceptual configuration, the diffuser will come off the main discharge pipe at a T-junction, which joins the 10 m long diffuser section to the pipeline, and it will have ten, two inch (0.0051 m) diameter ports spaced at one meter intervals.

**Table 3.4-1: Conceptual minimum design configuration for the PSMF discharge diffuser**

| | | |
|---|---|---|
| Discharge location | Offshore | An offshore discharge is preferred over a shore based discharge since it provides greater protection of nearshore habitats. |
| Pipe alignment | Parallel to shore | A parallel alignment was selected as it is the only practical orientation given the steep relief of the shoreline area. |
| Port orientation | Horizontal, perpendicular to shore | The horizontal orientation of the discharge ports directs the effluent further offshore away from nearshore habitats. |
| Depth | 3 to 5 m | A surfaced layer discharge is preferred to a deep water discharge as here the discharge is in an area of relatively higher currents and associated mixing. |
| Number of ports | 10 | A multi-port discharge is preferred to a single port discharge as it induces greater mixing through distribution of the discharge water along the full length of the diffuser. |
| Port diameter | 0.051 m (2 inch) | The diameter of ports was set to achieve an exit velocity in the range of 3 m/s to 7 m/s to promote mixing while minimizing potential effects to fish. |
| Diffuser length | 10 m | A 10 m long diffuser provides for sufficient mixing while occupying as little of the lake bottom as is practical. |

## 3.5 Predicted Water Quality in Hare Lake

### 3.5.1 Water Quality within the Mixing Zone

As indicated above, the conceptual diffuser configuration is designed to achieve a 30:1 mixing ratio (receiving water to PSMF discharge) within a distance of approximately 50 m from the diffuser, as illustrated in Figure 3.5-1. This degree of mixing ensures that the surface water quality benchmarks achieved within the mixing zone. The mixing ratio was calculated using a mathematical model called CORMIX. CORMIX was developed by Cornell University (Jirka and Akar, 1991), is supported by the United States Environmental Protection Agency, and is a widely recognized model for the analysis of mixing characteristics.

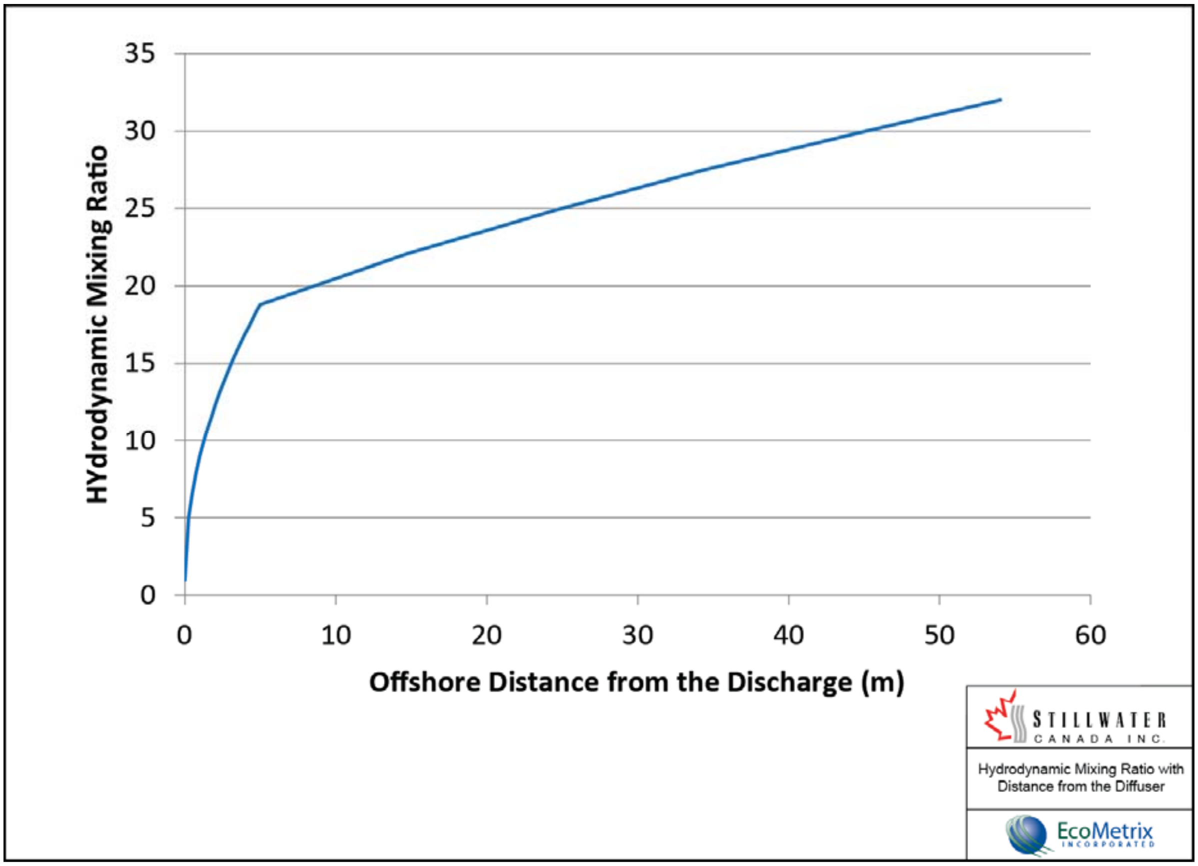


**Figure 3.5-1: Hydrodynamic mixing ratio with distance from the diffuser**

As illustrated in Figure 3.5-2, the mixing zone occupies a very small area relative to the overall size of Hare Lake.

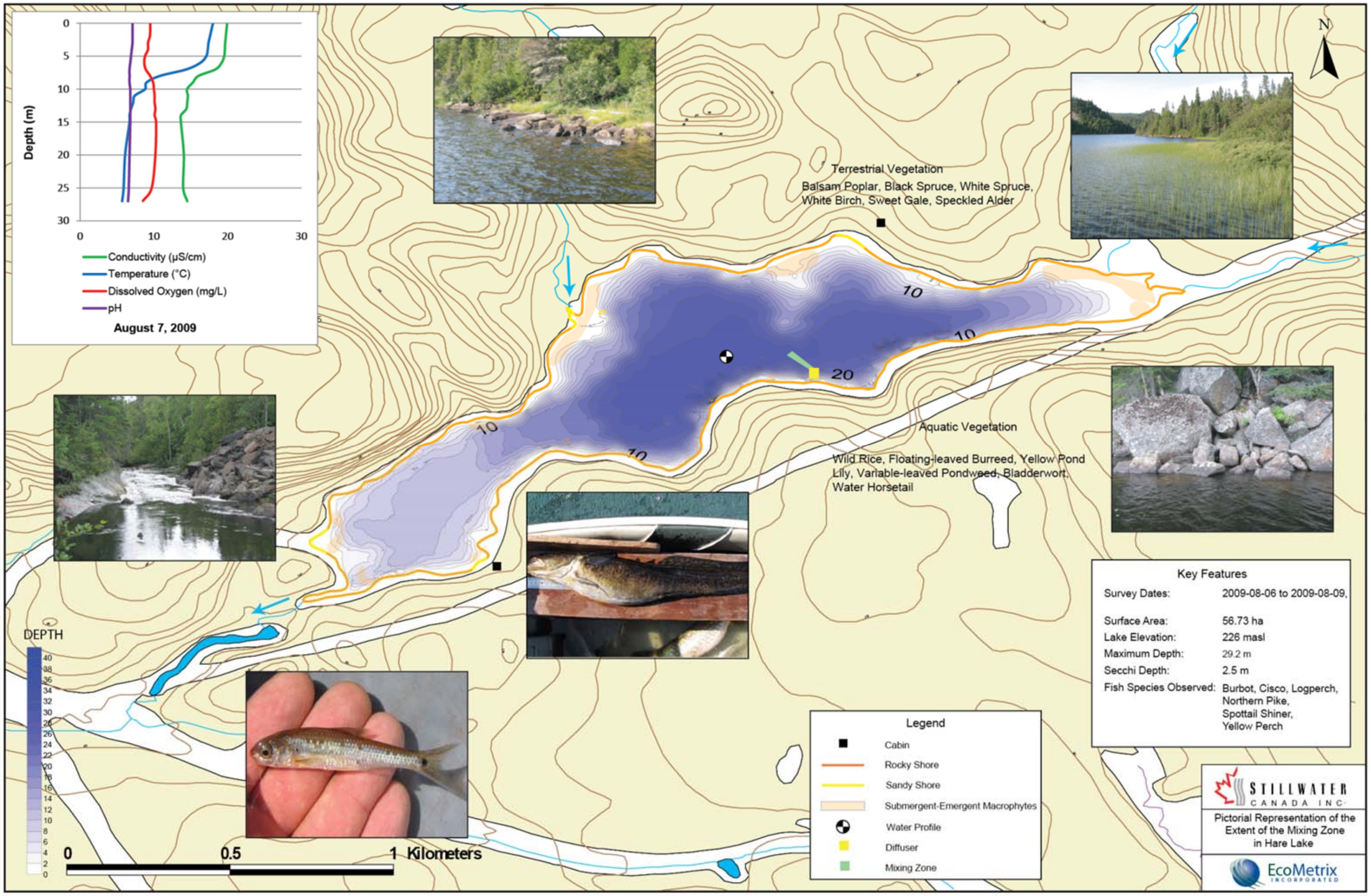


**Figure 3.5-2: Pictorial representation of the extent of the mixing zone in Hare Lake**

Table 3.5-1 provides the predicted maximum life-of-mine predicted COPC concentrations within the mixing zone for both the base case and upper bound PSMF discharge quality scenarios. In addition, surface water quality benchmarks (SWQBs) for Hare Lake are shown. As noted above, the benchmarks are the lower of PWQO and CCME surface water quality objectives, or background water quality in Hare Lake where a particular COPC is greater than the lower of the PWQO and CCME objectives.

In each case it can be seen that predicted COPC concentrations remain below their respective surface water quality benchmarks over the duration of mine life, even under the upper bound PSMF discharge quality scenario.

**Table 3.5-1: COPC concentrations within the mixing zone in Hare Lake for the base case and upper bound discharge quality scenarios compared with surface water quality benchmarks**

| COPC | PWQO (mg/L) | CCME (mg/L) | Background (mg/L) | Base Case (mg/L) | Upper Bound (mg/L) |
|---|---|---|---|---|---|
| Al | 0.075 | 0.1 | 0.14 | 0.14 | 0.14 |
| As | 0.005 | 0.005 | <0.001 | 0.001 | 0.001 |
| Cd | 0.0001 | 0.00001 | <0.00009 | 0.00009 | 0.00009 |
| Co | 0.0009 | - | <0.0005 | 0.0005 | 0.0006 |
| Cu | 0.005 | 0.002 | 0.001 | 0.001 | 0.002 |
| Fe | 0.3 | 0.3 | 0.97 | 0.97 | 0.97 |
| Mo | 0.04 | 0.073 | <0.001 | 0.013 | 0.013 |
| Ni | 0.025 | 0.025 | <0.002 | 0.002 | 0.002 |
| Pb | 0.001 | 0.001 | <0.001 | 0.001 | 0.001 |
| Se | 0.1 | 0.001 | <0.0004 | 0.0006 | 0.0006 |
| U | 0.005 | 0.015 | <0.005 | 0.005 | 0.005 |
| V | 0.006 | - | <0.001 | 0.002 | 0.002 |
| Zn | 0.02 | 0.03 | 0.006 | 0.006 | 0.006 |

### 3.5.2 Water Quality beyond the Mixing Zone

As indicated above, predicted COPC concentrations remain below their respective surface water quality benchmarks within the mixing zone over the duration of mine life, even under the upper bound PSMF discharge quality scenario.

Water quality within the lake beyond the mixing zone was predicted using a mathematical model based on principles of mass conservation, as represented in Equation 3-1 and Equation 3-2.

For the epilimnion

$$\frac{dC_{HL}}{dt} = \frac{Q_{PSMF} \cdot C_{PSMF} + Q_{up} \cdot C_{up} - Q_{out} \cdot C_{HL}}{V_{HL}}$$

**Equation 3-1**

For the hypolimnion

$$\frac{dC_{HL}}{dt} = 0$$

**Equation 3-2**

Where: $C_{HL}$ = concentration of COPC in Hare Lake (mg/L);

$C_{PSMF}$ = concentration of COPC from the PSMF discharge (mg/L);
$Q_{PSMF}$ = discharge rate from the PSMF ($m^3$/s);
$Q_{up}$ = inflow rate from upstream surface waters ($m^3$/s);
$C_{up}$ = inflow concentration from upstream surface waters (mg/L);
$Q_{out}$ = outflow rate from upstream surface waters ($m^3$/s);
$V_{HL}$ = volume of the epilimnion in Hare Lake ($m^3$);
$t$ = time (s).
(Standard unit conversions apply)

These partial differential equations are solved numerically as a function of time over the operational life of the Project. Equation 3-1 represents the potential change in water quality within the epilimnion (surface layer) of Hare Lake during stratified periods. Equation 3-2 represents the potential change in water quality within the hypolimnion (bottom layer) of Hare Lake during stratified periods. The model also accounts for the semi-annual mixing of the epilimnion and hypolimnion. Further assumptions that stem from empirical data collected during the baseline program on which the analysis is based include: Hare Lake stratifies during the summer discharge period; the discharge water is confined to the epilimnion during the summer and mixes into the hypolimnion during spring/fall turnover; current velocities in Hare Lake are sufficient to promote complete mixing of the epilimnion within days; and, for all practical purposes, the epilimnion and hypolimnion can be treated as well mixed, and that these layers mix together twice per year.

Figures 3.2-3 (base case) and 3.2.4 (upper bound), as well as Table 3.5-2, show the monthly predictions of COPC concentrations in both the epilimnion and hypolimnion beyond the mixing zone through mine life. For some COPCs minor increases in concentrations are seen during periods of effluent discharge, whereas for other COPC the predicted concentrations are indistinguishable from background. In all cases, COPC levels remain below surface water quality benchmarks at the edge of the mixing zone and on a lake-wide basis. Those COCPs that do show an increase in concentration during periods of PSMF discharge return to background levels soon after the cessation of mine operations.

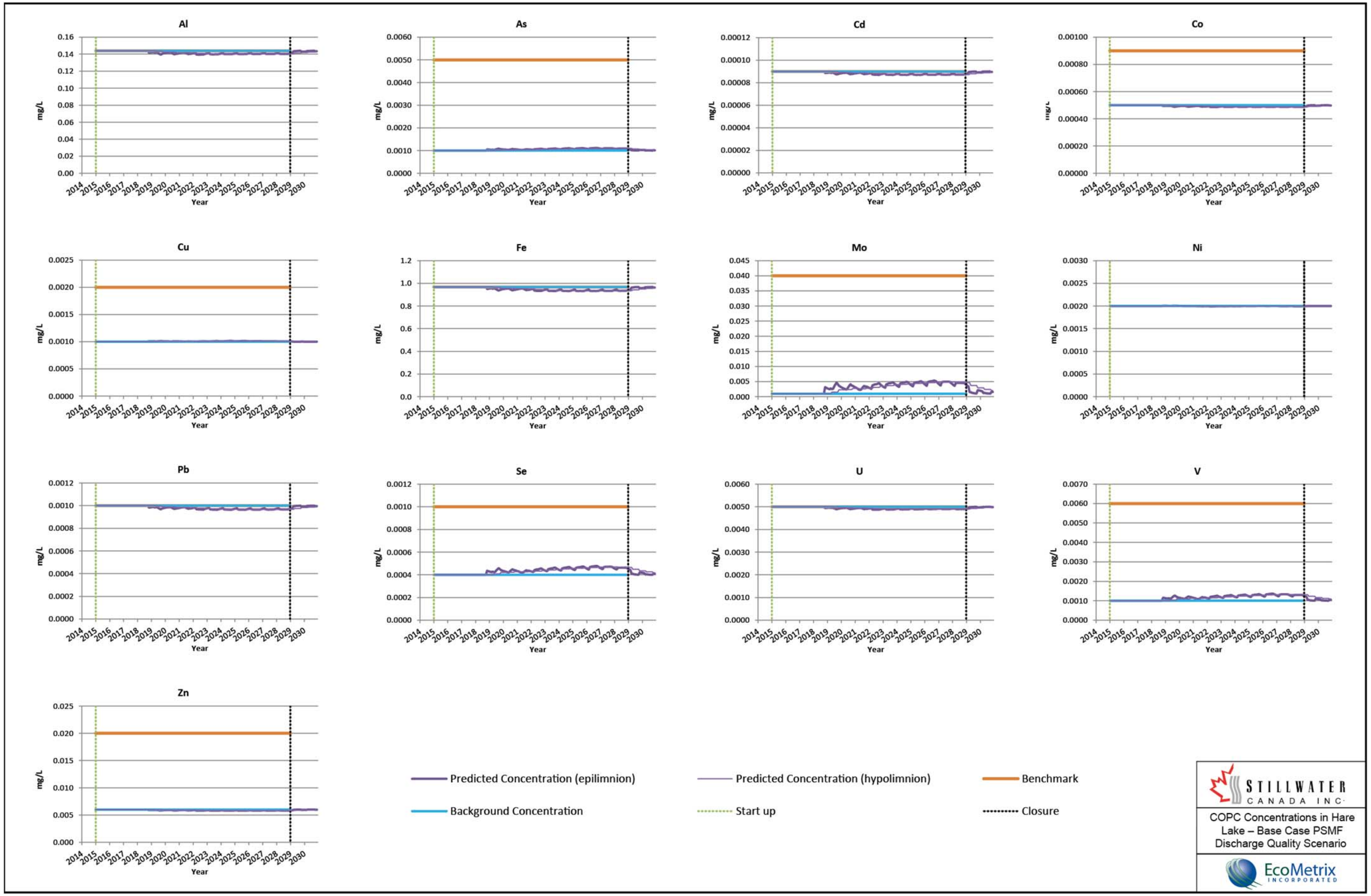


**Figure 3.5-3: COPC concentrations in Hare Lake – base case PSMF discharge quality scenario**

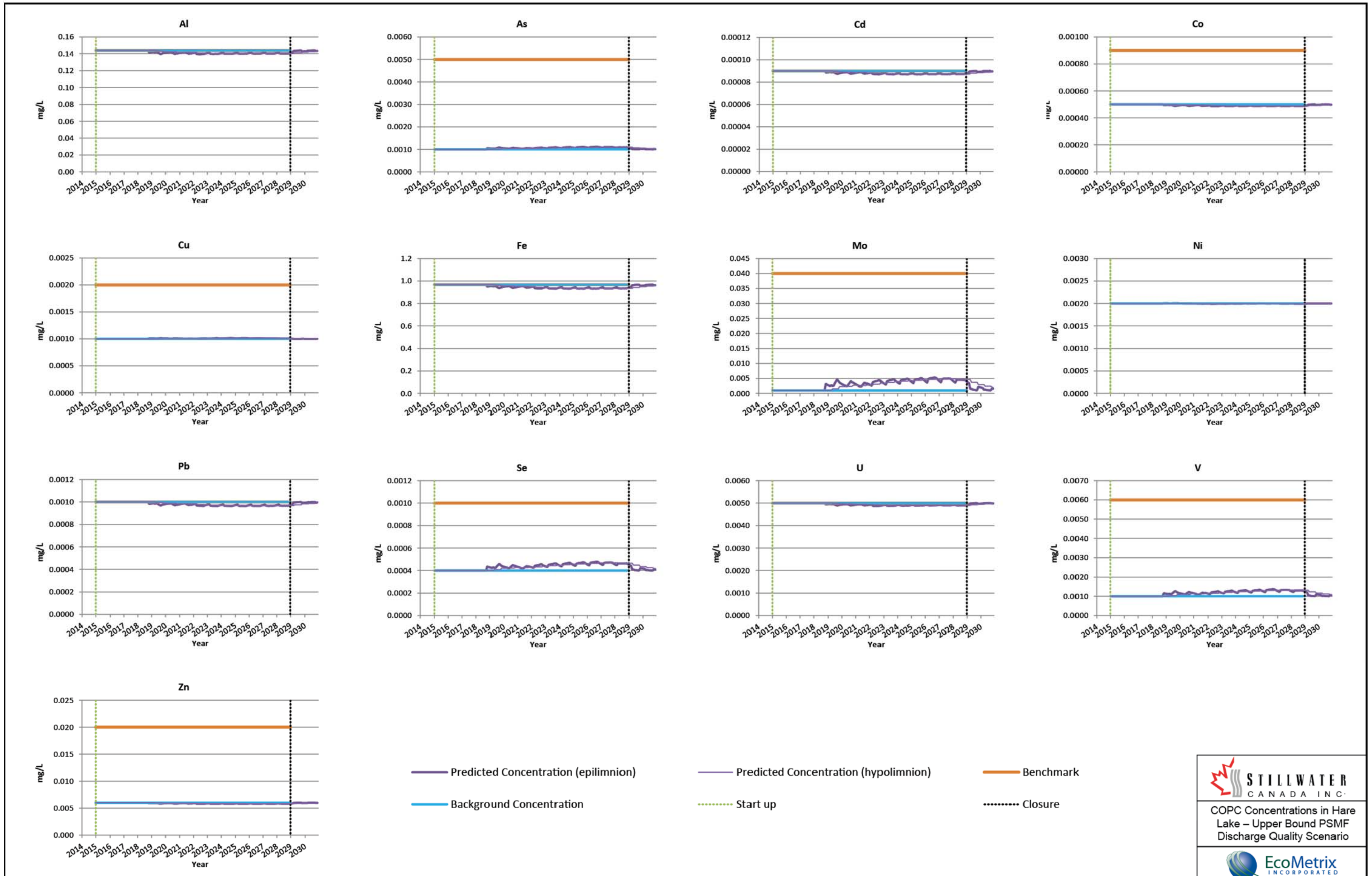


**Figure 3.5-4: COPC concentrations in Hare Lake – upper bound PSMF discharge quality scenario**

**Table 3.5-2: Updated predicted concentrations in Hare Lake beyond the mixing zone for base case and upper bound scenarios compared with Hare Lake SWQBs**

| COPC | SWQO (mg/L) | Base Case (mg/L) | | Upper Bound (mg/L) | |
|---|---|---|---|---|---|
| | | Epilimnion | Hypolimnion | Epilimnion | Hypolimnion |
| **Al** | 0.14[1] | 0.14 | 0.14 | 0.14 | 0.14 |
| **As** | 0.005[2] | <0.0011 | <0.0011 | <0.0012 | <0.0012 |
| **Cd** | 0.00009[1] | <0.00009 | <0.00009 | <0.00009 | <0.00009 |
| **Co** | 0.0009[2] | <0.0005 | <0.0005 | <0.0005 | <0.0005 |
| **Cu** | 0.002[3] | <0.0010 | <0.0010 | <0.0011 | <0.0011 |
| **Fe** | 0.97[1] | 0.97 | 0.97 | 0.97 | 0.97 |
| **Mo** | 0.04[2] | <0.0053 | <0.0049 | <0.0054 | <0.0049 |
| **Ni** | 0.025[2] | <0.0020 | <0.0020 | <0.0021 | <0.0020 |
| **Pb** | 0.001[2] | <0.0010 | <0.0010 | <0.0010 | <0.0010 |
| **Se** | 0.001[3] | <0.00048 | <0.00047 | <0.00052 | <0.00050 |
| **U** | 0.005[2] | <0.0050 | <0.0050 | <0.0050 | <0.0050 |
| **V** | 0.006[2] | <0.0014 | <0.0013 | <0.0014 | <0.0014 |
| **Zn** | 0.02[2] | 0.0060 | 0.0060 | 0.0060 | 0.0060 |

[1] background
[2] PWQO
[3] CCME

### 3.5.3 PSMF Discharge Buoyancy and Mixing

The relationship of water density, total dissolved solids (TDS) and temperature is shown in Figure 3.5-5. Highlighted are the densities of surface and bottom waters for temperatures that are typical in Hare Lake during the summer when the lake is thermally stratified, based on data collected during the baseline program. In addition, the density of the PSMF discharge water is shown both based on an end of pipe prediction of 250 mg/L TDS and following 10:1 mixing in the lake. Note that the minimum conceptual diffuser design configuration provides 10:1 mixing less than 5 m from the discharge and 30:1 mixing at 50 m from the discharge.

As can be seen on the graph the density of the PSMF discharge and the ambient water in the surface layer of Hare Lake are virtually indistinguishable from one another, particularly following 10:1 mixing. The PSMF discharge will neither sink nor float since it is discharged into water of similar density. In practical terms, this means that the PSMF discharge in the lake will not affect the normal dimictic thermal regime of the lake.

Moreover, under these conditions it is physically impossible for Hare Lake to become meromictic. Previously (EcoMetrix, 2012d; IR response 12.11), it was suggested that in the unlikely event that meromixis did develop that it could be mitigated via monitoring and manually causing the lake to turn over. Although this in fact is a practical solution to the development of meromixis there is no reason to believe that it will be necessary.

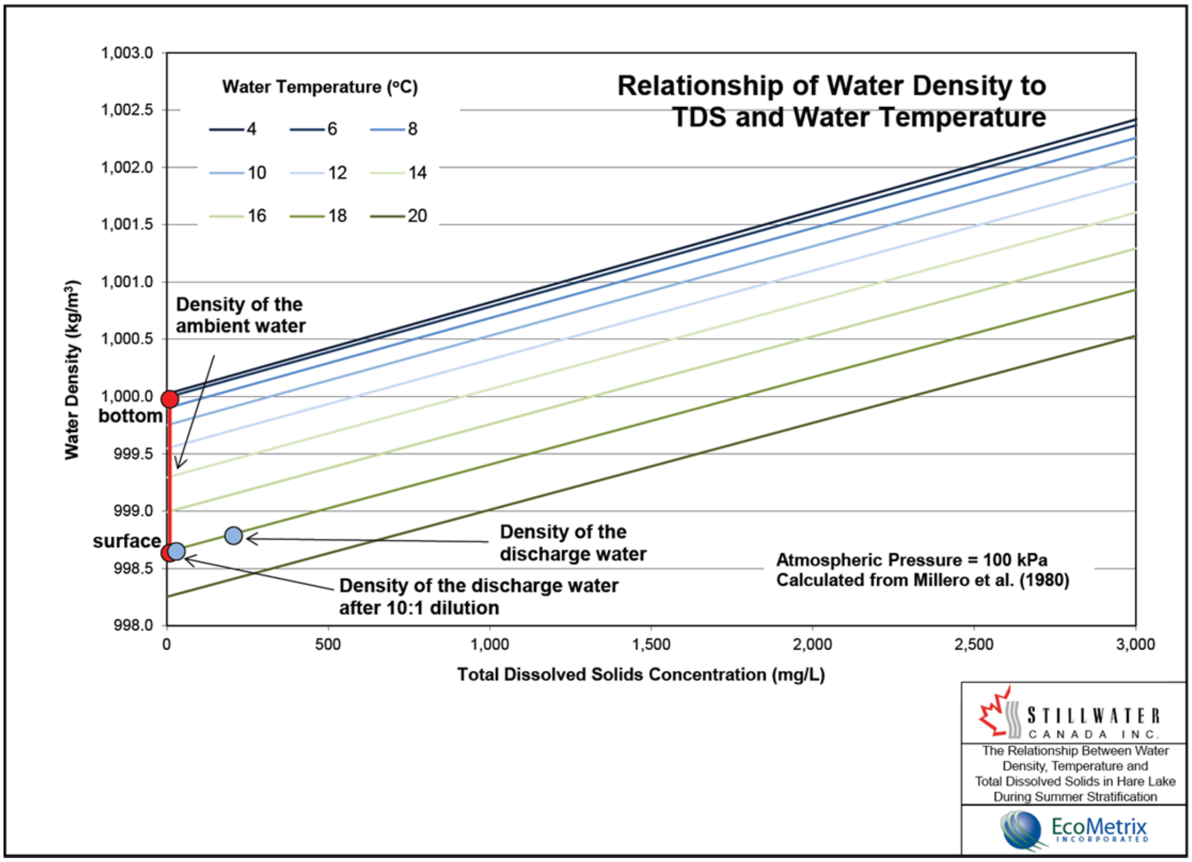


**Figure 3.5-5: The relationship between water density, temperature and total dissolved solids in Hare Lake during summer stratification**

## 3.5.4 Consideration of Temperature and the Thermal Regime of Hare Lake

As described in Section 3.3, the temperature of water in the PSMF during the proposed discharge period is expected to be similar to the surface layer of water, the epilimnion, in Hare Lake. Some small differences may be seen as there will be minor coldwater inputs to Hare Hake in the form of small cold-water tributaries, which are not present in the PSMF. Again though, overall any difference is expected to be minor.

In any event, any difference in temperature between the PSMF discharge and the ambient temperature in Hare Lake will be rapidly dissipated based on the mixing provided by the diffuser. As indicated in Section 3.5.2, the PSMF discharge is afforded 30:1 mixing within 50 m of release from the diffuser; accordingly it is expected that the PSMF discharge will be indistinguishable from background, with respect to temperature, within the mixing zone.

### 3.5.5 Hare Lake Sediment Quality Predictions

The IMPACT™ model was used to derive sediment quality predictions for COPCs for the base case and upper bound PSMF discharge scenarios. IMPACT™ ("Integrated Model for the Probabilistic Assessment of Contaminant Transport") is an environmental pathways model used to evaluate the transport and effects of contaminants of potential concern (COPCs) on environmental media and biological receptors, including humans. The IMPACT™ model simulates the transport of constituents from sources through various environmental media such as air, water, soil and sediment to receptors. The model estimates the concentration of constituents in environmental media, potential uptake by aquatic and terrestrial vegetation and animals, and potential intake by and dose to animals and humans. IMPACT™ is discussed in detail in response to IR 12.8.

The equation that is the basis for sediment concentration predictions is a partial differential equation that is solved within IMPACT™. The equation is characterized by a series of parameters that describe the physical and biochemical environment of the lake. The equation is solved iteratively, with the model estimating the change in sediment concentrations over time as follows:

$$\frac{dC_s}{dt} = \frac{g_w \cdot f_w \cdot C_{wc}}{z_s} + \frac{k_s}{z_s}\left[(1-f_w)\cdot C_{wc} - C_{pw}\right] - C_s \cdot \left[\frac{g_b}{z_s}\right]$$

Where:

- $dC_s$ is change in concentration over time
- dt is change in time
- $g_w$ is settling rate of particles in water column
- $f_w$ is fraction of a constituent that is particulate in the water column
- $C_{wc}$ is concentration of constituent in water column
- $Z_s$ is thickness of sediment layer
- $k_s$ is sediment-water transport coefficient
- $C_{pw}$ is concentration in the surficial sediment pore water
- $C_s$ is concentration of constituent in surficial sediments
- $g_b$ is burial rate of sediments

In the equation above, $f_w$ is a function of the water-to-sediment partitioning coefficient ($K_d$), or the manner by which a constituent in the water partitions to sediments, which is determined by the equation:

$$f_w = \frac{K_d \cdot \frac{\rho_s}{\varepsilon_s}}{1 + K_d \cdot \frac{\rho_s}{\varepsilon_s}}$$

Where:

$K_d$ is the water-to-sediment partitioning coefficient
$\rho_s$ is bulk density of surficial sediment
$\varepsilon_s$ porosity of surficial sediment

Sediment quality predictions associated with the discharge of excess water from the PSMF into Hare Lake are shown over the duration of mine life in Figure 3.5-6 (base case) and Figure 3.5.7 (upper bound). For both scenarios, a small increase in sediment COPC concentrations is noted coincident with the commencement of the PSMF discharge. The predictions for the base case and upper bound scenarios are largely indistinguishable from one another.

On average the incremental increase seen in sediment COPC concentrations is less than the background variability seen for individual COPCs in Hare Lake based on baseline data. It can be concluded therefore that the predicted incremental increases in COPC sediment levels are on average essentially indistinguishable from existing COPC levels.

The one exception to this pattern is molybdenum, for which about a three-fold increase in the sediment concentration is predicted. The predicted increase is a result of the incremental increase in molybdenum concentrations predicted for surface water. Predicted molybdenum concentrations in water however do not exceed the Hare Lake SWQB. There is no sediment quality objective provided for molybdenum by the provincial and federal governments, nor by the US EPA. Thompson et al. (2005) derived LEL and SEL concentrations using the Screening Level Concentration (SLC) approach for a number of metals and radionuclides associated with uranium mining and milling. For molybdenum, the LEL with the greatest predictive value was derived using the weighted method and was equal to 13.8 mg/kg. The maximum predicted molybdenum level in Hare Lake is about is about half the LEL.

Following the cessation of the PSMF discharge to Hare Lake COPC levels in sediments are predicted to return to their pre-discharge levels.

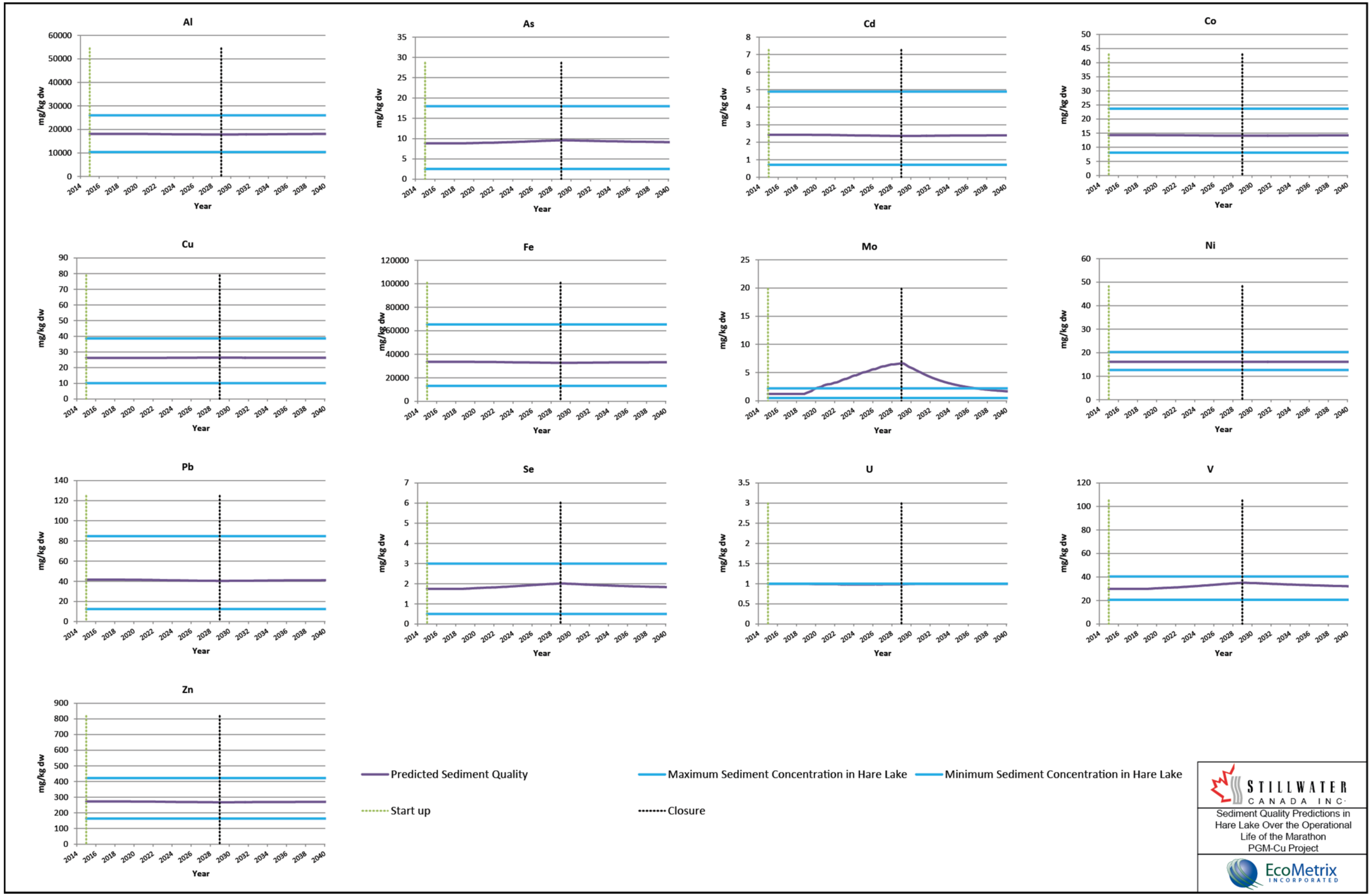


**Figure 3.5-6: Sediment quality predictions in Hare Lake over the operational life of the proposed Marathon PGM-Cu Project for the base case PSMF discharge scenario**

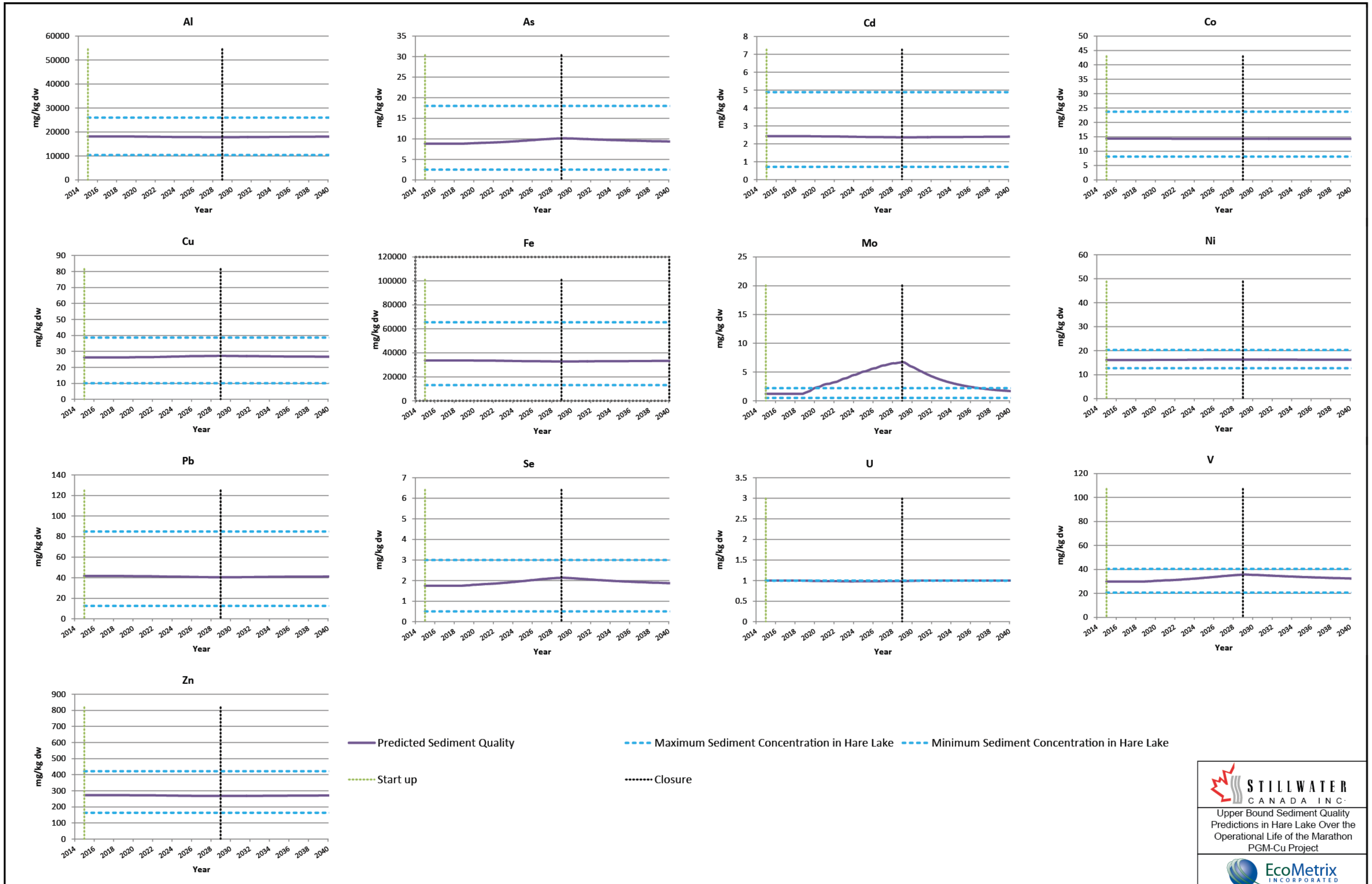


**Figure 3.5-7: Sediment quality predictions in Hare Lake over the operational life of the proposed Marathon PGM-Cu Project for the upper bound PSMF discharge scenario**

# 4.0 POTENTIAL EFFECTS OF PSMF DISCHARGE ON HARE LAKE AND HARE CREEK

## 4.1 Potential Effects on the Hydrology of the Stream 5 Subwatershed

The potential effects of the PSMF discharge on the hydrology of the Stream 5 subwatershed were assessed and documented by Calder Engineering (2012b; SID 21). This analysis has been reviewed with reference to the current conceptual mine plan and it was determined that the conclusions in SID 21 remain valid. The potential hydrological effects of the PSMF discharge would in fact be less than identified in SID 21, as projected PSMF discharge volumes to Hare Lake are less than previously assumed. The range of endpoints considered in the original Calder (2012b) analysis and the results of that analysis are summarized in the Table 4.4-1 (Hare Lake) and Table 4.1-2 (Hare Creek).

**Table 4.1-1: Summary of the effects analysis on the hydrology of Hare Lake associated with PSMF discharge**

| Assessment Endpoint | Assessment Conclusion |
|---|---|
| Lake levels | • No effect on lake levels are predicted<br>o Potential changes in lake levels will be within the natural seasonal and annual variations<br>o PSMF discharge will mimic the natural hydrograph of the subwatershed so that changes in natural pattern of changes in lake levels will be unaffected |
| Shoreline erosion | • No issues with shoreline erosion are predicted<br>o Shoreline is largely comprised of rock/cobble and steep rock outcrops<br>o Sandy shoreline areas are flat and have low susceptibility to erosion |

**Table 4.1-2: Summary of the effects analysis on the hydrology of Hare Creek associated with PSMF discharge**

| Assessment Endpoint | Assessment Conclusion |
|---|---|
| Flow regime | • No changes in stream flow regime are predicted<br>o PSMF discharge will mimic the natural hydrograph of the subwatershed so that changes in natural pattern of changes in lake levels will be unaffected |
| Erosion and channel morphology | • No erosion or stream morphology effects are predicted<br>o The upper- and mid-reaches of Hare Creek have been characterized as having low erosion susceptibility and the lower reach has been characterized as having low to moderate |

| | |
|---|---|
| | erosion susceptibility<br>o Projected flow increases will not increase the frequency of bank full flow conditions |
| Watercourse crossings | • No issues with water conveyance at the Hwy 17 and CP rail line crossings are predicted<br>o In both cases crossing capacity exceeds the predicted peak flows for the 100-year return period during mine operations |

## 4.2 Potential Effects on the Thermal Regime of Hare Lake and Hare Creek

The potential effects of the PSMF discharge on the thermal regime of Hare Lake were discussed in response to IR 12.6.1 and are considered herein in Sections 3.3 and 3.5.4. No effects on the thermal regime of the lake are predicted.

The assessment showed the conceptual discharge configuration provides a high degree of mixing (30:1) within 50 meters of the diffuser and that during periods of PSMF discharge water temperatures in Hare Lake will be indistinguishable from background variability within this small mixing zone. It can be concluded that water temperatures in Hare Lake will be unaffected by the discharge. The same conclusion would therefore apply to water temperatures downstream in Hare Creek.

The assessment further concluded that the discharge of excess water from the PSMF to the surface layer of the lake during periods of summer stratification will not affect stratification (i.e., will not break the stratification down prematurely) since the discharge water and lake water will have similar temperature and density (see Section 3.5.3).

## 4.3 Potential Effects on Water Chemistry in Hare Lake and Hare Creek

The potential effects of the PSMF discharge on water chemistry in Hare Lake were considered in Sections 3.5.1 and 3.5.2. This assessment showed that water chemistry in Hare Lake will meet SWQB levels within the mixing zone even under upper bound conditions. It can therefore be concluded that water chemistry in Hare Lake will be protected.

This same conclusion would apply to water chemistry downstream in Hare Creek.

## 4.4 Potential Effects on Sediment Quality in Hare Lake

The potential effects of the PSMF discharge on sediment chemistry in Hare Lake were considered in Section 3.5.5. As is common in inland lakes with high TOC levels in sediment (6 to 12% on average), natural background levels of many COPCs exceed lowest effect levels (LELs). COPCs at these concentrations would not adversely impact aquatic biota as they are not generally bioavailable in the presence of high organic carbon levels.

Increases in COPC levels in sediment are expected based on small anticipated increases in concentrations in water of some COPCs as a result of the PSMF discharge. The increases in water are predicted to be minor however, and on average COPC concentrations in sediment are predicted to be within the range of the concentrations measured in sediments in the baseline sampling program. In the case of molybdenum, predicted sediment concentrations will remain well below the LEL derived by Thompson et al. (2005).

It was therefore concluded that sediment chemistry in Hare Lake will not be adversely affected by the PSMF discharge.

## 4.5 Potential Effects on Nutrient Cycling between Hare Lake Sediments and the Overlying Water Column

No effects on nutrient cycling between Hare Lake sediments and the overlying water column will occur as the result of PSMF discharge to Hare Lake because no disruption of the pattern of twice yearly (spring, fall) lake turnover is predicted.

As described in Section 3.5.3 the density difference between the discharge water and the water in Hare Lake is small and it is therefore improbable that the lake could become meromictic.

## 4.6 Potential Effects on Primary Productivity in Hare Lake and Hare Creek

No effects on primary productivity in Hare Lake or Hare Creek are expected as the result of the discharge of excess water from the PSMF to Hare Lake.

As described in Sections 3.3 and 3.5.4, the discharge should not affect the thermal regime of Hare Lake or Hare Creek and therefore there is no basis to predict that primary productivity in the system will be stimulated by higher ambient water temperatures.

As described in Section 3.5.3, and above, no effects on nutrient cycling between Hare Lake sediments and the overlying water column will occur as the result of PSMF discharge to Hare Lake as no disruption of the pattern of twice yearly (spring, fall) lake turnover is predicted. Because primary productivity in Hare Lake or downstream in Hare Creek is dependent on the internal cycling of nutrients within the lake, there is no basis to predict effects on primary productivity in the system as a result of discharge to Hare Lake.

There will be no anthropogenic phosphorus load associated with the PSMF discharge stream. Therefore no increase in the level of phosphorus in Hare Lake is predicted and no concomitant increase in primary productivity in Hare Lake is expected.

As described in Sections 3.5.1 and 3.5.2, water chemistry in Hare Lake (and downstream in Hare Creek) will meet SWQOs within the mixing zone under upper bound conditions. Therefore no effects on primary productivity in Hare Lake or Hare Creek are predicted that could be attributed to chronic exposure of the phytoplankton/periphyton standing crop to COPCs associated with the PSMF discharge.

## 4.7 Potential Effects on Phytoplankton and Zooplankton Density and Diversity in Hare Lake and Hare Creek

No effects on phytoplankton and zooplankton density and diversity in Hare Lake or Hare Creek are expected as the result of the discharge of excess was from the PSMF to Hare Lake.

As described in Sections 3.3 and 3.5.4, the discharge will not affect the thermal regime of Hare Lake or Hare Creek and therefore phytoplankton and zooplankton density and diversity in the system should be unaffected by water temperatures.

No effects on nutrient cycling between Hare Lake sediments and the overlying water column will occur as the result of PSMF discharge, nor is there an anthropogenic phosphorus load associated with the PSMF discharge. To the extent therefore that phytoplankton and zooplankton density and diversity in Hare Lake or downstream in Hare Creek is dependent on nutrient cycling and nutrient levels there is no basis to predict that primary phytoplankton and zooplankton density and diversity in the system will be affected by the discharge of excess water from the PSMF.

As described Sections 3.5.1 and 3.5.2, water chemistry in Hare Lake (and downstream in Hare Creek) are predicted to meet SWQBs within the mixing zone even under upper bound conditions. Therefore there will be no effects on phytoplankton and zooplankton density and diversity in Hare Lake or Hare Creek that could be attributed to the PSMF discharge.

## 4.8 Potential Effects on Benthic Invertebrates in Hare Lake

Because Hare Lake is a depositional environment, the benthic community is dominated by “burrowers”, invertebrate taxa that burrow and live in the sediment. The primary COPC exposure pathway to benthic organisms is therefore through lake sediments. Predictions of potential effects on the benthic community in Hare Lake are related to the predictions of sediment quality provided in Section 3.5.5 of this report.

Any changes in sediment chemistry as the result of the discharge of excess water from the PSMF to Hare Lake are predicted to be relatively minor and on average within the range of the concentrations measured in sediments in the baseline sampling program. In the case of molybdenum, predicted sediment concentrations will remain well below the LEL derived by Thompson et al. (2005).

Therefore, it can be concluded that the benthic invertebrate community in Hare Lake will not be adversely affected by the PSMF discharge.

## 4.9 Potential Effects on Benthic Invertebrates in Hare Creek

Unlike Hare Lake, which is a depositional environment, Hare Creek is a running water environment and therefore the primary COPC exposure pathway for Hare Creek benthos is through water.

As described in Sections 3.5.1 and 3.5.2, water chemistry in Hare Lake will meet SWQBs within a small mixing zone even under upper bound conditions. It can therefore be concluded that water chemistry in Hare Creek will be protected and that the benthic invertebrate community in Hare Creek will not be adversely affected by the PSMF discharge.

## 4.10 Potential Effects on Fish in Hare Lake

The primary COPC exposure pathway for fish in Hare Lake is through water.

As defined, Hare Lake SWQBs are protective of aquatic life. No COPCs are predicted to exceed those benchmarks outside a small mixing zone as a result of the PSMF discharge. It can therefore be concluded that resident fish species in Hare Lake will not be adversely affected by the release of excess water from the PSMF to Hare Lake.

Exposure of fish in the small mixing zone is not ecologically meaningful. Potential exposure of fish to COPCs in the mixing zone will be transient both in space and time. The scale of the mixing zone is smaller than what would expected to be associated with the normal movement patterns of resident fish – that is, fish may move through the mixing zone but it is very unlikely that fish would reside solely within it. Discharge will occur between April and November and therefore exposure within the mixing zone will be further limited to that period. Moreover, the predicted concentrations of COPCs in the PSMF discharge water are well below acute toxicity thresholds and therefore the PSMF discharge would not adversely affect fish within the mixing zone. It is also noted that the PSMF discharge is only anticipated for the last half of mine life.

A potential effect associated with a small amount of habitat disruption in the immediate vicinity of the discharge structure both in-lake and along the shoreline could occur as the result of its construction and subsequent decommissioning. The specific manner by which the pipeline will enter the lake will be developed during the detailed design process in consultation with the Ontario Ministry of the Environment, and other agencies as appropriate. The pipeline could be buried below ground surface or could be on the ground surface and covered with a rip rap shell. Final design will be completed in consideration of the management of the physical conditions (e.g., currents, wave action, ice) that could affect discharge performance. The potential habitat disruption, including both in-water and on-shore or riparian components, is expected to be in the order of 25 to 30 $m^2$ assuming that the pipeline corridor will be one meter wide.

After mine closure, and the cessation of discharge to Hare Lake, the discharge pipeline will be decommissioned (i.e., removed). In order to facilitate the removal of the pipeline the same magnitude of disturbance (25 to 30 $m^2$) would be expected.

## 4.11 Potential Effects on Fish in Hare Creek

The primary COPC exposure pathway for fish in Hare Creek is through water.

Because water chemistry in Hare Lake will be protected it can be concluded that water chemistry in Hare Creek will also be protected. As such, resident and migratory fish species in Hare Creek will also be protected and no adverse effects from the PSMF discharge are anticipated.

## 4.12 Potential Bioaccumulation of COCPs in Biota in Hare Lake and Hare Creek

The potential effects of bioaccumulation of COPCs on biota considered the potential effects of the PSMF discharge on representative valued ecosystem components (VECs), including northern pike, mallard duck, mink and moose. These VECs reside within Hare Lake and/or its watershed including Hare Creek.

Northern pike are piscivores that reside in the shallow waters of Hare Lake and feed on insects and small bodied fish. Mallard ducks are omnivores that may spend a portion of the time in Hare Lake feeding on aquatic plants and insects. Mink are carnivores that may reside along the banks of Hare Lake or Hare Creek feeding on insects, small mammals and small bodied fish. Moose are herbivores that may spend a portion of the time feeding on aquatic plants in Hare Lake and potentially Hare Creek. For the purpose of this assessment, it is assumed that these animals reside exclusively in Hare Lake and feed exclusively on aquatic plants and/or aquatic animals from Hare Lake. This assumption is highly conservative and unrealistic for animals such as moose that occupy a larger home range. The assessment also inherently considers Hare Creek since water quality in Hare Lake is representative of water quality in Hare Creek.

IMPACT™ was used to provide a screening evaluation of the potential risk to these animals. For conservatism, the assessment considered upper bound water quality effects in Hare Lake and includes exposure pathways through ingestion of water and foods that have been exposed to Hare Lake water and sediment. The risk assessment follows methods described in Beak (2002), Suter (2000) and Sample (1996).

Table 4.12-1 presents the results of the screening level risk assessment. The table presents the calculated hazard quotients for various COPCs and VECs. The hazard quotient represents the ratio of COPC exposure level to a reference dose for that COPC that is considered to be non-toxic. A value less than 1.0 indicates no potential risk to the animal while a value greater than 1 suggests that the toxic exposure risk should be evaluated in more detail. As shown in Table 4.12-1, all hazard quotients are less than 1.0 for all COPCs and all animals included in the assessment, indicating no risk to the VECs as the result of COPC exposure.

**Table 4.12-1: Predicted Hazard Quotient for Selected Valued Ecosystem Components**

| **COPC**[7] | **Predicted Hazard Quotient (unitless)** | | | |
|---|---|---|---|---|
| | Northern Pike | Muskrat | Mink | Moose |
| Arsenic | < 0.01 | 0.34 | 0.19 | < 0.01 |
| Cobalt | < 0.01 | < 0.01 | < 0.01 | < 0.01 |
| Copper | 0.67 | < 0.01 | < 0.01 | < 0.01 |
| Lead | 0.10 | 0.02 | < 0.01 | < 0.01 |
| Molybdenum | < 0.01 | 0.05 | 0.08 | < 0.01 |
| Nickel | 0.76 | 0.09 | < 0.01 | < 0.01 |
| Selenium | 0.91 | 0.18 | 0.82 | 0.30 |
| Zinc | 0.62 | 0.06 | 0.23 | < 0.01 |

## 4.13 Summary of Potential Effects

The predicted effects associated with the discharge of excess water from the PSMF to Hare Lake during the last half of mine life are therefore generally limited to habitat disruption within the area, including both in-water and on-shore components, in which the installation of the PSMF discharge pipeline will occur.

## 4.14 Mitigation of Potential Effects

The following mitigation strategies will be implemented to limit that effect:

- implementing best management practices and following and conforming to appropriate DFO and MNR operational statements, guidance and protocols for working around water, including but not limited to:
    - scheduling the construction and decommissioning work to coincide with times of the year that minimize risk to resident fish species as necessary;
    - avoiding where possible or maintaining setbacks from sensitive features where necessary;

[7] The analysis included only those COPCs for which reference doses were available.

- isolating access and work areas with temporary sediment control features such as berms and providing for the collection of drainage from disturbed areas; and,
- the restoration of disturbed areas as soon as is practical following disturbance.

## 4.15 Potential Residual Effects

Based on the analysis described above, no residual adverse effects on the biological functions of Hare Lake and Hare Creek are predicted as the result of the release of excess water from the PSMF to Hare Lake.

# 5.0 SUMMARY AND CONCLUSIONS

Hare Lake is situate in the Stream 5 subwatershed to the northwest of the main part of the proposed mine site. Hare Lake receives inflows from Bamoos Creek, as well as a couple of other small tributaries and discharges to Hare Creek at the western end, which outlets to Lake Superior approximately 3 km downstream at Port Munroe.

The surface area of the lake is about 57 ha and the total lake volume is approximately 8.5 M $m^3$. The maximum depth of Hare Lake is approximately 30 m. Mean lake depth is approximately 15 m. Lake retention time, based on annual average flows is in the order of 6 to 7 months. Relatively long stretches of both the north and south sides of the lake shelve steeply and afford little in the way if littoral habitat. The majority of littoral zone habitat is isolated to the main inlet and outlet areas of the lake, as well as a couple of small embayments on both the north and south sides of the lake. Hare Lake supports a resident coolwater fish community, composed primarily of Spottail Shiner, a forage fish, and the large-bodied fish species Yellow Perch and Northern Pike.

The baseline environment program at Hare Lake included the assessment of water quality (inter- and intra-annual); sediment quality; benthic invertebrates; plankton communities and primary productivity; fish; and, fish usability.

Excess water from the PSMF will be released to Hare Lake between approximately Years 5 to 10 of operations. The conceptual discharge structure includes an offshore multiport diffuser that affords 30:1 mixing within 50 m of the discharge based on the proposed minimum design configuration. Predictions were made associated with the discharge as it concerns COPC levels in Hare Lake water, potential temperature and density related effects of the discharge, the buoyancy of the PSMF discharge and the potential for the lake to become meromictic, COPC levels in Hare Lake sediments, and the potential for COPCs to bioaccumulate.

The analysis of potential effects associated with the PSMF discharge to Hare Lake considered the following:

- the hydrology of the Stream 5 subwatershed;
- the thermal regime of Hare Lake and Hare Creek
- water chemistry in Hare Lake and Hare Creek;
- sediment quality in Hare Lake;
- nutrient cycling between Hare Lake Sediments and the overlying water column;
- primary productivity in Hare Lake and Hare Creek;
- phytoplankton and zooplankton density and diversity in Hare Lake and Hare Creek;
- benthic invertebrates in Hare Lake;
- benthic invertebrates in Hare Creek;
- fish in Hare Lake;
- fish in Hare Creek; and,

- potential bioaccumulation of COCPs in biota in Hare Lake and Hare Creek.

No hydrological effects on Hare Lake and Hare Creek are predicted as the result of the small incremental increase in flow as the result of the PSMF discharge. The release of excess water from the PSMF will not affect water levels in Hare Lake, nor will it cause shoreline erosion. No changes in stream flow regime will occur as the release of water from the PSMF will mimic the natural hydrograph of the subwatershed. No erosion or stream morphology effects are predicted for Hare Creek. No issues with water conveyance at the Hwy 17 and CP rail line crossings are predicted as in both cases crossing capacity exceeds the predicted peak flows for the 100-year return period during mine operations.

Minor potential differences in temperature and/or density of the PSMF discharge water as compared to Hare Lake water will be rapidly dissipated in the mixing zone to the point of being practically indistinguishable from ambient water. No effects on surface water temperatures and the dimictic temperature regime of the lake are predicted. Under these conditions (i.e., rapid mixing via the diffuser in the mixing zone), and given the predicted moderate total dissolved solids levels in the discharge, it is physically impossible for the lake to become meromictic as the result of the discharge of excess water from the PSMF to Hare Lake.

COPC levels in Hare Lake are predicted to be below SWQBs beyond the small mixing zone under all discharge quality scenarios. It can be concluded that water chemistry in Hare Lake will be protected, and moreover that water chemistry downstream in Hare Creek will also be protected.

On average sediment quality is predicted to remain within existing natural variability. On this basis it is concluded that sediment chemistry in Hare Lake will not be adversely affected by the release of excess water from the PSMF. In the case of molybdenum, concentrations are predicted to remain well below the LEL (Thompson et al., 2005).

Nutrient cycling between the lake sediments and the water column during spring and fall turnover will be unaffected by the release of excess water from the PSMF. As indicated above, any differences in temperature and/or density of the PSMF water relative to the ambient conditions in Hare Lake will be rapidly dissipated and therefore the discharge will not affect the dimictic nature of the lake.

No effects on primary productivity and phytoplankton or zooplankton density are predicted. The release of excess water from the PSMF is not predicted to affect the thermal regime of the lake, nor nutrient cycling and phosphorus levels and COPC levels will in the lake are predicted to remain below surface water quality benchmarks.

Benthic invertebrates in Hare Lake and Hare Creek will not be adversely affected by the PSMF discharge. As indicated above, water quality will be protected in Hare Lake and Hare Creek and on average sediment quality will remain within the range of existing background levels.

No effects on fish in Hare Lake or Hare Creek are predicted as the result of changes to water quality or the hydrology of the system associated with the release of excess water from the PSMF. A small disruption of fish habitat (25 to 30 $m^2$) will likely be associated with the commissioning and decommissioning of the PSMF discharge structure at Hare Lake. This effect will be mitigated by implementing best management practices and following and conforming to appropriate DFO and MNR operational statements, guidance and protocols for working around water, including but not limited to: scheduling the construction and decommissioning work to coincide with times of the year that minimize risk to resident fish species as necessary; avoiding where possible or maintaining setbacks from sensitive features where necessary; isolating access and work and access areas with temporary sediment control features such as berms and providing for the collection of drainage from disturbed areas; and, the restoration of disturbed areas as soon as is practical following disturbance.

The potential effects of bioaccumulation of COPCs on biota considered the potential effects of the PSMF discharge on representative valued ecosystem components (VECs), including northern pike, mallard duck, mink and moose, which reside within Hare Lake and/or its watershed including Hare Creek. Hazard quotients were less than 1.0 for all COPCs and all animals included in the assessment, indicating no risk to these VECs as the result of PSMF discharge to Hare Lake.

No residual adverse effects on the biological functions of Hare Lake and Hare Creek are predicted as the result of the release of excess water from the PSMF to Hare Lake from Years 6 to 10 of the projected mine life.

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# Appendix A Photo Appendix of Hare Lake Fish Species


Photo 1: Cisco (adult). Hare Lake supports a population of "dwarf form" Cisco. No "normal form" Ciscoes have been observed in the lake.


Photo 2: Northern Pike (adult). Northern Pike are the dominant predator species in Hare Lake.

Photo 3: Spottail Shiner (adult). Spottail Shiner is the most abundant forage species in Hare Lake. .


Photo 4: Longnose Sucker (juvenile). Longnose Suckers are uncommon in Hare Lake.

Photo 5:  Trout-perch (adult).  Trout-perch are uncommon in Hare Lake.

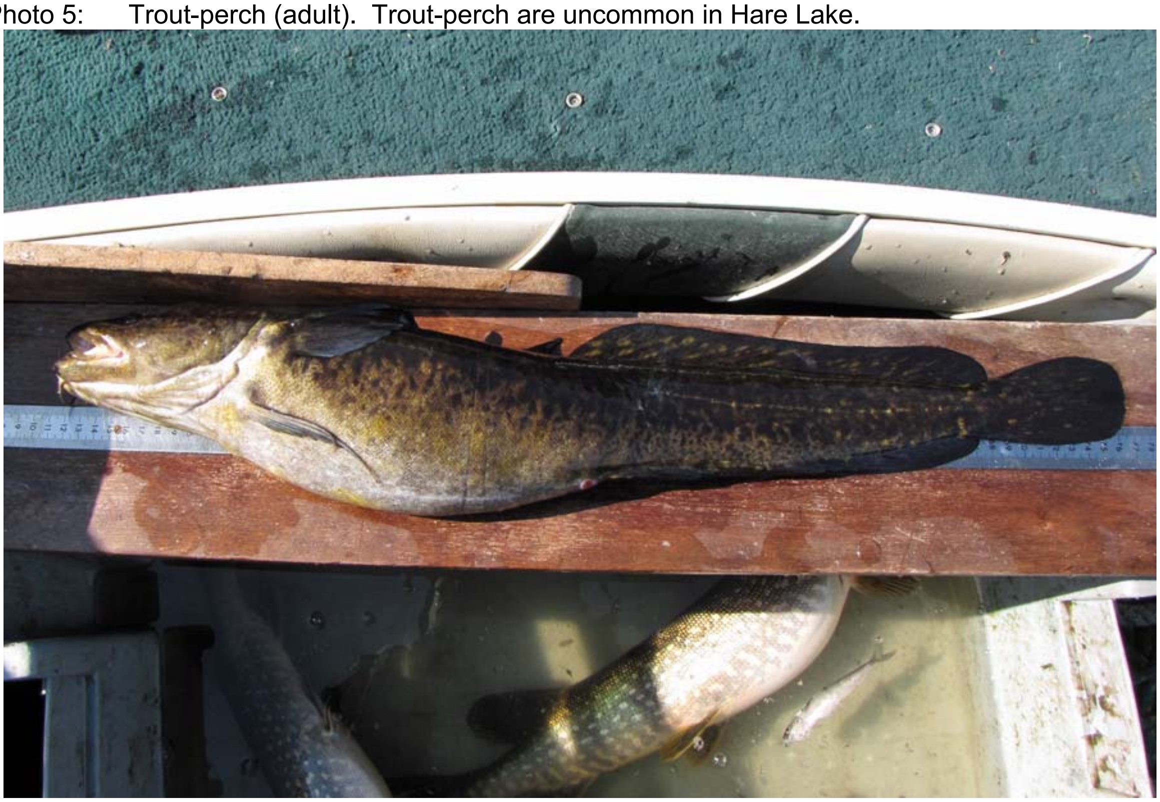

Photo 6:  Burbot (adult).  Burbot are rare in Hare Lake.

Photo 7: Slimy Sculpin (adult). A single specimen was captured in Hare Lake during August 2013.

Photo 8: Spoonhead Sculpin (adult). Spoonhead Sculpin inhabit the deep areas of Hare Lake below the thermocline. This species has been captured during two of the three surveys.

Photo 9: Yellow Perch (adult). Yellow Perch comprise the largest proportion of biomass in Hare Lake.

Photo 10: Logperch (adult). This species has only been captured in Hare Lake at the sandy beach near the lake outlet.