Fairwinds: Lake District
Nanoose Bay, BC

Enos Lake Protection & Monitoring Program

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List of Acronyms

COSEWIC	-	Committee on the Status of Endangered Wildlife in Canada
EIA	-	Environmental Impact Assessment (PGL, 2010)
ELPMP	-	Enos Lake Protection and Monitoring Program
ISMP	-	Integrated Stormwater Management Plan (KWL, 2013)
MOE	-	BC Ministry of Environment
MESL	-	MacDonald Environmental Services Ltd.
MWLAP	-	BC Ministry of Water, Land, and Air Protection
O&G	-	Oil & grease
PAH	-	Polycyclic aromatic hydrocarbons
PDA	-	Phased Development Agreement
PGL	-	PGL Environmental Consultants
QEP	-	Qualified Environmental Professional
RISC	-	Resource Inventory Standards Council
RDN	-	Regional District of Nanaimo
TOC	-	Total Organic Carbon
ToR	-	Terms of Reference
TSS	-	Total suspended solids

1.0 INTRODUCTION

Enos Lake is a small lake in a mostly undeveloped area of the Fairwinds Community located in Nanoose Bay, BC. The Enos Lake Protection and Monitoring Plan (ELPMP) outlines the tasks to monitor and inform the efforts to protect the ecology of the lake during future phases of development.

PGL Environmental Consultants (PGL) initially prepared this ELPMP on behalf of Fairwinds Community & Resort, and subsequently for FW Enterprises Ltd. (Fairwinds, or "the developer"). It is to be submitted to the Regional District of Nanaimo (RDN) as part of the developer's obligations under the Phased Development Agreement (PDA).

Earlier versions of this document were circulated for comment by the RDN and the BC Ministry of Environment (MOE) in February 2015 and April 2015. This iteration of the report has been updated and substantially revised, based on input from those parties. Of particular note, the monitoring program has been redesigned to meet the recommendations provided by RDN[1] in a letter dated July 7, 2015. As recommended by RDN, numerous parameters have been removed from the previous proposal, and the number of monitoring sites decreased. Conversely, the sampling frequency and intensity has been increased for the remaining parameters.

1.1 Enos Lake Overview

Enos Lake has a surface area of 18ha, with a watershed area of approximately 235ha. Within the watershed, 12ha has been previously developed with predominantly low-density residential housing. As part of the ongoing build-out of the Fairwinds community, another 86ha are scheduled for future development as the "Lakes District". This development is expected to occur over 10 to 20 years. Almost half of the watershed is designated for conservation and passive recreational uses, and will remain undeveloped as a public park.

Streams draining to the lake are minor: most are seasonal drainages that run dry in the summer. The lake discharges through its outlet at the north end to Enos Creek. The outlet has a weir structure to maintain water levels. The weir was installed in 1956, after which the lake was used as a community water source for a period. The weir and original dam were upgraded in 1994. The lake also has water licences for storage and irrigation that are in place for use by the Fairwinds golf course. The lake has thus been subject to water withdrawals since 1956, though from 1987 onwards this has been strictly seasonal use for golf course irrigation. The lake is no longer used for drinking water.

As is typical for lakes in BC, Enos Lake is monomictic, meaning that it is thermally stratified in the summer (cooler water with increasing depth) and is otherwise well mixed[2].

Enos Lake was home to an endangered stickleback species pair: the Enos Lake Benthic and Limnetic Threespine Stickleback pair (Committee on the Status of Endangered Wildlife in Canada [COSEWIC], 2012). Previously two distinct species, this pair now exists as an inter-breeding

[1] Letter from Randy Alexander, RDN, to Russel Tibbles, Fairwinds, Re: Enos Lake Monitoring Protection and Monitoring Program (sic)

[2] During very cold years when lake water temperatures fall below 4°C, thermal stratification may occur in winter, which would render Enos Lake "dimictic".

hybrid population. Recovery of two distinct populations does not appear possible and there are no habitat protection provisions in the most recent COSEWIC report (COSEWIC, 2012)[3]. The species pair previously had scientific value but was not commercially or culturally significant.

Aside from the stickleback pair, there are no other fish species confirmed to be present in Enos Lake[4].

1.2 Background of the Enos Lake Protection and Monitoring Plan

As part of the RDN approvals process, the Lakes District Neighbourhood Plan was subject to an Environmental Impact Assessment (EIA) (PGL, 2010). The EIA identified a number of potential effects from the development on the ecological integrity of Enos Lake. In addition to several mitigation measures to protect the lake, the EIA recommended that monitoring of the lake be conducted, as directed by the ELPMP. The need for an ELPMP was subsequently recognized in the Lakes District Neighbourhood Plan.

The Terms of Reference (ToR) for the ELPMP are set out in Schedule "BB" to the Phased Development Agreement between the RDN and the developer for the Lakes District and Schooner Cove neighbourhoods. The ToR was developed as part of an extensive public consultation process which also included input from the RDN and BC MOE.

Baseline water-quality data have been collected over several years, as described in Section 2.0. These data provide the foundation for ongoing monitoring of the lake

1.2.1 Relationship between ELPMP and ISMP

The management of stormwater from the development is a specific area of focus for environmental mitigation, as recommended in the EIA. Management of potential effects due to stormwater runoff (drainage patterns and contaminants) will be managed as per the Integrated Stormwater Management Plan (ISMP) (KWL, 2013). The ISMP includes a host of monitoring activities to ensure the plan is effective in its objectives. More generally, other potential pathways for development to impact Enos Lake require a monitoring program to achieve the general environmental protection objectives, hence the ELPMP.

Thus, the ELPMP and the ISMP are separate programs, but are related in that they both function to monitor aquatic health of the Enos Lake watershed. The ELPMP is primarily focused on water *quality* of the lake, whereas the ISMP is primarily focused on water *quantity* (both in the lake in runoff to the lake), although considerations for turbidity in stormwater runoff will also require consideration in the ISMP.

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[3] The genetic introgression of the two individual species into a hybrid population led some preliminary conclusions that these two species are extinct (Rosenfeld, 2008). The most recent COSEWIC assessment ultimately determined that it is possible some genetically pure individuals may still exist, hence the "endangered" categorization, but the same document concludes that "morphological and genetic evidence strongly indicates that Enos Lake sticklebacks now occur as a single hybrid swarm, and no longer satisfy the definition of a distinct species". Re-establishment of the two individual species does not appear possible (COSEWIC, 2012).

[4] The lake was stocked with trout in 1948, and in theory this species may still persist. Anecdotally, our understanding is this species has not been observed in recent times. Given the extensive recent sampling work for stickleback, it stands to reason that trout would have been captured in this work, if the species is present. There is virtually no spawning habitat for trout in this watershed and many past stocking programs in BC failed to create self-sustaining populations.

Ultimately, the ELPMP is also an effectiveness-monitoring tool for the ISMP (see Section 1.3), and it may provide feedback for stormwater management or monitoring. For instance, a number of water-quality parameters in the lake may be affected by changes to stormwater. If changes to water quality are noted through the ELPMP, the overseeing Qualified Environmental Professional(s) (QEP) may need to investigate if the changes could be linked to stormwater management. If the change can be attributed to stormwater-management practices (e.g., ineffective retention of hydrocarbons or suspended sediment), then adapted management practices may be recommended within the ISMP. Or, if the ISMP at that time is not currently providing the appropriate data to perform that investigation, then recommendations may be made to adapt the monitoring practices of the ISMP.

1.3 Program Objectives

The **primary objectives** of the ELPMP are as follows, based on the ToR (PGL, 2013; Schedule BB of the Phased Development Agreement):

a) Monitor the effectiveness of the ISMP relative to significant changes to the water quality and/or quantity in Enos Lake; and
b) Inform decisions regarding water management, as required.

The general management objective for Enos Lake is to maintain current (pre-development) water quality and to avoid eutrophication. Thus the ELPMP focuses primarily on potential eutrophication with periodic assessments of contaminants such as metals and hydrocarbons.

1.4 Document Structure

As outlined in the ToR, development of the ELPMP has involved (a) compilation and review of past historical environmental monitoring data for Enos Lake, and (b) detailed design of a sampling program, including selection of key monitoring parameters and targets. These are defined as follows:

- **Parameter**: a measurable property of the water, which can be used as an indicator for water quality (for example: Nitrogen concentration, temperature, pH, etc.); and
- **Target**: The specific value of a given parameter that will trigger a follow-up response, if applicable. Water quality targets were determined based on review of the baseline data, and in consideration of biological setting and overall management objectives for the lake. Actions to be taken in the event that a measured parameter exceeds the target will be determined and proposed by the QEP overseeing the monitoring program.

Due to database size, the full set of raw historical baseline data is not provided in this document. However, baseline data were screened for completeness and analyzed to compare to regulatory water-quality guidelines, as summarized herein. Analysis and presentation of baseline data will continue to be used as point of reference once operational monitoring begins.

This document provides the framework of the ELPMP, specifically including the following:

- Introduction and parameters of interest (Section 1);
- Monitoring history and existing data (Section 2);

- Water Quality (Section 3):
  - What parameters will be monitored and how;
  - Where and when sampling will be conducted; and
  - When and how data will be reviewed, stored, and analyzed.
- Water Quantity (Section 4):
  - Monitoring for changes to timing and magnitude of flow events through stormwater management.
- Biological Parameters (Section 5):
  - Avoidance and detection measures for invasive species.
- Program Management and Deliverables (Section 6)
  - Who will be responsible for what, and during various phases;
  - How results will be communicated to stakeholders; and
  - How results will be used for management decisions.

1.5 Effects Pathways

The general context of the ELPMP is to detect changes in water quality/lake ecology as a result of land development and expanded activity in the watershed. To that end, it is important to review the potential effects pathways that could lead to environmental change.

Residential land development and related recreational land use create relatively well understood and manageable effects pathways. The EIA (PGL, 2010) suggests parameters of interest, and these are included in the commonly accepted pathways for interaction summarized in Table 1-1. Each of these can also act in synergy with each other, and/or have chain-reaction consequences on lake ecology. Note that these are potential interaction pathways, and avoidance or mitigation measures are designed to reduce the magnitude and/or likelihood of actual effect pathways. The ISMP, for instance, estimates pollutant removal efficiencies from a rain garden of 15 to 95% (KWL, 2013).

Table 1-1. Overview of Effect Pathways Linking Community Development and Water Quality.

Activity	Parameters Potentially Affected
Residential pesticide or herbicide use, and resulting runoff	Highly dependent on pesticides used
Land clearing and landscaping, general construction, and stormwater runoff	Light penetration, organic or chemical inputs, and total suspended solids (TSS). Loss of riparian vegetation shading may lead to water temperature changes
Wastewater and fertilizer	Phosphorus, nitrogen
Industrial water use	Water levels, and related physical parameters (e.g., temperature, clarity)
Recreational use in and around the Lake	Hydrocarbons[a], invasive species introductions
Stormwater planning and runoff controls	Quantity and timing of runoff; pollutants in runoff from land-based activities.
Road construction and use	Salt content, TSS, organic nutrients, light penetration, hydrocarbons

[a]Upland activities only. No motorized boats are allowed on Enos Lake.

1.6 Parameters of Interest

The EIA and subsequent ToR identified that some common effects pathways in Table 1-1 provide obvious candidate parameters of concern that are most likely to be influenced by anthropogenic activity, and/or can be biological indicators of adverse change. However not all parameters are easily monitored, and in some cases it can be preferable to monitor an indirect indicator (e.g., turbidity field measurements in lieu of TSS laboratory measurements). Furthermore, unnecessary redundancy may be reduced if accepted proxies are available to represent multiple effect pathways.

The MOE provides direct guidance on developing a list of monitoring parameters, in "*Guidelines for Designing and Implementing a Water Quality Monitoring Program in British Columbia*" (Resource Inventory Standards Council [RISC], 1998). The rationale for the recommendations follow the same logical flow as the EIA effect-pathway summary from Table 1-1, and is reflected in Section 2 of the ToR.

RISC (1998) suggests the following parameters as a starting point for a monitoring program where road building and urban development[5] are involved:

- Turbidity;
- Suspended sediments;
- Dissolved oxygen;
- Conductivity;
- Oil & grease [O&G] (mineral[6]);
- Polycyclic aromatic hydrocarbons (PAHs);
- Metals;
- Coliform bacteria;
- Phosphorus;
- Nitrogen;
- Invertebrates; and
- Chlorophyll *a*.

This parameter list, either directly or indirectly, covers many but not all of the potential effects pathways identified for the Fairwinds development. For instance, the lake is subject to changes in water levels due to the exercise of water licences currently in place, and water levels in the lake are directly tied to the quantity and quality of aquatic habitat. The ISMP (Table 15 of KWL, 2013) identifies this concern and proposes collection of automated daily water level data. Thus, a list of additional candidate focal points and a brief rationale includes:

- Total organic carbon (TOC). This includes carbon sources from natural processes (e.g., decaying organic matter, metabolic activity) but also synthetic sources such as fertilizers or detergents. Community development has the potential to influence TOC.
- Hydrology: quantity and timing of water movement. Lake level management for regulated water licences, as well as stormwater management in developed areas, has the potential to alter the amount of water and the timing of water entering or exiting Enos Lake. Parameters

[5] Sewage treatment and effluent discharge into Enos Lake is not a component of the Fairwinds residential development. Sewage from the proposed community would discharge into a sewage treatment plant and subsequently to the ocean.
[6] The mineral distinction removes natural oils and greases (e.g. vegetable oils, animal fats) from the analysis.

falling under this category include water level in the lake, and an array of summary flow statistics to convey inflow and outflow from the numerous small streams in the watershed.

- Temperature. Water levels or changes in shading can have temperature effects on the lake, which can then have cascading effects on the ecosystem. Temperature at time of sampling is also necessary to interpret a number of the other monitoring parameters.
- Invasive plant and animal species. Development tends to increase the likelihood of invasive species establishment. "Hitchhikers" on boats or waders, escapes due to aquarium or ornamental pond species, and/or intentional releases of non-native plant or animal species are common pathways. In this case "parameters" for potential monitoring are actually species.

2.0 MONITORING HISTORY

Enos Lake has been studied and monitored for decades by various parties and under various approaches, with the primary focus having been an endangered species-pair of sticklebacks. Structured water quality monitoring with specific consideration for future residential build-out began in earnest in 2006. Work has primarily been carried out by QEPs on behalf of Fairwinds, with additional data collected by the MOE and "Friends of Enos Lake", a volunteer group. All data through 2014 have now been centralized[7] and are summarized in Table 2-1. All site locations are shown in Figure 1.

[7] Similar data were collected in spring and autumn 2015.

Table 2-1. Summary of Water Quality Sampling at Enos Lake Since 2006 Source: AquaTerra (2006–2014), MacDonald Environmental Services Ltd. [MESL] (2013), and Raw Data Provided by MOE and Friends of Enos Lake. Sites are mapped on Figure 1.

Site	UTM (10U, NAD83)[a]		Description	Parameters and Dates	Depth[b]
	Easting	Northing			
SWMP-01	416252	5458943	Southern portion of Enos Lake. Inlet.	• 2006–2014: Metals, nutrients, physical parameters. • Mixed conditions: November 13, 2007, October 20, 2008, November 13, 2009, December 20, 2010, November 14, 2011, March 1, 2013, and December 3, 2013. • Stratified conditions: September 15, 2006, April 13, 2007, April 24, 2008, April 20, 2009, May 3, 2010, May 9, 2011, and August 27, 2012.	• 2006–2012: Profiles for field parameters, surface for laboratory parameters. • 2013 - 2014: Surface water and deep water for laboratory parameters, and ongoing profiles for field parameters.
SWMP-02	415993	5459113	40m southwest of the raised marsh (island), mid-lake. Deep area.	• 2006–2008: Metals, nutrients, physical parameters. September 15, 2006, April 13, 2007, November 13, 2007, April 24, 2008, and October 20, 2008. • 2009–2014: Temperature, pH, conductivity, ORP, dissolved oxygen. April 20, 2009, November 13, 2009, November 13, 2009, May 3, 2010, December 20, 2010, May 9, 2011, November 14, 2011, August 27, 2012, March 1, 2013, and December 3, 2013.	• Profiles for field parameters, surface only for laboratory parameters.
SWMP-03	415803	5459374	300m north of the raised marsh (island) near deepest part of lake. Deep area.	• 2006–2014: Metals, nutrients, physical parameters. • Mixed conditions: November 13, 2007, October 20, 2008, November 13, 2009, December 20, 2010, November 14, 2011, March 1, 2013, and December 3, 2013. • Stratified conditions: September 15, 2006, April 13, 2007, April 24, 2008, April 20, 2009, May 3, 2010, May 9, 2011, and August 27, 2012	• 2006–2012: Profiles for field parameters, surface for laboratory parameters. • 2013 - 2014: Surface water and deep water for laboratory parameters, and ongoing profiles for field parameters.
SWMP-04	415497	5459797	North edge of Enos Lake, near the dam. Outlet.	• 2006–2014: Metals, nutrients, physical parameters. • Mixed conditions: November 13, 2007, October 20, 2008, November 13, 2009, December 20, 2010, November 14, 2011, March 1, 2013, December 3, 2013. • Stratified conditions: September 15, 2006, April 13, 2007, April 24, 2008, April 20, 2009, May 3, 2010, May 9, 2011, August 27, 2012	• 2006–2012: Profiles for field parameters, surface for laboratory parameters. • 2013 - 2014: Surface water and deep water for laboratory parameters, and ongoing profiles for field parameters.

Site	UTM (10U, NAD83)[a]		Description	Parameters and Dates	Depth[b]
SWMP-05	415628	5459598	Southeast edge of the deep portion of Enos Lake. Deep portion.	• 2006–2007: Spring and autumn samples for temperature, dissolved oxygen. September 15, 2006, April 13, 2007, and November 13, 2008. • 2008–2014: Added pH, conductivity, ORP. April 24, 2008, October 20, 2008, April 20, 2009, November 13, 2009, May 3, 2010, December 20, 2010, May 9, 2011, November 14, 2011, August 27, 2012, March 1, 2013, December 3, 2013.	• Profiles.
SWMP-06	416425	5458804	Southern tip of the lake where wetland drains to lake. Inlet.	• 2007–2008: Turbidity and TSS (laboratory). November 13, 2007, April 24, 2008. • 2008–2014: Added field measurement of temperature, pH, conductivity, ORP, dissolved oxygen. October 20, 2008, April 20, 2009, November 13, 2009, May 3, 2010, December 20, 2010, May 9, 2011, November 14, 2011, August 27, 2012, and March 1, 2013.	• Surface only.
WET-1	416692	5458607	Wetland area southeast of Enos Lake	• 2007–2014: Turbidity and TSS. • As strictly surface samples, stratification is irrelevant; sampling was conducted: 13 November 13, 2007, 14 April 14, 2008, 20 October 20, 2008, 20 April 20, 2009, 13 November 13, 2009, May 3, 2010, December 20, 2010, May 9, 2011, November 14, 2011, August 27, 2012, March 1, 2013, and December 3, 2013.	• Surface.
EL-01	415946	5569266	150m north of the raised marsh (island), near the lake nadir. Deep portion.	• 2011: Weekly temperature and Secchi depth, August and September. • 2012: Weekly temperature and Secchi depth through summer (early June through to mid-September). • 2013: Weekly temperature, Secchi depth, dissolved oxygen and conductivity. June 13 through September 25.	• Profiles.

Site	UTM (10U, NAD83)[a]		Description	Parameters and Dates	Depth[b]
EL-02[c]	415764	5459411	350m north of the raised marsh (island), over the nadir. Deep portion.	• Early March 2009, and mid-February 2011 and 2012: Samples for metals, nutrients, temperature, colour, dissolved oxygen, ORP, conductivity, pH (MOE sampling). • 2011: Weekly temperature and Secchi depth, August and September; • 2012: surface samples for phytoplankton and zooplankton (mid-February) • 2012: Weekly temperature and Secchi depth through summer (early June to mid-September). • 2013: Weekly temperature, Secchi depth, dissolved oxygen and conductivity (mid-June to late-September).	• March 2009 and February 2011 and 2012: One deep/one shallow for laboratory parameters, profiles for field parameters. • 2011–2013 weekly sampling: Profiles. • Phytoplankton and zooplankton, Feb 2012: surface only (0.5m).
EL-03	415648	5459557	150m southeast of the lake outlet/dam. Deep portion.	• 2011: Weekly temperature and Secchi depth, August and September. • 2012: Weekly temperature and Secchi depth through summer (early June to mid-September). • 2013: weekly temperature, Secchi depth, dissolved oxygen and conductivity (mid-June to late September).	• Profiles.
E272798	415856	5459313	Northwest half of the lake, approximately 200m northwest of the raised marsh (island). Deep portion.	• August 2008: One-time sample for alkalinity, nutrients.	• Surface only.

[a]Actual sample locations may vary +/- 10m from year to year.
[b]Surface only, combination of deep/shallow water, or full depth profiles at approx. 1m intervals.
[c]This site also includes the MOE site EL275383, as the locations overlap.

With the exception of extremely cold winters, Enos Lake is monomictic, meaning that from autumn through to early spring the water is generally fully mixed, but from mid-spring through summer there is temperature-driven stratification of the lake into an epilimnion (well-mixed upper layer) and hypolimnion (well-mixed lower layer), separated by a thermocline (narrow mixing zone of rapid temperature change). Lake mixing is integral to the limnology and drives seasonal changes in water quality parameters. Water quality monitoring must therefore differentiate between mixed and stratified conditions.

Sampling has shown that the thermal gradient at the deep part of the lake is typically less than 1˚C from October through to early March, whereas surface-vs-bottom temperatures vary by anywhere from 3.4 to 12.5˚C from April through September (Table 2-2).

Table 2-2. Thermal difference between surface sample (0.5m) and deep sample (~11m), at the deep portion of Enos Lake: 2006 – 2013. [Based on data from AquaTerra (2006) through AquaTerra (2013), and raw data provided by MOE]

Stratified Conditions		Mixed Conditions	
Date	**Thermal Difference**	**Date**	**Thermal Difference**
September 15, 2006	7.1 ˚C[a]	October 20, 2008	0.75˚C[a]
April 13, 2007	3.4 ˚C[a]	November 13, 2009	0.06˚C[a]
April 24, 2008	3.9 ˚C[a]	March 11, 2009	0.35˚C[b]
April 20, 2009	5.2 ˚C[a]	December 20, 2010	0.38˚C[a]
May 3, 2010	5.2 ˚C[a]	February 16, 2011	0.0˚C[b]
May 9, 2011	7.2 ˚C[a]	November 14, 2011	0.03˚C[a]
August 27, 2012	12.5 ˚C[a]	March 1, 2013	0.11˚C[a]
		December 3, 2013	0.05˚C[a]

[a]data from AquaTerra
[c]data from BC Ministry of Environment

2.1 Mixed Conditions - Overview

Further to the summary in Table 2-1, an overview of data collected under mixed conditions is provided below.

2.1.1 *In Situ* Parameters

Water quality profile data[8] under mixed lake conditions is comprehensive, with annual sampling generally from 2006 through 2013. The data include shallow points at both ends of the lake and the deep spot in the middle of the lake. The variability of timing among years gives very good coverage of typical mixed conditions over the course of the year.

[8] E.g., physical *in situ* parameters: turbidity, temperature, clarity, pH, dissolved oxygen, etc.

2.1.2 Laboratory Parameters

Laboratory data[9] for surface water also has good coverage through the mixed period, with annual sampling all years from 2006–2014 (Table 2-1). Sampling sites cover the outlet/inlet sides of the lake and deepest part of the lake (Table 2-1). Deep water laboratory samples were not collected in 2006 or 2007, and thus there is reasonably good baseline data but not for the same period of record as the surface water samples. However, as this sampling is under mixed conditions, the inclusion of deep water samples serves primarily to confirm uniformity of sampling parameters at shallow or deep water under fully mixed conditions[10]. Baseline monitoring revealed all parameters to be typical for the habitat, to be within relevant guidelines for aquatic life (where guidelines exist), and to portray annual variability but no obviously discernible trends (AquaTerra, 2014).

2.2 Stratified Conditions - Overview

Thermal stratification can start to occur as early as March, and continues through the end of summer (Table 2-2). Baseline data collection under stratified conditions includes:

- A monitoring program in 2013 included weekly sampling events from mid-June through late September (17 weeks total). Each sampling event included three locations within the elongated “bowl” that forms the deep part of the lake. Parameters collected in this field program include depth profiles of temperature, dissolved oxygen, specific conductivity, and water clarity.
- Weekly measurements in 2012 from early June through mid-September, covering temperature and clarity (Secchi depth), at three stations (the same ones used for 2013, the bullet point above).
- A detailed field and laboratory assessment paralleling the annual work undertaken for mixed conditions, performed in 2006 (September), 2007 (April), 2008 (April), 2009 (April), 2010 (May), 2011 (May) and 2012 (August).

Higher solar radiation in summer leads to thermal stratification, with warmer and relatively well mixed water in the upper layer (epilimnion). In Enos Lake, the epilimnion has been observed to extend from approximately 3.5m to 6m depth, in early and late summer, respectively (MESL, 2014). Conversely the depth of the cooler, mixed layer (hypolimion) has been shown to be relatively constant (MESL, 2014), meaning that as the epilimnion deepens, it is the thermocline layer that narrows, as opposed to compaction of the hypolimnion. All of which is to say, Enos Lake portrays a typical summer thermal regime for a monomictic lake in a temperate climate.

Enos Lake baseline data for stratified conditions provides a strong understanding of thermal mixing in the spring and summer, and a point of comparison for key field and laboratory parameters against the longer-term mixed-conditions dataset. Summer 2012 was particularly warm and dry (AquaTerra, 2012) and the results from the weekly Level 1 program, combined with late-August laboratory sampling, provide a sense of higher-than-normal stress level for thermally-driven processes.

[9] pH, hardness, anions, nutrients, metals, colour.

[10] Review of data from AquaTerra (2013) showed that all lab parameters between the shallow and deep samples under mixed conditions are essentially equal, with differences falling within normal sample variance. The one exception is chlorophyll *a*, for which the deep water sample was roughly twice the surface water sample in early March 2013. This may be attributed to downward drift of plant cells during the dormant season (AquaTerra, 2013).

Of particular relevance, dissolved oxygen in summer – particularly late summer – is frequently below 5.0mg/L at depths below 5.5m, and can be as low as 1.0mg/L at depths below 6m. Concentrations in the epilimnion show relatively little variance and ranged from 7.90–9.61mg/L in 2012 (MESL, 2014). It can be generalized that the hypolimnion is presently subjected to hypoxia in the summer, whereas the epilimnion maintains oxygen levels well above the BC guidelines for aquatic life (5.0mg/L).

Conductivity and clarity profiles reveal nothing unusual about Enos Lake. Although conductivity showed some coupling with thermal stratification (MESL, 2014), all summer measurements were within the range also measured over the longer spring and autumn time series.

2.3 Baseline Conditions by Parameter

The following discussion provides a general summary of baseline results by parameter, as measured at Enos Lake between 2006 and 2014.

2.3.1 Turbidity

Turbidity can be affected by residential development if land clearing during construction is poorly managed, or if road runoff over the long term is not well managed by the stormwater detention facilities.

Sediment loading in Enos Lake is typically low. The highest value recorded in open water sampling, covering 10 events from 2008 through 2013, is 2.38NTU (Table 3-1). Monitoring has covered all seasons and weather conditions, and thus Enos Lake can be characterized with high confidence as generally clear regardless of season.

Table 2-3. Summary of baseline turbidity data for surface samples at Enos Lake. Based on data from AquaTerra, 2014.

Date	Turbidity (NTU)		
	SWMP-04	SWMP-03	SWMP-01
17-Nov	NM	NM	NM
24-Apr-08	NM	1.2	1.2
10-Oct-08	1.3	1.4	1.3
20-Apr-09	1.5	1.5	1.5
11-Nov-09	1.2	0.84	0.81
03-May-10	2.2	2.1	2.1
20-Dec-10	2.38	2.32	2.06
09-May-11	2.13	2.09	2.19
14-Nov-11	1.73	1.78	1.75
27-Aug-12	0.76	0.79	1
01-Mar-13	2.09	2.09	2.01
03-Dec-13	1.33	1.21	1.35
Mean value	***1.66***	***1.57***	***1.57***
Standard deviation	***0.53***	***0.54***	***0.48***

2.3.2 Dissolved Oxygen

Residential development or ancillary activities may affect nutrient loading or cycling in the lake, which can in turn cause algal blooms that could reduce oxygen concentration. Temperature increases or salt-loading may also decrease oxygen solubility in water, leading to decreased concentrations.

Baseline sampling for dissolved oxygen in Enos Lake is extensive, with *in situ* profiles taken over multiple years, all seasons, and at a variety of locations in the lake. Sampling has shown that under mixed conditions in autumn through late winter, dissolved oxygen is typically in the 9–12mg/L range. In stratified conditions during the summer, the epilimnion (from 0 to 4.5–5.5m deep) concentrations have typically been 7–10mg/L. The highest concentration in the summer has been in the upper thermocline, likely attributable to mixing with an oxygenated surface layer but with cooler water temperatures and thus higher solubility, and also lower biological oxygen demand as the thermocline is below the euphotic zone. Summer dissolved oxygen concentration in the hypolimnion has frequently been shown to be below the 5.0mg/L guideline for BC aquatic life, and often below 1.0mg/L (MESL, 2014). This is a natural existing condition and the Enos Lake ecosystem is habituated to such occurrences – hence the monitoring focus on the epilimnion where hypoxia would represent an adverse change to the local ecosystem.

2.3.3 Conductivity

Specific conductivity (hereafter, simply “conductivity”) provides a measurement of water’s ability to transmit an electrical current. Conductivity is thus a measure of salt content, and therefore also an indicator of total dissolved solids. Conductivity can also be an early indicator of hydrocarbon, nitrate, chloride, or phosphate pollution. Thus, it provides an easily measured multiple-lines-of-evidence parameter for water quality monitoring programs.

Conductivity has been extensively sampled in Enos Lake, with bi-annual profiles taken from 2007-2013 at multiple locations on the lake, and weekly profiles taken at three deep locations in 2013. Values have ranged from approximately 80µS/cm to 180µS/cm (AquaTerra, 2014; MESL, 2014; MOE, 2009, 2011 and 2012). The highest values were recorded in 2008 and 2009, when deep water sampling and shallow water sampling each had higher mean conductivity (166µS/cm and 120µS/cm, respectively; *n*=4) compared with the years that followed (121µS/cm and 105µS/cm, respectively; *n*=7).

2.3.4 Metals

Metals contamination is a potential concern from multiple sources of industrial or residential land use. While the “metals package” laboratory analysis will return an entire suite of parameter values, a sub-set are commonly focused on.

Metals have been sampled from surface locations under mixed and stratified conditions over multiple years in Enos Lake (AquaTerra, 2014). This includes deep and shallow water samples, at locations at the inlet, outlet, and mid-lake. Additionally, MOE provided raw data output for metals sampled near SWMP-03 in 2009 and 2011. A review of all dissolved metals samples collected to date was completed, and showed that all values were below the approved BC Water Quality Guidelines for aquatic life (maximum instantaneous guideline) (Table 3-2). The AquaTerra data is limited to dissolved metals, whereas the MOE values represent total metals. The concentrations reported by both sources are extremely similar, confirming that dissolved metals constitute the dominant fraction in Enos Lake.

Table 2-4. Metals Baseline Results for Enos Lake Monitoring.

Metal	BC Water Quality Guideline (Aquatic Life - Maximum)	Baseline Maximum Value (2006 – 2013)[e]
Aluminum	0.1[a]mg/L	0.04mg/L (MOE, 2011)
Arsenic	5.0µg/L	0.2µg/L (AquaTerra, 2010)
Boron	1.2mg/L	<0.1mg/L (AquaTerra, all years)
Cobalt	110µg/L	<0.5µg/L (AquaTerra, all years)
Copper	[0.094(hardness)+2][b]µg/L	<0.1µg/L (AquaTerra, all years)
Iron	0.35 mg/L	<0.05mg/L (AquaTerra, all years)
Lead	3µg/L[c]	<0.5µg/L (AquaTerra, all years)
Manganese	1.6[d]mg/L	0.051mg/L (AquaTerra, 2009)
Molybdenum	2mg/L	0.00014mg/L (MOE, 2011)
Selenium	2µg/L	0.07µg/L (MOE, 2011)
Silver	0.1[d]µg/L	<0.0002µg/L (AquaTerra, all years)
Zinc	33[d]µg/L	1.5µg/L (MOE, 2009)

[a]Presumes pH > 6.5, which has always been the case for Enos Lake.
[b]Hardness as mg/L $CaCO_3$. Given typical values of hardness for Enos Lake (~55mg/L), this threshold is approximately 5 µg/L.
[c]Presumes hardness as mg/L $CaCO_3$ greater than 8mg/L. Baseline hardness data for Enos Lake are extensive and very consistently were measured at approximately 55 mg/L.
[d]Values are highly dependent on hardness. Criteria reported here is based on the background values reported to date.
[e]Baseline values are presented mostly for dissolved metals, with the exception of the MOE data which were total metals.

2.3.5 Phosphorus

Phosphorus, along with nitrogen, is one of two limiting nutrients for aquatic productivity. The effect of excessive phosphorus can be eutrophication of a lake. In extreme circumstances, eutrophication involves rapid and massive blooms of algae, causing in turn unsustainable biological oxygen demand and decreased light penetration. The end result tends to be a collapse of the trophic web, as anoxic water chokes out other life and decreased euphotic depth causes a collapse of primary productivity below the surface. Fertilizer-laden runoff, sewage effluent, and detergents in stormwater discharge have been implicated in anthropogenic eutrophication for decades.

Phosphorus has been part of the laboratory analyses for the bi-annual sampling program since it was initiated in 2006. Detection limits for laboratory analysis have changed over the course of the program, and the sites that have been monitored have expanded somewhat over time, but in general there is good coverage across the lake surface and at shallow/deep locations, for both mixed and stratified conditions. Data from sites SWMP-04, SWMP-03, and SWMP-01 are summarized in Table 3-3 , though only from 2010 onwards when a lower detection limit was applied to the analyses.

Table 2-5. Summary of baseline Phosphorus concentrations (surface water samples; based on data from AquaTerra, 2014)

Date	Phosphorus Concentration (µg/L)		
	SWMP-04	SWMP-03	SWMP-01
03-May-10	8	8	9
20-Dec-10	12.2	12.1	13.3
09-May-11	10.8	10.6	11.6
14-Nov-11	10.2	12.2	11.7
27-Aug-12	6.5	6.6	8.2
01-Mar-13	12.8	11.7	12.7
03-Dec-13	11.7	14.1	12
Mean value	***10.31***	***10.76***	***11.21***
Standard deviation	***2.30***	***2.61***	***1.90***

Phosphorus levels in Enos Lake have ranged from a low of 8µg/L to a high of 14.1µg/L (AquaTerra, 2014), although until 2009 the detection limit was 20µg/L, and results were simply reported as less than the detection limit. Independent sampling by the MOE in 2009 and 2011 reported similar values, approximately 10–11µg/L. Phosphorus has thus been fairly consistent across years, seasons, depths, and sampling teams at Enos Lake, but also falls somewhat near to the guidelines on occasion.

2.3.6 Nitrogen

Nitrogen, along with phosphorus, is one of two limiting nutrients for aquatic productivity. As with phosphorus, the effect of excessive nitrogen in the water can be the undesirable eutrophication of a lake.

Nitrogen (in the form of Ammonia Nitrogen, Nitrate and Nitrite, and total Kjeldahl Nitrogen) was analyzed in the bi-annual sampling since 2007[11]. Values have shown variability that is typical to freshwater systems, but always well below the BC water quality guidelines. The maximum value of Nitrate + Nitrite (combined; “N&N”) has been approximately 0.11mg/L, and values more typically have been less than 0.05mg/L. Ammonia has also been typically less than 0.05mg/L, and in some cases an order of magnitude less (AquaTerra, 2014). Independent sampling by the MOE in 2009 and 2011 (winter) reported approximately 0.1mg/L of N&N.

2.3.7 Chlorophyll *a*

Chlorophyll *a* is a plant pigment, and is very commonly used as a laboratory-measured indicator of water quality. Nutrient loading of watercourses can led to planktonic blooms, which would be detectable in higher levels of chlorophyll *a*. This parameter therefore is consistent with the multiple-lines-of-evidence approach embedded in this monitoring program, as eutrophication of the lake should be identifiable with an evident increase in at least two of chlorophyll *a*, dissolved oxygen, nitrogen, and/or phosphorous.

The two mid-February samples from MOE (2011, 2012) resulted in values of 9.5 and 7.03µg/L, respectively.

[11] Ammonia Nitrogen was included since September 2006 program initiation; the remaining forms were added in November 2007.

Chlorophyll *a* was added to the bi-annual sampling program at Enos Lake in 2009, and thereafter was measured at SWMP-01, SWMP-03, and SWMP-04, representing locations near the lake inlet/outlet, and mid-point over the deep spot (Table 3-4).

Table 2-6. Baseline data for Chlorophyll a (surface samples only; based on data from AquaTerra, 2014 and MOE raw data)

Date	Chlorophyll a concentration (µg/L)		
	SWMP-04	SWMP-03[a]	SWMP-01
11-Mar-09	NM	11.3	NM
04-Apr-09	18.5	18.1	19.8
11-Nov-09	0.1	0.17	0.17
03-May-10	8.5	5.5	7
20-Dec-10	1.44	7.14	5.42
16-Feb-11	NM	9.5	NM
09-May-11	4.21	5.36	2.05
14-Nov-11	7.75	10.2	10
15-Feb-12	NM	7.03	NM
27-Aug-12	1.83	1.08	0.468
01-Mar-13	10.2	4.25	10.8
03-Dec-13	1.67	5.02	3.27

[a]Also includes samples from MOE taken in 2009, 2011, and 2012, in a very nearby location.

Sampling was initially limited to surface samples only, but a deep sample was added to SWMP-03 in 2012. Based on the data collection from 2009 through 2013, chlorophyll *a* has been highly variable, ranging from 0.17µg/L to 19.8µg/L (Table 3-4). Values have typically been in the range of 4–5µg/L, but there is no consistent seasonality to the few cases where values have exceeded 10µg/L – having been measured as such in November, March, and April. However, that the highest overall values obtained (average 19µg/L across three locations) happened to occur in late April 2009 may be indicative of an algal bloom at that time. Nitrogen and phosphorus levels were coincidently low at that event, which suggest the monitoring may have been timed shortly after nutrient uptake by growing phytoplankton.

2.3.8 Total Organic Carbon

TOC is a very common water quality indicator, with the primary pollution concern being hydrocarbon contribution to this parameter. Point-source or surface runoff of hydrocarbons from road development and use and general industrial activity can contribute to elevated TOC levels.

TOC has been part of the bi-annual laboratory monitoring at sites SWMP-01, SWMP-03, and SWMP-04 since 2008. Deep water sampling was added to SWMP-03 in 2013. Values have typically ranged from 4.5–6.5mg/L, with some minor exceptions. TOC has been relatively consistent and sampling has been evenly dispersed, as evidenced by the nearly-equivalent mean versus median values (5.9mg/L vs. 6.1mg/L, respectively).

3.0 WATER QUALITY MONITORING PROGRAM

This section presents the water quality monitoring program. It includes sampling protocols, a list of parameters to be sampled, and relevant thresholds against which the results can be compared.

3.1 Sampling Procedures

Guidelines for collection of water quality samples are provided in the *Ambient Freshwater and Effluent Sampling Manual* (BC Ministry of Water, Land, and Air Protection [MWLAP], 2003). The sampling for the ELPMP will adopt the following approach, which is based on those guidelines. Note that sampling instructions must also be provided by the laboratory chosen for the analysis, when the containers are provided. Sampling requirements stipulated by the laboratory (e.g., holding times, sample preservation, etc.) will supersede the general requirements outlined here, and should be considered the most up to date with current technical standards.

Note this procedure outline also includes *in situ* data that will be read and recorded directly in the field.

Where possible, field personnel should include appropriately qualified professionals with accreditation (R.P.Bio. or other similar). Recognizing that this program may be undertaken with support from volunteer organizations, professional credentials are not a strict requirement. However, any field personnel should at the very least have received training and instruction from a qualified professional.

3.1.1 Preparation

A general target is to have samples provided to the laboratory within 24 hours of sampling, and this requires proper communication and preparation. It is recommended that an accredited analytical laboratory be contacted at least two weeks ahead of the work, to arrange for shipping of sampling containers, preservative, and instructions. Schedule the actual fieldwork in consultation with the laboratory to avoid holding time conflicts with laboratory analysis. For instance, many laboratories may have little to no service on Saturdays or Sunday, and so fieldwork should avoid sampling on a Friday or a Saturday.

- Be familiar with sample locations ahead of time, and have coordinates pre-entered to a hand-held GPS.
- Sample containers are to be pre-labeled while they are dry, before going into the field.
- Sampling at Enos Lake will require use of a boat, and access to private land. Ensure the relevant land owner(s) have been contacted and have provided consent, prior to conducting the work. Contact info, as of March 2016, is as follows:
  - Fairwinds: info@fairwinds.ca; 250-468-5303.
- Safety considerations are always paramount, particularly when a boat is involved. A site-specific health and safety plan is recommended for any field trip, and life jackets should always be worn. Be particularly careful when doing winter sampling. Ice cover of Enos Lake is very rare but may occur, and hypothermia is a serious risk during any winter work.
- Prepare a checklist of necessary field equipment ahead of time. Mobilizing to the site without necessary equipment or preparation can undermine the sampling program. This may include, at minimum:
  - Sampling jars, pre-labeled;
  - Sample preservatives;

- o Print-out of any sampling instructions from the laboratory. This should be laminated or placed in a Ziploc bag;
- o Ice packs and coolers;
- o Chain-of-custody forms, partially filled out ahead of time;
- o Field meters and spare batteries;
- o Notebook, pencil; and
- o Emergency contact information and protective gear, such as cell phone (in Ziploc bag), first aid kit, sufficient fuel (if necessary), oars, PFDs, personal clothing suitable for a variety of field conditions, etc.

3.1.2 Documentation

Detailed notes must be kept – on waterproof paper – for all field trips. Standard information to be kept for all trips includes:

- Date and time of sampling;
- Current weather, and general summary of weather in the days leading up to the work;
- All field staff involved in the work;
- Method of accessing the sites;
- Sampling coordinates (presumes use of hand-held GPS unit);
- Any unusual conditions noted (e.g. hydrocarbon sheen, odour, new construction [docks, moorings], very high or very low water levels, etc.);
- Samples intended for analysis;
- At each site, record:
  - o Time of access, and time of samples;
  - o *In situ* profile data, and methods for measurement, if relevant; and
  - o Any challenges noted that required deviation from the monitoring program.
  - o Any observation of new invasive species introductions to Enos Lake (refer to Section 5.0).

Field notes should be scanned and saved to a secure server with appropriate back up.

3.1.3 Sample Collection

Collect samples from a boat or dock at all times. Wading into the water can contaminate the sample due to sediment entrainment. Sampling will be somewhat different for surface water vs. deep water vs. profile (*in situ*) data.

<u>Quality Assurance/Quality Control</u>

Quality Assurance/Quality Control measures are necessary during field sampling to detect whether the sampling methodology is influencing the results. All field sampling procedures shall include the following quality control measures:

- Sample containers will be used only in accordance with instruction by the laboratory. Different parameters require different container materials or colours or preservatives, and the laboratory will provide the necessary instruction. These requirements can vary over time as analytical methods change, so do not presume that an older set of instructions are valid for the next sampling event.

    - Furthermore, the MOE website should be consulted well ahead of the field trip to check if any standard water sampling protocols have been updated. Any protocols dated 2016 or later should be reviewed against this document, with field methods updated as necessary.
- The inner surface of the sampling container (including the cap) should not be touched with anything other than sample water.
- Dirty hands can contaminate samples. This most commonly occurs due to handling food, tobacco products, or petroleum products. Samplers must be aware of this risk and take precautions accordingly.
- Collect samples at the bow of the boat, and keep the bow pointed into the wind. This will reduce the likelihood of the boat contaminating the samples.
- A note regarding filtration: a number of parameters (chlorophyll *a*, metals, and low-level nutrients) must be filtered before analysis. While MWLAP (2003) recommends filtering immediately after collection, filtration can also be done by the analysing laboratory. The general guidance for this program is to minimize sample handling in the less-controlled field situation, and to request lab filtration. Discuss with the laboratory ahead of time.
- Field meters should be calibrated as per the manufacturer's guidelines. Documentation on calibration should be kept as part of the QA/QC program.
- Replicate sampling. At a minimum of one sampling site, a complete duplicate will be collected. A replicate sample tests for the precision of the entire sampling process (collection, handling, and analysis).

Surface Water Samples

Once at sample site, remove cap from sample container. Do not touch the inside of the cap, and in general be cautious about any source of contamination.

Plunge the bottle into the water, targeting depth of approximately 0.5m (1.5ft). If there is any current, face the mouth of the bottle into the current and move it slowly upstream. Recap the bottle and immediately place it in a cooler, where it can be kept dark and cool. Proceed to collect all samples in as short a period as safely practical.

Deep Water Samples

Deep water sampling requires use of a Van Dorn sampler or a Kemmerer sampler. It is presumed that whomever is contracted to carry out the sampling has access to a sampler and is familiar with its use. If unfamiliar with use protocols, refer to MWLAP (2003) for further instructions.

Care should be taken to avoid dropping the sampler all the way to the lake bottom, as this will entrain sediment and potentially bias samples. Deep water sampling (at SWMP-03/EL-02, for instance) should target approximately 10.5–11m to avoid hitting the bottom at the deepest part of the lake (~12m).

Use the drain valve of the sampler to fill sample containers. Take precautions against sample contamination, and allow a small amount of water to flush the valve before collecting in a sampling bottle. The most common areas of contamination are via handling the inside of the bottle cap, or by contacting the drain valve.

In Situ (Field) Samples

A number of parameters will be sampled, measured, and recorded directly in the field. It is possible to measure all of these parameters with a multi-parameter sonde (a.k.a. YSI). A sonde with depth-marked cabling allows multiple parameters to be simultaneously measured at repeated depths.

Alternatively, and less preferred, values may be recorded with a variety of hand-held devices such as a pH pen, turbidity meter, conductivity probe, dissolved oxygen meter, etc. In this case, the Van Dorn sampler will be required to bring samples from desired depth, where they can be measured after discharging water to a (clean) 1L sampling jar.

Chemical titration methods are available for a number of field parameters, and MWLAP (2003) provides the protocol details. However, given the frequency of sampling and the anticipated number of individuals that could be involved in this program, field titration should be avoided.

Regardless of whether sampling occurs with a multi-parameter sonde, a variety of hand-held devices, or a combination thereof, ensure that all instruments are cleaned and calibrated according to the manufacturer's instructions, prior to use.

Where a sonde is available, field parameters should be measured as profiles, at 1m increments. Either attach a flexible tape measure to the sonde cable, or use a tape ahead of time to mark 1m increments on the cable itself. Maximum sampling depth for Enos Lake is expected to be 11m, so the cable must be capable of reaching at least 11m.

3.1.4 Submission

Samples shall be immediately transferred to a cooler, with either ice or ice packs to keep samples cool. Fill out the chain-of-custody form, insert it in a plastic bag, and attach it to the outside of the cooler. Secure the cooler with tape, and avoid opening unless absolutely necessary to minimize exposure to light or ambient air temperature.

The cooler(s) should be submitted to the laboratory as soon as possible, either via direct drop off or courier. A number of commercial laboratories have offices on Vancouver Island, or drop-off depots for free transfer to mainland laboratories. ALS Global Inc. has been used for the majority of the baseline data collection used in this program.

Analytical methods must be capable of detection limits below the water quality guidelines stated in Section 3.3. Analytical techniques and possible detection limits evolve over time. Discuss the desired detection limits with the laboratory at the time of or prior to sample submission.

3.2 Data Storage

It is anticipated that leadership of this monitoring program may involve multiple parties. It will be necessary to maintain a central and well documented database in case of handover between program managers. The BC MOE maintains a central database (EMS) for water quality data, and has offered to incorporate the data from this program into the EMS to ensure access to all parties indefinitely. The logistics of data sharing should be discussed with MOE as the program proceeds.

In general, data should be entered into a central database and reviewed by the QEP as results are returned by the lab. There may be time-sensitive follow-up work recommended by the overseeing QEP, and thus it is preferable that data not be archived strictly for annual review.

Summary analysis of the program as a whole will be part of the annual reporting framework outlined in Section 6.0.

3.3 Parameters and Sampling Program

Where relevant, the BC Water Quality Guidelines (BC, 2015) are being used as target values for parameters.

These values have been chosen on the following grounds:

- They are based on accepted, peer-reviewed scientific literature for protection of aquatic health, and are endorsed by the province; and
- The extensive baseline water quality monitoring for Enos Lake shows that all parameters have consistently fallen below these guideline values, where present.

These guidelines tend to be updated periodically and care should be taken to refer to the most up-to-date guidelines as monitoring progresses.

The program is generally structured for quarterly monitoring at a single location (site SWMP-03, the deep spot of the lake) for most parameters, with additional sampling on five-year increments for a smaller number of parameters. This represents a large change to the initial proposal (e.g. past drafts of this document), and adopts all of the feedback provided by RND in July of 2015.

Candidate water quality parameters for sampling were outlined in Section 1.0. From this candidate list, multiple parameters were removed (and some added), through discussion with MOE and RDN. The suite of parameters below are considered the most likely to see changes from regional development. The list of monitoring parameters is as follows:

- Dissolved oxygen;
- Temperature;
- pH
- Conductivity;
- Redox potential;
- Hardness;
- Secchi depth;
- PAHs;
- Metals;
- Coliform bacteria;
- Phosphorous;
- Nitrogen; and
- Chlorophyll *a.*

The monitoring approach and water quality target (if applicable) for each parameter is outlined in Table 3-5. A sampling calendar for each parameter is provided in Appendix 1. Note, this calendar suggests the onset of a regular operational monitoring schedule in 2017, as it is PGL's understanding that no significant development will occur in the Enos Lake watershed until at least the end of 2017. If construction within the Enos Lake watershed is delayed, it may be sensible to augment monitoring after 2017 to be every two or three years until construction begins, at which point annual monitoring would recommence.

For all parameters, an exceedence of the target should not be construed as a project-related serious effect on the environment. It should be treated as a warning signal requiring further investigation, the extent of which will depend on the nature of the results obtained. This program intentionally lacks the prescriptive follow-up triggers that may be required under, for instance, a mining program with oversight under the Metals Mining Effluent Regulations portion of the *Fisheries Act*. This allows the program to remain flexible for multiple, and uncertain, managing partners and funding sources in the years to come.

Table 3-1. Summary of Water Quality Monitoring Program for Enos Lake

Parameter (units)		Water Quality Target	Future Monitoring[a]
Field Parameters (profiles at 1m increments)	Secchi Depth (m)	None – supporting context only	Quarterly sampling[b] at site SWMP-03, starting in 2017 and repeated annually
	Dissolved Oxygen (mg/L and % saturation)	• ≥5 mg/L epilimnion • ≥2 mg/L hypolimnion	Quarterly sampling[b] at site SWMP-03, starting in 2017 and repeated annually
	Conductivity (µS/cm)	None – supporting context only	Quarterly sampling[b] at site SWMP-03, starting in 2017 and repeated annually
	Temperature (°C)	None – supporting context only	Quarterly sampling[b] at site SWMP-03, starting in 2017 and repeated annually
	pH	None – supporting context only	Quarterly sampling[b] at site SWMP-03, starting in 2017 and repeated annually
	Redox (mV)	None – supporting context only	Quarterly sampling[b] at site SWMP-03, starting in 2017 and repeated annually
Laboratory Parameters	*E. coli* (# per mL)	BC Water Quality Guidelines (recreation – secondary contact)[c]	August 2017: 5 times in 30 days. Surface sample from SWMP-03 and any two shoreline locations. Repeat on 5 year increment.
	PAHs (µg/mg)	BC Water Quality Guidelines (freshwater sediments)	August 2017: surface sediment from three locations: SWMP-06, SWMP-04 and SWMP-03.
	Metals (various)	BC Water Quality Guidelines (total metals, freshwater aquatic life). Both average and short-term maximum guidelines apply, where applicable.	February 2017 and August 2017: five samples in a 30 day period. Each sample to occur at three depths from SWMP-03. Sampling to be repeated on five year increments.
	Chlorophyll *a* (µg/L)	Avoid any increase	Quarterly sampling at site SWMP-03, starting in 2017, and repeated annually. Samples to be taken from three depths (surface, mid, deep water)
	Hardness (as $CaCO_3$)	None – required to interpret metals data	February 2017 and August 2017: five samples in a 30 day period. Each sample to occur at three depths from SWMP-03. Sampling to be repeated on five year increments. Data required to interpret metals concentrations.
	Phosphorous (mg/L)	12 µg/L	Quarterly sampling at site SWMP-03, starting in 2017. Samples to be taken from three depths (surface, mid, deep water)

[a]Future monitoring is limited to the scope being taken on by the Developer and will continue until at least one year post build-out within the Enos Lake watershed. It is anticipated that some form of longer term monitoring will be undertaken by RDN in support of long term operation of stormwater infrastructure.
[b]Quarterly sampling is defined as February, May, August, and November.
[c]It is assumed that swimming will not be a recreational use of Enos Lake. If that assumption is incorrect, primary contact guidelines should apply.

4.0 WATER QUANTITY

Hydrology parameters require monitoring in tandem with the water quality monitoring outlined in Section 3.0. Changes to runoff parameters or lake water levels will yield clues to causation, if any of the water quality parameters deviate substantially from the baseline values.

Monitoring of flow regime is already a recommended component in the Fairwinds ISMP; (KWL, 2013). The precise structure, timing, extent, and duration of monitoring for ISMP hydrologic effectiveness remains to be finalized. Key parameters in the ISMP include minimum summer water level, 200-year high water level, and the actual (as opposed to allowable) water withdraws from Enos Lake. More generally, it is important to note that MOE already requires monthly lake level monitoring, as per the long-standing Water Licences held by other parties (see Section 1.0).

This monitoring will be designed and undertaken by the ISMP leads, and the results thereof are to be communicated to the manager of this more general ELPMP for incorporation in the data interpretation. Similarly, and as outlined in Section 1.2.1, the ELPMP results will be highly relied upon for ongoing adaptive management of the ISMP.

5.0 INVASIVE SPECIES MANAGEMENT PRACTICES

Aquatic invasive species can be culturally, environmentally, and economically devastating. For example, invasive crayfish are largely blamed for the demise of the Enos Lake Stickelback pair as individual benthic and limnetic species. Eradication of established species can be impossible for all practical intents and purposes, and early detection or avoidance altogether are the most effective means to keep invasive species out of natural ecosystems.

Residential development can exacerbate the so-called “propagule pressure”[12] and create new vectors where none previously existed. Boat fouling, foot traffic, contaminated personal gear (waders, boots, etc.), aquarium abandonment, and cultural practices are all relevant vectors for consideration. Awareness is the best protective measure.

The ToR for the ELPMP included a focal element on invasive species. Recognizing the inherent difficulties in a comprehensive plan for an issue of this scope, the following general recommendations are provided:

- During any onsite work for water quality monitoring, the overseeing QEP will monitor for any incidental observation of invasive species.
- Include prevention practices in Homeowner’s Manual. A QEP should be contracted for the input to the manual, as best management practices and focal species have been evolving fairly rapidly over the past 15 years and may continue to do so prior to full build-out of the community.

[12] The likelihood of an invasion occurring is correlated the number of opportunities potential species are given to establish themselves. The higher the vector traffic, the higher the number of “propagules” that are likely to be released, and ultimately this leads to a higher overall probability of establishment.

- Public signage along trails and viewpoints should include prevention practices and also "species to watch for", with visual aids. At time of writing this report, common target freshwater invasive species in BC (as per BC Invasive Species Council) are:
  - Eurasian milfoil;
  - Parrotfeather;
  - Didymo;
  - Zebra mussel;
  - Quagga mussels;
  - Common carp;
  - Smallmouth bass; and
  - Largemouth bass.

In addition to the list above, trout species (usually rainbow) have historically been introduced in many BC lakes for recreational angling. Particular effort should be taken to dissuade people from introducing any species for angling purposes.

Note, this section does not imply these are the only species of concern. Signage should encourage the public to report any species if they suspect it is not native. Species lists should also be updated on five-year increments to screen for newly problematic species.

The BC Invasive Species Council (http://bcinvasives.ca) should be contacted in the event of any positive or suspected identification, whether as a part of structured monitoring or not. Their contact information should be included on any public signage.

6.0 PROGRAM MANAGEMENT AND DELIVERABLES

This section addresses the role of various parties in implementing and interpreting the ELPMP throughout its duration.

6.1 Program Leadership

Implementation and oversight of the ELPMP will initially be the responsibility of the developer. Day-to-day management of program logistics and technical interpretation will fall to the QEP working on behalf of the developer. It is intended that community volunteers and other interested stakeholders will be engaged to assist with data collection.

The developer ultimately will be responsible for ensuring relevant stakeholders are brought into decision making as necessary. This responsibility will remain with the developer from formal commencement of the ELPMP, which will begin with quarterly monitoring in 2017, through to one year after completion of build out. For the purpose of the ELPMP, "build out" refers to all residential construction phases that lie within the Enos Lake Watershed.

Post-build out, leadership of the ELPMP will revert to the RDN, or the RDN's designate.

6.2 Data Collection and Management

So long as the ELPMP remains under the direction of the developer, all field data shall be provided directly to the developer as soon as possible after data collection. Field notes should be scanned or mailed, and laboratory results copied directly to the developer.

As stated in Section 3.2, a shared centralized EMS database through MOE will be explored, but until and unless this database is established, the developer will retain overall responsibility to see that data are managed responsibly.

6.3 Reporting

Data should be reviewed against targets as soon as possible after each sampling event; however, formal reporting is only required once per year. From the onset of construction through to one year beyond build-out, analysis and reporting will be led by the developer's QEP. If monitoring continues beyond that temporal scope, reporting requirements will be at the discretion of the RDN or whoever assumes responsibility for the monitoring.

Annual reports will be submitted by December 31 for each calendar year in which work was performed. Reports will include, at minimum:

- A summary of work performed, including dates, individuals, weather conditions, methods, QA/QC protocols, and any challenges encountered during the work.
- A presentation of the water quality results, including but not limited to data summaries (graphical or tabular) compared against the targets listed in this document (where relevant).
- Any anecdotal observations related to Enos Lake ecology, including but not limited to aquatic invasive species.
- A summary of preventative actions taken with respect to aquatic invasive species undertaken in the past year (e.g. signage, educational materials for residents or visitors, etc.)
- A discussion interpreting the results of the program for the past year, including but not limited to input provided for stormwater management practices or new phases of construction.
- Recommendations for augmentation to the program, if relevant.
- Laboratory certificates and raw data for the year, as appendices.

6.4 Informing Management Decisions

The ELPMP is a monitoring program, not a management plan. As such, it provides technical details on what information will be collected, when, where, and by whom. The rationale behind the ELPMP is to provide decision makers with information to support future actions. Results of the ELPMP may feedback into construction practices or monitoring approaches. This "plan / act / learn" loop is the foundation of a contemporary adaptive management strategy (Diagram 1)

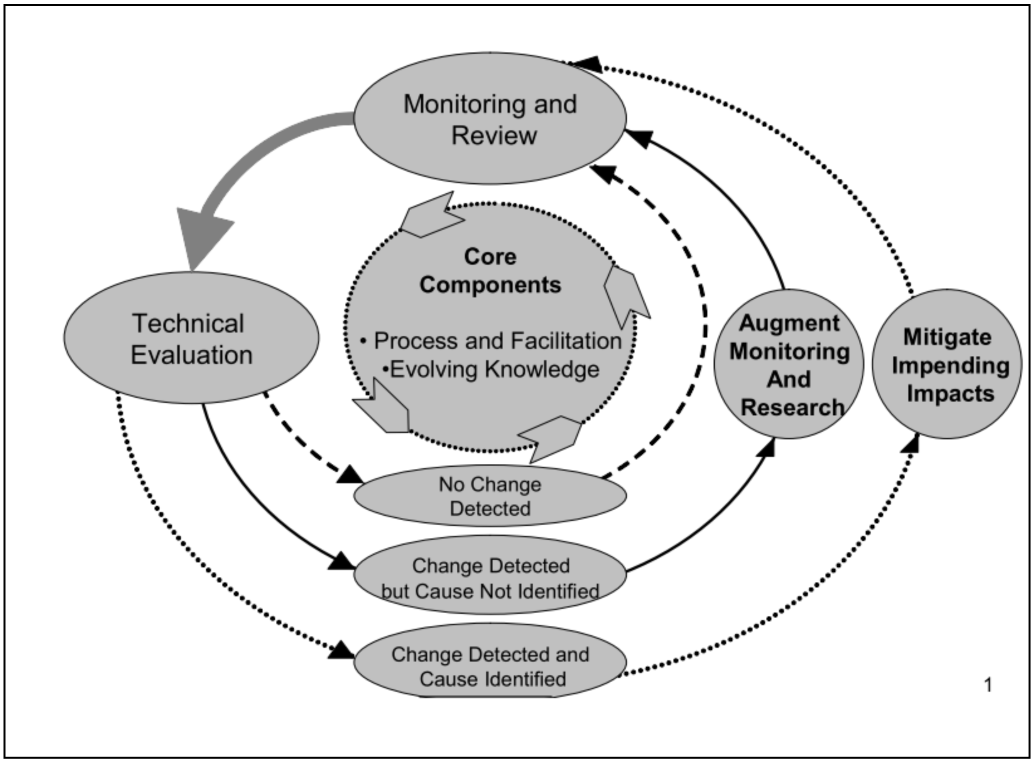

Diagram 1. Illustration of feedback loop for an adaptive management process. (From Elner, 2005).

There are no prescriptive triggers for action in this program, in the event that a water quality parameter exceeds a defined target. Should this occur, the follow-up actions will be determined by the circumstances surrounding that particular result. However, despite this discretionary approach, some formality is required as part of the RDN's subdivision approval. To this end, each subdivision application for new residential phases will include in the submission, a letter from the engineer stating how the ISMP has been interpreted based on the latest ELPMP Annual Report, and applied to the stormwater infrastructure design and planned construction practices.

6.5 Summary: Deliverables and Schedule

A number of actions and deliverables are detailed in this document. These have been summarized below (Table 6-1).

Table 6-1. Summary of actions and deliverables for ELPMP implementation

Deliverable/Action	Timing	Responsible Party	Recipient	Comment
Implementation / planning meeting	Q1-Q4, 2016 (flexible)	Developer and RDN (required); MOE and BC LSS representatives (optional)	N/A	To determine short term roles and responsibilities, and identify partnerships for data collection / entry.
Initiate regular monitoring schedule, per Table 3-1	February 2017	Developer – either via volunteer group or QEP	All parties (part of overall database)	All data to be submitted to developer as first point of contact.
Enter all water quality data (2006 – present) into a centralized database	Q2-Q4, 2016 (flexible)	Developer	All parties	Requires further discussion between Developer's QEP and MOE (per Row 1 of this table)
Interim review of sampling results for monitoring program	Following immediately after each sampling event.	Developer	Depends on outcome of review.	In the event of an exceedance of target, QEP to recommend next steps – whether additional data collection or change to ISMP (in consultation with design team).
Develop invasive species awareness materials (signage, Homeowner's Manual, etc.)	Prior to start of construction in Fairwinds District	Developer	Homeowners, local residents	Described in Section 5.
Annual ELPMP Progress Report, as outlined in Section 6.2	December 31 of each year in water sampling was conducted.	Developer	Developer and design team	Report is intended as an input mechanism into ISMP adaptive management, and is to be formally recognized during subsequent subdivision applications, within the ISMP (per ISMP s. 4.3) and Construction Environmental Management Plan, per PDA s. 44(d)(x). Report will also be provided to the RDN.
Ongoing post-build out water quality monitoring, as per Table 3-1.	Beginning one year after completion of build-out	RDN or designate.	Discretion of RDN	Longer term monitoring to be scoped based on results through build out and management objectives at that time. It is anticipated that long term operation of stormwater service area will benefit from this monitoring or an augmented version of it.

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7.0 CONCLUSION

This document presents the Enos Lake Protection and Monitoring Program, as per the October 2013 ToR. The ELPMP is largely based on provincial guidelines for developing and implementing a water quality monitoring program, with site-specific considerations for hydrology and invasive species concerns.

The ultimate duration of the monitoring program is open-ended. This document commits to extending at least one year beyond full build-out within the Enos Lake catchment area. However, consideration of monitoring results, available resources, and management objectives at that time may determine that additional monitoring is required. Re-evaluation of the monitoring program after the build-out is complete is recommended.

8.0 REFERENCES

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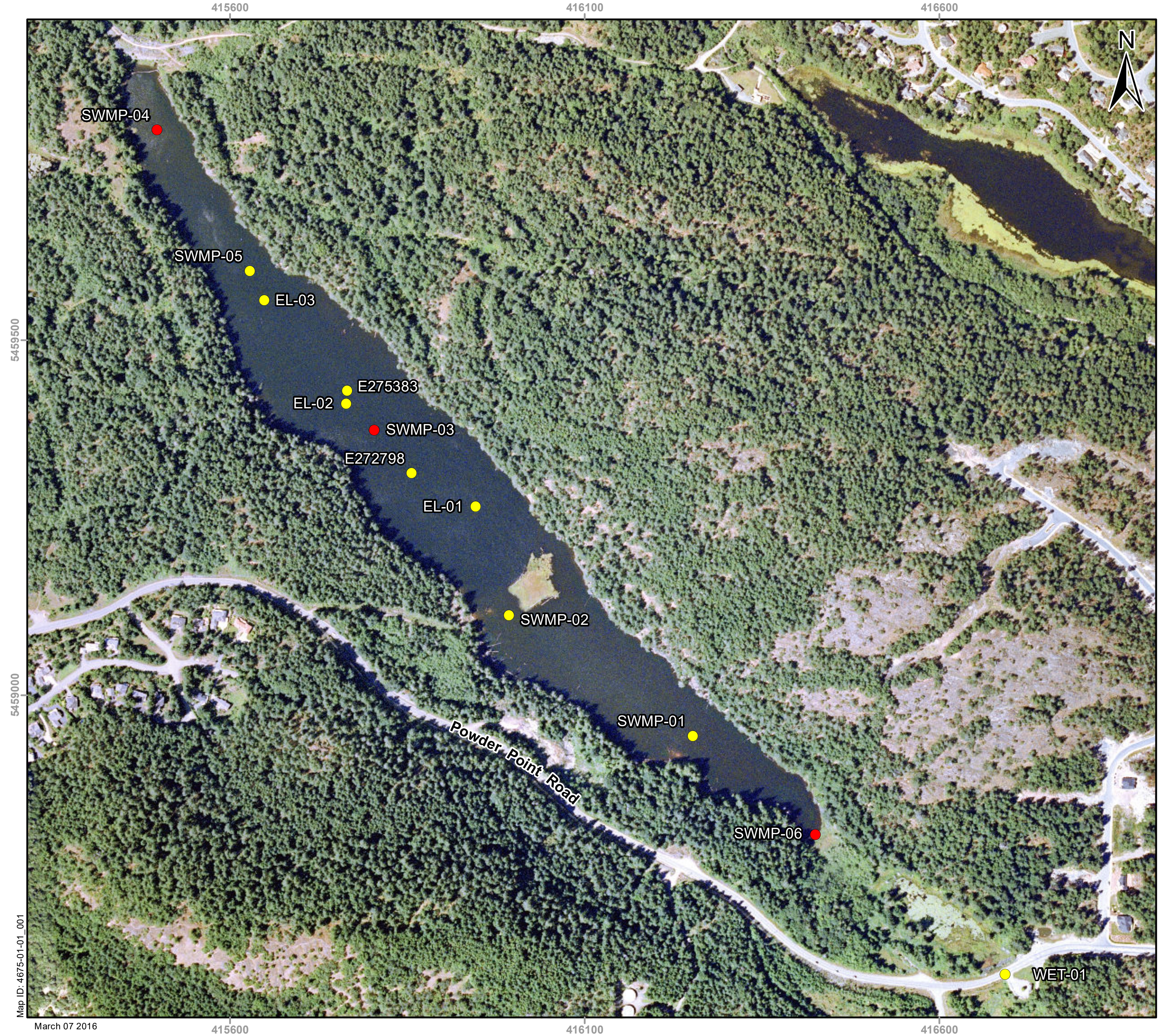
Figure



Enos Lake Monitoring Locations 2006 – present

- Monitoring sites used, 2006-2014 (yellow dot)
- Monitoring sites for future use (red dot)

1:7,500

0 100 200

Metres

Coordinate System: NAD 1983 UTM Zone 10N

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Figure 1

Appendix 1

Proposed ELPMP Monitoring Schedule by Year and by Parameter

PGL

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Appendix 1
Proposed ELPMP Monitoring Schedule by Year and by Parameter
Fairwinds: Lake District, PGL File: 4675-01.01

2017												
Parameter	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sept**	**Oct**	**Nov**	**Dec**
Dissolved Oxygen		F			F			F			F	
Temperature		F			F			F			F	
Redox potential		F			F			F			F	
pH		F			F			F			F	
Secchi Depth		F			F			F			F	
Chlorophyl *a*		L			L			L			L	
Phosphorhus		L			L			L			L	
E Coli								E				
Metals		M						M				
Hardness		M						M				
PAH								P				

Legend

L = Water sample from three depths at SWMP-03
F = 1m in situ profiles from SWMP-03
E = Five samples in 30 days, from SWMP-03 and any two shoreline locations.
M = Five samples in 30 days, from SWMP-03
P = Surface sediment from SWMP-03, SWMP-06 and SWMP-04

2018												
Parameter	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sept**	**Oct**	**Nov**	**Dec**
Dissolved Oxygen		F			F			F			F	
Temperature		F			F			F			F	
Redox potential		F			F			F			F	
pH		F			F			F			F	
Secchi Depth		F			F			F			F	
Chlorophyl *a*		L			L			L			L	
Phosphorhus		L			L			L			L	
E Coli												
Metals												
Hardness												
PAH												

Legend

L = Water sample from three depths at SWMP-03
F = 1m in situ profiles from SWMP-03
E = Five samples in 30 days, from SWMP-03 and any two shoreline locations.
M = Five samples in 30 days, from SWMP-03
P = Surface sediment from SWMP-03, SWMP-06 and SWMP-04

Appendix 1
Proposed ELPMP Monitoring Schedule by Year and by Parameter
Fairwinds: Lake District, PGL File: 4675-01.01

2019												
Parameter	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sept**	**Oct**	**Nov**	**Dec**
Dissolved Oxygen		F			F			F			F	
Temperature		F			F			F			F	
Redox potential		F			F			F			F	
pH		F			F			F			F	
Secchi Depth		F			F			F			F	
Chlorophyl *a*		L			L			L			L	
Phosphorhus		L			L			L			L	
E Coli												
Metals												
Hardness												
PAH												
Legend	*L = Water sample from three depths at SWMP-03* *F = 1m in situ profiles from SWMP-03* *E = Five samples in 30 days, from SWMP-03 and any two shoreline locations.* *M = Five samples in 30 days, from SWMP-03* *P = Surface sediment from SWMP-03, SWMP-06 and SWMP-04*											

2020												
Parameter	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sept**	**Oct**	**Nov**	**Dec**
Dissolved Oxygen		F			F			F			F	
Temperature		F			F			F			F	
Redox potential		F			F			F			F	
pH		F			F			F			F	
Secchi Depth		F			F			F			F	
Chlorophyl *a*		L			L			L			L	
Phosphorhus		L			L			L			L	
E Coli												
Metals												
Hardness												
PAH												
Legend	*L = Water sample from three depths at SWMP-03* *F = 1m in situ profiles from SWMP-03* *E = Five samples in 30 days, from SWMP-03 and any two shoreline locations.* *M = Five samples in 30 days, from SWMP-03* *P = Surface sediment from SWMP-03, SWMP-06 and SWMP-04*											

Appendix 1
Proposed ELPMP Monitoring Schedule by Year and by Parameter
Fairwinds: Lake District, PGL File: 4675-01.01

2021												
Parameter	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sept**	**Oct**	**Nov**	**Dec**
Dissolved Oxygen		F			F			F			F	
Temperature		F			F			F			F	
Redox potential		F			F			F			F	
pH		F			F			F			F	
Secchi Depth		F			F			F			F	
Chlorophyl *a*		L			L			L			L	
Phosphorhus		L			L			L			L	
E Coli												
Metals												
Hardness												
PAH												
Legend	*L = Water sample from three depths at SWMP-03* *F = 1m in situ profiles from SWMP-03* *E = Five samples in 30 days, from SWMP-03 and any two shoreline locations.* *M = Five samples in 30 days, from SWMP-03* *P = Surface sediment from SWMP-03, SWMP-06 and SWMP-04*											

2022												
Parameter	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sept**	**Oct**	**Nov**	**Dec**
Dissolved Oxygen		F			F			F			F	
Temperature		F			F			F			F	
Redox potential		F			F			F			F	
pH		F			F			F			F	
Secchi Depth		F			F			F			F	
Chlorophyl *a*		L			L			L			L	
Phosphorhus		L			L			L			L	
E Coli								E				
Metals		M						M				
Hardness		M						M				
PAH								P				
Legend	*L = Water sample from three depths at SWMP-03* *F = 1m in situ profiles from SWMP-03* *E = Five samples in 30 days, from SWMP-03 and any two shoreline locations.* *M = Five samples in 30 days, from SWMP-03* *P = Surface sediment from SWMP-03, SWMP-06 and SWMP-04*											