BRITISH COLUMBIA | Ministry of Environment and Climate Change Strategy

ENVIRONMENTAL PROTECTION DIVISION

MINISTRY OF ENVIRONMENT & CLIMATE CHANGE STRATEGY

# Water Quality Objectives Attainment for Shawnigan Lake (2006-2014)

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## Executive Summary

Water quality objectives (WQO) were developed for Shawnigan Lake in 2007 and were designed to protect existing and future water uses (Rieberger, 2007). Ambient WQOs were set for dissolved oxygen, water clarity (Secchi depth), total phosphorus, total nitrogen, N:P ratio, turbidity, total organic carbon, chlorophyll *a, E. coli*, enterococci and fecal coliforms. WQO attainment monitoring was conducted between 2006 and 2014 to determine if these objectives were being met and to understand the overall state of water quality in Shawnigan Lake.

Non-point sources of pollution are the only major input of pollutants to Shawnigan Lake proper. These are potentially derived from urban runoff, land development, on-site sewage systems, agriculture, and forestry activities. Despite the increase in development and land-use changes in the watershed, the WQO attainment data presented in this report indicate that the overall state of lake water quality continues to be good. While some of the WQOs were exceeded, the data show that the lake remains oligotrophic (low nutrients and low biological productivity), and there is no indication of overall deterioration in water quality.

## Introduction

As part of the Province of British Columbia Ministry of Environment and Climate Change Strategy's (ENV) mandate to manage water bodies, water quality assessments and WQO reports have been created for numerous lakes, rivers and marine surface waters. These reports provide a list of objectives to protect water quality that are tailored to the specific water body for which they have been created, considering natural local water quality, water uses, water movement, and waste discharges. While the WQOs currently have no legal standing, they can direct resource managers aiming to protect the water body in question and are used as a standard against which to measure the water quality of that water body. The science based information and trends identified help inform local government drinking water, liquid waste and land use planning processes, including water quality targets and effective monitoring of those plans. Once objectives have been developed, periodic monitoring (approximately every three to five years) is undertaken to determine whether they are being met.

Shawnigan Lake is located within the Shawnigan Lake watershed as part of the Nanaimo Lowland (NAL) ecoregion (Figure 1). WQOs for the lake were developed by Rieberger (2007) to protect drinking water, primary contact recreation, and aquatic life (Table 1). Objectives were based on data collected between 2003 and 2005, as well as historical data. Water quality monitoring to determine objectives attainment occurred between 2007 and 2014; results are presented in this report. Due to local concerns, additional data were collected in 2013 at other sites in the watershed to assess potential impacts from anthropogenic activities around the lake and in the upper watershed; these data are presented separately in Kopat *et al. (*2019).

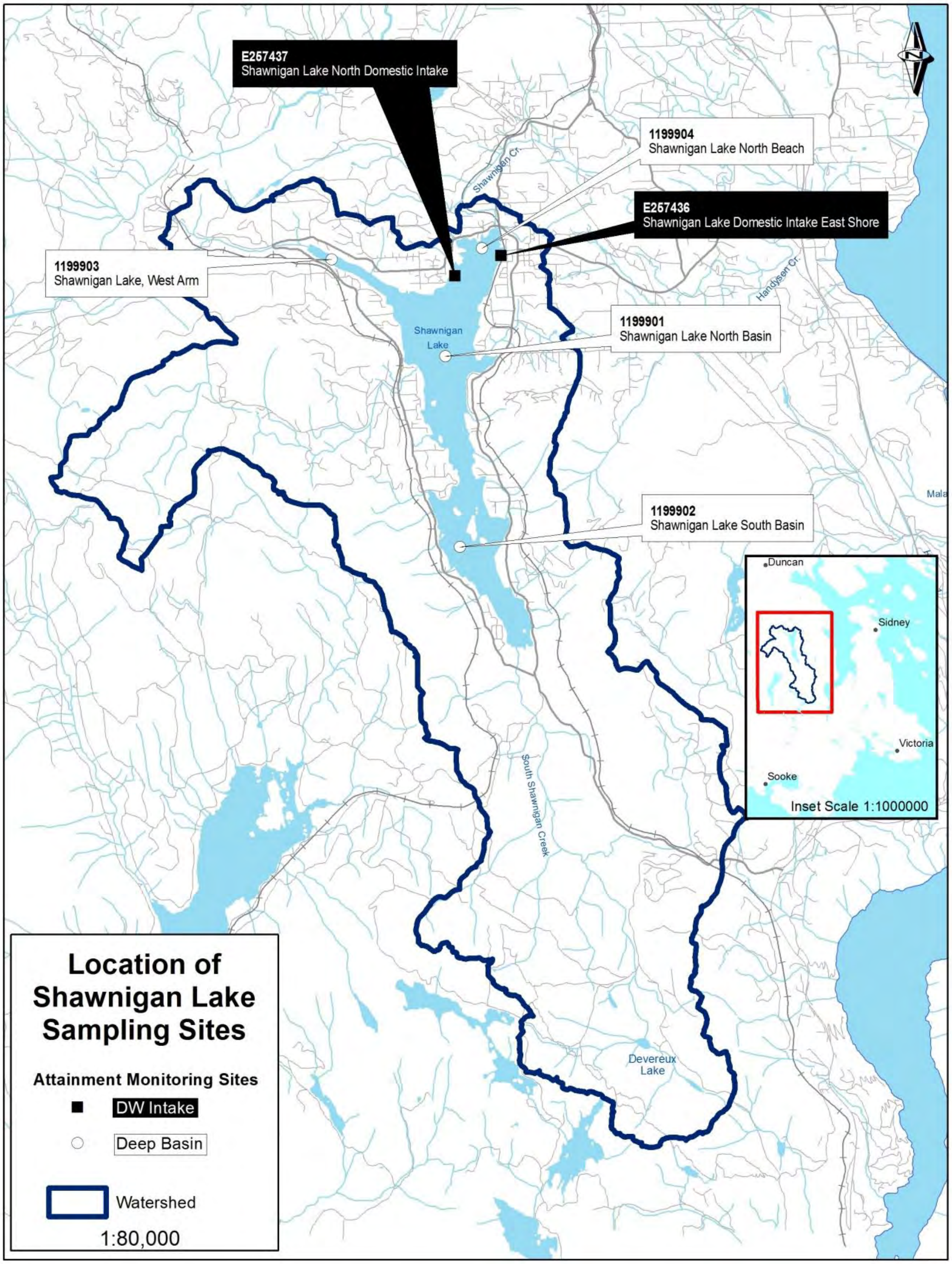



Figure 1. Water quality attainment sampling sites within the Shawnigan Lake watershed (2006-2014).

Table 1. Water Quality Objectives for Shawnigan Lake.

<table>
<tr><th>Site</th><th>1199901</th><th>1199902</th><th>1199903</th><th>1199904</th><th>E257436</th><th>E257437</th></tr>
<tr><td>Designated Water Uses</td><td colspan="6">Drinking water, recreation (primary contact), aquatic life</td></tr>
<tr><td>Characteristics</td><td colspan="6"></td></tr>
<tr><td>Dissolved Oxygen[1]</td><td colspan="4">≥ 5 mg/L</td><td></td><td></td></tr>
<tr><td>Secchi Depth[2]</td><td colspan="4">≥ 5 m</td><td></td><td></td></tr>
<tr><td>Total Phosphorus[3]</td><td colspan="4">≤ 8 μg/L at spring overturn</td><td></td><td></td></tr>
<tr><td>Total Nitrogen[4]</td><td colspan="2">≤ 250 μg/L</td><td></td><td></td><td></td><td></td></tr>
<tr><td>N:P Ratio[5]</td><td colspan="4">≥ 30:1</td><td></td><td></td></tr>
<tr><td>Turbidity[6]</td><td></td><td></td><td colspan="2">≤ 1 NTU</td><td></td><td></td></tr>
<tr><td>Total Organic Carbon</td><td colspan="4">≤ 4 mg/L</td><td></td><td></td></tr>
<tr><td>Chlorophyll a[7]</td><td colspan="2">≤ 2 μg/L</td><td></td><td></td><td></td><td></td></tr>
<tr><td>Escherichia coli[8]</td><td></td><td></td><td colspan="4">≤ 10 CFU/100 mL (90th percentile)</td></tr>
<tr><td>Enterococci[8]</td><td></td><td></td><td colspan="4">≤ 3 CFU/100 mL (90th percentile)</td></tr>
<tr><td>Fecal coliforms[8]</td><td></td><td></td><td colspan="4">≤ 10 CFU/100 mL (90th percentile)</td></tr>
</table>

*1 This objective applies to any depth of the water column throughout the year.*
*2 Annual mean.*
*3 This objective applies to the average of at least three samples taken throughout the water column (surface, mid depth, one metre above bottom) for sites 1199901 and 1199902 and to the average of at least two samples (surface and one metre above bottom) for sites 1199903 and 1199904.*
*4 This objective applies to the average of at least three samples taken throughout the water column (surface, mid depth, one metre above bottom) for sites 1199901 and 1199902, at spring overturn.*
*5 The N:P ratio is calculated using average total nitrogen and total phosphorus concentrations.*
*6 This objective applies to any grab sample taken within 10 m of a domestic water intake (E257436 and E257437). It also applies to sites 1199903 and 1199904 which likely reflect conditions near domestic intakes on the lake.*
*7 Values are to be growing season averages for epilimnetic water in the main basin of the lake.*
*8 The 90th percentiles are calculated from at least five weekly samples collected in a period of 30 days. For values recorded as <1, a value of 0 should be used to calculate the statistic. If any of the objectives are exceeded, further sampling should be conducted during the summer low flow and fall freshet periods, consisting of at least 5 weekly samples in a 30-day period.*

## Changes in the watershed since water quality objectives were developed

- The watershed supports a population of 8558 people (2016 Census; CVRD, 2016), which represents a 5% increase relative to the 2011 population, and a 129% increase relative to the 1986 population.
- Two parcels of land (64 ha and 120 ha) in the southern portion of the watershed have been transferred to the Malahat First Nations as part of a treaty process.
- In 2010, the 1000-acre parcel of second-growth forest land known as Elkington Forest was re-zoned by the Cowichan Valley Regional District (CVRD) to a Community Land Stewardship Zone, under which portions were conserved under covenants.
- Cobble Hill Holdings Ltd. (South Island Aggregates - SIA) maintained a quarry off South Shawnigan Lake Road for which a waste discharge permit (PE-105809) was issued in August 2013 under the *Environmental Management Act* (EMA), to establish a soil remediation facility and landfill in the Shawnigan Lake Watershed. The permit allowed the company to treat contaminated soil, landfill soil that cannot be treated, and discharge treated effluent to an ephemeral stream. The permit was cancelled in February 2017, and there are currently no discharges to the receiving environment. More information can be found at https://www2.gov.bc.ca/gov/content/environment/air-land-water/site-permitting-compliance/sia.
- There are three water bodies in the watershed that are licensed for water withdrawal: Shawnigan Lake, Shawnigan Creek, and McGee Creek. The number of water licenses and the quantity of water permitted for withdrawal are less than the reported values in the 2007 objectives report. In 2007, 225 licenses were permitted to extract over 7000 $m^3/d$, whereas at the time of this report, 218 licenses were permitted to extract about 6800 $m^3/d$ (BC FLNRO, 2015).

## Sampling and Analytical Methods

Six water quality sites within Shawnigan Lake were sampled between March 2006 and February 2014, as part of the WQO attainment monitoring - four deep basin sites and two water intake sites (Table 2). As recommended by Rieberger (2007), spring overturn sampling occurred on March 28, 2006, March 1, 2007, February 25, 2008, February 25, 2010, and February 2, 2014. In addition to the recommended sampling and to investigate summer conditions, monthly sampling occurred from May to August 2008; while to look at seasonal differences, quarterly sampling was conducted in 2013-14 (May, August, November 2013, and February 2014). All sampling was conducted as per standard ENV sampling protocols (BC ENV, 2013).

Table 2. Recommended water quality sampling program including EMS IDs, timing of sampling events and characteristics to be measured.

<table>
<tr><th>Site</th><th>Depth</th><th>Parameters</th><th>Timing</th></tr>
<tr><td>1199901<br>1199902</td><td>●Surface<br>●mid-depth<br>●bottom (1m above surface)</td><td rowspan="4">●Anions: dissolved chloride<br>●Field Measurements: DO profile, temperature profile, Secchi depth<br>●Nutrients: total P, dissolved P, total N, total organic N, $NO_3$-N+$NO_2$-N, $NO_2$-N, ammonia, total organic C, total inorganic C<br>●Physical Properties: conductivity, pH, total solids, total dissolved solids, turbidity<br>●Total Metals<br>●Biological: phytotoplankton(1), zooplankton(2), chlorophyll a</td><td rowspan="5">Spring overturn (preferably before February 28)</td></tr>
<tr><td></td><td></td></tr>
<tr><td>1199903<br>1199904</td><td>●Surface<br>●bottom (1m above surface)</td></tr>
<tr><td></td><td></td></tr>
<tr><td>E257436<br>E257437</td><td>●Surface<br>●bottom (1m above surface)</td><td>E. coli, enterococci, fecal coliforms(3)</td></tr>
</table>

*1. Surface (0.5 m) unconcentrated 1 L sample preserved with Lugol's solution.*

*2. Vertical haul from 10 m to surface. Preserved in 5% formalin. Mouth size of net must be recorded.*

*3. If any of these results exceed objective levels, further sampling should be conducted during the summer low flow period and the fall freshet, consisting of at least 5 weekly samples in a 30-day period.*

Microbiological monitoring did not occur as recommended in Rieberger (2007) at the West Arm (1199903) and North Beach (1199904) sites in 2008, 2010 and 2013. However, sampling did occur at the two domestic water intake sites (E257436 and E257437). In 2013 additional perimeter sites around the lake were sampled, primarily focused on nutrient and microbiological inputs. These data are included as part of the Upper Shawnigan Creek assessment monitoring report (Kopat *et al*, 2019). The requisite sampling frequency at the intake sites (a minimum of five samples within a 30-day period) was not conducted on a few occasions, especially during the fall 2013 sampling period, primarily due to limited resources (i.e., not having staff or volunteers able to collect the samples on a weekly basis).

## Objectives Attainment

A summary of WQOs attainment results are presented in Tables 3 to 6. Several additional water quality parameters were recommended for monitoring by Rieberger (2007) that provide important information regarding the overall water quality of Shawnigan Lake (Table 2). Some of these data (e.g. temperature, pH, true colour, phytoplankton, and zooplankton) are presented alongside the attainment parameters, while the remaining data are summarized in Appendix I. Site-specific raw data can be obtained by contacting the ENV Nanaimo regional office.

Table 3. Attainment results for North Basin Site (1199901) for spring overturn sampling.

| PARAMETER | OBJECTIVE | 2006-03-28 | 2007-03-01 | 2008-02-25 | 2010-02-25 | 2014-02-12 |
|---|---|---|---|---|---|---|
| | | Spring Overturn Sampling | | | | |
| Dissolved Oxygen | ≥ 5 mg/L | Y | Y | Y | Y | Y |
| N : P Ratio | > 30:1 | Y | Y | Y | Y | Y |
| Total Organic Carbon | ≤ 4 mg/L | Y | Y | Y | Y | Y |
| Total Nitrogen | ≤ 250 µg/L | **N** | Y | **N** | Y | **N** |
| Total Phosphorus | ≤ 8 µg/L at spring overturn | Y | Y | Y | Y | Y |
| Secchi Depth | **Annual** Mean ≥ 5 m | INSD (n=1) | ND | Y (n=5) | INSD (n=1) | Y (n=9) |
| Chlorophyll *a* | ≤ 2 µg/L (**Annual growing** season average, May - August samples) | ND | ND | Y | ND | ND |

*Y = Objective Met, N = Objective Not Met, ND = No Data Collected, INSD = Insufficient Data*

Table 4. Attainment results for South Basin site (1199902) for spring overturn sampling.

| PARAMETER | OBJECTIVE | 2006-03-28 | 2007-03-01 | 2008-02-25 | 2010-02-25 | 2014-02-12 |
|---|---|---|---|---|---|---|
| | | Spring Overturn Sampling | | | | |
| Dissolved Oxygen | ≥ 5 mg/L | Y | Y | Y | Y | Y |
| N : P Ratio | > 30:1 | Y | Y | Y | Y | Y |
| Total Organic Carbon | ≤ 4 mg/L | Y | Y | Y | Y | Y |
| Total Nitrogen | ≤ 250 µg/L | Y | Y | Y | Y | **N** |
| Total Phosphorus | ≤ 8 µg/L at spring overturn | Y | Y | Y | Y | Y |
| Secchi Depth | **Annual** Mean ≥ 5 m | INSD (n=1) | INSD (n=1) | Y (n=5) | INSD (n=1) | INSD (n=1) |
| Chlorophyll *a* | ≤ 2 µg/L (**Annual growing** season average, May - August samples) | ND | ND | **N** | ND | ND |

*Y = Objective Met, N = Objective Not Met, ND = No Data Collected, INSD = Insufficient Data*

Table 5. Attainment results for West Arm site (1199903) for spring overturn sampling.

| PARAMETER | OBJECTIVE | 2006-03-28 | 2007-03-01 | 2008-02-25 | 2010-02-25 | 2014-02-12 |
|---|---|---|---|---|---|---|
| | | Spring Overturn Sampling | | | | |
| Dissolved Oxygen | ≥ 5 mg/L | Y | Y | Y | Y | Y |
| N : P Ratio | > 30:1 | Y | Y | Y | Y | Y |
| Total Organic Carbon | ≤ 4 mg/L | Y | Y | Y | Y | Y |
| Total Phosphorus | ≤ 8 µg/L at spring overturn | Y | Y | Y | Y | Y |
| Secchi Depth | **Annual** Mean ≥ 5 m | INSD (n=1) | ND | **N** | INSD (n=1) | INSD (n=1) |
| Turbidity | **Monthly** Mean ≤ 1 NTU | **N** | Y | Y | **N** | Y |
| | Instantaneous ≤ 5 NTU | Y | Y | Y | Y | Y |
| *E. coli* | ≤ 10 CFU/100 mL (90th percentile) | ND | ND | ND | ND | ND |
| Enterococci | ≤ 3 CFU/100 mL (90th percentile) | ND | ND | ND | ND | ND |
| Fecal Coliform | ≤ 10 CFU/100 mL (90th percentile) | ND | ND | ND | ND | ND |

*Y = Objective Met, N = Objective Not Met, ND = No Data Collected, INSD = Insufficient Data*

Table 6. Attainment results for North Beach site (1199904) for spring overturn sampling.

| PARAMETER | OBJECTIVE | 2006-03-28 | 2007-03-01 | 2008-02-25 | 2010-02-25 | 2014-02-12 |
|---|---|---|---|---|---|---|
| | | Spring Overturn Sampling | | | | |
| Dissolved Oxygen | ≥ 5 mg/L | Y | Y | Y | Y | Y |
| N : P Ratio | > 30:1 | Y | Y | Y | Y | Y |
| Total Organic Carbon | ≤ 4 mg/L | Y | Y | Y | Y | Y |
| Total Phosphorus | ≤ 8 µg/L at spring overturn | Y | Y | Y | Y | Y |
| Secchi Depth | **Annual** Mean ≥ 5 m | INSD (n=1) | ND | Y (n=5) | INSD (n=1) | INSD (n=1) |
| Turbidity | **Monthly** Mean ≤ 1 NTU | Y | Y | Y | **N** | Y |
| | Instantaneous ≤ 5 NTU | Y | Y | Y | Y | Y |
| *E.coli* | ≤ 10 CFU/100 mL (90th percentile) | ND | ND | ND | ND | ND |
| Enterococci | ≤ 3 CFU/100 mL (90th percentile) | ND | ND | ND | ND | ND |
| Fecal Coliform | ≤ 10 CFU/100 mL (90th percentile) | ND | ND | ND | ND | ND |

*Y = Objective Met, N = Objective Not Met, ND = No Data Collected, INSD = Insufficient Data*

Table 7. Attainment results for intake sites East Shore E257436 and North E257437

| Site | PARAMETER | OBJECTIVE | February | Summer Sampling (CFU/100 mL) | | Fall Sampling (CFU/100 mL) | |
|---|---|---|---|---|---|---|---|
| | | | 2010 | 2008 | 2013 | 2008 | 2013 |
| **East Shore E257436** | *E. coli* | ≤ 10 CFU/100 mL (90th percentile) | INSD (n=1) | **N** | Y | ND | INSD (n=4) |
| | Enterococci | ≤ 3 CFU/100 mL (90th percentile) | INSD (n=1) | **N** | ND | ND | ND |
| | Fecal Coliform | ≤ 10 CFU/100 mL (90th percentile) | INSD (n=1) | **N** | ND | ND | ND |
| **North E257437** | *E. coli* | ≤ 10 CFU/100 mL (90th percentile) | INSD (n=1) | INSD (n=4) | Y | ND | INSD (n=3) |
| | Enterococci | ≤ 3 CFU/100 mL (90th percentile) | INSD (n=1) | INSD (n=4) | ND | ND | ND |
| | Fecal Coliform | ≤ 10 CFU/100 mL (90th percentile) | INSD (n=1) | INSD (n=4) | ND | ND | ND |

*Y = Objective Met, N = Objective Not Met, ND = No Data Collected, INSD = Insufficient Data*

## Temperature

While there are no WQOs for temperature in Shawnigan Lake, temperature is a key parameter for water quality in lakes. Water quality guidelines for temperature have been developed in BC for several water uses (Oliver and Fidler, 2001). For drinking water supplies, it is recommended that water temperature be less than 15 °C to protect the aesthetic quality of the water. For the protection of aquatic life in streams, the optimum temperature ranges for salmonids are based on specific life history stages such as incubation, rearing, migration and spawning. However, in lakes, the allowable change in temperature is ±1 °C from naturally occurring levels (Oliver and Fidler, 2001).

Water temperature was measured at each lake site, and vertical profiles of temperature in the water column at the deep stations are illustrated in Figure 2. Note that there was no temperature profile taken in February 2014, as the sensor on the probe malfunctioned. Generally, the water column in Shawnigan Lake is well mixed during the winter/early-spring months, and then becomes thermally stratified during the summer months, with a thermocline occurring between 5 m and 10 m in depth (depending on the site). This stratifies the water column into two primary zones, the epilimnion (warmer surface waters) and the hypolimnion (cooler bottom waters). The water temperature ranged from a minimum of 4$^{o}$C to 6$^{o}$C in the winter months to a maximum surface water temperature of 23$^{o}$C to 24$^{o}$C in July and August for all sites.

Although surface water temperatures in the summer months exceed the BC WQO Water Quality Guidelines (WQGs) for aquatic life, there is sufficient cooler, oxygenated water available for fish at lower depths in the lake, especially at the North Basin site.

Surface water temperatures at the lake intake sites were collected by the CVRD during summer sampling in 2012 and 2013 (Appendix I, Table 13). Temperatures at these sites were quite warm, ranging from 20 to 22.5 °C, but were similar to surface temperatures observed at the deep station sites, indicating consistent lake-wide surface temperatures. The drinking water intakes are located at about 5 m deep (for the North Domestic Intake site (E257437) (B. Dennison, pers.comm.)), and at about 6.1 m deep (for the East Shore Domestic Intake site (E257436) (J. Motherwell, pers.comm)). Water temperature at the intake depths were not collected, and it is unknown if the intake temperatures at these sites are a concern. Based on the temperature profiles for the other sites on the lake (Figure 2), the intakes are near the thermocline, and therefore temperatures would be cooler than in the surface waters. It is recommended that future monitoring include vertical temperature profiles at the intake sites to determine the actual temperatures of intake water.

## Dissolved Oxygen

Dissolved oxygen (DO) concentrations are critical for the survival of aquatic organisms, especially species sensitive to low oxygen levels, such as salmonids. When deeper waters no longer mix with surface waters due to thermal stratification (see temperature profiles, Figure 2), concentrations of DO can decrease. This often occurs because of decomposition of organic material (e.g., phytoplankton algae) in the water column, especially in eutrophic (high levels of nutrients and high biological productivity) lakes.

The DO objective for Shawnigan Lake (≥ 5 mg/L at any depth) was met during every spring overturn sampling date from 2006 to 2014. However, during other times of the year (primarily in the late-summer) the DO objective was not met at the South (1199902) and West (1199903) sites, and, on one occasion only, at the North (1199901) basin site. The South basin had DO concentrations below 5 mg/L on May 22, July 15, and August 13, 2008, and August 14 and November 20, 2013 in the bottom 5-10 m (Figure 3). The West Basin exhibited low summer DO (< 5 mg/L) in the bottom 2 meters on July 15, 2007, August 13, 2008 and August 14, 2013 (Appendix I, Figure 7). The north basin had low DO (< 5 mg/L) in the lower 20 m on November 20, 2013 (Appendix I, Figure 7), likely tied to higher than normal fall temperatures.

While there was limited DO in the bottom waters of the South Basin and West Arm of Shawnigan Lake, there was still sufficient oxygenated water throughout the remainder of the water column. It is likely that fish will have avoided the deep de-oxygenated waters, in addition to the warm surface waters, and resided in mid-depths where there would have been optimal temperature and oxygen conditions.

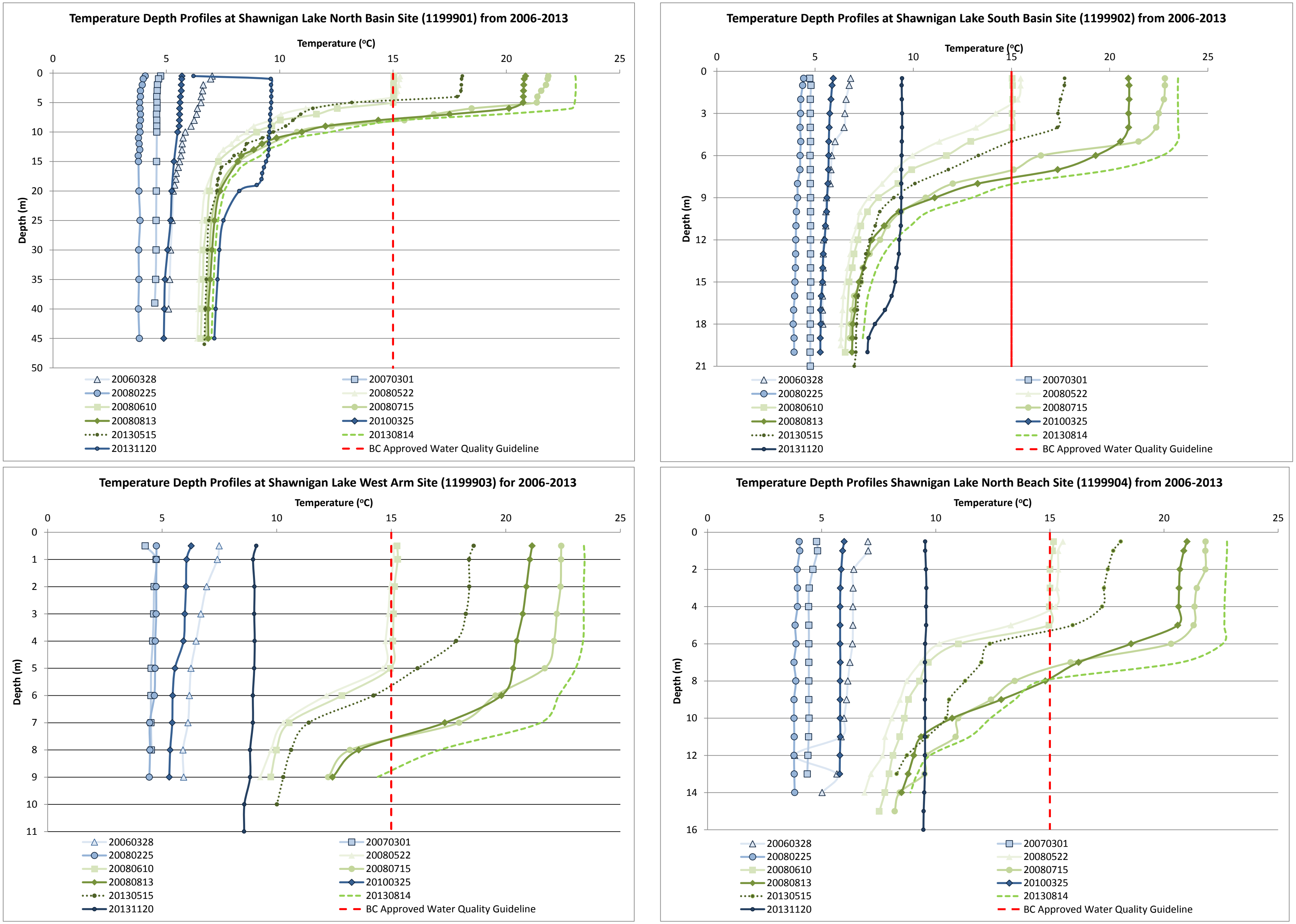



Figure 2. Temperature profiles for Shawnigan Lake deep basin sites (2006-2013).

In addition to aquatic life concerns, low DO concentrations at the lake bottom can increase the potential for internal nutrient loading. This happens under anoxic conditions, when nutrients (e.g., phosphorus) and some metals can be released from lake-bottom sediments and re-suspended back into the water column (Wetzel, 2001). Increases in nutrients can lead to algal blooms and subsequently further deplete DO levels when these algae die.

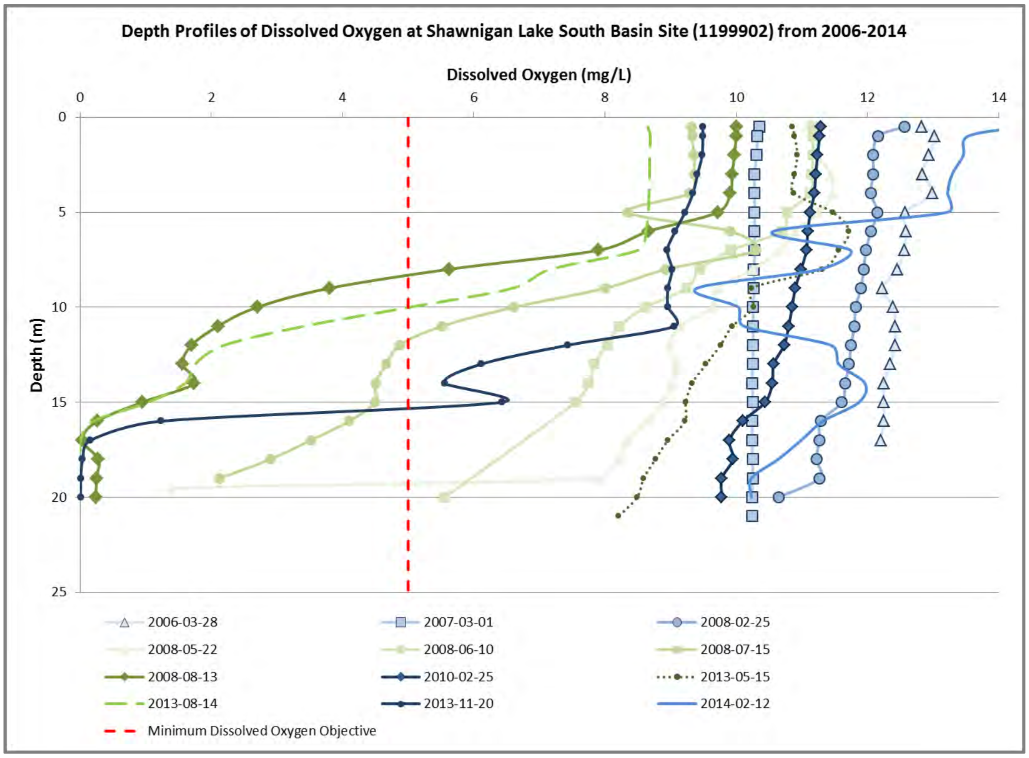



Figure 3. Shawnigan Lake South Basin dissolved oxygen profiles (2006-2014).

## pH

Surface water pH in BC is governed primarily by the amount of precipitation and the rate of weathering of the surrounding soils and bedrock (McKean and Nagpal, 1991). Low pH levels (acidic conditions) can have a variety of lethal and sub-lethal effects on fish, including physical damage to the gills and numerous physiological impacts. While there is no WQO for pH, the provincial water quality guideline for the protection of aquatic life is a pH range between 6.5 and 9.0 pH units (McKean and Nagpal, 1991). An aesthetic guideline was also developed for drinking water, which is a range of 6.5 and 8.5 pH units. Corrosion of metal plumbing may occur outside the low and high ends of this range, while scaling or encrustation of metal pipes may occur at high pH (McKean and Nagpal, 1991). The effectiveness of chlorine as a disinfectant is also reduced outside of this range.

At the deep basin sites in Shawnigan Lake, field measurements of pH taken between 2007 and 2013 ranged from 6.05 to 8.85, while laboratory measurements of pH in samples collected from these locations ranged from 7.25 to 7.62. There are often differences between lab and field pH values, due to holding times of the samples. It is best to record pH in the field, and on occasion use two different probes, comparing results from each to conduct QA/QC.

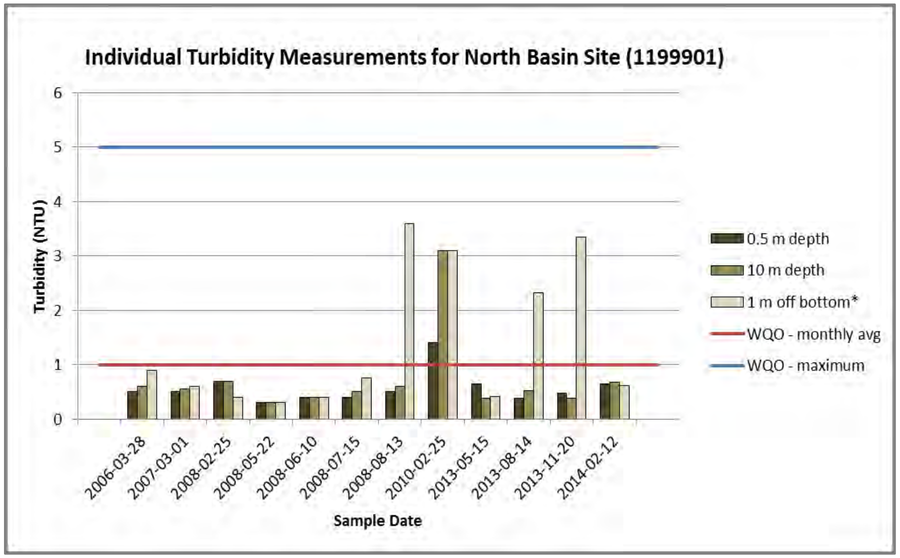
The general pattern for all the deep basin sites in the summer months was decreasing pH with increasing depth (Appendix I, Figure 9). There were several instances where pH was below the minimum objective of 6.5 in each of the deep basin sites. However, a decrease in pH with increasing depth is quite common and likely due to an increase in $CO_2$ concentrations from myriad decomposition processes in the hypolimnion (Wetzel, 2001).

The higher pH levels observed on August 13, 2008 and May 15, 2013 may be the result of algal blooms, which tend to increase oxygen and pH levels (Wetzel, 2001). Cyanobacteria (blue-green algae) counts were significantly elevated (>74%) at the North Basin and West Arm sites on August 13, 2008. While there was no phytoplankton data for May 15, 2013, all chlorophyll-*a* (a measure of phytoplankton productivity) values at the four basin sites were elevated (3.63 µg/L to 10.7 µg/L). The low pH values observed at all depths on March 28, 2006 were likely due to a faulty probe.

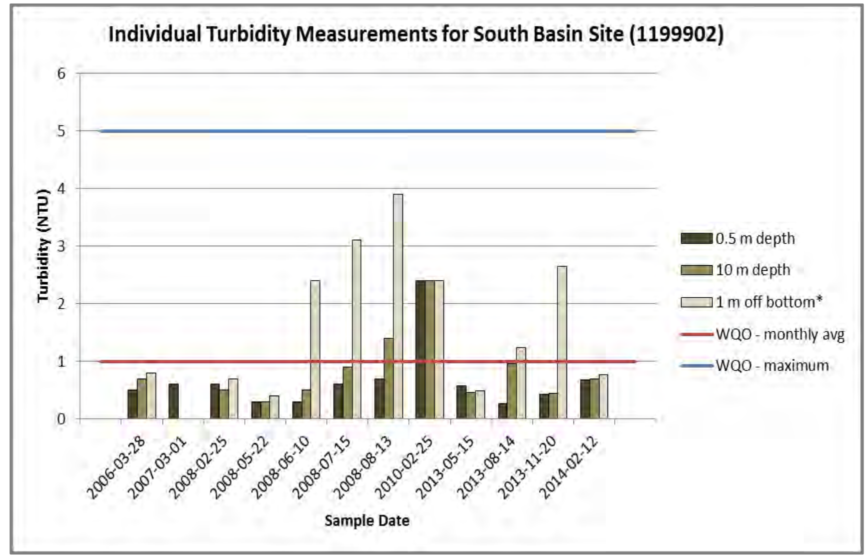
### Water Clarity - Turbidity

Turbidity is a measurement of suspended particulate matter in water (e.g., silt, clay, organic material, micro-organisms), and high levels of turbidity increases the risk of bacterial growth on the suspended particulates, along with interfering with the disinfection of drinking water (Rieberger, 2007).  The turbidity objective for Shawnigan Lake is a mean monthly value that does not exceed 1 NTU, with no individual sample to exceed 5 NTU. This applies only to the West Arm (1199903) and North Beach (1199904) sites, as it was established to protect the quality of the drinking water near domestic intakes. The sampling frequency was insufficient to determine monthly means (which requires a minimum of five samples collected within a 30-day period), and therefore individual measurements were compared to both the mean value as well as the maximum objective. In addition, the data from the two deep basin sites were compared to the objective to help understand overall lake conditions.

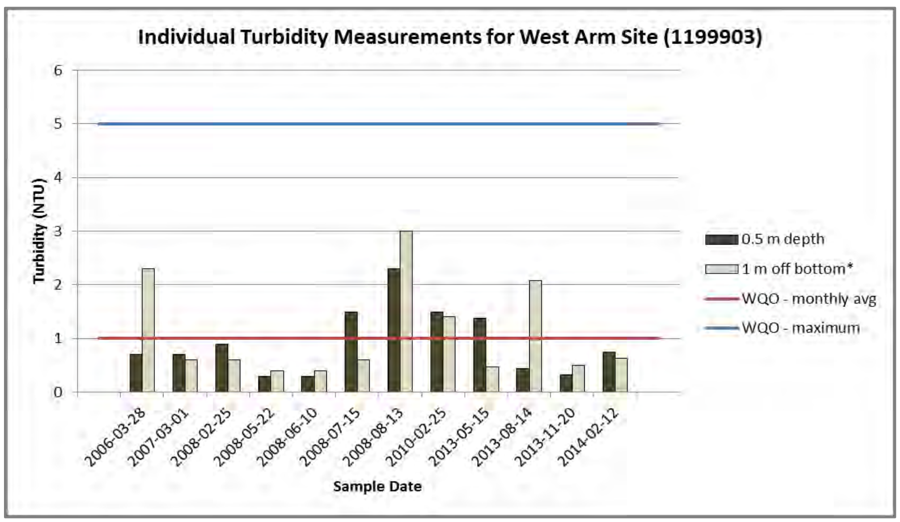
Turbidity results for all four deep station sites are shown in Figure 4. Samples were collected at two depths for the West Arm and North Beach sites, and at three depths for the North and South basin lake sites. On February 25, 2010, all four sites at all depths had elevated turbidity levels. It appears the lake was experiencing an algal bloom as indicated by elevated numbers of phytoplankton (Appendix I; Table 17 and Table 18).



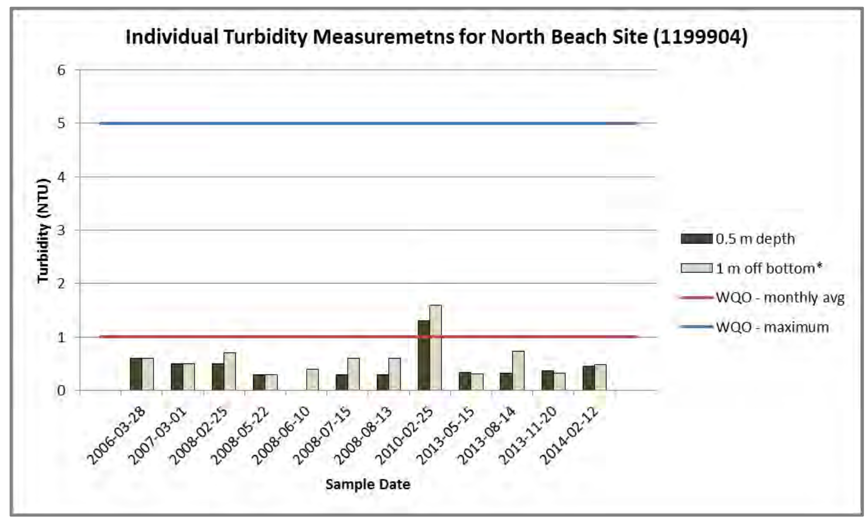

**Note that sampling depths ranged from 19 m to 49 m.*




**Note that sampling depths ranged from 16 m to 47 m.*




**Note that sampling depths ranged from 8 m to 9.5 m.*




**Note that sampling depths ranged from 13 m to 16 m.*

Figure 4. Turbidity field monitoring results for Shawnigan Lake deep basin sites (2006-2014).

In general, individual turbidity values at all sites remained below the mean objective of 1 NTU. There are some slight exceedances observed during the summer months, with a maximum value of 3.9 NTU observed at the South Basin site. Most exceedances were found at the bottom depths of sampling stations during the summer, which is likely due to the internal nutrient loading processes, and increased decomposition of material near the sediment surface. An exception to this is the March 28, 2006 turbidity result from the West Arm bottom measurement, which was elevated somewhat (2.3 NTU). This might be a result of sediment disturbance when sampling, as all other sites (as well as other depths at this site) had low turbidity on this date. The two deep stations (North and South), had elevated turbidity at the bottom in November 2013, the only date in the dataset where a distinct thermocline was observed that late in the year; as mixing had not yet occurred, there may have been a concentration of organic matter from plankton die off. There were no exceedances of the maximum WQO of 5 NTU.

Vancouver Island Health Authority's (VIHA) goal for sources of drinking water where the systems do not receive filtration (which includes Shawnigan Lake) is turbidity levels of 1 NTU or less (95% of days) and not above 5 NTU on more than 2 days in a 12-month period, when sampled at the intake (Charmaine Enns, VIHA pers. comm., 2009). It should be noted that turbidity values above 2 NTU are considered likely to affect disinfection in a chlorine-only system. An alternative to this would be to treat the raw water prior to chlorination (e.g., filtration) to remove some of the turbidity and increase chlorine efficiency.

### Water Clarity – Secchi Depth

Another common measure of water clarity in lakes is Secchi depth, which is assessed by lowering a standard 20 cm black and white Secchi disc into the water column until it is no longer visible. As water clarity is primarily affected by colour, suspended solids, and algal growth, Secchi disc readings provide a simple, inexpensive means of indicating changes in water quality (Rieberger, 2007). Furthermore, it can be compared to historical data which has been collected for decades. Mean annual Secchi depth readings taken by BC ENV and by the BC Lake Stewardship Society (BCLSS) volunteers (North Basin site only) (Figure 5) generally met the objective of ≥5 meters (Appendix I Figure 10). However, in most years, only one measurement was collected (at spring overturn), which makes it difficult to compare against an annual average. In more recent years, the BCLSS volunteer data has helped fill those gaps. Secchi depth values failed to meet the objective at the West Arm site in 2008 and 2013 (Table 5, Table 8). This is likely due to the shallow, constricted nature of the West Arm, in addition to increased recreational boating activity (which creates turbulence in the surface waters).

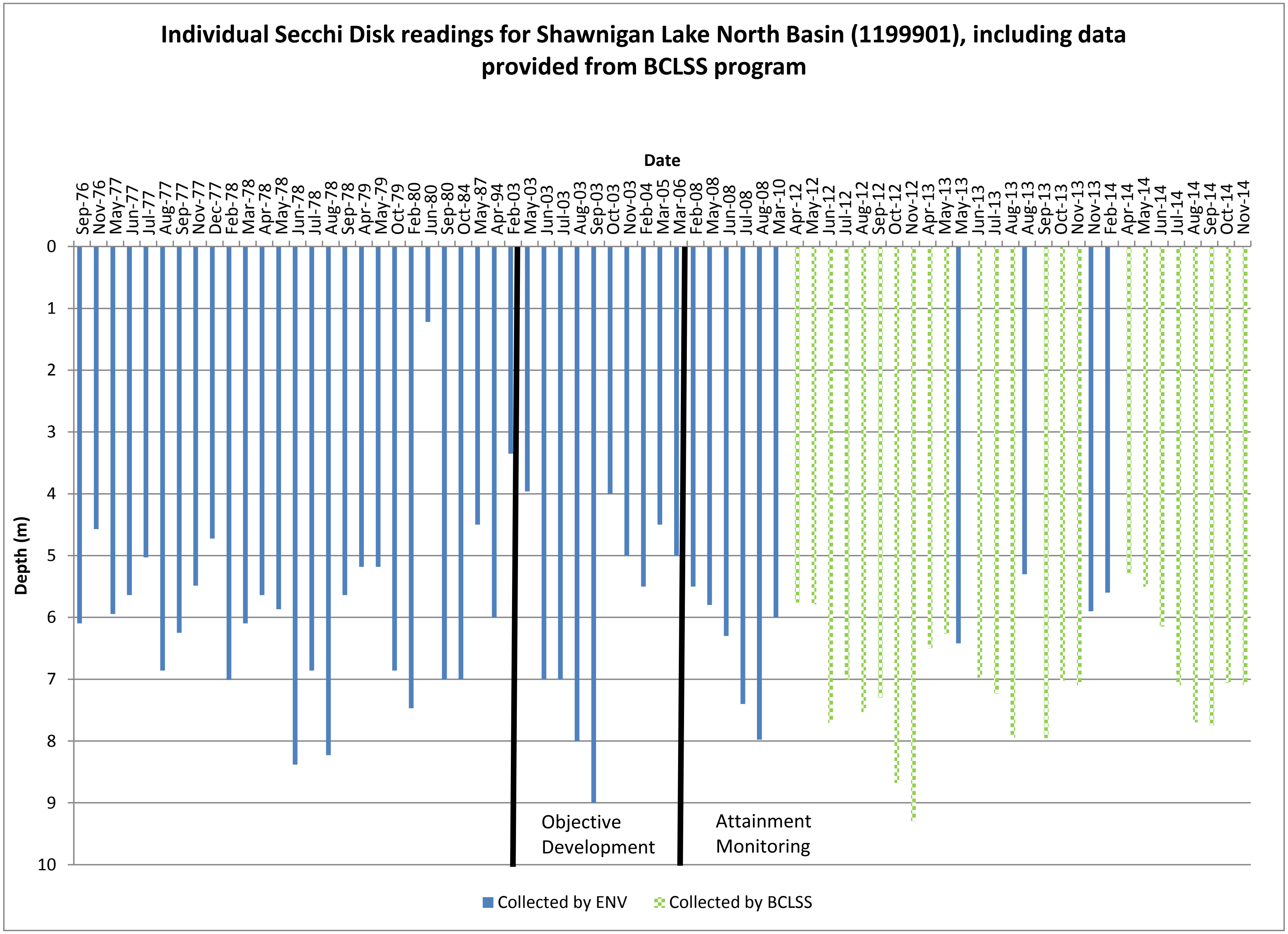



Figure 5. Individual Secchi disk readings for Shawnigan Lake North Basin site (1199901) (1976-2014).

Table 8. Annual mean Secchi depths (m) for the Shawnigan Lake Basin Sites*. **Highlighted** values do not meet the WQO.

| Year | North Basin 1199901 | | South Basin 1199902 | | West Arm 1199903 | | North Beach - 1199904 | |
|---|---|---|---|---|---|---|---|---|
| | Mean | n | Mean | n | Mean | n | Mean | n |
| 1976-1979 | 6.1 | 26 | 5.8 | 23 | | | | |
| 1980-1987 | 5.4 | 5 | 7.0 | 1 | | | | |
| 1994 | 6.0 | 1 | | | | | | |
| 2003-2005 | 5.6 | 9 | 5.9 | 8 | 5.9 | 9 | 6.3 | 7 |
| 2006 | 5.0 | 1 | 5.5 | 1 | 5.0 | 1 | 4.5** | 1 |
| 2007 | | | 4.0** | 1 | | | | |
| 2008 | 6.6 | 5 | 6.1 | 5 | **4.5** | 5 | 6.7 | 5 |
| 2010 | 6.0 | 1 | 5.3 | 1 | 5.8 | 1 | 5.2 | 1 |
| 2012 | 7.1 | 10 | | | | | | |
| 2013 | 6.8 | 11 | 5.6 | 3 | **4.6** | 3 | 6.6 | 3 |
| 2014 | 6.6 | 9 | 4.5** | 1 | 4.1** | 1 | 5.0 | 1 |

*Note that historical data (1977-2005) was included in this table, but the WQO applies only to data collected between 2006-2014.

**In some instances, Secchi depths were only measured on one day for the year, and therefore no average Secchi depth could be calculated. In those instances, guideline attainment could not be assessed.

## True Colour

Colour in water is attributed to the presence of organic and inorganic matter absorbing different light frequencies. True colour is a measure of the dissolved colour in water after the particulate matter has been removed. An increase in true colour can affect the aesthetic acceptability of water, and if a drinking water source with high organic matter content and true colour is chlorinated, disinfection by-products may be produced, posing a risk to human health (Health Canada, 2006). Rieberger (2007) did not propose a true colour WQO for Shawnigan Lake, however, the provincial recreational Water Quality Guideline is that the 30-day average (based on a minimum of five samples) should not exceed 15 True Colour Units (TCU) (Moore and Caux, 1997).

True colour ranged from below detection limits (< 5 TCU) to a maximum of 80 TCU at the South Basin site (Table 9). The recreational guideline was exceeded on several dates at each site, with more of the exceedances in the 2013 data than in the 2006/08 data. Colour exceedance at all four sites on February 25, 2010 at all depths are likely linked to the spring algal bloom which was occurring at the time of sampling. The same could be said for the August 14, 2013 sample which had higher true color levels at the surface. The phytoplankton results at this time confirmed that algal concentrations were high, with the dominant species comprised mainly of Cyanobacteria (blue-green algae) (Table 20).

Table 9. True colour (TCU) results for the Shawnigan Lake basin sites during attainment monitoring (2006-2014). Elevated (>15 TCU) true colour results are highlighted.

| Date | North Basin (1199901) | | | South Basin (1199902) | | | West Arm (1199903) | | North Beach (1199904) | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Surface | 10 m | Bottom | Surface | 10 m | Bottom | Surface | Bottom | Surface | Bottom |
| 28-Mar-2006 | 5 | 5 | 5 | <5 | <5 | 5 | <5 | 5 | 5 | 5 |
| 01-Mar-2007 | 15 | 10 | 10* | 10 | -- | -- | 15 | 15 | 10 | 10 |
| 25-Feb-2008 | 5 | 5 | 5 | 5 | 10 | 10 | 10 | 10 | 5 | 10 |
| 22-May-2008 | <5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | <5 |
| 10-Jun-2008 | <5 | <5 | <5 | 5 | <5 | 5 | <5 | 5 | -- | <5 |
| 15-Jul-2008 | <5 | <5 | <5 | <5 | <5 | **40** | <5 | <5 | <5 | <5 |
| 13-Aug-2008 | <5 | <5 | 10 | 5 | 15 | **50** | 5 | **30** | 5 | <5 |
| 2010-02-25 (algae bloom) | **20** | **20** | **20** | **20** | **20** | **20** | **20** | **20** | **20** | **20** |
| 15-May-2013 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 5 | 10 |
| 14-Aug-2013 | 15 | **20** | 15 | **20** | **50** | 10 | **40** | **20** | 15 | **20** |
| 20-Nov-2013 | 5 | 5 | **30** | 5 | 5 | **80** | <5 | <5 | <5 | 5 |
| 12-Feb-2014 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 |

*extra meaurement taken on this date at 20 m (20 TCU)

## Nutrients - Nitrogen

Nitrogen is an important nutrient for lakes and can influence the biological productivity and ecology of waters. The balance between phosphorus and nitrogen also plays an important role. Nitrogen sources include: atmospheric deposition, nitrogen fixation in the water and sediments, and watershed inputs from surface and groundwater sources (e.g., sewage and agriculture) (Wetzel, 2001). In watersheds where drinking water is a priority, it is desirable that nutrient levels remain low to avoid algal blooms and foul-tasting water.

The objective for total nitrogen (≤ 250 µg/L at spring overturn, when the lake is well mixed) was exceeded at the North and South basin sites; with exceedances ranging from 250 to 329 µg/L (Table 10). There was some variation between years, with 2007 and 2010 showing no exceedances, while 2006, 2008 and 2014 exceeded the objective. The results indicate that total nitrogen concentrations have been more variable in recent years, and the difference between years appears to be larger. Total nitrogen measurements can vary depending on processes occurring during the time of sampling (e.g., temperature, light, algal biomass at the sampling location), and are therefore difficult to interpret. Mazumder (2015) studied water quality trends in Shawnigan Lake from 2001-2007 and found that there was a gradual increasing trend of nitrogen and phosphorus concentrations in the lake. With a larger data set (including data collected between 2008 and 2014) the trend becomes more apparent. If future attainment monitoring continues to show an increasing trend in total nitrogen, further investigation should be made into causal factors and implications of nitrogen increases in the lake.

Table 10. Mean spring overturn total nitrogen concentrations (µg/L) for the Shawnigan Lake basin sites (1977-2014)*

| Date | North Basin 1199901 | South Basin 1199902 | West Arm 1199903 | North Beach 1199904 |
|---|---|---|---|---|
| 11-May-77 | 230 | **257** | 200 | |
| 17-Apr-78 | 245 | **275** | **300** | 230 |
| 08-Mar-79 | **257** | 235 | -- | -- |
| 21-Feb-80 | **253** | -- | -- | -- |
| 10-Mar-83 | 227 | -- | -- | -- |
| 04-Mar-84 | 223 | -- | -- | -- |
| 26-Mar-97 | 225 | -- | -- | -- |
| 08-Apr-99 | 235 | -- | -- | -- |
| 22-Mar-00 | **260** | -- | -- | -- |
| 07-Feb-01 | **263** | **283** | -- | -- |
| 21-Mar-01 | 195 | 247 | -- | -- |
| 11-Feb-03 | **250** | -- | **290** | **265** |
| 12-Feb-04 | **270** | 313 | 460 | 340 |
| 10-Mar-05 | 234 | 226 | **307** | **290** |
| 28-Mar-06 | **277** | 240 | **255** | **255** |
| 01-Mar-07 | 220 | 200 | 235 | 220 |
| 25-Feb-08 | **313** | **250** | **250** | 245 |
| 25-Feb-10 | 153 | 167 | 215 | 205 |
| 12-Feb-14 | **302** | **329** | **261** | **287** |

*Mean of at least three samples taken throughout the water column (surface, mid-depth, one metre above bottom) for sites 1199901 and 1199902 and at least two samples (surface and one metre above bottom) for sites 1199903 and 1199904, at spring overturn.

**Note that 1977-2005 results are shown only for the purpose of demonstrating trends for this parameter.

***For 2006-2014 sample results, grey highlighted values exceed the proposed WQO for total nitrogen of ≤ 250 µg/L.

## Nutrients - Phosphorus

Phosphorus is a key nutrient that is used by phytoplankton (floating algae), and is the biological limiting nutrient in most freshwater systems. Increased phosphorus leads to increased algal production, reduced water clarity, increased taste and odour concerns for drinking water purveyors, and undesirable conditions (e.g., reduced oxygen) for some fish species. Phosphorus levels in lakes increase due to inputs of sewage, sediments eroded from soils in the watershed, seepage from septic tanks, fertilizers from agricultural activities and internal loading (Wetzel, 2001).

The phosphorus objective (≤ 8 µg/L) was met during every spring overturn (mixed lake conditions) sampling date from 2006 to 2014 (Table 11). Phosphorus concentrations approached the objective at the South Basin (1199902) and the West Arm (1199903) sites (7.3 µg/L and 7.5 µg/L respectively), in February 2014.

Table 11. Spring overturn (January – March) mean* total phosphorus concentrations (µg/L) for the Shawnigan Lake basin sites.

| Year | North Basin (1199901) | South Basin (1199902) | West Arm (1199903) | North Beach (1199904) |
|---|---|---|---|---|
| 1979 | 8.3 | 7.0 | -- | -- |
| 1980 | 8.7 | -- | -- | -- |
| 1984 | 8.0 | -- | -- | -- |
| 1992 | 4.0 | -- | -- | -- |
| 1993 | 3.0 | -- | -- | -- |
| 1995 | 3.0 | -- | -- | -- |
| 1997 | 6.0 | -- | -- | -- |
| 2000 | 7.0 | -- | -- | -- |
| 2001 | 7.5 | -- | -- | -- |
| 2003 | 4.3 | 4.0 | 4.5 | 4.0 |
| 2004 | 2.3 | 3.7 | 3.5 | 3.5 |
| 2005 | 2.3 | 3.0 | 3.5 | 3.5 |
| 2006 | 3.3 | 3.3 | 3.0 | 2.5 |
| 2007 | 6 | 4.3 | 6 | 5 |
| 2008 | 6 | 5.7 | 5.5 | 6.5 |
| 2010 | 3.7 | 3.7 | 3.5 | 3.5 |
| 2014 | 5.0 | 7.3 | 7.5 | 5.1 |

* *Mean of at least three samples taken throughout the water column (surface, mid-depth, one metre above bottom) for sites 1199901 and 1199902 and to the average of at least two samples (surface and one metre above bottom) for sites 1199903 and 1199904, at spring overturn.*

Lake sediments can be a major source of phosphorus when hypolimnetic oxygen becomes depleted, producing anoxic conditions. Phosphorus is usually bound with bottom sediments, but in anoxic conditions phosphorus can be released into the water column from the sediments. This release of phosphorus from lake sediments is known as internal loading (see section on dissolved oxygen), and can lead to algal blooms, along with a further depletion of dissolved oxygen when these algae die. This process of internal phosphorus loading can be a natural occurrence in many lakes but is often the result of excessive external nutrient loading to the lake (Wetzel, 2001). In Shawnigan Lake, phosphorus values during the late-spring to summer (May – September) were reviewed as concentrations can be elevated at this time of year, especially at depth. The total phosphorus values in the hypolimnion ranged from 2 µg/L to 15.5 µg/L, with the South Basin site having the highest value. The elevated hypolimnetic phosphorus concentrations observed here are most likely the result of internal loading and reduced mixing of the water during the summer stratification period.

## Nutrients – Nitrogen to Phosphorus Ratio

Nitrogen to Phosphorus (N:P) ratios are useful indicators in lakes to determine whether primary production is limited by phosphorus or nitrogen concentrations (Rieberger, 2007). In general, if N:P <20, lakes are N limited and if N:P >20, lakes are P limited (Rieberger, 2007). Different algae utilize nitrogen and phosphorus in different ratios and comparing these values to what is available in the water can be a valuable diagnostic tool (Nordin, 1985). Most lakes, including Shawnigan, are phosphorus limited, and N:P ratios tend to decrease with increasing eutrophication, thus, decreasing N:P ratios would indicate deteriorating water quality. The proposed water quality objective for N:P ratios in Shawnigan Lake is 30:1. All sites met the objective, and values ranged from 35:1 to 102:1 (Appendix I; Table 14).

## Nutrients – Total Organic Carbon

Organic carbon is another important nutrient in lakes, but it is also an important water quality parameter to consider with respect to drinking water sources. The B.C. provincial water quality guideline for total organic carbon (TOC) in source water with chlorination is 4 mg/L to prevent the production of disinfection by-products during treatment with chlorine (Moore, 1998). Rieberger (2007) followed this guideline (Max TOC of 4 mg/L at any time) to minimize the formation of hazardous by-products from chlorination of any domestic water sources in Shawnigan Lake. Most sampling dates met the objective, but there were a few relatively minor exceedances in 2008, and one date in August 2013 (Appendix I; Table 15).

## Biological Analyses

## Chlorophyll-*a*

Chlorophyll-*a* is the primary photosynthetic pigment of algae, cyanobacteria, and other photosynthetic organisms (Wetzel, 2001). Measuring chlorophyll-*a* is a standard approach used to quantify phytoplankton in lakes and is used as a surrogate of phytoplankton biomass. There is generally a strong positive relationship between phosphorus and chlorophyll-*a*, and often an inverse relationship with water clarity (Nordin, 1985).

In 2008, the objective for chlorophyll-*a* (≤2 µg/L based on growing season average for the main basin) was exceeded at the South Basin site (Table 12). Additional measurements taken during quarterly sampling in 2013 showed exceedances in both the North and South Basin sites. These exceedances are similar to values seen during the 1977 – 1979 sampling period. There were more data collected in the 1970's, but these samples were outside of the growing season so were not included in the calculated averages.

The chlorophyll-*a* objective does not apply to the West Arm and North Beach sites and it was previously acknowledged that these two areas of the lake generally show higher chlorophyll-*a* concentrations (Rieberger, 2007). For trend analysis purposes, the chlorophyll-*a* concentrations at all four sites were tabulated (Table 12). The highest concentration (14.4 mg/L) and highest average summer concentration (6.4 mg/L) was measured at the West Arm site. These averages were substantially higher than levels observed during WQO development monitoring, suggesting that conditions have changed in the West Arm of the lake. It is likely that these results reflect the ideal conditions for algal growth at this site (increased nutrients, sunlight, and temperature, lower wind, and shallower depth).

Table 12. Annual growing season averages (April-Oct.) for chlorophyll-*a* concentrations (µg/L) for Shawnigan Lake basin sites. Shaded values represent objective exceedances (means calculated for data collected prior to 2008 not compared to guideline, and guideline does not apply to West Arm and North Beach sites).

| Year | Measure | North Basin (1199901) | South Basin (1199902) | West Arm (1199903) | North Beach (1199904) |
|---|---|---|---|---|---|
| 1977-79 | Mean (µg/L) | 3.04 | 2.95 | 2.24 | 0.30 |
| | N | 12 | 10 | 8 | 3 |
| 2003-2004 | Mean (µg/L) | 0.78 | 0.94 | 1.24 | 0.78 |
| | N | 8 | 8 | 7 | 8 |
| 2008 | Mean (µg/L) | 1.77 | **2.75** | 6.38 | 1.17 |
| | N | 8 | 4 | 4 | 3 |
| 2013 | Mean (µg/L) | **2.94** | **3.10** | 6.40 | 2.32 |
| | N | 2 | 2 | 2 | 2 |

## Phytoplankton

Phytoplankton communities in lakes are typically comprised of a diverse assemblage of taxonomic algal groups (Wetzel, 2001). These communities are constantly changing in response to changes in nutrients, available light, mixing conditions and other growing conditions. While there are no WQO for phytoplankton in Shawnigan Lake, these key primary producers are important to monitor in aquatic ecosystems, since changes in community composition may indicate changes in lake water chemistry (Rieberger, 2007). Excessive nutrients can lead to algal blooms and surfacing scums which can impart taste and odours to drinking water, requiring more expensive treatment to remove algal particles. Furthermore, these blooms can reduce water clarity, decrease hypolimnetic oxygen levels, and increase the risk of toxins produced by cyanobacteria (Rieberger, 2007).

Overall, the number of phytoplankton species observed and the total phytoplankton concentrations were similar between all four sites in Shawnigan Lake. During 2006 to 2014, there was a broad range of diversity with a total of 153 species identified, and 15 dominant species. Although most species or genera that were reported in previous studies (Nordin and McKean, 1984; Rieberger, 2007) were present, the dominant species differed. It is important to note that there is likely considerable interannual variability in phytoplankton community composition, as demonstrated in comparisons between sampling periods.

All sampling sites in Shawnigan Lake had relatively higher number of species present and greater overall abundance during the summer growing season (May -August), as compared to the spring overturn months (February and March)(Table 16). The phytoplankton data collected at the four deep basin sites were summarized, and the dominant species are listed for the North and South Basins in Appendix I (Table 17), and for the West Arm and North Beach sites in Appendix I (Table 18).

General phytoplankton dynamics for oligotrophic lakes as outlined by Rieberger (2007) are consistent with taxanomic results for this report. Diatoms and cryptophytes were dominant in March 2007 and the cyanobacteria populations peaked in August 2008. Similarities of the dominant species and the months in which they occurred were the diatom *Asterionella formosa* in May, the golden-brown algae *Dinobryon divergens* in June, and the blue-green algae genera, *Anacystis* and *Gomphophaeria* in July and August.

The North Basin and West Arm sites had higher total species richness with 125 and 120 species found, compared to 85 species at the South Basin site and 91 species at the North Beach site (Appendix I; Table 19). This difference in diversity may be attributed to the reduced sampling frequency of the South Basin and North Beach sites.

## Zooplankton

Zooplankton are important to the aquatic food web and are largely influenced by the number and types of phytoplankton they feed upon, along with predation pressure from planktivorous fish like kokanee, juvenile rainbow trout, and introduced species such as bass and perch (Rieberger, 2007; Gregory, 2014). As with phytoplankton, there are no zooplankton WQO in Shawnigan Lake. However, sampling was conducted from 2006-2014 since zooplankton are sensitive to changes in water quality and are useful indicators of change. Specifically, zooplankton respond to dissolved oxygen concentrations, various contaminants, and changes in food quality/abundance (Nordin and McKean, 1984).

As with most lakes, Shawnigan Lake zooplankton communities vary seasonally. Data from attainment sampling is consistent with Rieberger (2007), indicating a dominance of rotifers and some early-season peaks in copepods that are likely feeding on an abundance of phytoplankton during the late-winter/early-spring blooms. The attainment data are somewhat limited, but the zooplankton communities are consistent with oligotrophic conditions (Wetzel, 2001). A summary of the dominant species from 2006-2014 are found in Appendix I (Table 20).

## Microbiological Indicators

Bacteria often enter surface waters via non-point sources, including wild and domestic animal feces, as well as seepage from leaking or failing septic systems. Microbiological indicators are monitored to evaluate of the risk of disease from these various pathogens (Warrington, 1988). Studies have shown that *Escherichia coli* is the main thermo-tolerant coliform species present in fecal samples (94%) of humans and other endotherms such as birds and mammals, (Tallon *et al*., 2005), and at contaminated bathing beaches (80%) (Davis *et al.*, 2005). Where fecal coliform concentrations are higher than those of *E. coli*, one can assume a high likelihood of contributions from non-fecal sources. Thus, there is limited benefit in measuring both groups.

Bacteriological indicators were sampled in Shawnigan Lake at the intake sites (E257436 and E257437) between 2008 and 2013 (Table 21). In 2008, *E. coli*, Enterococci, and fecal coliforms were analyzed, while in 2013, only *E. coli* was analyzed. This was due to changes in ENV's monitoring recommendations that identified *E. coli* as the most appropriate microbial indicator to use for the assessment of risks to human health (Rieberger, 2010).

The *E. coli* objective for Shawnigan Lake is a $90^{th}$ percentile of ≤10 CFU/100mL (based on at least five weekly samples in 30 days) and applies to areas of the lake where drinking water is withdrawn (Rieberger, 2007). *E. coli* was measured 16 times between 2008 and 2013 at the East Shore intake site (E257436), with concentrations ranging from below detection limits (< 1 CFU/100 mL/100 mL) to a maximum of 110 CFU/100 mL (on August 6, 2008). Except for this one high value, all other samples had concentrations below 5 CFU/100 mL.

The requisite sampling frequency (a minimum of five samples in a 30-day period) was met on two occasions, and $90^{th}$ percentiles ranged from 2.8 CFU/100 mL to 66.4 CFU/100 mL. At the North intake (E257437), *E. coli* was measured 14 times between 2008 and 2013, with all concentrations at or below detection limits (1 CFU/100 mL/100 mL). The requisite sampling frequency was met on one occasion in 2013, and the $90^{th}$ percentile was 1 CFU/100 mL. The highest levels of *E. coli* were observed at the intake sites during the summer low-flow period, corresponding to the peak population and recreation season, warmest temperatures, and maximum retention times. Of the three times when the requisite sampling frequency was met at the two intake sites, the objective was exceeded on one occasion (66.4 CFU/100 mL) on August 2008 at the East Shore site. There were no exceedances of the BC WQGs for primary recreation for *E. coli* (200 CFU/100mL, based on geometric mean) at either site.

Enterococci and fecal coliforms were measured in 2008 at the two intake sites and one sample was collected on February 2010 at both sites. The requisite sampling frequency for both Enterococci and fecal coliforms was met only once, at the East Shore domestic intake site (E257436). Relatively elevated concentrations of fecal coliforms (110 CFU/mL) were observed in the sample collected on August 6, 2008. Enterococci concentrations were lower, with a maximum of 8 CFU/100 mL occurring on August 27, 2008. Concentrations of both bacteriological indicators were generally at or below detection limits in the remainder of the samples. On the one occasion when the 90$^{th}$ percentile could be calculated (August 2008), the objectives for enterococci (≤3 CFU/100 mL) and fecal coliforms (≤10 CFU/100 mL) were exceeded.

## Summary and Conclusions

Overall, the state of Shawnigan Lake water quality continues to be good. While some of the water quality objectives were exceeded, the data presented in this report indicate that the lake remains oligotrophic, and there is no indication of overall lake deterioration. There was local concern that an increase in development and land-use changes in the watershed, (i.e., urban runoff, land development, on-site sewage systems, agriculture, and logging activities) were impacting water quality, but the 2006-2014 data indicate few WQO exceedances in Shawnigan Lake. For analysis of data from tributary creeks, see Kopat *et al.* (2019).

Attainment results for the main basins (north basin site 1199901 and south basin site 1199902) of Shawnigan Lake are representative of overall lake conditions. Several key water quality parameters (total phosphorus, dissolved oxygen, N:P ratio, total organic carbon) in these two basins consistently met WQO in all years of sampling. On the other hand, results for total nitrogen, Secchi depth, and chlorophyll-*a* were either met intermittently or there were insufficient data to compare to the WQO, or no data were collected. Future total nitrogen data should be considered with historical data to confirm if an apparent increasing trend is occurring and, if so, what action can be taken and what the potential implications are to Shawnigan Lake.

Similar to the main basins, the west arm site (1199903) and north beach site (1199904), also consistently met WQO for total phosphorus, dissolved oxygen, N:P ratio, and total organic carbon. Results for Secchi depth either met intermittently or there were insufficient data to compare to the WQO. These shallower basins have additional WQO for turbidity and bacteria, which were met in almost all cases (turbidity), or there was insufficient data collected to compare to WQO (bacteria). However, the few bacteriological samples that were collected at the drinking water intake sites (E257436 & E257437) indicate relatively low concentrations of bacteria, with minor exceedances during the summer.

To enable comparison to all WQOs in place for Shawnigan Lake, it is recommended that effort be made to obtain the appropriate data (sampling frequency and locations) for parameters for which insufficient or no data were collected.

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# APPENDIX I

## Objectives Attainment Water Quality Results

Table 13. Surface water temperatures at Shawnigan Lake intake - CVRD sampling.

| Station | Sample Year | Summer Temperature (°C) | | | | |
|---|---|---|---|---|---|---|
| | | Count | Min | Max | Avg | StDev |
| Shawnigan Lake Domestic Intake East Shore | 2012 | 1 | 22 | 22 | 22 | 0 |
| Shawnigan Lake Domestic Intake East Shore | 2013 | 4 | 20 | 22.5 | 21.375 | 1.11 |
| Shawnigan Lake North Domestic Intake | 2012 | 1 | 22 | 22 | 22 | 0 |
| Shawnigan Lake North Domestic Intake | 2013 | 4 | 20 | 22.5 | 21.5 | 1.22 |

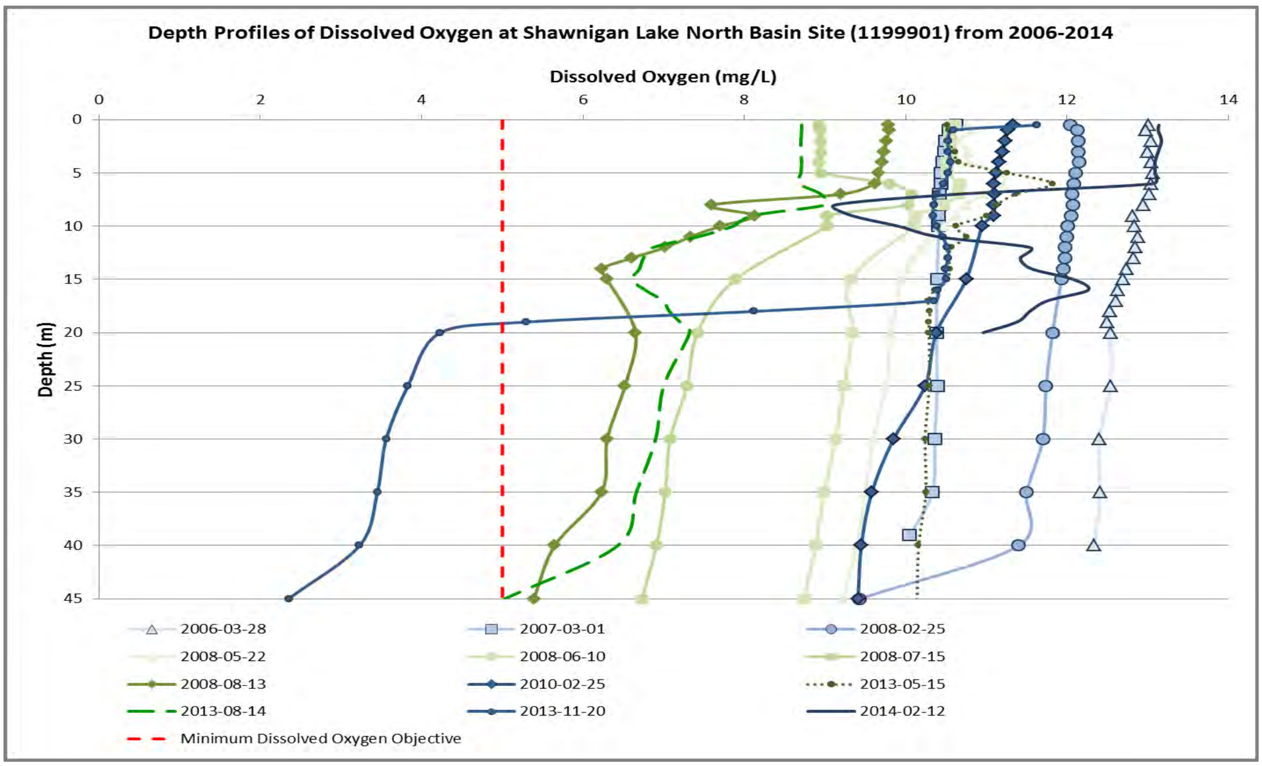



Figure 6. Shawnigan Lake North Basin dissolved oxygen profiles (2006-2014).

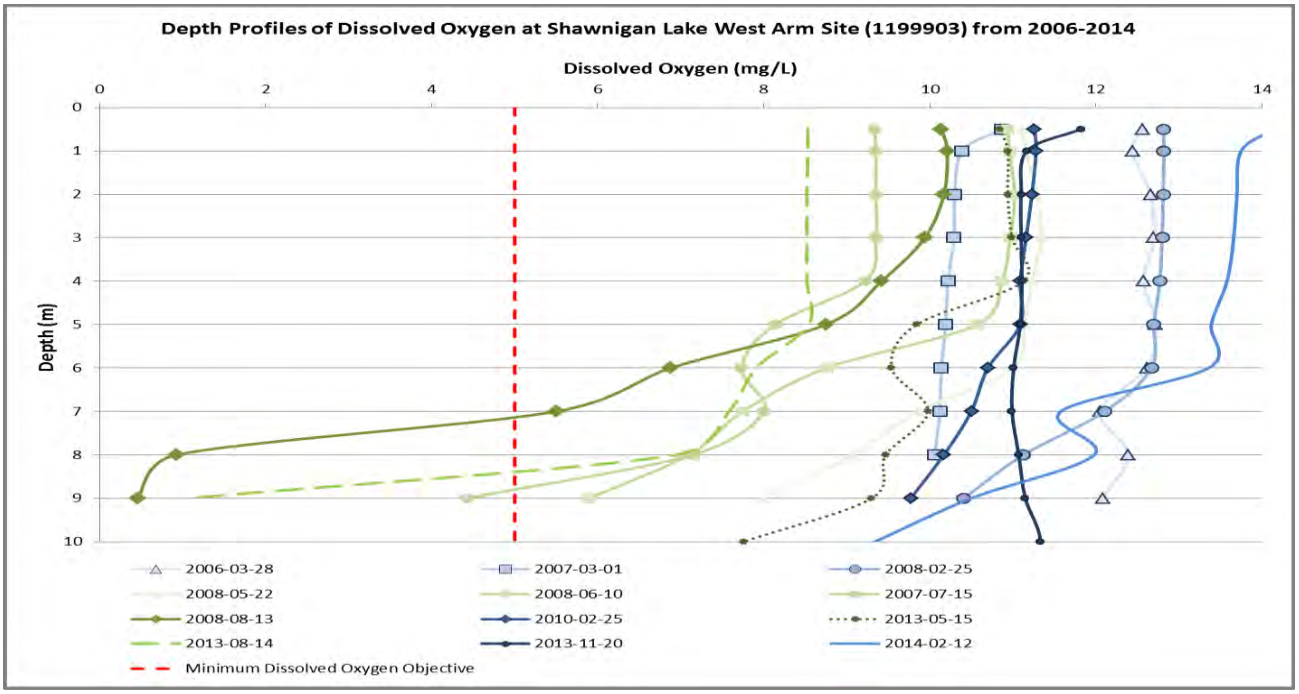



Figure 7. Shawnigan Lake West Arm dissolved oxygen profiles (2006-2014).

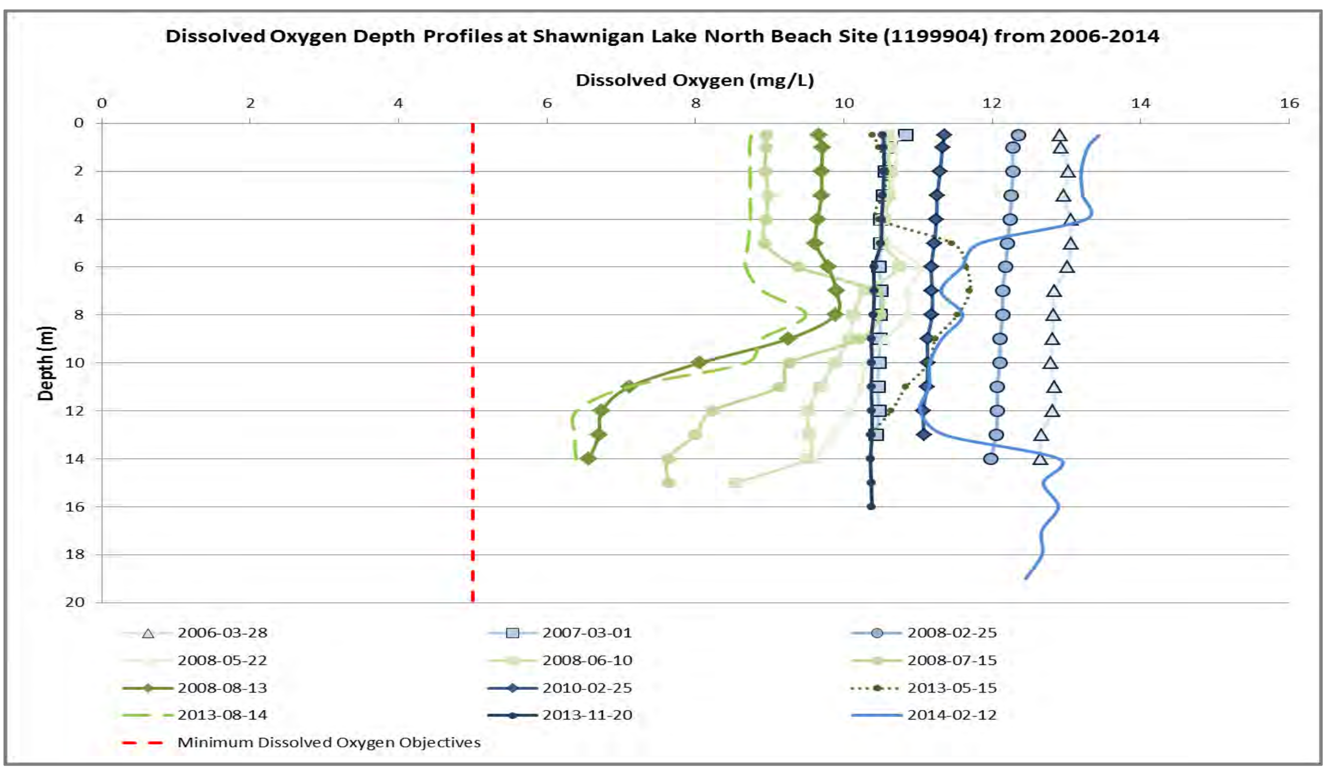



Figure 8. Shawnigan Lake North Beach dissolved oxygen profiles (2006-2014).

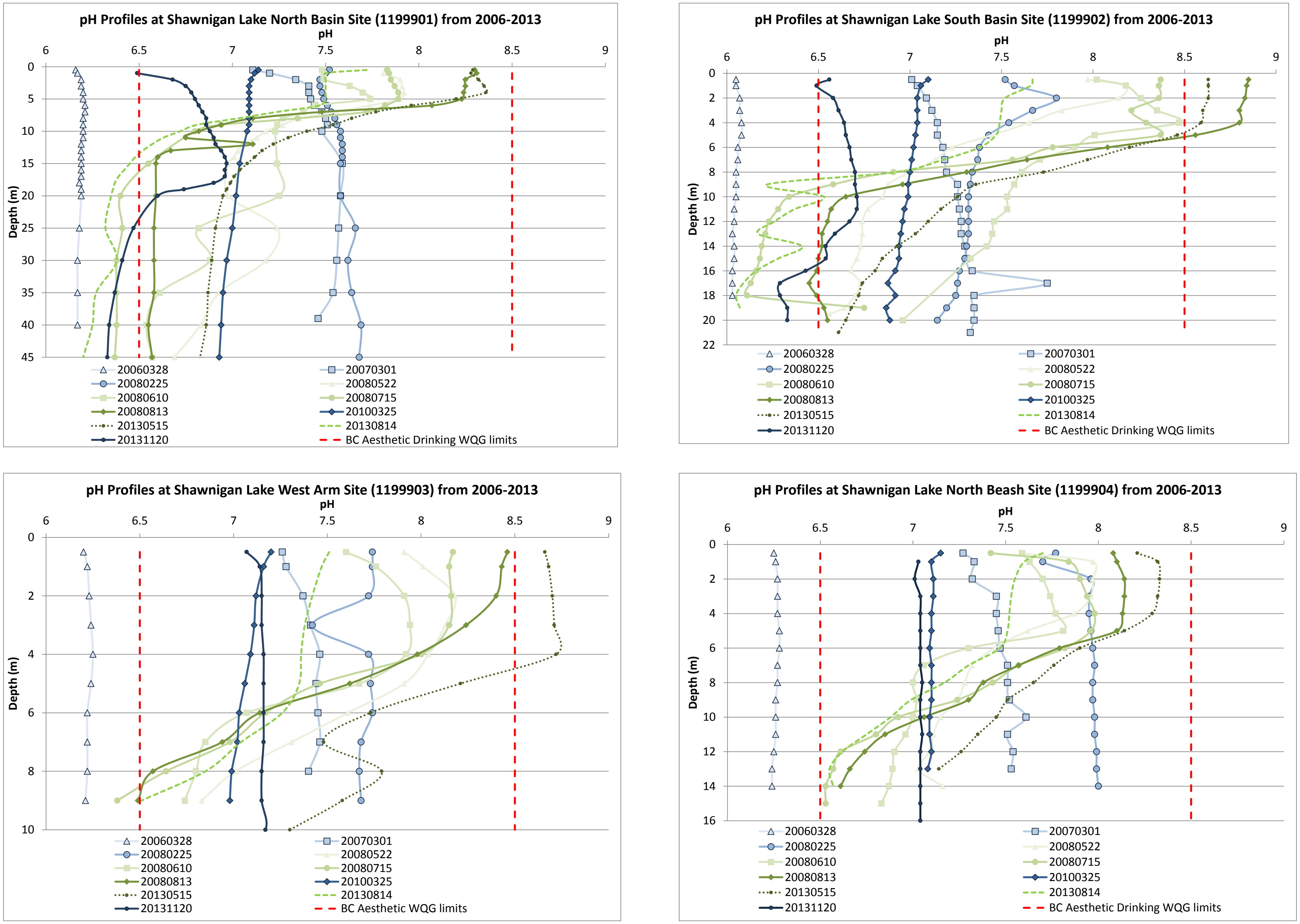



Figure 9. pH profiles for Shawnigan Lake Deep Basin sites (2006-2013).

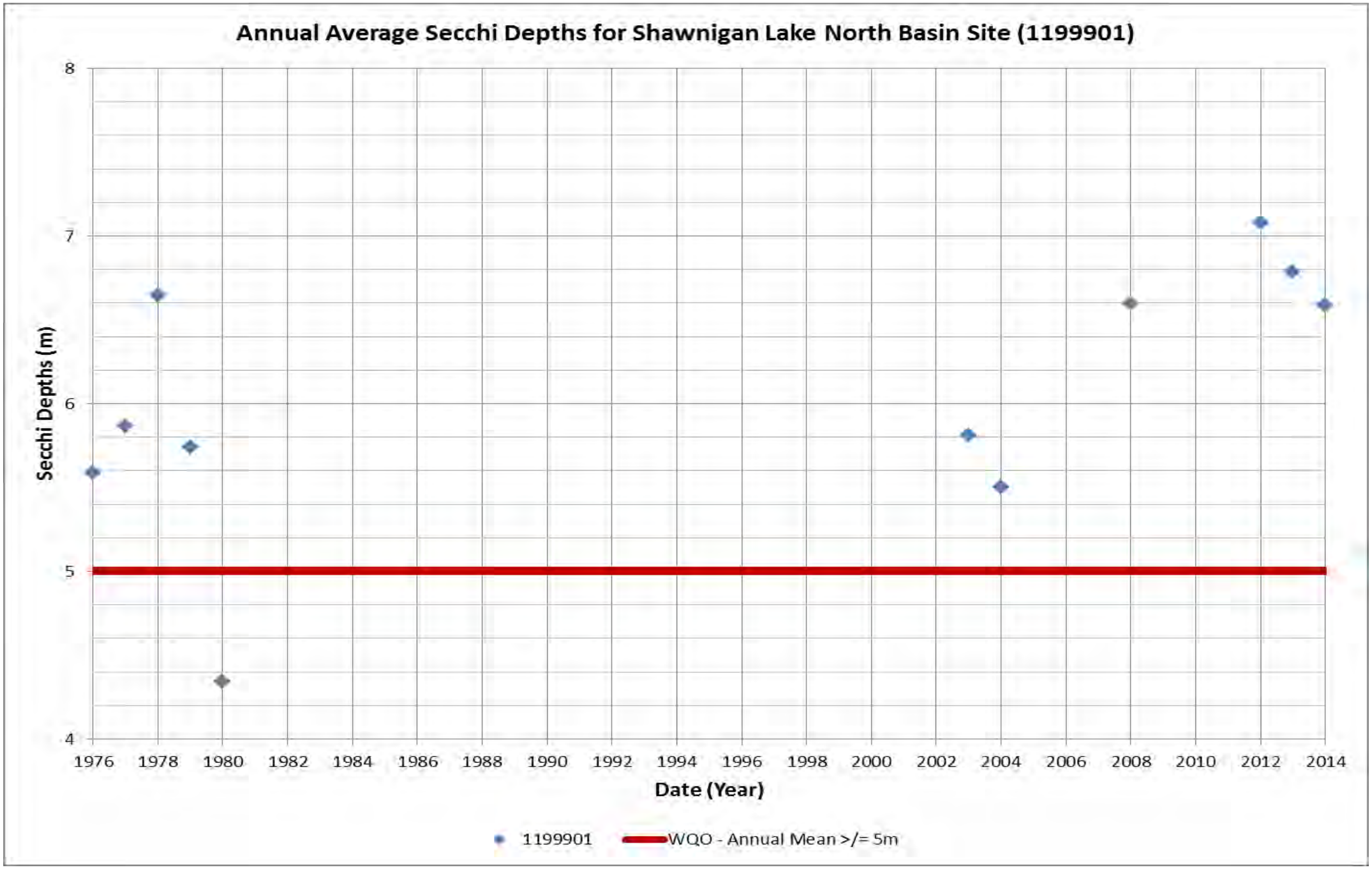


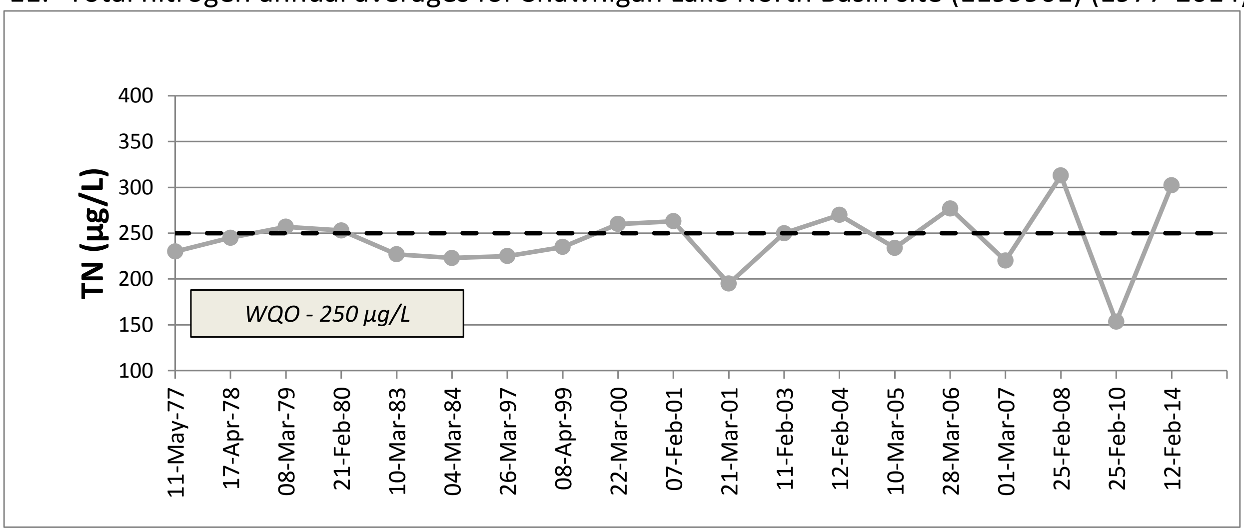

Figure 10. Annual average Secchi depths for Shawnigan Lake North Basin site (1199901) (1976-2014).

Table 14. Nitrogen:Phosphorus ratios for the Shawnigan Lake basin sites (1976-2014)

| Year | North Basin (1199901) | South Basin (1199902) | West Arm (1199903) | North Beach (1199904) |
|---|---|---|---|---|
| | N:P ratios (mean total N (µg/L) : mean total P (µg/L)) | | | |
| 1976-1979 | 30:1 | 34:1 | 36:1 | 33:1 |
| 1980-1989 | 34:1 | 26:1 | -- | -- |
| 1990-1999 | 58:1 | -- | -- | -- |
| 2000-2005 | 36:1 | 32:1 | 54:1 | 58:1 |
| 2006 | 83:1 | 72:1 | 85:1 | 102:1 |
| 2007 | 37:1 | 46:1 | 39:1 | 44:1 |
| 2008 | 52:1 | 44:1 | 45:1 | 38:1 |
| 2010 | 42:1 | 45:1 | 61:1 | 59:1 |
| 2014 | 61:1 | 45:1 | 35:1 | 56:1 |

**Mean of at least three samples taken throughout the water column (surface, mid-depth, one meter above bottom).*

Figure 11. Total nitrogen annual averages for Shawnigan Lake North Basin site (1199901) (1977-2014).




** Mean of at least three samples taken throughout the water column (surface, mid-depth, one meter above bottom), at spring overturn.*

Table 15. Total organic carbon for the Shawnigan Lake basin sites (2006-2014). Exceedances are highlighted.

| Date | North Basin (1199901) | | | South Basin (1199902) | | | West Arm (1199903) | | North Beach (1199904) | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Surface (mg/L) | 10 m (mg/L) | Bottom (mg/L) | Surface (mg/L) | 10 m (mg/L) | Bottom (mg/L) | Surface (mg/L) | Bottom (mg/L) | Surface (mg/L) | Bottom (mg/L) |
| 28-Mar-2006 | 2.9 | 3 | 3.1 | 3.3 | 3.4 | 3.4 | 3.3 | 3.4 | 3.3 | 3.1 |
| 01-Mar-2007 | 3.0 | 2.8 | 2.9 | 2.8 | 2.7 | 3.1 | 2.6 | 2.6 | 2.7 | 3.1 |
| 25-Feb-2008 | 2.7 | 2.7 | 2.7 | 2.7 | 2.9 | 3.1 | 3.0 | 2.9 | 3.0 | 2.7 |
| 22-May-2008 | 2.4 | 2.4 | 3.4 | 3.1 | 2.6 | 2.6 | 4.6 | 4 | 4.1 | 4.2 |
| 10-Jun-2008 | 4.6 | 4.5 | 5.1 | 2.4 | 2.2 | 2.4 | 5.6 | 5.2 | -- | 2.6 |
| 15-Jul-2008 | 2.6 | 2.5 | 2.65 | 2.6 | 2.6 | 3.4 | 2.6 | 2.8 | 2.9 | 2.8 |
| 13-Aug-2008 | 3.2 | 3.4 | 3.4 | 3.3 | 3.35 | 4.0 | 3.2 | 4.7 | 3.2 | 3.0 |
| 25-Feb-2010 | 2.8 | 2.9 | 2.8 | 3.1 | 3.0 | 3.3 | 2.6 | 3.0 | 2.8 | 2.9 |
| 15-May-2013 | 2.5 | 2.28 | 2.77 | 1.98 | 1.9 | 2.32 | 2.41 | 2.26 | 2.96 | 2.35 |
| 14-Aug-2013 | 3.24 | 3.26 | 3.56 | 3.96 | 3.66 | 4.3 | 3.78 | 3.88 | 3.86 | 2.61 |
| 20-Nov-2013 | 2.02 | 2.64 | 3.12 | 3.15 | 2.21 | 2.89 | 2.36 | 3.12 | 3.31 | 2.4 |
| 12-Feb-2014 | 1.82 | 1.79 | 1.8 | <0.5 | 2.63 | 2.86 | 2.82 | 2.62 | 3.05 | 2.61 |

Table 16. Seasonal averages of total number of species and cell count for all phytoplankton data for Shawnigan Lake deep basin sites (2006-2014).

| Sample Year | Sample Month | Total Number of Species | | | | | Total number of cells/mL | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | North Basin (1199901) | South Basin (1199902) | West Arm (1199903) | North Beach (1199904) | Average | North Basin (1199901) | South Basin (1199902) | West Arm (1199903) | North Beach (1199904) | Average |
| 2006 | March | 42 | 47 | 53 | 48 | **48** | 288.4 | 305.2 | 373.8 | 449.4 | **354** |
| 2007 | March | 35 | 37 | 43 | 32 | **37** | 331.8 | 344.4 | 225.4 | 338.8 | **310** |
| 2008 | February | 41 | -- | -- | -- | **41** | 231 | -- | -- | -- | **231** |
| 2008 | May | 65 | -- | 62 | -- | **64** | 397.6 | -- | 404.6 | -- | **401** |
| 2008 | June | 71 | -- | 66 | -- | **69** | 501.2 | -- | 557.2 | -- | **529** |
| 2008 | July | 66 | -- | 62 | -- | **64** | 434.2 | -- | 463.4 | -- | **449** |
| 2008 | August | 41 | -- | 55 | -- | **48** | 450.8 | -- | 1405.6 | -- | **928** |
| 2010 | February | 28 | 31 | 41 | 37 | **34** | 263.2 | 403.2 | 329 | 365.4 | **340** |
| 2013 | August | 80 | 56 | 74 | 62 | **68** | 474.6 | 330.6 | 357 | 305.2 | **367** |
| 2014 | February | 44 | 31 | 34 | 44 | **38** | 431.2 | 991.2 | 315 | 744.8 | **621** |
| **Total Species Richness for Site** | | **125** | **85** | **120** | **91** | | | | | | |

Table 17. Summary of dominant (i.e. >10% of sample) Phytoplankton species for the North Basin and South Basin sites (2006-2014).

| Group | Species | Date | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | March 28, 2006 | March 1, 2007 | Feb. 25, 2008 | May 21, 2008 | June 10, 2008 | July 15, 2008 | Aug. 13, 2008 | Feb. 25, 2010 | Aug. 14, 2013 | Feb. 12, 2014 |
| **North Basin Site (EMS 1199901)** | | Number of cells/mL (% of total sample) | | | | | | | | | |
| Diatoms | **Order: Centrales** | | | | | | | | | | |
| | Melosira italica | 35 (12.1%) | -- | -- | -- | -- | -- | -- | -- | -- | 100.8 (23.4%) |
| | **Order: Pennales** | | | | | | | | | | |
| | Asterionella formosa | 61.6 (21.4%) | -- | 98 (42.4%) | 60.2 (15.1%) | 119 (23.7%) | -- | -- | 102.2 (38.8%) | -- | -- |
| | Fragilaria crotonensis | -- | -- | -- | -- | -- | -- | -- | -- | -- | 124.6 (28.9%) |
| Cyanophyta (Blue-green) | **Order: Chroococcales** | | | | | | | | | | |
| | Anacystis cf limneticus | -- | -- | -- | -- | -- | -- | -- | -- | 100.8 (21.2%) | -- |
| | Anacystis elachista | 56 (19.4%) | -- | -- | -- | -- | 154 (35.5%) | 392 (87%) | -- | -- | -- |
| | Anacystis limneticus | -- | -- | -- | -- | -- | 106.6 (24.6%) | -- | -- | -- | -- |
| Chlorophyta (Green) | **Order: Chlorococcales** | | | | | | | | | | |
| | Botryococcus braunii | -- | -- | -- | -- | 72.8 (14.5%) | -- | -- | -- | -- | -- |
| | **Order: Tetrasporales** | | | | | | | | | | |
| | Gloeocystis sp. | -- | -- | -- | -- | -- | 44.8 (10.3%) | -- | -- | -- | -- |
| Cryptophyte | **Order: Cryptomonadales** | | | | | | | | | | |
| | Chroomonas acuta | -- | 285.6 (86.1%) | 92.4 (40%) | 68.6 (17.3%) | 77 (15.4%) | -- | -- | -- | -- | 85.4 (19.8%) |
| | Cryptomonas ovata / erosa | -- | -- | -- | 84 (21.1%) | -- | -- | -- | -- | -- | -- |
| Chrysophyta (Golden Brown) | **Order: Ochromonadales** | | | | | | | | | | |
| | Dinobryon divergens[1] | -- | -- | -- | -- | 63 (12.6%) | -- | -- | 50.4 (19.1%) | -- | -- |
| | **Total Number of Cells per Sample** | **288** | **332** | **231** | **398** | **501** | **434** | **451** | **263** | **475** | **431** |
| **South Basin Site (EMS 1199902)** | | | | | | | | | | | |
| Diatoms | **Order: Centrales** | | | | | | | | | | |
| | Melosira italica | 72.8 (23.9%) | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| | **Order: Pennales** | | | | | | | | | | |
| | Asterionella formosa | 96.6 (31.7%) | 65.8 (19.1%) | -- | -- | -- | -- | -- | 166.6 (41.3%) | -- | 165.2 (16.7%) |
| | Fragilaria crotonensis | -- | -- | -- | -- | -- | -- | -- | -- | -- | 610.4 (61.6%) |
| Cyanophyta (Blue-green) | **Order: Chroococcales** | | | | | | | | | | |
| | Anacystis cf limneticus | -- | -- | -- | -- | -- | -- | -- | -- | 78.4 (23.7%) | -- |
| | Gomphosphaeria aponina | -- | -- | -- | -- | -- | -- | -- | -- | 67.2 (20.3%) | -- |
| Cryptophyte | **Order: Cryptomonadales** | | | | | | | | | | |
| | Chroomonas acuta | 67.2 (22%) | 198.8 (57.7%) | -- | -- | -- | -- | -- | 117.6 (29.2%) | -- | -- |
| Chrysophyta (Golden Brown) | **Order: Ochromonadales** | | | | | | | | | | |
| | Dinobryon divergens[1] | -- | -- | -- | -- | -- | -- | -- | 40.6 (10.1%) | -- | -- |
| | **Total Number of Cells per Sample** | **305** | **344** | **NS** | **NS** | **NS** | **NS** | **NS** | **403** | **331** | **991** |

[1]*Note : Some of the Dinobryon divergens and Dinobryon sertularia are similar and difficult to distinguish.*
*NS = not sampled; UID = unidentified due to lack of size and/or missing morphological characters.*

Table 18. Summary of dominant (i.e. >10% of sample) Phytoplankton species for the West Arm and North Beach sites (2006-2014).

| Group | Species | Date | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | March 28, 2006 | March 1, 2007 | Feb 25, 2008[1] | May 21, 2008 | June 10, 2008 | July 15, 2008 | Aug 13, 2008 | Feb 25, 2010 | Aug 14, 2013 | Feb 12, 2014 |
| **West Arm Site (EMS 1199903)** | | Number of cells/mL (% of total sample) | | | | | | | | | |
| **Diatoms** | **Order: Centrales** | | | | | | | | | | |
| | *Melosira italica* | 47.6 (12.7%) | -- | -- | -- | -- | -- | -- | -- | -- | 53.2 (16.9%) |
| | *Rhizosolenia eriensis/longiseta* | -- | -- | -- | -- | 224 (40.2%) | 61.6 (13.3%) | -- | -- | -- | -- |
| | **Order: Pennales** | | | | | | | | | | |
| | *Asterionella formosa* | 105 (28.1%) | -- | -- | 79.8 (19.7%) | -- | -- | -- | 78.4 (23.8%) | -- | -- |
| | *Fragilaria crotonensis* | -- | -- | -- | -- | -- | -- | -- | -- | -- | 70 (22.2%) |
| **Cyanophyta (Blue-green)** | **Order: Chroococcales** | | | | | | | | | | |
| | *Anacystis cf limneticus* | -- | -- | -- | -- | -- | -- | -- | -- | 39.2 (11%) | -- |
| | *Anacystis elachista* | -- | -- | -- | -- | -- | 182 (39.3%) | 1050 (74.7%) | -- | -- | -- |
| | *Anacystis limneticus* | -- | -- | -- | -- | -- | 67.2 (14.5%) | -- | -- | -- | -- |
| | *Gomphosphaeria cf aponina* | -- | -- | -- | -- | -- | -- | -- | -- | 67.2 (18.8%) | -- |
| | **Order: Nostocales** | | | | | | | | | | |
| | *Anabaena sp.* | -- | -- | -- | -- | -- | -- | -- | -- | 42 (11.8%) | -- |
| **Cryptophyte** | **Order: Cryptomonadales** | | | | | | | | | | |
| | *Chroomonas acuta* | 63 (16.9%) | 163.8 (72.7%) | -- | -- | -- | -- | -- | 106.4 (32.3%) | -- | 51.8 (16.4%) |
| **Chrysophyta (Golden Brown)** | **Order: Ochromonadales** | | | | | | | | | | |
| | *Dinobryon divergens*[1] | 79.8 (21.3%) | -- | -- | -- | -- | -- | -- | 57.4 (17.4%) | -- | -- |
| **Pyrrophyta (Dinoflagellates)** | **Order: Dinokontae** | | | | | | | | | | |
| | *Peridinium/Glenodinium* | -- | -- | -- | -- | -- | -- | 240.8 (17.1%) | -- | -- | 46.2 (14.7%) |
| | **Total Number of Cells per Sample** | **374** | **225** | **NS** | **405** | **557** | **463** | **1406** | **329** | **357** | **315** |
| **North Beach Site (EMS 1199904)** | | | | | | | | | | | |
| **Diatoms** | **Order: Centrales** | | | | | | | | | | |
| | *Melosira italica* | 58.8 (13.1%) | -- | -- | -- | -- | -- | -- | -- | -- | 128.8 (17.3%) |
| | *Melosira sp.* | 53.2 (11.8%) | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| | **Order: Pennales** | | | | | | | | | | |
| | *Asterionella formosa* | 58.8 (13.1%) | -- | -- | -- | -- | -- | -- | 82.6 (22.6%) | -- | 109.2 (14.7%) |
| | *Fragilaria crotonensis* | 78.4 (17.4%) | -- | -- | -- | -- | -- | -- | -- | 46.2 (15.1%) | 333.2 (44.7%) |
| **Cyanophyta (Blue-green)** | **Order: Chroococcales** | | | | | | | | | | |
| | *Anacystis cf elachista* | -- | -- | -- | -- | -- | -- | -- | -- | 42 (13.8%) | -- |
| | *Anacystis cf limneticus* | -- | -- | -- | -- | -- | -- | -- | -- | 75.6 (24.8%) | -- |
| | *Anacystis elachista* | 63 (14%) | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| **Cryptophyte** | **Order: Cryptomonadales** | | | | | | | | | | |
| | *Chroomonas acuta* | 61.6 (13.7%) | 243.6 (71.9%) | -- | -- | -- | -- | -- | 126 (34.5%) | 33.6 (11%) | -- |
| | *Cryptomonas ovata / erosa* | -- | 37.8 (11.2%) | -- | -- | -- | -- | -- | -- | -- | -- |
| **Chrysophyta (Golden Brown)** | **Order: Ochromonadales** | | | | | | | | | | |
| | *Dinobryon divergens*[1] | -- | -- | -- | -- | -- | -- | -- | 67.2 (18.4%) | -- | -- |
| | **Total Number of Cells per Sample** | **449** | **339** | **NS** | **NS** | **NS** | **NS** | **NS** | **365** | **305** | **745** |

*[1]Note : Some of the Dinobryon divergens and Dinobryon sertularia are similar and difficult to distinguish.*
*NS = not sampled; UID = unidentified due to lack of size and/or missing morphological characters.*

Table 19. Seasonal averages of total number of species and cell count for all phytoplankton data for Shawnigan Lake (2006-2014).

| Sample Year | Sample Month | Total Number of Species | | | | | Total number of cells/mL | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | North Basin (1199901) | South Basin (1199902) | West Arm (1199903) | North Beach (1199904) | Average | North Basin (1199901) | South Basin (1199902) | West Arm (1199903) | North Beach (1199904) | Average |
| 2006 | March | 42 | 47 | 53 | 48 | **48** | 288.4 | 305.2 | 373.8 | 449.4 | **354** |
| 2007 | March | 35 | 37 | 43 | 32 | **37** | 331.8 | 344.4 | 225.4 | 338.8 | **310** |
| 2008 | February | 41 | -- | -- | -- | **41** | 231 | -- | -- | -- | **231** |
| 2008 | May | 65 | -- | 62 | -- | **64** | 397.6 | -- | 404.6 | -- | **401** |
| 2008 | June | 71 | -- | 66 | -- | **69** | 501.2 | -- | 557.2 | -- | **529** |
| 2008 | July | 66 | -- | 62 | -- | **64** | 434.2 | -- | 463.4 | -- | **449** |
| 2008 | August | 41 | -- | 55 | -- | **48** | 450.8 | -- | 1405.6 | -- | **928** |
| 2010 | February | 28 | 31 | 41 | 37 | **34** | 263.2 | 403.2 | 329 | 365.4 | **340** |
| 2013 | August | 80 | 56 | 74 | 62 | **68** | 474.6 | 330.6 | 357 | 305.2 | **367** |
| 2014 | February | 44 | 31 | 34 | 44 | **38** | 431.2 | 991.2 | 315 | 744.8 | **621** |
| **Total Species Richness for Site** | | **125** | **85** | **120** | **91** | | | | | | |

Table 20. Summary of dominant (>10% of sample) Zooplankton species for Shawnigan Lake (2006 – 2014).

| Group | Species | Stage | March 28, 2006 | March 1, 2007 | Feb. 25, 2008 | May 22, 2008 | June 10, 2008 | July 15, 2008 | Aug. 13, 2008 | Aug. 14, 2013 | Feb. 12, 2014 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | **Date** | | | | | | | | |
| **North Basin Site (1199901)** | | | **Number of cells/mL (% of total sample)** | | | | | | | | |
| **Phylum Arthropoda, Class Maxillopoda, Subclass Copepoda** | Copepod nauplii | | — | 2633.3 (18.07%) | 6700 (43.48%) | — | — | — | — | — | — |
| | **Order : Cyclopoida** | | | | | | | | | | |
| | *Diacyclops thomasi* | adult | — | — | — | — | — | — | — | 1481 (14.14%) | 912 (12.22%) |
| | *Diacyclops thomasi* | copepodid | 1400 (12.24%) | 1866.7 (12.81%) | — | — | — | — | — | — | 1278 (17.12%) |
| | UID | copepodid | — | — | — | — | — | — | — | — | — |
| | **Order : Calanoida** | | | | | | | | | | |
| | UID Calanoida / Cyclopoida | nauplii | — | — | — | — | — | — | — | 2808 (26.81%) | 3059 (40.99%) |
| **Phylum Rotifera** | *Kellicottia longispina* | | — | — | — | — | 10200 (11.98%) | — | — | 1598 (15.26%) | 867 (11.62%) |
| | *Keratella cochlearis* | | 5666.7 (49.56%) | 7400 (50.78%) | 3033.3 (19.68%) | 42700 (59.96%) | 35500 (41.69%) | 52750 (63.81%) | 20000 (50.84%) | 2457 (23.46%) | 912 (12.22%) |
| | *Polyarthra spp.* | | — | — | — | — | 23100 (27.13%) | 10625 (12.85%) | 5200 (13.22%) | — | — |
| | *Ptygura libera* | | — | — | — | — | — | — | 6800 (17.29%) | — | — |
| **Total Number of Cells per Sample** | | | **11,434** | **14,574** | **15,410** | **71,209** | **85,145** | **82,664** | **39,337** | **10,475** | **7,463** |
| **South Basin Site (1199902)** | | | | | | | | | | | |
| **Phylum Arthropoda, Class Maxillopoda, Subclass Copepoda** | Copepod nauplii | | 2633.3 (16.34%) | 3050 (30.21%) | — | — | — | — | — | — | — |
| | **Order : Cyclopoida** | | | | | | | | | | |
| | *Diacyclops thomasi* | copepodid | — | 1225 (12.13%) | — | — | — | — | — | — | — |
| | UID | copepodid | — | — | — | — | — | — | — | — | — |
| | **Order : Calanoida** | | | | | | | | | | |
| | UID Calanoida / Cyclopoida | nauplii | — | — | — | — | — | — | — | 9756 (34.51%) | 3781 (38.49%) |
| **Phylum Rotifera** | *Keratella cochlearis* | | 7466.7 (46.34%) | 3975 (39.37%) | — | — | — | — | — | 10651 (37.67%) | 1341 (13.65%) |
| **Total Number of Cells per Sample** | | | **16,113** | **10,097** | **NS** | **NS** | **NS** | **NS** | **NS** | **28,273** | **9,823** |
| **West Arm Site (1199903)** | | | | | | | | | | | |
| **Phylum Arthropoda, Class Maxillopoda, Subclass Copepoda** | Copepod nauplii | | 3233 (10.81%) | 3733.3 (19.49%) | — | — | — | — | — | — | — |
| | **Order : Cyclopoida** | | | | | | | | | | |
| | *Diacyclops thomasi* | adult | — | — | — | — | — | — | — | — | 3528 (16.33%) |
| | *Diacyclops thomasi* | copepodid | — | 3333.3 (17.41%) | — | — | — | — | — | — | 3135 (14.51%) |
| | UID | copepodid | — | — | — | — | — | — | — | 1248 (14.11%) | |
| | **Order : Calanoida** | | | | | | | | | | |
| | UID Calanoida / Cyclopoida | nauplii | — | — | — | — | — | — | — | 1920 (21.7%) | 9015 (41.73%) |
| **Phylum Rotifera** | *Keratella cochlearis* | | 18350 (61.38%) | 9200 (48.04%) | — | 169600 (85.91%) | 32200 (34.71%) | 25875 (62.38%) | 10733.3 (53.88%) | 3936 (44.49%) | — |
| | *Polyarthra spp.* | | — | — | — | — | 31800 (34.28%) | — | 3400 (17.07%) | — | — |
| | *Ptygura libera* | | — | — | — | — | — | — | 2666.7 (13.39%) | — | — |
| **Total Number of Cells per Sample** | | | **29,897** | **19,151** | **NS** | **197,405** | **92,762** | **41,477** | **19,920** | **8,846** | **21,604** |
| **North Beach Site (1199904)** | | | | | | | | | | | |
| **Phylum Arthropoda, Class Maxillopoda, Subclass Copepoda** | Copepod nauplii | | 6000 (16.1%) | 1966.7 (17.47%) | — | — | — | — | — | — | — |
| | **Order : Cyclopoida** | | | | | | | | | | |
| | UID | copepodid | — | — | — | — | — | — | — | 1735 (15.63%) | — |
| | **Order : Calanoida** | | | | | | | | | | |
| | UID Calanoida / Cyclopoida | nauplii | — | — | — | — | — | — | — | 3781 (34.07%) | 2019 (42.53%) |
| **Phylum Rotifera** | *Kellicottia longispina* | | — | — | — | — | — | — | — | — | 608 (12.81%) |
| | *Keratella cochlearis* | | 22950 (61.57%) | 7050 (62.64%) | — | — | — | — | — | 1239 (11.17%) | 691 (14.56%) |
| **Total Number of Cells per Sample** | | | **37,275** | **11,255** | **NS** | **NS** | **NS** | **NS** | **NS** | **11,097** | **4,747** |
| **Average Total per Sample** | | | **23,680** | **13,769** | **15,410** | **134,307** | **88,953** | **62,070** | **29,629** | **14,673** | **10,909** |

*NS = not sampled; UID = unidentified due to lack of size and/or missing morphological characters.*

Table 21. Summary of *E.coli*, enterococci and fecal coliform (CFU/100mL) samples collected at the East Shore (E257436) and North (E257437) domestic water intake sites.

| Parameter | Site | Sample Year | Count | Min | Max | Avg | SD | Geomean | 90th percentile |
|---|---|---|---|---|---|---|---|---|---|
| **E.coli** | East Shore E257436 | 2008 summer | 5 | <1 | 110 | 22.8 | 48.8 | 2.6 | **66.4** |
| | East Shore E257436 | 2010 (Feb) | 1 | <1 | N/A | N/A | N/A | N/A | N/A |
| | East Shore E257436 | 2013 summer | 5 | <1 | 4 | 1.6 | 1.3 | 1.3 | 2.8 |
| | East Shore E257436 | 2013 fall | 4 | <1 | 2 | 1.5 | 0.6 | 1.4 | 2 |
| | North E257437 | 2008 summer | 4 | <1 | 1 | 1 | 0 | 1 | 1 |
| | North E257437 | 2010 (Feb) | 1 | <1 | N/A | N/A | N/A | N/A | N/A |
| | North E257437 | 2013 summer | 5 | <1 | 1 | 1 | 0 | 1 | 1 |
| | North E257437 | 2013 fall | 3 | <1 | 2 | 1.3 | 0.6 | 1.3 | 1.8 |
| **enterococci** | East Shore E257436 | 2008 summer | 5 | <1 | 8 | 2.6 | 3.1 | N/A | **5.6** |
| | East Shore E257436 | 2010 (Feb) | 1 | 1 | NA | NA | NA | N/A | NA |
| | North E257437 | 2008 summer | 4 | <1 | 2 | 1.3 | 0.5 | N/A | 1.7 |
| | North E257437 | 2010 (Feb) | 1 | 1.5 | NA | NA | NA | N/A | NA |
| **fecal coliforms** | East Shore E257436 | 2008 summer | 5 | <1 | 110 | 24.8 | 47.8 | N/A | **70.4** |
| | East Shore E257436 | 2010 (Feb) | 1 | <1 | NA | NA | NA | N/A | NA |
| | North E257437 | 2008 summer | 4 | <1 | 5 | 2 | 2 | N/A | 3.8 |
| | North E257437 | 2010 (Feb) | 1 | <1 | NA | NA | NA | N/A | NA |

*Statistics are calculated based on five samples collected in a 30 day period, unless the sample count indicates otherwise. Grey highlighted 90th percentile values exceed the applicable WQO.*

Table 22. Summary of 2006-2013 general chemistry water grab samples taken at Shawnigan Lake North Basin site (1199901).

| Parameter | Units | Minimum | Maximum | Average | Std Dev | Count |
|---|---|---|---|---|---|---|
| **GENERAL** | | | | | | |
| Alkalinity Total 4.5 | mg/L | 13 | 24 | 15.6 | 2.9 | 24 |
| Ammonia (N) | mg/L | < 0.005 | 0.045 | 0.012 | 0.011 | 24 |
| Carbon, Inorganic - Total | mg/L | 2.8 | 4.9 | 3.9 | 0.62 | 24 |
| Carbon, Organic - Total | mg/L | 1.77 | 5.1 | 2.9 | 0.72 | 36 |
| Carbon, Organic - Dissolved | mg/L | 2.2 | 3.5 | 2.9 | 0.42 | 12 |
| Chlorophyll *a* | mg/L | 0.0005 | 0.00521 | 0.0022 | 0.0016 | 16 |
| Hardness - Total | mg/L | 20.4 | 20.8 | 20.6 | 0.21 | 3 |
| Hardness - Dissolved | mg/L | 22 | 22.9 | 22.3 | 0.49 | 3 |
| Kjeldahl Nitrogen - Total | mg/L | 0.03 | 0.22 | 0.12 | 0.053 | 24 |
| Nitrate (N) - Dissolved | mg/L | < 0.002 | 0.137 | 0.066 | 0.047 | 18 |
| Nitrate + Nitrite | mg/L | < 0.002 | 0.139 | 0.077 | 0.051 | 24 |
| Nitrogen - Nitrite, Dissolved | mg/L | < 0.002 | 0.005 | 0.0025 | 0.0009 | 18 |
| Nitrogen (N) - Total | mg/L | 0.09 | 0.348 | 0.21 | 0.074 | 27 |
| Nitrogen, Organic - Total | mg/L | < 0.02 | 0.2 | 0.10 | 0.05 | 21 |
| Ortho-Phosphate - Dissolved | mg/L | < 0.001 | 0.003 | 0.002 | 0.0007 | 12 |
| pH | pH units | 7.1 | 7.72 | 7.4 | 0.18 | 36 |
| Phosphorus (P) - Total | mg/L | 0.002 | 0.0155 | 0.005 | 0.002 | 36 |
| Phosphorus - Dissolved | mg/L | < 0.002 | 0.005 | 0.003 | 0.001 | 12 |
| Specific Conductivity | µS/cm | 54 | 64 | 58.1 | 2.8 | 24 |
| Sulphate (SO4) - Dissolved | mg/L | 2.1 | 6 | 3.0 | 1.1 | 12 |
| Total Dissolved Solids | mg/L | 22 | 56 | 41.8 | 11.7 | 12 |
| True Colour | Col. Unit | 5 | 30 | 9.03 | 6.3 | 36 |
| Turbidity | NTU | 0.3 | 3.6 | 0.89 | 0.3 | 36 |
| **METALS/SEMI-METALS** | | | | | | |
| Ag - T (Silver) | mg/L | < 0.000005 | < 0.00002 | N/A | N/A | 15 |
| Ag - D | mg/L | < 0.000005 | < 0.00002 | N/A | N/A | 6 |
| Al - T (Aluminum) | mg/L | 0.0116 | 0.0398 | 0.0298 | 0.0093 | 15 |
| Al - D | mg/L | 0.00645 | 0.2860 | 0.0604 | 0.111 | 6 |
| As - T (Arsenic) | mg/L | < 0.0001 | 0.00015 | 0.00012 | 0.000018 | 15 |
| As - D | mg/L | < 0.0001 | 0.000142 | 0.000119 | 0.000021 | 6 |
| B - T (Boron) | mg/L | 0.008 | < 0.05 | N/A | N/A | 9 |
| B - D | mg/L | < 0.05 | < 0.05 | N/A | N/A | 3 |
| Ba - T (Barium) | mg/L | 0.00457 | 0.00601 | 0.0051 | 0.00038 | 15 |
| Ba - D | mg/L | 0.00433 | 0.0048 | 0.0046 | 0.00016 | 6 |
| Be - T (Beryllium) | mg/L | < 0.00001 | 0.00002 | 0.00001 | 0.000005 | 15 |

| Parameter | Units | Minimum | Maximum | Average | Std Dev | Count |
|---|---|---|---|---|---|---|
| Be - D | mg/L | < 0.00001 | < 0.00002 | N/A | N/A | 6 |
| Bi - T (Bismuth) | mg/L | < 0.000005 | < 0.00002 | N/A | N/A | 15 |
| Bi - D | mg/L | < 0.000005 | < 0.00002 | N/A | N/A | 6 |
| C - T (Carbon) | mg/L | 5.8 | 9 | 7.0 | 0.87 | 24 |
| Ca - T (Calcium) | mg/L | 15.17014 | 15.79958 | 15.47211 | 0.31549 | 3 |
| Ca- D | mg/L | 6.6 | 6.93 | 6.7 | 0.17 | 3 |
| Cd - T (Cadmium) | mg/L | < 0.000005 | 0.00001 | 0.000007 | 0.000002 | 15 |
| Cd - D | mg/L | < 0.000005 | < 0.00001 | N/A | N/A | 6 |
| Cl - D (Chloride) | mg/L | 4.4 | 5.4 | 4.89 | 0.32 | 24 |
| Co - T (Cobalt) | mg/L | 0.000014 | 0.000047 | 0.000025 | 0.000009 | 15 |
| Co - D | mg/L | < 0.000005 | 0.00001 | 0.000007 | 0.000003 | 6 |
| Cr - T (Chromium) | mg/L | < 0.0001 | 0.0002 | 0.0001 | 0.00005 | 15 |
| Cr - D | mg/L | < 0.0001 | < 0.0002 | N/A | N/A | 6 |
| Cu T (Copper) | mg/L | 0.000537 | 0.00126 | 0.000734 | 0.000203 | 15 |
| Cu - D | mg/L | 0.000436 | 0.0005 | 0.00050 | 0.000035 | 6 |
| Fe - T (Iron) | mg/L | 0.0869 | 0.094 | 0.089 | 0.0039 | 3 |
| Fe - D | mg/L | 0.0559 | 0.0583 | 0.0569 | 0.00127 | 3 |
| Li - T (Lithium) | mg/L | 0.00005 | < 0.0005 | 0.0003 | 0.0002 | 15 |
| Li - D | mg/L | < 0.00005 | 0.0005 | 0.00029 | 0.00023 | 6 |
| Mg - T (Magnesium) | mg/L | 1.19 | 1.37 | 1.308333 | 0.070261 | 6 |
| Mg - D | mg/L | 1.1 | 1.36 | 1.2 | 0.13 | 6 |
| Mn - T (Manganese) | mg/L | 0.00275 | 0.0558 | 0.0131 | 0.0132 | 15 |
| Mn - D | mg/L | 0.000661 | 0.0054 | 0.0020 | 0.0018 | 6 |
| Mo - T (Molybdenum) | mg/L | < 0.00005 | 0.00007 | 0.00006 | 0.000007 | 15 |
| Mo - D | mg/L | < 0.00005 | 0.0001 | 0.000059 | 0.000006 | 6 |
| Ni - T (Nickel) | mg/L | < 0.00005 | 0.00171 | 0.0002 | 0.0004 | 15 |
| Ni - D | mg/L | < 0.00005 | 0.0001 | 0.000066 | 0.000018 | 6 |
| Pb - T (Lead) | mg/L | 0.000027 | 0.00016 | 0.000070 | 0.000041 | 15 |
| Pb - D | mg/L | < 0.000007 | 0.00003 | 0.00001 | 0.000009 | 6 |
| Sb - T (Antimony) | mg/L | 0.000016 | 0.00003 | 0.000025 | 0.000004 | 15 |
| Sb - D | mg/L | 0.000018 | 0.00003 | 0.000025 | 0.000005 | 6 |
| Se - T (Selenium) | mg/L | < 0.00004 | < 0.0002 | N/A | N/A | 15 |
| Se - D | mg/L | < 0.00004 | 0.0002 | 0.00012 | 0.000087 | 6 |
| Si - D (Silica) | mg/L | 5.6 | 6.8 | 6.2 | 0.39 | 12 |
| Sn - T (Tin) | mg/L | < 0.00001 | 0.0003 | 0.00009 | 0.0001 | 15 |
| Sn - D | mg/L | < 0.00001 | 0.0002 | 0.00011 | 0.0001 | 6 |
| Sr - T (Strontium) | mg/L | 0.0208 | 0.0295 | 0.0245 | 0.00280 | 15 |
| Sr - D | mg/L | 0.0206 | 0.0274 | 0.0241 | 0.003 | 6 |
| Tl - T (Thallium) | mg/L | < 0.000002 | 0.000009 | 0.000003 | 0.000003 | 15 |

| Parameter | Units | Minimum | Maximum | Average | Std Dev | Count |
|---|---|---|---|---|---|---|
| Tl - D | mg/L | < 0.000002 | < 0.000002 | N/A | N/A | 6 |
| U - T (Uranium) | mg/L | 0.000003 | 0.000007 | 0.000005 | 0.000001 | 15 |
| U - D | mg/L | 0.000003 | 0.00001 | 0.000004 | 0.000001 | 6 |
| V - T (Vanadium) | mg/L | 0.0001 | 0.00023 | 0.0002 | 0.00004 | 15 |
| V - D | mg/L | 0.00006 | 0.0002 | 0.0001 | 0.00008 | 6 |
| Zn - T (Zinc) | mg/L | 0.00068 | 0.019 | 0.0046 | 0.0060 | 15 |
| Zn - D | mg/L | 0.00029 | 0.0045 | 0.0020 | 0.0018 | 6 |

Table 23. Summary of 2006-2013 general chemistry water grab sample statistics taken at Shawnigan Lake South Basin site (1199902).

| Parameter | Units | Minimum | Maximum | Average | Std Dev | Count |
|---|---|---|---|---|---|---|
| **GENERAL** | | | | | | |
| Alkalinity Total 4.5 | mg/L | 10.8 | 18 | 13 | 2 | 24 |
| Ammonia (N) | mg/L | < 0.005 | 0.071 | 0.011 | 0.015 | 24 |
| Carbon, Inorganic - Total | mg/L | 1.2 | 5.4 | 3.5 | 0.97 | 24 |
| Carbon, Organic - Total | mg/L | < 0.5 | 4.25 | 2.9 | 0.68 | 36 |
| Carbon, Organic - Dissolved | mg/L | 2.1 | 3.3 | 2.7 | 0.39 | 12 |
| Chlorophyll *a* | mg/L | 0.0005 | 0.0059 | 0.0026 | 0.0017 | 12 |
| Hardness - Total | mg/L | 16.1 | 16.5 | 16.2 | 0.23 | 3 |
| Hardness - Dissolved | mg/L | 19.8 | 21.3 | 20.5 | 0.75 | 3 |
| Kjeldahl Nitrogen - Total | mg/L | 0.02 | 0.19 | 0.12 | 0.042 | 24 |
| Nitrate (N) - Dissolved | mg/L | < 0.002 | 0.094 | 0.05 | 0.04 | 18 |
| Nitrate + Nitrite | mg/L | 0.002 | 0.1 | 0.06 | 0.04 | 24 |
| Nitrogen - Nitrite, Dissolved | mg/L | < 0.002 | 0.004 | 0.002 | 0.001 | 18 |
| Nitrogen (N) - Total | mg/L | 0.07 | 0.345 | 0.20 | 0.071 | 27 |
| Nitrogen, Organic - Total | mg/L | < 0.02 | 0.19 | 0.11 | 0.040 | 21 |
| Ortho-Phosphate - Dissolved | mg/L | < 0.001 | 0.005 | 0.003 | 0.001 | 12 |
| pH | pH units | 7 | 7.66 | 7.3 | 0.2 | 36 |
| Phosphorus - Dissolved | mg/L | < 0.002 | 0.005 | 0.0030 | 0.0015 | 9 |
| Phosphorus (P) - Total | mg/L | 0.003 | 0.0272 | 0.0065 | 0.0045 | 36 |
| Specific Conductivity | µS/cm | 48 | 68 | 55 | 5.6 | 24 |
| Sulphate (SO4) - Dissolved | mg/L | 1.0 | 9.7 | 2.8 | 2.2 | 12 |
| Total Dissolved Solids | mg/L | 22 | 52 | 39 | 11 | 12 |
| True Colour | Col. Unit | < 5 | 80 | 14 | 16 | 36 |
| Turbidity | NTU | 0.27 | 3.9 | 1.0 | 0.92 | 36 |
| **METALS/SEMI-METALS** | | | | | | |
| Ag - T (Silver) | mg/L | < 0.000005 | < 0.00002 | N/A | N/A | 15 |
| Ag - D | mg/L | < 0.000005 | < 0.00005 | N/A | N/A | 6 |
| Al - T (Aluminum) | mg/L | 0.0316 | 0.0642 | 0.0464 | 0.00899 | 15 |
| Al - D | mg/L | 0.0192 | 0.0394 | 0.029083 | 0.010721 | 6 |
| As - T (Arsenic) | mg/L | < 0.0001 | 0.00013 | 0.00011 | 0.000011 | 15 |
| As - D | mg/L | < 0.0001 | 0.000137 | 0.00012 | 0.000019 | 6 |
| B - T (Boron) | mg/L | 0.008 | < 0.05 | 0.036 | 0.021 | 9 |
| B - D | mg/L | < 0.05 | < 0.05 | N/A | N/A | 3 |
| Ba - T (Barium) | mg/L | 0.00381 | 0.0049 | 0.0042 | 0.00032 | 15 |
| Ba - D | mg/L | 0.00374 | 0.0378 | 0.00973 | 0.013757 | 6 |

| Parameter | Units | Minimum | Maximum | Average | Std Dev | Count |
|---|---|---|---|---|---|---|
| Be - T (Beryllium) | mg/L | < 0.00001 | < 0.00002 | N/A | N/A | 15 |
| Be - D | mg/L | < 0.00001 | < 0.00002 | N/A | N/A | 6 |
| Bi - T (Bismuth) | mg/L | < 0.000005 | < 0.00002 | N/A | N/A | 15 |
| Bi - D | mg/L | < 0.000005 | < 0.00002 | N/A | N/A | 6 |
| C - T (Carbon) | mg/L | 3.9 | 9 | 6.5 | 1.2 | 24 |
| Ca - T (Calcium) | mg/L | 12.06436 | 12.382 | 12.198 | 0.165 | 3 |
| Ca- D | mg/L | 5.95 | 6.45 | 6.18 | 0.25 | 3 |
| Cd - T (Cadmium) | mg/L | < 0.000005 | 0.000032 | 0.00001 | 0.000007 | 15 |
| Cd - D | mg/L | < 0.000005 | < 0.00001 | N/A | N/A | 6 |
| Cl - D (Chloride) | mg/L | 3.9 | 6.5 | 5.1 | 0.71 | 24 |
| Co - T (Cobalt) | mg/L | 0.000023 | 0.000047 | 0.000031 | 0.000007 | 15 |
| Co - D | mg/L | 0.000009 | 0.000015 | 0.000012 | 0.000002 | 6 |
| Cr - T (Chromium) | mg/L | < 0.0001 | 0.0002 | 0.0001 | 0.00005 | 15 |
| Cr - D | mg/L | < 0.0001 | < 0.0002 | N/A | N/A | 6 |
| Cu T (Copper) | mg/L | 0.00056 | 0.00245 | 0.00090 | 0.00050 | 15 |
| Cu - D | mg/L | 0.00052 | 0.00085 | 0.000613 | 0.000124 | 6 |
| Fe - T (Iron) | mg/L | 0.101 | 0.111 | 0.105 | 0.00513 | 3 |
| Fe - D | mg/L | 0.0671 | 0.0725 | 0.0701 | 0.00275 | 3 |
| Li - T (Lithium) | mg/L | < 0.00005 | < 0.0005 | 0.0003 | 0.0002 | 15 |
| Li - D | mg/L | < 0.00005 | < 0.0005 | N/A | N/A | 6 |
| Mg - T (Magnesium) | mg/L | 0.96 | 1.3 | 1.1 | 0.16 | 6 |
| Mg - D | mg/L | 0.97 | 1.25 | 1.1 | 0.14 | 6 |
| Mn - T (Manganese) | mg/L | 0.0027 | 0.012 | 0.0068 | 0.0030 | 15 |
| Mn - D | mg/L | 0.00213 | 0.0034 | 0.0028 | 0.00044 | 6 |
| Mo - T (Molybdenum) | mg/L | < 0.00005 | 0.000056 | 0.000051 | 0.000002 | 15 |
| Mo - D | mg/L | < 0.00005 | 0.00006 | 0.000055 | 0.000005 | 6 |
| Ni - T (Nickel) | mg/L | < 0.00005 | 0.00041 | 0.00015 | 0.000090 | 15 |
| Ni - D | mg/L | < 0.00005 | 0.000193 | 0.00009 | 0.000056 | 6 |
| Pb - T (Lead) | mg/L | 0.000032 | 0.00043 | 0.000088 | 0.00010 | 15 |
| Pb - D | mg/L | < 0.00001 | 0.000025 | 0.000015 | 0.000006 | 6 |
| Sb - T (Antimony) | mg/L | 0.000015 | 0.000028 | 0.000020 | 0.000003 | 15 |
| Sb - D | mg/L | 0.000014 | 0.000026 | 0.000020 | 0.000005 | 6 |
| Se - T (Selenium) | mg/L | < 0.00004 | < 0.0002 | N/A | N/A | 15 |
| Se - D | mg/L | < 0.00004 | < 0.0002 | N/A | N/A | 6 |
| Si - D (Silica) | mg/L | 5.9 | 6.8 | 6.3 | 0.31 | 12 |
| Sn - T (Tin) | mg/L | < 0.00001 | 0.00052 | 0.00012 | 0.00015 | 15 |
| Sn - D | mg/L | 0.00001 | 0.0002 | 0.00011 | 0.00010 | 6 |
| Sr - T (Strontium) | mg/L | 0.0188 | 0.0276 | 0.0225 | 0.00282 | 15 |
| Sr - D | mg/L | 0.0184 | 0.0289 | 0.0237 | 0.00521 | 6 |

| Parameter | Units | Minimum | Maximum | Average | Std Dev | Count |
|---|---|---|---|---|---|---|
| Tl - T (Thallium) | mg/L | < 0.000002 | 0.000008 | 0.000003 | 0.000002 | 15 |
| Tl - D | mg/L | < 0.000002 | < 0.000002 | N/A | N/A | 6 |
| U - T (Uranium) | mg/L | 0.000003 | 0.000007 | 0.000005 | 0.000001 | 15 |
| U - D | mg/L | 0.000002 | 0.000004 | 0.000004 | 0.000001 | 6 |
| V - T (Vanadium) | mg/L | 0.00016 | 0.00027 | 0.00020 | 0.00003 | 15 |
| V - D | mg/L | 0.0001 | 0.00022 | 0.00016 | 0.000059 | 6 |
| Zn - T (Zinc) | mg/L | 0.00069 | 0.0229 | 0.0057 | 0.0063 | 15 |
| Zn - D | mg/L | 0.00029 | 0.00736 | 0.00261 | 0.00273 | 6 |

Table 24. Summary of 2006-2013 general chemistry water grab sample statistics taken at Shawnigan Lake West Arm site (1199903).

| Parameter | Units | Minimum | Maximum | Average | Std Dev | Count |
|---|---|---|---|---|---|---|
| **GENERAL** | | | | | | |
| Alkalinity Total 4.5 | mg/L | 14 | 30 | 20 | 4.6 | 16 |
| Ammonia (N) | mg/L | < 0.005 | 0.016 | 0.007 | 0.003 | 16 |
| Carbon, Inorganic - Total | mg/L | 2.6 | 8.1 | 4.9 | 1.4 | 16 |
| Carbon, Organic - Total | mg/L | 2.26 | 5.6 | 3.3 | 0.92 | 24 |
| Carbon, Organic - Dissolved | mg/L | 2.4 | 3.9 | 3.0 | 0.58 | 8 |
| Chlorophyll *a* | mg/L | 0.0008 | 0.0144 | 0.0052 | 0.0042 | 12 |
| Hardness - Dissolved | mg/L | 25.4 | 27.3 | 26.4 | 1.34 | 2 |
| Kjeldahl Nitrogen - Total | mg/L | 0.07 | 0.19 | 0.12 | 0.033 | 16 |
| Nitrate (N) - Dissolved | mg/L | < 0.002 | 0.112 | 0.044 | 0.046 | 12 |
| Nitrate + Nitrite | mg/L | < 0.002 | 0.128 | 0.0605 | 0.050 | 16 |
| Nitrogen - Nitrite, Dissolved | mg/L | < 0.002 | 0.003 | 0.002 | 0.0003 | 12 |
| Nitrogen (N) - Total | mg/L | 0.09 | 0.299 | 0.19 | 0.064 | 18 |
| Nitrogen, Organic - Total | mg/L | 0.05 | 0.19 | 0.12 | 0.037 | 14 |
| Ortho-Phosphate - Dissolved | mg/L | < 0.001 | 0.004 | 0.003 | 0.001 | 8 |
| pH | pH units | 7.1 | 7.69 | 7.4 | 0.18 | 24 |
| Phosphorus - Dissolved | mg/L | < 0.002 | 0.006 | 0.004 | 0.001 | 8 |
| Phosphorus (P) - Total | mg/L | 0.003 | 0.014 | 0.006 | 0.003 | 24 |
| Specific Conductivity | µS/cm | 59 | 87 | 67 | 8.5 | 16 |
| Sulphate (SO4) - Dissolved | mg/L | 1.4 | 7 | 3.1 | 1.7 | 8 |
| Total Dissolved Solids | mg/L | 28 | 78 | 52 | 18 | 8 |
| True Colour | Col. Unit | 5 | 40 | 11 | 9.2 | 24 |
| Turbidity | NTU | 0.3 | 3 | 1 | 0.76 | 24 |
| **METALS/SEMI-METALS** | | | | | | |
| Ag - T (Silver) | mg/L | < 0.000005 | < 0.00002 | N/A | N/A | 10 |
| Ag - D | mg/L | < 0.000005 | < 0.00002 | N/A | N/A | 4 |
| Al - T (Aluminum) | mg/L | 0.000026 | 0.0409 | 0.027 | 0.012396 | 11 |
| Al - D | mg/L | 0.0076 | 0.0297 | 0.018203 | 0.011987 | 4 |
| As - T (Arsenic) | mg/L | < 0.0001 | 0.00014 | 0.00012 | 0.000015 | 10 |
| As - D | mg/L | < 0.0001 | 0.000144 | 0.00012 | 0.000025 | 4 |
| B - T (Boron) | mg/L | 0.008 | < 0.05 | 0.04 | 0.02 | 6 |
| B - D | mg/L | < 0.05 | < 0.05 | N/A | N/A | 2 |
| Ba - T (Barium) | mg/L | 0.00523 | 0.00711 | 0.00590 | 0.000705 | 10 |
| Ba - D | mg/L | 0.0051 | 0.00579 | 0.0055 | 0.00028 | 4 |
| Be - T (Beryllium) | mg/L | < 0.00001 | < 0.00002 | N/A | N/A | 10 |

| Parameter | Units | Minimum | Maximum | Average | Std Dev | Count |
|---|---|---|---|---|---|---|
| Be - D | mg/L | < 0.00001 | < 0.00002 | N/A | N/A | 4 |
| Bi - T (Bismuth) | mg/L | < 0.000005 | < 0.00002 | N/A | N/A | 10 |
| Bi - D | mg/L | < 0.000005 | < 0.00002 | N/A | N/A | 4 |
| C - T (Carbon) | mg/L | 5.8 | 11.1 | 8.4 | 1.585967 | 16 |
| Ca- D | mg/L | 7.87 | 8.47 | 8.17 | 0.42 | 2 |
| Cd - T (Cadmium) | mg/L | < 0.000005 | 0.0001 | 0.00002 | 0.00003 | 10 |
| Cd - D | mg/L | < 0.000005 | 0.00001 | 0.000008 | 0.000003 | 4 |
| Cl - D (Chloride) | mg/L | 4.6 | 7.5 | 5.4 | 0.69 | 16 |
| Co - T (Cobalt) | mg/L | 0.000014 | 0.000039 | 0.000024 | 0.000008 | 10 |
| Co - D | mg/L | 0.000006 | 0.000011 | 0.000008 | 0.000003 | 4 |
| Cr - T (Chromium) | mg/L | < 0.0001 | < 0.0002 | N/A | N/A | 10 |
| Cr - D | mg/L | < 0.0001 | < 0.0002 | N/A | N/A | 4 |
| Cu T (Copper) | mg/L | 0.00058 | 0.00376 | 0.0012 | 0.000955 | 10 |
| Cu - D | mg/L | 0.000546 | 0.00097 | 0.00070 | 0.00019 | 4 |
| Fe - T (Iron) | mg/L | 0.0845 | 0.0891 | 0.0868 | 0.00325 | 2 |
| Fe - D | mg/L | 0.0454 | 0.048 | 0.047 | 0.0018 | 2 |
| Li - T (Lithium) | mg/L | < 0.00005 | 0.0005 | 0.0004 | 0.00019 | 10 |
| Li - D | mg/L | < 0.00005 | 0.0005 | 0.0003 | 0.0002 | 4 |
| Mg - T (Magnesium) | mg/L | 1.22 | 1.52 | 1.41 | 0.131 | 4 |
| Mg - D | mg/L | 1.18 | 1.51 | 1.40 | 0.151 | 4 |
| Mn - T (Manganese) | mg/L | 0.00311 | 0.0135 | 0.00758 | 0.0030 | 10 |
| Mn - D | mg/L | 0.000727 | 0.00277 | 0.00167 | 0.000959 | 4 |
| Mo - T (Molybdenum) | mg/L | < 0.00005 | 0.000072 | 0.000054 | 0.000008 | 10 |
| Mo - D | mg/L | < 0.00005 | 0.000057 | 0.000053 | 0.000004 | 4 |
| Ni - T (Nickel) | mg/L | < 0.00005 | 0.00471 | 0.00061 | 0.0014 | 10 |
| Ni - D | mg/L | < 0.00005 | 0.000094 | 0.000072 | 0.000025 | 4 |
| Pb - T (Lead) | mg/L | 0.000026 | 0.00046 | 0.000093 | 0.00013 | 10 |
| Pb - D | mg/L | < 0.000008 | 0.00001 | 0.000009 | 0.000001 | 4 |
| Sb - T (Antimony) | mg/L | 0.000016 | 0.000031 | 0.000023 | 0.000005 | 10 |
| Sb - D | mg/L | 0.000016 | 0.000029 | 0.000023 | 0.000006 | 4 |
| Se - T (Selenium) | mg/L | < 0.00004 | < 0.0002 | N/A | N/A | 10 |
| Se - D | mg/L | < 0.00004 | < 0.0002 | N/A | N/A | 4 |
| Si - D (Silica) | mg/L | 6 | 9.2 | 7.2 | 1.1 | 8 |
| Sn - T (Tin) | mg/L | < 0.00001 | 0.00243 | 0.00032 | 0.00075 | 10 |
| Sn - D | mg/L | < 0.00001 | 0.00228 | 0.00067 | 0.0011 | 4 |
| Sr - T (Strontium) | mg/L | 0.0243 | 0.0339 | 0.0282 | 0.00377 | 10 |
| Sr - D | mg/L | 0.0232 | 0.0311 | 0.0278 | 0.00384 | 4 |
| Tl - T (Thallium) | mg/L | < 0.000002 | 0.000008 | 0.000003 | 0.000003 | 10 |
| Tl - D | mg/L | < 0.000002 | < 0.000002 | N/A | N/A | 4 |

| Parameter | Units | Minimum | Maximum | Average | Std Dev | Count |
|---|---|---|---|---|---|---|
| U - T (Uranium) | mg/L | 0.000004 | 0.000006 | 0.000005 | 0.000001 | 10 |
| U - D | mg/L | 0.000003 | 0.000004 | 0.000004 | 0.000001 | 4 |
| V - T (Vanadium) | mg/L | 0.00014 | 0.00031 | 0.00020 | 0.000045 | 10 |
| V - D | mg/L | < 0.0001 | 0.00022 | 0.00017 | 0.000055 | 4 |
| Zn - T (Zinc) | mg/L | 0.00095 | 0.0697 | 0.0092 | 0.021 | 10 |
| Zn - D | mg/L | 0.00041 | 0.00395 | 0.0017 | 0.0015 | 4 |

Table 25. Summary of 2006-2013 general chemistry water grab sample statistics taken at Shawnigan Lake North Beach site (1199904).

| Parameter | Units | Minimum | Maximum | Average | Std Dev | Count |
|---|---|---|---|---|---|---|
| **GENERAL** | | | | | | |
| Alkalinity Total 4.5 | mg/L | 12 | 21 | 15.2 | 2.6 | 15 |
| Ammonia (N) | mg/L | < 0.005 | 0.026 | 0.01 | 0.006 | 16 |
| Carbon, Inorganic - Total | mg/L | 2.4 | 5.7 | 4.0 | 0.9 | 15 |
| Carbon, Organic - Total | mg/L | 2.35 | 4.2 | 3.0 | 0.5 | 23 |
| Carbon, Organic - Dissolved | mg/L | 2.5 | 3.8 | 3.0 | 0.5 | 7 |
| Chlorophyll *a* | mg/L | 0.0007 | 0.0038 | 0.0019 | 0.0012 | 11 |
| Hardness - Dissolved | mg/L | 22.4 | 22.7 | 22.6 | 0.2 | 2 |
| Kjeldahl Nitrogen - Total | mg/L | 0.07 | 0.15 | 0.11 | 0.03 | 16 |
| Nitrate (N) - Dissolved | mg/L | < 0.002 | 0.112 | 0.052 | 0.046 | 12 |
| Nitrate + Nitrite | mg/L | 0.002 | 0.114 | 0.06 | 0.05 | 16 |
| Nitrogen - Nitrite, Dissolved | mg/L | < 0.002 | 0.002 | 0.002 | 0.0000 | 10 |
| Nitrogen (N) - Total | mg/L | 0.08 | 0.314 | 0.19 | 0.073 | 18 |
| Nitrogen, Organic - Total | mg/L | 0.04 | 0.14 | 0.10 | 0.03 | 14 |
| Ortho-Phosphate - Dissolved | mg/L | < 0.001 | 0.004 | 0.002 | 0.001 | 8 |
| pH | pH units | 7 | 7.66 | 7.4 | 0.2 | 23 |
| Phosphorus - Dissolved | mg/L | 0.003 | 0.007 | 0.004 | 0.001 | 8 |
| Phosphorus (P) - Total | mg/L | 0.002 | 0.0074 | 0.004 | 0.001 | 24 |
| Specific Conductivity | µS/cm | 54 | 64 | 57.9 | 2.8 | 15 |
| Sulphate (SO4) - Dissolved | mg/L | 2.4 | 3.7 | 2.8 | 0.42 | 8 |
| Total Dissolved Solids | mg/L | 28 | 60 | 47 | 11.1 | 8 |
| True Colour | Col. Unit | < 5 | 20 | 8.3 | 5.4 | 23 |
| Turbidity | NTU | 0.3 | 1.6 | 0.5 | 0.3 | 23 |
| **METALS/SEMI-METALS** | | | | | | |
| Ag - T (Silver) | mg/L | < 0.000005 | < 0.00002 | N/A | N/A | 10 |
| Ag - D | mg/L | < 0.000005 | < 0.00002 | N/A | N/A | 4 |
| Al - T (Aluminum) | mg/L | 0.0132 | 0.055 | 0.032 | 0.012 | 10 |
| Al - D | mg/L | 0.00617 | 0.028400 | 0.0168 | 0.0121 | 4 |
| As - T (Arsenic) | mg/L | < 0.0001 | 0.00015 | 0.00012 | 0.00002 | 10 |
| As - D | mg/L | < 0.0001 | 0.000151 | 0.00013 | 0.000029 | 4 |
| B - T (Boron) | mg/L | 0.009 | < 0.05 | 0.04 | 0.021 | 6 |
| B - D | mg/L | < 0.05 | < 0.05 | N/A | N/A | 2 |
| Ba - T (Barium) | mg/L | 0.0045 | 0.00544 | 0.005 | 0.00027 | 10 |
| Ba - D | mg/L | 0.00439 | 0.00464 | 0.00453 | 0.000109 | 4 |
| Be - T (Beryllium) | mg/L | < 0.00001 | < 0.00002 | N/A | N/A | 10 |

| Parameter | Units | Minimum | Maximum | Average | Std Dev | Count |
|---|---|---|---|---|---|---|
| Be - D | mg/L | < 0.00001 | < 0.00002 | N/A | N/A | 4 |
| Bi - T (Bismuth) | mg/L | < 0.000005 | < 0.00002 | N/A | N/A | 10 |
| Bi - D | mg/L | < 0.000005 | < 0.00002 | N/A | N/A | 4 |
| C - T (Carbon) | mg/L | 5.1 | 8.8 | 7.1 | 0.94 | 15 |
| Ca- D | mg/L | 6.78 | 6.89 | 6.84 | 0.078 | 2 |
| Cd - T (Cadmium) | mg/L | < 0.000005 | 0.00003 | 0.000009 | 0.000008 | 10 |
| Cd - D | mg/L | < 0.000005 | < 0.00001 | N/A | N/A | 4 |
| Cl - D (Chloride) | mg/L | 4.4 | 5.7 | 5.1 | 0.39 | 15 |
| Co - T (Cobalt) | mg/L | 0.000015 | 0.000036 | 0.000023 | 0.000007 | 10 |
| Co - D | mg/L | < 0.000005 | 0.00001 | 0.000007 | 0.000002 | 4 |
| Cr - T (Chromium) | mg/L | < 0.0001 | < 0.0002 | N/A | N/A | 10 |
| Cr - D | mg/L | < 0.0001 | < 0.0002 | N/A | N/A | 4 |
| Cu T (Copper) | mg/L | 0.00054 | 0.00142 | 0.00073 | 0.00029 | 10 |
| Cu - D | mg/L | 0.00044 | 0.00055 | 0.00050 | 0.000046 | 4 |
| Fe - T (Iron) | mg/L | 0.0882 | 0.0902 | 0.0892 | 0.00141 | 2 |
| Fe - D | mg/L | 0.0517 | 0.0526 | 0.0522 | 0.000636 | 2 |
| Li - T (Lithium) | mg/L | < 0.00005 | < 0.0005 | N/A | N/A | 10 |
| Li - D | mg/L | < 0.00005 | 0.0005 | 0.0003 | 0.0002 | 4 |
| Mg - T (Magnesium) | mg/L | 1.15 | 1.39 | 1.27 | 0.125 | 4 |
| Mg - D | mg/L | 1.09 | 1.33 | 1.21 | 0.133 | 4 |
| Mn - T (Manganese) | mg/L | 0.0025 | 0.0122 | 0.0078 | 0.0030 | 10 |
| Mn - D | mg/L | 0.000602 | 0.00238 | 0.00151 | 0.000887 | 4 |
| Mo - T (Molybdenum) | mg/L | < 0.00005 | 0.00006 | 0.00005 | 0.000003 | 10 |
| Mo - D | mg/L | 0.00005 | 0.000056 | 0.000052 | 0.000003 | 4 |
| Ni - T (Nickel) | mg/L | < 0.00005 | 0.00066 | 0.00016 | 0.00018 | 10 |
| Ni - D | mg/L | < 0.00005 | 0.000097 | 0.00007 | 0.000024 | 4 |
| Pb - T (Lead) | mg/L | 0.000026 | 0.000263 | 0.000088 | 0.000078 | 10 |
| Pb - D | mg/L | 0.000008 | 0.00001 | 0.00001 | 0.000001 | 4 |
| Sb - T (Antimony) | mg/L | 0.000018 | 0.000026 | 0.000022 | 0.000003 | 10 |
| Sb - D | mg/L | 0.00002 | 0.000026 | 0.000024 | 0.000003 | 4 |
| Se - T (Selenium) | mg/L | < 0.00004 | < 0.0002 | N/A | N/A | 10 |
| Se - D | mg/L | < 0.00004 | < 0.0002 | N/A | N/A | 4 |
| Si - D (Silica) | mg/L | 5.9 | 7 | 6.3 | 0.43 | 8 |
| Sn - T (Tin) | mg/L | < 0.00001 | 0.00031 | 0.0001 | 0.0001 | 10 |
| Sn - D | mg/L | < 0.00001 | 0.0002 | 0.0001 | 0.00011 | 4 |
| Sr - T (Strontium) | mg/L | 0.02 | 0.0283 | 0.024 | 0.0027 | 10 |
| Sr - D | mg/L | 0.0201 | 0.0297 | 0.0247 | 0.00467 | 4 |
| Tl - T (Thallium) | mg/L | < 0.000002 | 0.000008 | 0.000003 | 0.000003 | 10 |
| Tl - D | mg/L | < 0.000002 | < 0.000002 | N/A | N/A | 4 |

| Parameter | Units | Minimum | Maximum | Average | Std Dev | Count |
|---|---|---|---|---|---|---|
| U - T (Uranium) | mg/L | 0.000003 | 0.000005 | 0.000005 | 0.000001 | 10 |
| U - D | mg/L | 0.000003 | 0.000004 | 0.000004 | 0.000001 | 4 |
| V - T (Vanadium) | mg/L | 0.00008 | 0.00023 | 0.0002 | 0.00005 | 10 |
| V - D | mg/L | < 0.00006 | < 0.0002 | N/A | N/A | 4 |
| Zn - T (Zinc) | mg/L | 0.00071 | 0.0161 | 0.0035 | 0.0048 | 10 |
| Zn - D | mg/L | 0.00031 | 0.00499 | 0.0019 | 0.0021 | 4 |