WATER QUALITY OBJECTIVE SERIES

Water Quality Objectives for Shuswap Lake

Province of British Columbia and Pespesellkwe te Secwepemc

BRITISH COLUMBIA

WORKING TOGETHER TOWARD INDEPENDENCE

SKWLAX
LITTLE SHUSWAP LAKE BAND

No. WQO-06

The **Water Quality Objective Series** is a collection of British Columbia (B.C.) water quality objectives. Water quality objectives are developed for a specific body of water to promote the protection and stewardship of provincially significant waterbodies. Once approved, Water Quality Objectives constitute formal provincial policy and must be considered in any decision affecting water quality made within the Ministry of Environment and Climate Change Strategy. The policy may also be used by other agencies to inform resource management or land use decisions. For additional information visit: https://www2.gov.bc.ca/gov/content/environment/air-land-water/water/water-quality/water-quality-objectives.

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Cover Photo: Photo taken by Ministry of Environment and Climate Change Strategy on Shuswap Lake in summer 2020.

Acknowledgements

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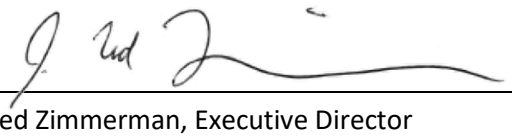
The Water Quality Objectives (WQO) for Shuswap Lake represent a collaborative effort of the Adams Lake Indian Band, Splatsin, Little Shuswap Lake Band with the Province of British Columbia (B.C.). The WQOs represent benchmarks to inform the management of water quality in Shuswap Lake and protect the water values for the benefit of all.

The Shuswap Lake WQO Policy Report may be updated as more information becomes available. Changes to this document will not be made without the approval of the Ministry of Land, Water and Resource Stewardship (LWRS), Adams Lake Indian Band, Splatsin and Little Shuswap Lake Band.

While efforts will be made to continue monitoring the water quality of Shuswap Lake, approval of the Shuswap Lake WQO does not imply any obligation to conduct monitoring by either B.C., Adams Lake Indian Band, Splatsin or the Little Shuswap Lake Band.

Once approved, the Shuswap Lake WQO constitute formal provincial policy and must be considered in any decision affecting water quality made within the Ministry of Environment and Climate Change Strategy. The policy may also be used by other agencies to inform resource management or land use decisions.

Signed on behalf of the Province of British Columbia:



Date: September 28, 2022

Ted Zimmerman, Executive Director
Water Protection and Sustainability Branch

EXECUTIVE SUMMARY

Section 5(e) of the *Environmental Management Act* (EMA) provides the Ministry of Environment and Climate Change Strategy (ENV) the authority to prepare and publish "policies, strategies, objectives, guidelines and standards for the protection and management of the environment". British Columbia's (B.C.) Water Quality Objectives (WQO) are provincial policy statements that apply to specific waterbodies and must be considered in relevant statutory decisions made within ENV (e.g., waste management permitting decisions under EMA); they can also be used to inform other processes, such as land use decisions, *Water Sustainability Act* objectives, and promote water sustainability and stewardship. Water Quality Objectives are derived to protect the most sensitive uses and values of the waterbody being examined. Attainment of WQO indicates water uses and values are at low risk of adverse effects with respect to a given parameter.

Shuswap Lake is in the traditional territory of the Pespesellkwe te Secwepemc and is an important waterbody in the Columbia Shuswap Region of B.C. Water quality objectives were developed for Shuswap Lake to promote the full protection and improvement of current water quality and the associated water uses and values. The water uses and values to be protected in Shuswap Lake include the cultural values of the Pespesellkwe te Secwepemc, drinking water, aquatic life, recreation and aesthetics, and wildlife. The Shuswap Lake WQO were developed in partnership with the Pespesellkwe te Secwepemc.

A water quality assessment was completed with data from four mid-lake sampling stations in the Salmon Arm and Main Arm of Shuswap Lake to inform the WQO. Phosphorus and nitrogen concentrations are the primary water quality concern, especially in Tappen Bay near the mouth of the Salmon River where extensive algal blooms have been occurring. Setting WQOs for nutrients and chlorophyll a to decrease the potential for algal blooms is a key aspect of this WQO policy. The WQO are summarized in the following table:

Water Quality Objectives for Shuswap Lake

Parameter	E208723 Armstrong Point	0500123 West of Sorrento	0500124 Marble Point	E206771 Sandy Point
Dissolved Oxygen[1] (mg/L)	≥ 5	≥ 5	≥ 5	≥ 5
Secchi Depth[2] (m)	≥ 6	≥ 6	≥ 6	≥ 6
Total Phosphorus[3] (µg/L)	10	10	10	15
Total Nitrogen[3] (µg/L)	300	300	300	300
Nitrogen:Phosphorus[4]	≥ 30:1	≥ 30:1	≥ 30:1	≥ 20:1
Chlorophyll *a*[5] (µg/L)	4	4	4	7
Total Organic Carbon[6] (mg/L)	4	4	4	4
E. coli (CFU/100 mL)	Primary contact recreation: ≤ 200 (geometric mean[7]) or ≤ 400 (single-sample maximum)			
	Drinking water source: ≤ 10 (90th percentile)			

[1] Instantaneous minimum at any depth.
[2] Annual mean from quarterly measurements.
[3] Average of 5 weekly samples collected in 30 days at 3 depths throughout the water column (surface, mid depth and 1 m above the bottom) during spring overturn.
[4] The N:P ratio is calculated using average total nitrogen and total phosphorus concentrations at spring overturn.
[5] Calculated from monthly surface water samples collected May to October.
[6] Maximum from samples collected in the vicinity of intakes with chlorinated drinking water treatment.
[7] Geometric means are calculated from at least 5 weekly samples collected in a 30-day period.

A water quality monitoring program is recommended to determine attainment of the WQO.

CONTENTS

FIGURES

TABLES

ACRONYMS

ALR	Agricultural Land Reserve
B.C.	British Columbia
CEQG	Canadian Environmental Quality Guideline(s)
CSRD	Columbia Shuswap Regional District
ENV	British Columbia Ministry of Environment and Climate Change Strategy
EMA	*Environmental Management Act*
EMS	Environmental Monitoring System database
WQG	Water quality guideline(s)
WQO	Water quality objective(s)
WSC	Water Survey of Canada

1. INTRODUCTION

Water Quality Objectives (WQO) are approved provincial policy statements that apply to specific waterbodies and must be considered in statutory decisions affecting water quality made within the Ministry of Environment and Climate Change Strategy (ENV) (e.g., decisions under the *Environmental Management Act*). Water Quality Objectives can also guide other processes, such as land use decisions and the establishment of water objectives under the *Water Sustainability Act*. Water Quality Objectives may include braiding together western science and Indigenous Knowledge to set benchmarks to inform environmental impact assessments, formalize water quality goals for the protection or enhancement of important waterbodies in British Columbia (B.C.), and promote water sustainability and stewardship.

Water quality objectives are derived from the best available information, sound scientific methods and processes, and current technical protocols that define safe levels of contaminants for a waterbody and represent low-risk conditions for designated water uses and values. Attainment of WQO indicate water uses and values are at low risk of adverse effects with respect to a given contaminant. Following *Guidance for the Derivation and Application of Water Quality Objectives in British Columbia* (ENV 2021a), WQOs are derived to protect the most sensitive uses or values of the waterbody being examined. WQOs consider the characteristics of the waterbody, including: the ambient water quality and its assimilative capacity; the aquatic life, wildlife, and related habitat; the hydrology; the sediments; the impacts to water quality from land use activities; and the social and cultural values associated with a waterbody, including those of Indigenous Nations and communities.

Located in the Southern Interior of British Columbia, Shuswap Lake is the centerpiece of the Columbia Shuswap Region. Shuswap Lake provides critical fish habitat supporting a diverse community of aquatic life with 18 species of native fish including the world-famous Adams River Sockeye salmon. Shuswap Lake is the drinking water source for a large part of the region, supporting local communities and hundreds of lakeshore residents. Recreation and tourism are essential to the region's economy and Shuswap Lake is a premier destination for houseboating, fishing, jet-skiing, paddling, and swimming. The Lake's extensive shoreline includes numerous beaches and parks that provide excellent hiking and camping opportunities.

Shuswap Lake is located on traditional Secwepemc territory and is represented by Pespesellkwe te Secwepemc, which is comprised of the Adams Lake Indian Band, Little Shuswap Lake Band, and Splatsin (collectively, the "Secwepemc Lakes Division" with the Shuswap Indian Band). The Secwepemc Lakes Division are Yucwmenlúcwu (caretakers of the land) who hold Aboriginal Title and Rights within the Shuswap watershed, including Shuswap Lake and all surrounding lands and waters. The Secwepemc Lakes Division continue to exercise these rights, in part, through the development of collaborative government-to-government initiatives to protect the land, water, sky and energy/fire worlds within the watershed. Secwepemc peoples are embedded in a relationship with water and the land which demands that water be understood as having rights and people having responsibilities for the care of the water.

Nutrients, such as phosphorus and nitrogen, are the primary water quality concern for Shuswap Lake. Previous studies have indicated that the main sources of phosphorus to Shuswap Lake come from anthropogenic activities in incremental flow sub-watersheds in the Shuswap and Salmon River watersheds. Incremental flow sub-watersheds include phosphorus inputs from seasonal streams, ditches, surface run-off and groundwater (Ludwig 2018). Other sources of nutrients include residential and commercial development and recreational activities. Concerns regarding nutrients intensified during recent algal bloom events, demonstrating excessive or potentially harmful algal growth can occur in this large, clear, oligotrophic lake.

Water quality objectives have also been developed for the Salmon River, a main tributary of Shuswap Lake. Attainment of the Salmon River WQOs helps to maintain the good water quality in Shuswap Lake and manage phosphorus levels and subsequent algal bloom issues in Tappen Bay.

Water quality objectives for Shuswap Lake were collaboratively developed by ENV and the Pespesellkwe te Secwepemc. Neskonlith Indian Band communicated the importance of this work to their community but were

unable to participate at the time of WQO development. The main goal of these WQOs is full protection and improvement of the current, generally healthy water quality to protect the identified water uses and values of this important interior B.C. lake, recognizing Pespesellkwe te Secwepemc and Neskonlith's shared caretakership and stewardship principles for Shuswap Lake. These WQOs highlight the Indigenous presence surrounding Shuswap Lake for at least the last 10, 000 years. It is of key importance to protect the water quality of Shuswap Lake now and for future generations.

2. PESPESELLKWE TE SECWEPEMC

The information contained in this report is a partial and limited depiction of the dynamic and living system of use and knowledge maintained by Pespesellkwe te Secwepemc governments, elders, and citizens. This information is provided for the purposes of developing WQOs for Shuswap Lake. It should not be relied upon to inform any other processes, assessments, or decisions except with written consent from authorized representatives for each of the participating communities. The information provided is summary in nature and does not exhaustively describe, depict, or in any way limit or alter the nature and extent of the Pespesellkwe te Secwepemc title, rights, interests, or concerns.

The Secwepemc Lakes Division have occupied the Shuswap Lake watershed and surrounding area for at least 10,000 years (Figure 1) relying heavily on healthy lands, waters, and resources to exercise Aboriginal Title and Rights in adherence with Secwepemc laws and customs. The Secwepemc peoples are embedded in a relationship with the water and land which demands the understanding that the water has rights and people have responsibilities to care for the water. Water is a humble spirit and sacred gift of life. It is essential to all living things. It is connected with ceremony and should be understood in its relationship with other living beings like plants, trees, and animals. The waterways and watersheds are a finite resource that must be managed with respect; what goes on upstream will affect what happens downstream. Water is central to land stewardship; honouring the Ancestor's teachings of caretakership ensures the security and well-being of future generations.

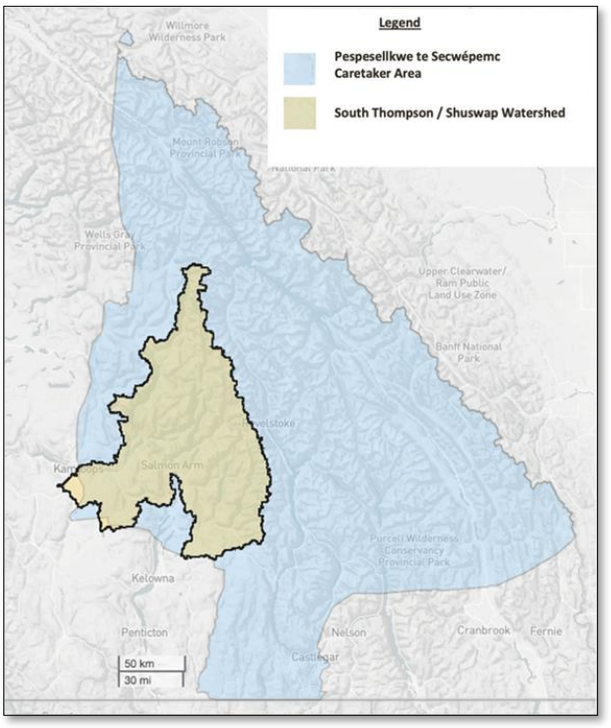


Figure 1. Pespesellkwe te Secwepemc traditional territory and the South Thompson / Shuswap Watershed.

2.1 Adams Lake Indian Band

The Adams Lake Indian Band has a sacred relationship with water, with a promise to care for the water on their sacred and traditional lands and territories. They recognize, honor, and respect water as sacred, sustaining all life and use traditional knowledge, laws, and ways of life to care for this sacred gift.

The relationship between the Adams Lake Indian Band and their lands, territories, and water is the fundamental physical, cultural, and spiritual basis of their existence. Their relationship to Mother Earth requires the conservation of freshwaters for the survival of present and future generations. The Adams Lake Indian Band assert their role as caretakers with rights and responsibilities to defend and ensure the protection, availability, and purity of water. They stand united to follow and implement the knowledge and traditional laws and exercise their right of self-determination to preserve water (Adams Lake Indian Band 2010).

2.2 Little Shuswap Lake Band

The Little Shuswap Lake People are known as the Skw'lax (Black Bear) People. The Skw'lax re Tmicw (land of the Skw'lax peoples), have always regarded séwllkwe (water) as most sacred to their people – it is the life-giving force for all living things. Little Shuswap has five separate "Indian Reserves" (IR) spread over the Interior Plateau of British Columbia. These are Quaaout ("Skwlax"), Chum Creek, Meadow Creek, Scotch Creek, and North Bay (Tappen) ("Silketkwa"). Séwllkwe is seen as good medicine for the people, plants, animals, and forests (Secwepemcúl'ecw). Skw'lax are all born from the séwllkwe in the mother's womb, from the sacred union of their mothers and fathers.

Séwllkwe is one of the five elements of the Skw'lax world (Séwllkwe, air, earth, fire, space) and its protection is critical to the health and balance of the ecosystems in which they live.

The Skw'lax People's health and wellbeing depends on the protection of séwllkwe while melding the past, present, and future connections to the land and resources.

The sacred medicine wheel has connections to séwllkwe: the four seasons, four races, four directions, and the mental-emotional-spiritual-physical realms of the Skw'lax Peoples existence. They depend on this sacred balance. The Skw'lax People respect the sacred ceremonies such as the sq̓ílye (sacred sweat lodge). The sq̓ílye helps to balance one's connection to the spirit world to the ancestors – while connecting their mental, emotional, and physical selves. Here, the elements of fire, earth, air, space, and Séwllkwe combine to help keep Skw'lax People balanced and healthy (Little Shuswap Lake Band 2020).

2.3 Splatsin

Splatsin is the most southern community of the Secwepemc Nation. The origin of their name comes from the late elder, Cindy Williams who explained that Splatsin, which is pronounced "splajeen", means riverbanks, which is where they lived and continue to occupy today along both the banks of the Eagle, Salmon and Shuswap Rivers.

Since time immemorial, the Splatsinac, have acted as *Yucwmenulúcw* (caretakers of the land). They managed the land through controlled burning, selective hunting and fishing, cyclical plant harvesting and pruning, and by ensuring that resources were not overused or wasted. Splatsin recognizes that the land, water and all living things are interconnected, and they uphold their responsibility to care for the environment and the biodiversity in their territory.

"Our ancestors appreciated the great value of the environment and through their teachings, we understand the importance of caring for the land, water and air. We consider ourselves to be stewards of this place and of the living organisms, plants, and animals within our territory. The land is not ours to keep, it is ours to use respectfully and wisely so it will remain healthy and rich for generations to come" (Splatsin 2013).

3. SITE AND WATERBODY DESCRIPTION

Shuswap Lake lies between Sicamous and Chase on the Trans Canada Highway within the South Thompson River drainage basin, and the larger Fraser River drainage basin. The city of Salmon Arm is the largest city surrounding the Lake with a population of about 17,000 residents. The Lake has an atypical "H" shape and is comprised of four long "arms" called Shuswap Lake (Main Arm), Salmon Arm, Anstey Arm, and Seymour Arm (Figure 2). The lake has a mean depth of 62 m, a maximum depth of 171 m, and a surface area of 310 km^2. Shuswap Lake is located at an elevation of approximately 350 m with watershed area of 17,478 km^2 spanning several biogeoclimatic zones.

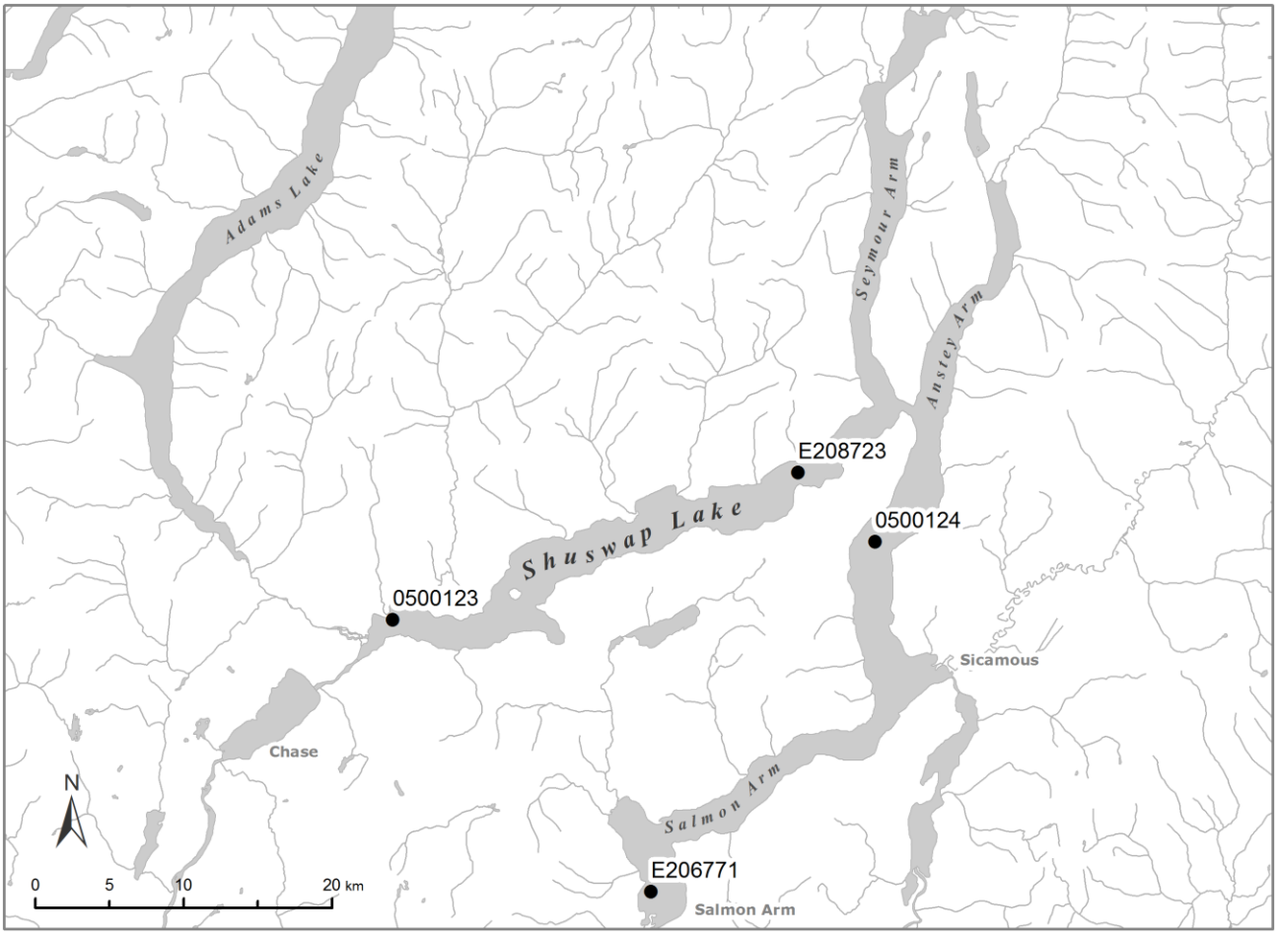


Figure 2. Shuswap Lake and monitoring site overview.

Shuswap Lake is influenced by several upstream sub-drainages (Figure 3). There are eight major tributaries and three relatively large lakes that flow into Shuswap Lake including the Shuswap River, Adams River, Salmon River, Eagle River, Seymour River, Scotch Creek, Anstey River, Celista Creek, Adams Lake, Mara Lake and Mabel Lake. The main outlet flows southwest through Little Shuswap Lake via Little River into the South Thompson River at Chase B.C. The total mean annual inflow to Shuswap Lake is 236 m^3/s and the mean annual outflow is 292 m^3/s, resulting in a relatively short hydraulic residence time of about two years. The major tributaries to the lake are further described in ENV (2022).

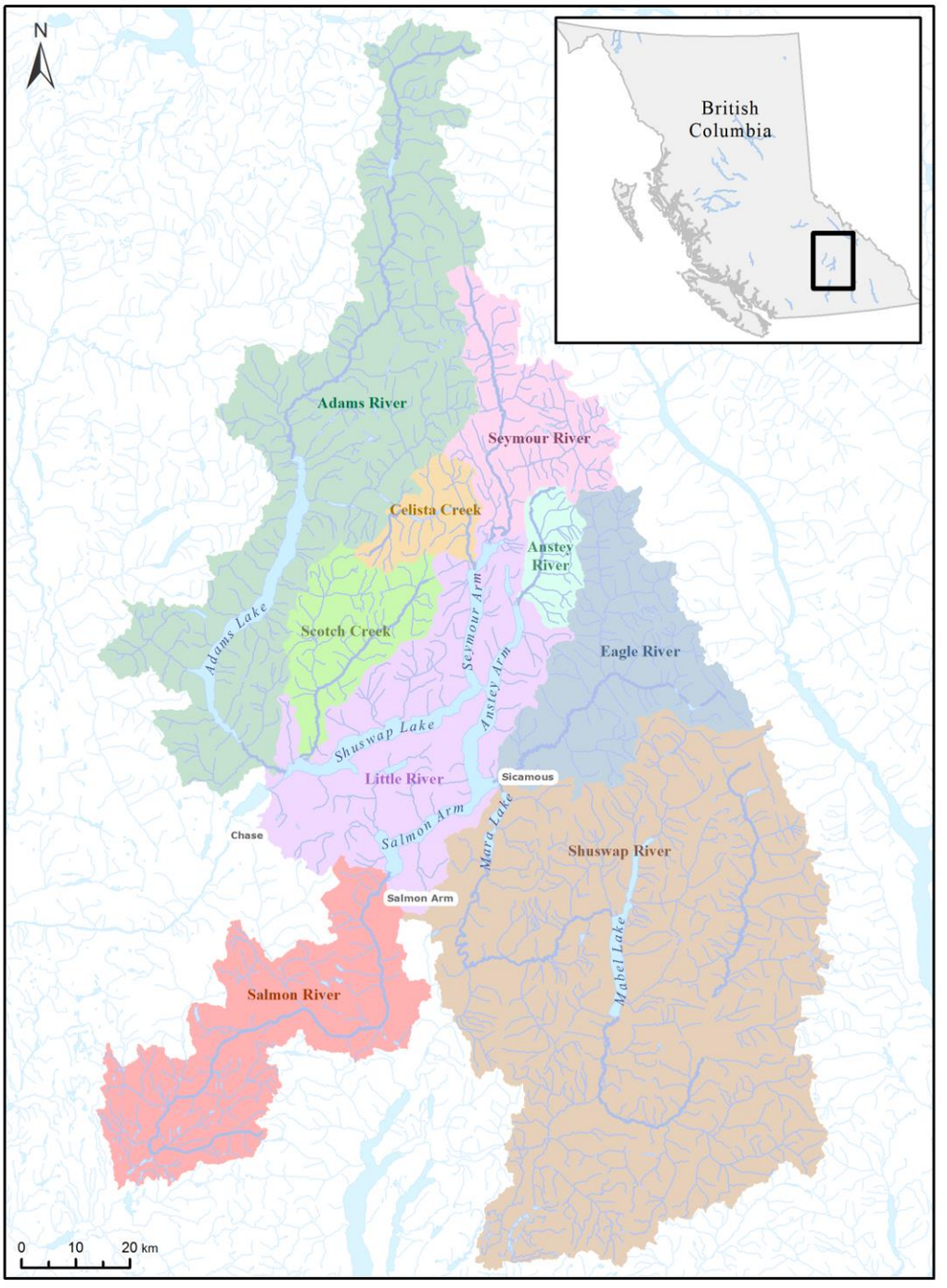


Figure 3. Shuswap Lake major tributary watersheds.

Shuswap Lake water levels are monitored by a Water Survey Canada (WSC) station at Salmon Arm (WSC Station 08LE070). The hydrology of the tributary rivers, and therefore Shuswap Lake, is driven by spring snowmelt. Lake water levels typically peak after spring freshet in June and July with the lowest levels observed in March and April. The most recent flood years were observed in 2012, 2017, and 2018. Flooding also occurred in 2020 but the data were not available at the time of this report.

There is some variation in weather between the four arms of the Lake, however, the general pattern is seasonally warm summer temperatures with cold winters. Like many large temperate lakes, it is thermally stratified during the summer and exhibits turnover in the spring and fall. Shuswap Lake does not usually freeze, therefore typically remains unstratified during the winter months.

Shuswap Lake is largely oligotrophic, characterized by low nutrient concentrations, relatively low biological productivity, and clear water. However, there is some localized variation in water chemistry, especially within the Tappen Bay area of Salmon Arm, where higher nutrient levels and primary productivity indicators suggest a mesotrophic status.

3.1 Influences on Water Quality

For a more detailed description of influences on water quality, see the Water Quality Assessment for Shuswap Lake (ENV 2022).

There are many activities which influence Shuswap Lake water quality, however elevated nutrient levels are the primary water quality concern in Shuswap Lake. The tributaries provide over 90% of the total phosphorus (TP) and total nitrogen (TN) to Shuswap Lake. The area between Mabel and Mara Lakes is the largest source of nutrients (TP and TN), with the Salmon and Eagle Rivers as the second and third largest contributors, respectively. A small percentage of nutrients come from point source discharges to surface water and groundwater (e.g., wastewater treatment plants). Private on-site wastewater (septic) systems discharging to ground do not require individual authorizations but are likely contributing nutrients to the lake in localized areas, especially around riparian habitat. Agriculture is the largest anthropogenic land use in the non-forested parts of the watershed with a large portion of the land within the B.C. Agricultural Land Reserve (ALR). Agricultural operations like dairy and poultry farms dominate the landscape along the Shuswap, Salmon, and Eagle Rivers. In the Shuswap and Salmon Rivers specifically, anthropogenic activities like urban runoff and agricultural activities account for about 90% of total phosphorus loading (Ludwig 2018).

There are other anthropogenic activities in and around Shuswap Lake which may influence water quality. The Lake provides significant recreational opportunities to the area; water quality could be impacted by activities around boat launches, docks, beaches, houseboats, and motorboats, as well as in parks and campgrounds. While the risk of impacts from recreation are likely highest during the summer months when most lake-based activities occur, the overall contribution to nutrient loading is considered low. There could however be increased bacteria counts from houseboat greywater when they are close to the shoreline.

Climate change and large landscape disturbances like fire are a rising concern and have the potential to alter the water balance of Shuswap Lake in the future. This could have long-term implications for water quality and the health of the Lake.

Several invasive aquatic species have been identified in the Shuswap Lake watershed. One of the primary concerns within the Shuswap Lake system is Eurasian water milfoil (*Myriophyllum spicatum*). Eurasian water milfoil has colonized large parts of Shuswap Lake, with Salmon Arm Bay the most affected area. Other invasive species of concern in Shuswap Lake include the Asian clam and zebra and quagga mussels, which have the potential to cause millions of dollars of damage to infrastructure and negatively impact ecosystems and recreational activities.

4. WATER VALUES

The goal of the Shuswap Lake WQOs is to protect the existing good quality water for future generations. The uses and values to be protected for Shuswap Lake include Pespesellkwe te Secwepemc cultural values, drinking water, aquatic life, recreation and aesthetics, and wildlife as described in the following sections. By protecting the most sensitive values of drinking water and aquatic life, the other values are also protected.

4.1 Pespesellkwe te Secwepemc Cultural Values

To the Pespesellkwe te Secwepemc, the water in Shuswap Lake is the life-giving force. Water sustains all life forms, from microorganisms to larger plants, salmon and other aquatic species, and wildlife which rely on the water in its various forms that interact within the Lake. Riparian and littoral zones are other important and sensitive areas that need protection; they are key to clean water. Important plants in these essential areas include cattails, rushes, and sedges. Areas of fish spawning are also a key value for protection as are all areas that provide an inflow of fresh water to Shuswap Lake. Protecting and, where necessary, improving water quality and quantity is imperative. Culturally, there are numerous ceremonies and practices relevant to water. Shuswap Lake is a sensitive area and requires protection as it is connected to physical, mental, emotional, and especially spiritual realms of Pespesellkwe te Secwepemc peoples. These values are important to ensure Indigenous ceremonies and enjoyment can perpetuate into the future.

4.1.1 Adams Lake Indian Band

The Adams Lake Indian Band is concerned about the condition of their waters given the water pollution issues from chemicals, waste, sewage, and the damage to the water from diversion, damming, mining, and unsustainable industrial and recreational development. When water is disrespected, misused, and poorly managed, the life-threatening impacts on all of creation are seen.

The Adams Lake Indian Band's Water Declaration states their right to water and self determination. This includes the practice of cultural and spiritual relationships with water, and the exercise of authority to govern, use, manage, regulate, recover, conserve, enhance and renew their water sources without interference. They highlight the importance of traditional practices which are dynamically regulated systems based on natural and spiritual laws, ensuring sustainable use through traditional resource conservation. The Adams Lake Indian Band supports the implementation of strong measures to allow the full and equal participation of Indigenous Peoples to share experience, knowledge, and concerns in water management given the narrow application of modern scientific tools has contributed to the degradation of water. The Adams Lake Indian Band reserves the right to make decisions about waters at all levels; they are not opposed to development on Adams Lake Indian Band territory, if it is sustainable. The Adams Lake Indian Band has a detailed plan of action to protect water and sustain their ancestral and historical relationships with water and assert their inherent and inalienable rights to their water (Adams Lake Indian Band 2010).

4.1.2 Little Shuswap Lake Band

Séwllkwe is the miraculous connection between Father Sky and Mother Earth. Shuswap Lake and its lands (Secwepemcúl'ecw) have been revered as the center of life connections for the Skw'lax People. The Little Shuswap Lake Band recognized how important good clean séwllkwe is for their health and wellbeing long before there were homes with running séwllkwe. The Skw'lax people packed séwllkwe from the streams. Séwllkwe has been respected for drinking, bathing, cleansing, transportation, and giving birth. Good healthy séwllkwe systems will provide a bounty of resources for all peoples to live harmoniously with the fish, plants, and animals alike. Life itself was sustained from the plants and animals that flourished in and around beautiful séwllkwe whether they be streams, springs, or lakes. From time immemorial, Skw'lax People have used séwllkwe to cleanse their bodies in the sq̓ílye. Séwllkwe helped mother earth grow the willow trees and animals whose hides cover the sweat lodge, tea made from various sacred plants and the heat from the red-hot grandfather rocks – sacred fire. Steam from the tea poured onto the grandfather rocks cleansed the sweating bodies within the lodge and is again recycled into the air – this cycle continues.

4.1.3 Splatsin

Water in all its forms is considered a central component of Secwépemc spirituality and worldview. The Shuswap Lake watershed supports a vast array of fish and wildlife species, including many protected species, a range of critical habitats and is a source of drinking water for Secwépemc people. Lakes and streams within this watershed are central to Secwépemc cultural practices and use and have served as a transportation artery connecting communities for thousands of years. Salmon and other fish species have important cultural, socioeconomic, and

ecosystem values and have historically been the cornerstone of Secwépemc food, social, and ceremonial practices. More recently, the considerably lower returns of migrating salmon populations mean that there are far less marine-derived nutrients being distributed throughout the watershed.

Splatsin knowledge keepers are concerned about the health of the water and the health of the people, animals, fish, and plants who rely on the water. Impacts of climate events such as drought, floods, extreme temperatures, wildfires and changing precipitation patterns on the water quality and the interacting lifeforms that rely on this water are also of great importance to the Splatsin people.

4.2 Drinking Water

Shuswap Lake is a major source of drinking water in the region and accounts for the largest volume of water withdrawn from Shuswap Lake. There are eight major water distribution systems and 589 domestic water licences withdrawing from the Lake (ENV 2022).

4.3 Aquatic Life

Salmon are the "keystone species" in the Shuswap watershed, with the Shuswap Lake system among the most important salmonid producing lake systems in B.C. and home to important juvenile fresh water rearing habitat. In particular, the Adams River is one of the most important sockeye salmon breeding areas in North America. Anadromous species supported by Shuswap Lake and its tributaries include Sockeye, Chinook, Coho, and Pink Salmon and Steelhead Trout. Other salmonids include Lake Trout and Rainbow Trout, both of which are extensively targeted for recreational fishing. Foreshore areas around Shuswap Lake provide critical habitat for spawning of both anadromous and non-anadromous salmonids. See ENV (2022) for further discussion on aquatic life and their habitat in Shuswap Lake.

4.4 Recreation and Aesthetics

The Shuswap Lake watershed has been identified as an important tourist destination in the B.C. Interior and provides year-round recreational activities for residents and visitors. Key lake-based recreation activities include fishing, houseboating, swimming and pleasure boating (ENV 2022).

4.5 Wildlife

The Shuswap Lake watershed supports a wide range of wildlife species such as deer, elk, moose, mountain goats, bears, wolves, cougars, beavers, otters, bats, small mammals, amphibians, and reptiles. The shoreline provides habitat for numerous birds including western grebe and osprey. There are also several red- and blue-listed species within the Shuswap Lake watershed (ENV 2022).

5. WATER QUALITY IN SHUSWAP LAKE

The water quality of Shuswap Lake was assessed based on data collected in the last twenty years (2000 – 2020) from four key sampling stations located at or near the deepest points of the lake, except for E206771 in Tappen Bay which is shallow (Figure 2) (ENV 2022). The less impacted areas of Shuswap Lake, Seymour Arm and Anstey Arm, were not included in the assessment. The monitoring sites chosen focus on the areas of interest representing potential impacts to water quality:

- E206771 – southwest end of Tappen Bay, opposite Sandy Point in Salmon Arm;
- 0500124 – opposite Marble Point, mid-way between Sicamous and Cinnemousun Narrows in Salmon Arm;
- E208723 – off Armstrong Point in the Main Arm; and
- 0500123 - west of Sorrento located near the Shuswap Lake outflow, at the west end of the Main Arm.

5.1 General Characteristics

5.1.1 Temperature and Dissolved Oxygen

Temperature is a key influencing factor on water density, and the thermal stratification patterns and dissolved oxygen (DO) concentrations in a lake. Surface water temperatures in Shuswap Lake follow the typical seasonal pattern of northern temperate lakes. The lake thermally stratifies during the growing season from May through October with the thermocline formed between 10 – 16 m (ENV 2022). Surface water temperatures ranged from 10 – 25 ˚C with the cool deep waters of the hypolimnion constant at 4 ˚C. The temperature profiles for Shuswap Lake are representative of natural conditions with the cooler, well oxygenated water below 10 m providing refugia for fish to avoid heat stress. Water temperature is not a concern in Shuswap Lake, therefore no WQO is proposed for temperature.

Dissolved oxygen is an important characteristic of aquatic habitats and crucial to the survival of aquatic life. With the occasional exception of E206771, there is no evidence of hypolimnetic oxygen depletion or anoxic conditions at any time in Shuswap Lake. Surface water DO concentrations ranged from 8 – 12 mg/L. Since the lake does not completely freeze over in winter, the atmospheric transfer of oxygen to surface waters occurs all year long and mixing of the water column occurs during winter months (ENV 2022).

In general, DO concentrations remained at levels > 8 mg/L throughout the year (ENV 2022). **The WQO for dissolved oxygen is an instantaneous minimum of ≥ 5 mg/L at any depth**. This WQO is based on the B.C. aquatic life water quality guideline (WQG) and represents the minimum concentration at any time to minimize stress in salmonids and to protect shore-spawning Sockeye.

5.1.2 Water Clarity (Secchi Depth)

Secchi depth is a standard, yet simple, measure of water clarity used to indicate water quality changes in colour, suspended sediments, and algal abundance. Water clarity is the distance that light can penetrate a body of water. The greater the Secchi depth measurement, the better the water clarity.

In general, water clarity was lowest during the spring months when freshet introduces silts and particulate matter to the lake and lake temperatures grow warmer increasing primary productivity. Water clarity is slightly higher during mid-summer, with the greatest clarity occurring during the winter months (Figure 4). Secchi depths at E206771 ranged from 3 – 8 m in Salmon Arm, and were consistently less than the other stations throughout the year which ranged from 5 – 13 m. The reduction in water clarity at E206771 throughout the spring and summer months reflects the mesotrophic to meso-eutrophic conditions at this station as opposed to the oligotrophic conditions observed at the other three stations. The Canadian recreational water quality guideline for water clarity of 1.2 m (Health Canada 2012) was consistently attained at all stations in Shuswap Lake.

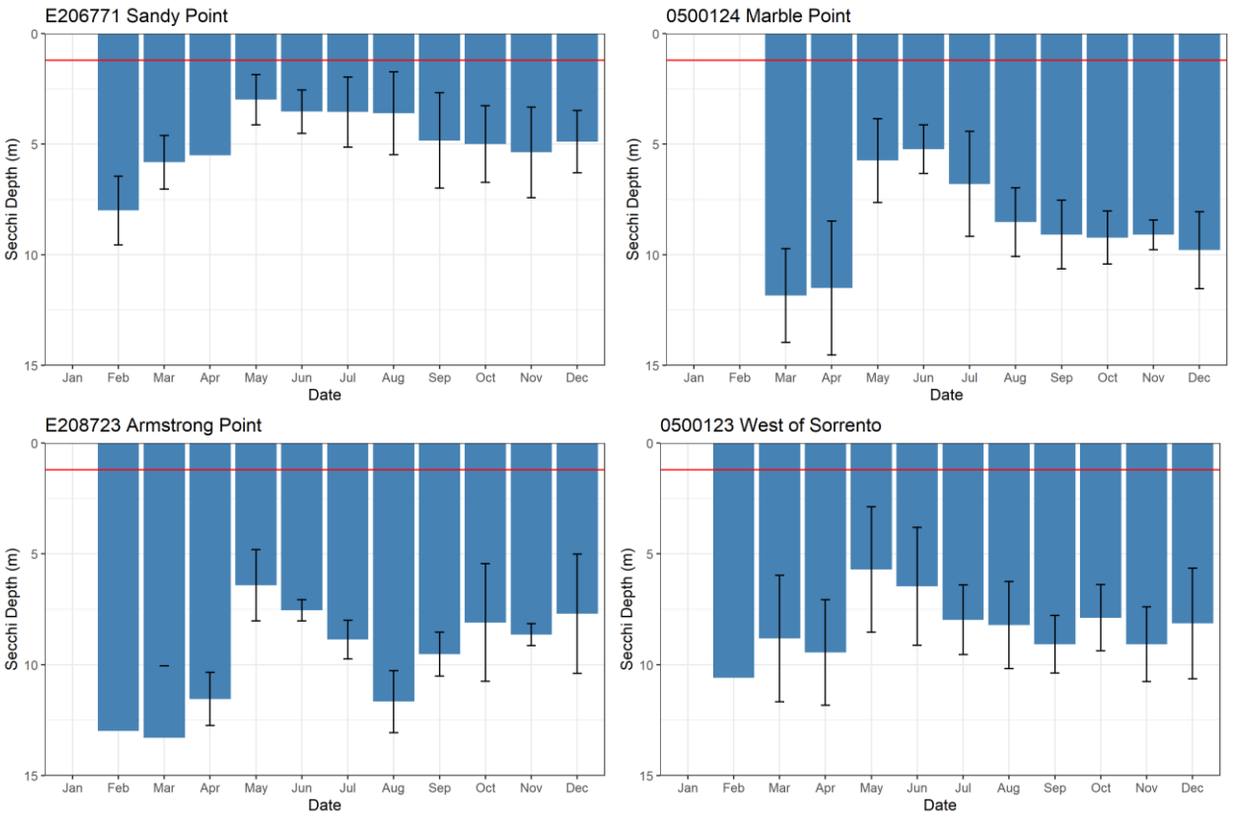


Figure 4. Monthly variation in Secchi depth between 2000 – 2020. The red line is the Canadian recreational aesthetic water clarity guideline of 1.2 m. Sites are presented in order from upstream in Salmon Arm to downstream near the outlet.

Based on the current water quality, **the WQO for Secchi depth is an annual mean of ≥ 6 m to protect the exceptional aesthetic and recreational value of Shuswap Lake**. The calculation of the annual mean Secchi depth is based on a minimum of four quarterly measurements.

5.2 Nutrients

Nutrients are defined as any material assimilated by organisms for growth and maintenance. In freshwater ecosystems, the primary nutrients for algal growth are phosphorus (P) and nitrogen (N). Cultural eutrophication, the process where a waterbody becomes more biologically productive due to an increase in the anthropogenic loading of nutrients, is the primary water quality concern in Shuswap Lake. Increased nutrients can lead to excessive algal growth, reduced water clarity, odour problems, aquatic life stressors, and reduced drinking water quality. For Shuswap Lake, excellent water quality is essential to the cultural, aquatic, drinking and recreational values of the lake. Water quality is generally good in this large oligotrophic lake, but elevated nutrient levels have been observed in some areas during the warmer growing season, especially during flood years.

Although the various forms of N and P in the aquatic environment can be measured, total P and total N are the most widely used variables for predicting eutrophication responses. They tend to overestimate the actual amount of bioavailable N and P but are considered the most reliable indicators because of the dynamic nature of nutrient forms in aquatic environments.

5.2.1 Phosphorus

Historical Phosphorus Levels

Deep lake sediments are the natural archives of lakes and can be used to estimate and assess nutrient loadings on lake ecosystems over time. Sediment cores were collected from Shuswap Lake in 2007 from three locations:

West of Sorrento (near the lake outflow between Scotch and Lee Creeks), Fraser's Beach (near Sunnybrae), and Marble Point (near Tillis Landing). The diatom assemblages within the cores were used to infer historical total P concentrations by comparing them to a P model developed from 268 freshwater lakes in British Columbia (Cummings *et al.* 2007).

Sediment core analyses estimated total P concentrations in mid-summer to range from 5 µg/L to 21 µg/L. Fraser's Beach, the shallowest location, had the highest total P estimates, approximately 14 µg/L to 21 µg/L, throughout the core indicating that conditions at that location have been consistently mesotrophic. Marble Point and West of Sorrento were classified as oligotrophic to mesotrophic with estimated total P concentrations ranging from 8 µg/L and 10 µg/L and 5 µg/L and 9 µg/L, respectively. Compositional changes in diatom species in the three sediment cores analyzed indicated slightly increasing P levels in Shuswap Lake beginning around 1970.

Current Phosphorus Conditions

Average total P concentrations in the epilimnion were examined by month for data collected between 2000-2020 (Figure 5). In Salmon Arm, average total P concentrations were highest at 10 µg/L for station E206771 and slightly lower at 5 µg/L for station 0500124. The maximum concentrations were 40 µg/L (95th percentiles at 25 µg/L) and 19 µg/L (95th percentiles of 9 µg/L) for stations E206771 and 0500124, respectively. At both Main Arm locations, stations E208723 and 0500123, average P concentrations over 20 years were 3 µg/L and 4 µg/L, respectively. The highest concentration measured at E208273 was 7 µg/L with a 95th percentile of 6 µg/L, whereas the highest P concentration was observed at station 0500123 at 35 µg/L with a 95th percentile of 7 µg/L. With a few exceptions, total P concentrations were below 5 µg/L in the Main Arm and at the lower end of the range for the aquatic life WQG (ENV 2021b), and generally represents oligotrophic conditions.

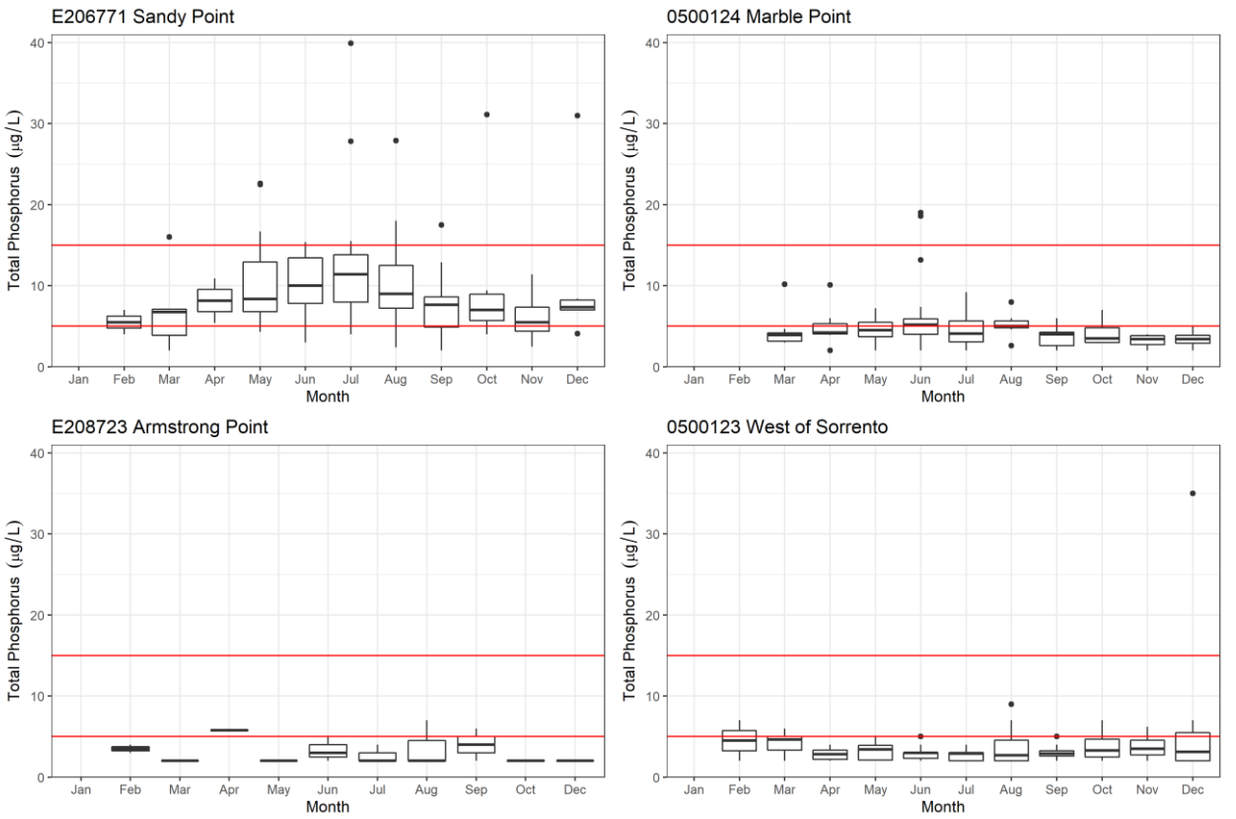


Figure 5. Monthly variation in epilimnetic total phosphorus concentrations for data collected between 2000-2020. The red lines represent the range of 5 to 15 µg/L for the B.C. water quality guideline for aquatic life. Sites are presented in order from upstream in Salmon Arm to downstream near the outlet.

As shown in Figure 5, Salmon Arm showed an opposite pattern from the Main Arm as total P concentrations were higher during the warmer May to October growing season. This pattern was more pronounced at station E206771 and exceedances of the aquatic life WQG upper range of 15 µg/L occurred in 14% of the samples collected where P levels approached mesotrophic conditions. Many of these exceedances were observed during flood years when high water levels were extended into the growing season.

The higher concentrations of total P in Salmon Arm reflected contributions from the Salmon River. Both the Salmon River and Shuswap River are a main source of P to Shuswap Lake. Most of the P comes from anthropogenic activities like agriculture and urban runoff in incremental flow sub-watersheds in the Shuswap and Salmon River watersheds. As the upper reaches of these watersheds naturally have very low nutrient levels, the Shuswap River, Salmon River, and downstream Mara and Shuswap Lakes are very sensitive to additional P inputs. This means increases in P loading along these rivers can cause large proportional changes downstream in Shuswap Lake (Ludwig 2018). Overall, P concentration in Shuswap Lake did not show any increasing trends and it was generally within the historical levels estimated from the sediment core analyses.

Existing development and recreational activities, coupled with the potential for algal blooms on Shuswap Lake, support the establishment of a WQO for total P to ensure current conditions are protected. Based on the B.C. aquatic life WQG, and to consider some productivity necessary for fish populations, the **WQO for total P in Shuswap Lake is 15 µg/L for station E206771 and 10 µg/L for the other stations**. This objective applies to the average of 5 weekly samples collected in 30 days consisting of at least three samples taken throughout the water column (surface, mid depth, and 1 m above the bottom) at the stations during spring overturn. The difference in the objectives reflects the mesotrophic to meso-eutrophic conditions at E206771 as opposed to oligotrophic conditions observed at the other three stations.

5.2.2 Nitrogen

Total N concentrations were examined by monthly average with data from the last 20 years. Average total N concentrations were low at all stations ranging from 120 µg/L to 197 µg/L (Figure 6). There is no B.C. WQG for total N and the concentrations for key N forms which have guidelines (NO_2, NO_3, NH_3) were generally below laboratory method detection limits (ENV 2022). Like total P, total N concentrations were slightly lower in the Main Arm compared to Salmon Arm with the highest concentrations measured at E206771. The primary difference observed between total P and total N was that total N concentrations were highest during the cooler season (winter/spring) instead of the warmer growing season (summer/fall). The lower concentrations of total N in the summer were likely due to the denitrification process where fixed N (primarily as N_2) is lost to the atmosphere and not found as readily in the water.

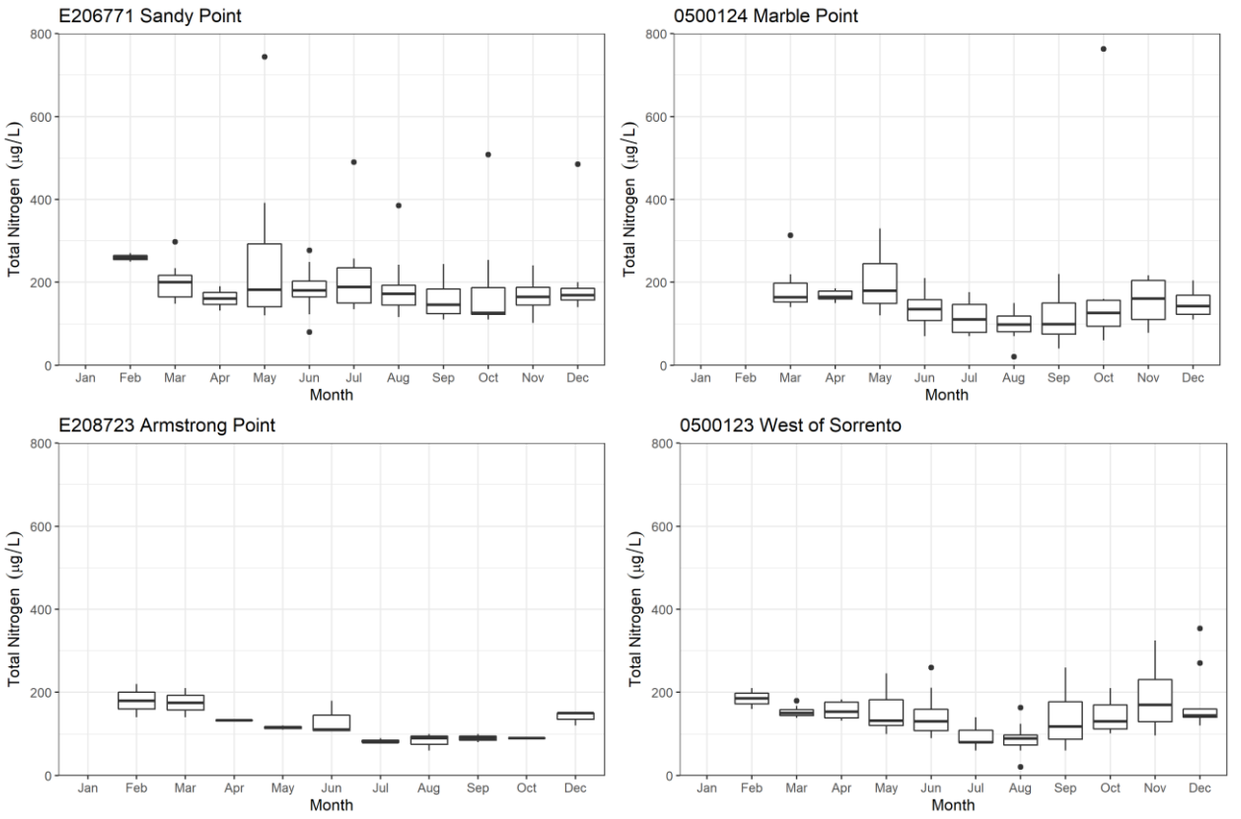


Figure 6. Monthly variation in epilimnetic total nitrogen concentrations for data collected between 2000-2020. Sites are presented in order from upstream in Salmon Arm to downstream near the outlet.

Based on current water quality and to maintain the low total N concentrations in Shuswap Lake, **the WQO is 300 µg/L at all four sites**. This objective applies to the average of 5 weekly samples collected in 30 days and composed of at least three samples taken throughout the water column (surface, mid depth, and 1 m above the bottom) during spring overturn.

5.2.3 Nitrogen:Phosphorus Ratio

The nitrogen:phosphorus (N:P) ratio is a useful indicator of lake trophic status and whether primary production is limited by P or N concentrations (ENV 2001). Shuswap Lake is P-limited and N:P ratios tend to decrease with increasing eutrophication, either natural or anthropogenically mediated (Table 1). Therefore, decreasing N:P ratios would indicate deteriorating water quality.

N:P ratios were calculated by dividing the average spring overturn total N concentration by the average spring overturn total P concentration in 2014, 2015 and 2019Table 1. Nitrogen:phosphorus (N:P) ratios in Shuswap Lake.. Based on the TN:TP ratios, E206771 is weakly P-limited and is mesotrophic, where as 0500124, E208723, and 0500123 would be considered strongly P-limited and oligotrophic. The N:P ratios could be altered by changes in hydrology with higher ratios expected during low runoff years and lower ratios expected during high runoff and flood years (ENV 2005).

Table 1. Nitrogen:phosphorus (N:P) ratios in Shuswap Lake.

Station	2014	2015	2019
E206771 Salmon Arm Reach	18:1	23:1	23:1
0500124 Sicamous Reach	28:1	21:1	37:1
E208723 Main Arm Reach	29:1	46:1	35:1
0500123 Sorrento Reach	29:1	53:1	39:1

To protect the good current water quality, **the WQO for N:P ratios in Shuswap Lake are ≥ 20:1 at E206771 and ≥ 30:1 at the other sites.** The calculation of N:P ratios is based on the average total N and total P concentrations measured at spring overturn.

5.3 Biological Parameters

5.3.1 Phytoplankton

Phytoplankton populations in Shuswap Lake are sparse, although recent algal blooms have demonstrated that excessive growth or potentially harmful algal blooms can happen in this large, clear, oligotrophic lake. A widespread noxious algal bloom occurred in June 2008 when spring conditions were ideal for excessive golden-brown algae growth (SLIPP 2014). In the summer of 2020, an algal bloom dominated by green algae covered the majority of the Salmon Arm (Interior Health Authority 2020). The bloom persisted much longer than what is typical for Shuswap Lake and, while visually unappealing, did not pose any health risks. Continued monitoring for phytoplankton community composition is recommended as a measure of aquatic ecosystem health and primary productivity. No WQO is proposed at this time.

5.3.2 Zooplankton

Changes to zooplankton species composition and abundance can indicate environmental disturbance in the aquatic ecosystem. Zooplankton are an intermediary species in the food web transferring energy from primary producers such as phytoplankton to the higher trophic levels such as larger invertebrate predators and fish. The results of monthly sampling conducted between 2011 to 2013 during the open water growing season show that abundance was relatively low, but species diversity was high. This result is consistent with the oligotrophic status of Shuswap Lake. Continued monitoring for zooplankton community composition is recommended as a measure of aquatic ecosystem health and food availability. No WQO is proposed at this time.

5.3.3 Chlorophyll a

Chlorophyll *a* is a measure of phytoplankton biomass and indicates the productivity of a waterbody. Values below 3 µg/L are considered an indication of low productivity and values above 15 µg/L generally indicate high productivity.

Chlorophyll *a* concentrations in surface water samples were relatively low during the May to October growing season in Shuswap Lake (Figure 7). Like nutrients, chlorophyll *a* concentrations were highest at station E206771 in Tappen Bay and ranged between 2 µg/L to 6 µg/L. Two exceptions were observed in 2018 and 2020 when chlorophyll *a* concentrations were exceptionally high at 20 and 26 µg/L, respectively. These elevated concentrations were associated with flood years which could have resulted in an increase of nutrients in the lake coming from upland sources. However, more data should be collected if flooding continues. At Station 0500124, chlorophyll *a* concentrations were lower with the highest concentration at 4 µg/L corresponding to the 2010 algal bloom. The growing season mean chlorophyll *a* concentration in the Main Arm was less than 2.0 µg/L except for station 0500123 in 2014 which had a concentration of 2.46 µg/L.

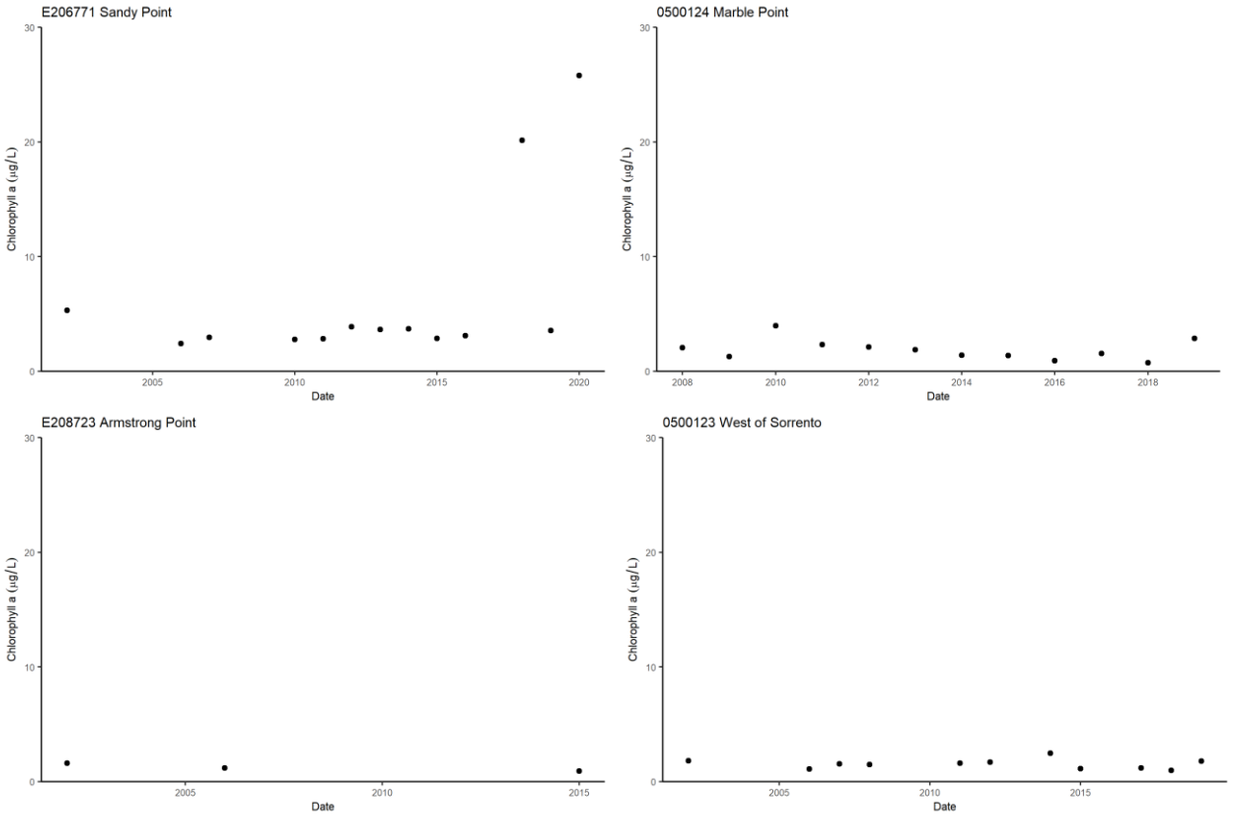


Figure 7. Epilimnetic growing season means (May-October) for chlorophyll a concentrations between 2000-2020. Sites are presented in order from upstream in Salmon Arm to downstream near the outlet.

Based on current water quality, to protect the existing conditions of the lake and to decrease potential for algal blooms, **the WQO for chlorophyll *a* in Shuswap Lake is a maximum growing season mean concentration of 7 µg/L at station E206771 and 4 µg/L at the other stations**. The growing season mean is calculated using epilimnetic chlorophyll *a* concentrations from May to October.

5.4 Total Organic Carbon

Organic carbon is an important water quality parameter to consider with respect to drinking water sources. The primary concern is the production of carcinogenic disinfection by-products (e.g., trihalomethanes) during chlorination of raw drinking water that are high in carbon.

The B.C. source drinking water quality guideline (SDWQG) for total organic carbon (TOC) is 4 mg/L and was used to assess the data (ENV 2020b). In Shuswap Lake, TOC ranged from 1.2 mg/L to 8.7 mg/L, with higher concentrations more frequently observed at station E206771 in Salmon Arm (Figure 8). At monitoring location 0500124 in Salmon Arm there were periodic concentrations above the guideline prior to 2015, but in the last six years TOC has remained below the B.C. TOC guideline for drinking water sources. There were only two TOC measurements taken for station E208723, both in 2015, where TOC concentrations were approximately 2 mg/L. Other than one measurement taken in 2014, TOC concentrations at site 0500123 were below the TOC SDWQG.

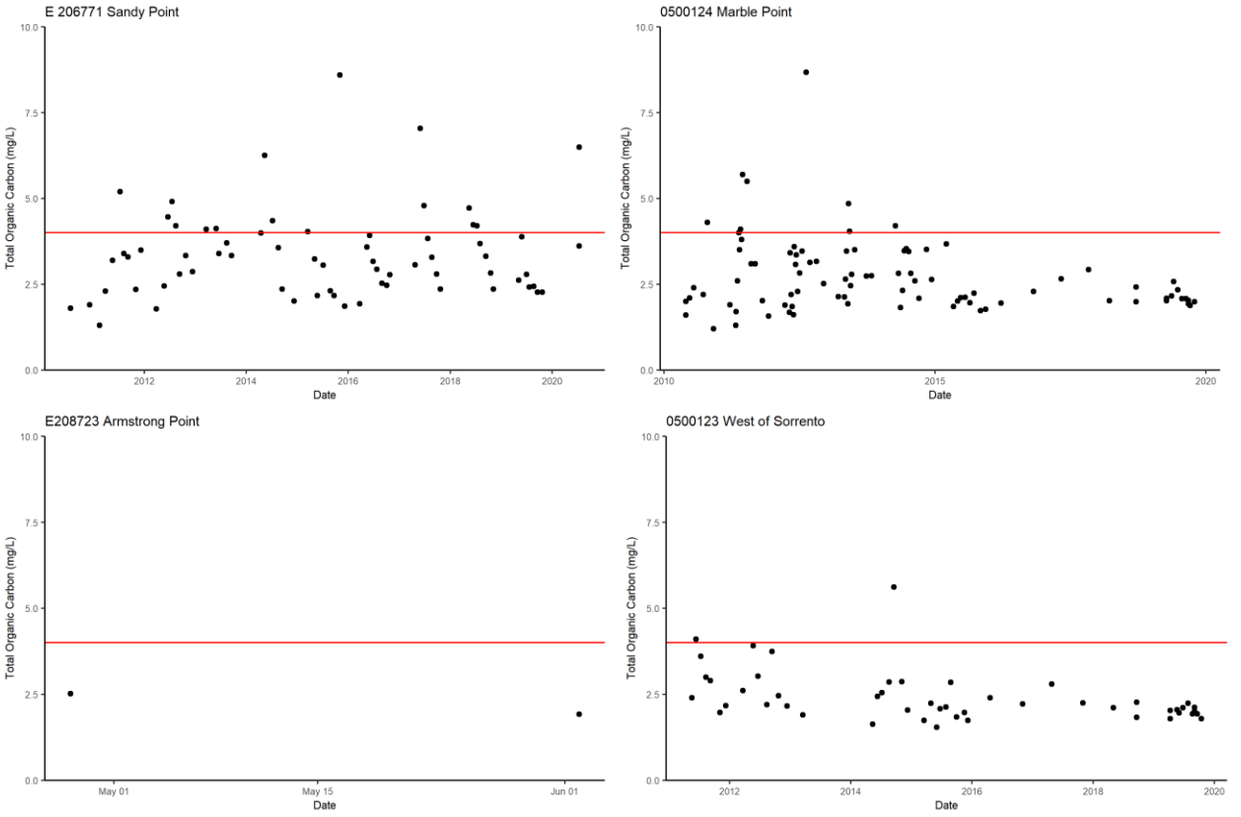


Figure 8. Epilimnion total organic carbon concentrations for data collected between 2000-2020. Sites are presented in order from upstream in Salmon Arm to downstream near the outlet.

Shuswap Lake is the City of Salmon Arm's primary drinking water source and provides drinking water to other communities in the region. The City of Salmon Arm has a sophisticated treatment system to ensure drinking water standards are met. Site E206771 is a shallow site and close to the water intake for the City of Salmon Arm, so attainment of the WQO at this site is of importance. The **WQO for TOC is a maximum of 4 mg/L at all times** to protect human health. Sampling should be conducted near drinking water intakes that use chlorination as treatment to adequately assess attainment of this WQO.

5.5 Microbiological Indicators

Fecal contamination in Shuswap Lake is a concern because it is an important recreational destination and drinking water source. The Interior Health Authority monitors several popular beaches on the lake and is responsible for advisories and warnings associated with coliform bacteria.

The B.C. SDWQG of ≤ 10 colony forming units (CFU) *E. coli*/100 mL (90th percentile) was used to assess Shuswap Lake water quality for risk to drinking water (ENV 2020b). There were 85 results for *E. coli* at E206771, near the City of Salmon Arm, and had six detectable concentrations ranging from 2 CFU/100 mL to 5 CFU/100 mL. The measured *E. coli* concentrations at E206771 were very low (< 5 CFU/100 mL), however this one monitoring station does not adequately represent the potential risk to this drinking water source.

The Drinking Water Protection Regulation under the *Drinking Water Protection Act* requires zero presence of *E. coli* and other microbiological indicators in finished potable water. Although raw drinking water must be treated to ensure compliance with the Drinking Water Protection Regulation, a WQO is provided, to protect the existing quality of drinking water sources and to prevent its deterioration over time. Based on the B.C. SDWQG, the **WQO for *E. coli* is a 90th percentile of ≤ 10/100 mL (most probable number (MPN) or CFU)**, based on a minimum of 5 weekly samples collected within a 30-day period.

An additional WQO is provided to protect the recreational and cultural uses of Shuswap Lake. Based on the B.C. Recreational Water Quality Guideline (ENV 2019), the **WQO for *E. coli* is a geomean of ≤ 200 (MPN or CFU)/100 mL or single sample maximum value of ≤ 400 (MPN or CFU)/100 mL** based on a minimum of 5 weekly samples collected within a 30-day period. Units will depend on the analytical method used, multiple tube fermentation (results expressed as MPN) or membrane filtration (results expressed as CFU), either of which is acceptable.

6. WATER QUALITY OBJECTIVES FOR SHUSWAP LAKE

Water quality objectives are established to protect the most sensitive uses and values of Shuswap Lake and are summarized in Table 2. To maintain the current water quality of Shuswap Lake, WQOs are set for dissolved oxygen, water clarity, and nutrients (phosphorus, nitrogen, chlorophyll *a*) for the protection of aquatic life. Total organic carbon and microbiological objectives have also been established for the protection of drinking water and microbiological objectives for recreational uses. These objectives aim to protect the Secwepemc cultural values (as they relate to biological, chemical, and physical conditions), recreational, and wildlife uses in the watershed. The WQOs recommended here consider background conditions, impacts from current land use, and any potential future activities within the watershed. These objectives will help prevent impairment of water uses and values now and for future generations.

Table 2. Summary of water quality objectives for Shuswap Lake.

Parameter	E208723 Armstrong Point	0500123 West of Sorrento	0500124 Marble Point	E206771 Sandy Point
Dissolved Oxygen[1] (mg/L)	≥ 5	≥ 5	≥ 5	≥ 5
Secchi Depth[2] (m) (Water clarity)	≥ 6	≥ 6	≥ 6	≥ 6
Total Phosphorus[3] (µg/L)	10	10	10	15
Total Nitrogen[3] (µg/L)	300	300	300	300
Nitrogen:Phosphorus[4]	≥ 30:1	≥ 30:1	≥ 30:1	≥ 20:1
Chlorophyll *a*[5] (µg/L)	4	4	4	7
Total Organic Carbon[6] (mg/L)	4	4	4	4
E. coli (CFU/100mL)	Primary contact recreation: ≤ 200 (geometric mean[7]) or ≤ 400 (single-sample maximum)			
	Drinking water source: ≤ 10 (90th percentile)			

[1] Instantaneous minimum at any depth.
[2] Annual mean from quarterly measurements.
[3] Average of 5 weekly samples collected in 30 days at 3 depths throughout the water column (surface, mid depth and one metre above the bottom) during spring overturn.
[4] The N:P ratio is calculated using average total nitrogen and total phosphorus concentrations at spring overturn.
[5] Calculated from monthly surface water samples collected May to October.
[6] Maximum from samples collected in the vicinity of intakes with chlorinated drinking water treatment.
[7] Geometric means are calculated from at least 5 weekly samples collected in a 30-day period.

7. MONITORING RECOMMENDATIONS

To assess attainment of the WQOs for Shuswap Lake, a recommended monitoring program is included (Table 3). For phosphorus and nitrogen, attainment of the WQO is based on concentrations measured at spring overturn although monthly sampling collected during the growing season would be ideal to provide an understanding of trends (see Section 5 for each parameter's requirements and ENV 2022 for more details). Routine sampling of non-WQO parameters is recommended to understand the general water quality conditions in Shuswap Lake and to support data interpretation. These monitoring recommendations provide an outline and do not limit the addition of other parameters or locations. The Shuswap Lake WQO attainment monitoring program should be conducted yearly and follow the methods and quality assurance and quality control protocols provided in ENV 2020a.

It is also recommended to conduct water quality sampling in Mara Lake to monitor the nutrient inflow from the Shuswap River and the associated algae blooms occurring there.

Table 3. Recommended water quality objective attainment monitoring program for Shuswap Lake.

Parameter	Frequency and Timing	Station Locations	Depths
In situ profiles – dissolved oxygen, water temperature, pH, specific conductivity	Every time sampling is conducted	E206771 0500124 E208723 0500123	Every metre throughout the water column to a depth of 20 m and then every 5 m to within 1 m of the bottom
Secchi depth	Once per season (winter, spring, summer, and fall)		
Phosphorus – total, dissolved, orthophosphate	Collection of 5 weekly samples in 30 days at spring overturn		3 samples collected throughout the water column (surface, mid-depth and one metre above the bottom)
Nitrogen - total, dissolved, nitrate, nitrite, ammonia			
Chlorophyll *a*	Monthly sampling during the growing season[1]		Sample collected from surface waters
Total Organic Carbon	Every time sampling is conducted	Near drinking water intakes that use chlorination for treatment*	Sample collected from deeper waters near intakes
E. Coli	Monthly sampling during the growing season[1]	At beaches and primary contact water use areas^; Near drinking water intakes*	Sample collected from surface waters
Routine supporting parameters: Total suspended solids, true color, major ions, hardness, alkalinity, sulphate	Monthly sampling during the growing season[1]	E206771 0500124 E208723 0500123	3 samples collected throughout the water column (surface, mid-depth and 1 m above the bottom)
Plankton: Community composition and biomass	Spring and late summer during the growing season[1]	E206771 0500124 E208723 0500123	Sample collected from surface waters (phytoplankton) Sample collected throughout water column (zooplankton)

[1] Growing season defined as May to October

^ Interior Health Authority monitors water quality at beaches during the summer months

[*] There are almost 600 drinking water intakes; key locations should be tested for attainment monitoring. See Table 3-2 in ENV 2022 for more information on waterworks utilities on Shuswap Lake.

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