BC Lake Stewardship and Monitoring Program

Osoyoos Lake 2005-2020

A partnership between the BC Lake Stewardship Society and the BC Ministry of Environment and Climate Change Strategy

The Importance of Osoyoos Lake & its Watershed

British Columbians want lakes to provide good water quality, aesthetics, and recreational opportunities. When these features are not apparent in recreational lakes, questions arise. People begin to wonder if the water quality is getting worse, if the lake has been affected by land development, and what conditions will result from more development within the watershed.

The BC Lake Stewardship Society (BCLSS), in collaboration with the Ministry of Environment and Climate Change Strategy (ENV), has designed a program, entitled *The BC Lake Stewardship and Monitoring Program*, to address these concerns. Through regular water sample collections, we can come to understand a lake's current water quality, identify the preferred uses for a given lake, and monitor water quality changes resulting from land development within the lake's watershed. There are different levels of lake monitoring and assessment. The level appropriate for a particular lake depends on the funding and human resources available. In some cases, data collected as part of a Level I or II program can point to the need for a more in-depth Level III program. This report provides the 2005-2020 results of a Level I volunteer monitoring program for Osoyoos Lake and includes recent Level II data collected by ENV from 2018-2020 as part of the BC Lake Monitoring Network. The Osoyoos Lake Water Quality Society collected an extensive data set of Secchi depth, temperature, dissolved oxygen, and specific conductivity readings from 2005-2020. Volunteer monitoring took place at five sites on Osoyoos Lake: the North End, Packing House, White Sands, Central Basin, and South Basin and datasets are published on the Osoyoos Lake Water Quality Society's website. The ENV data were collected at the Monashee (Packing House) site in the North basin, the Central basin, and South basin. The lake basins and monitoring site locations are shown on the bathymetric map on page 5.

The BCLSS can provide communities with both lake-specific monitoring results and educational materials on general lake protection issues. This useful information can help communities play a more active role in the protection of the lake resource. Finally, this program allows government to use its limited resources efficiently with the help of local volunteers and the BCLSS.

A **watershed** is defined as the entire area of land that moves the water it receives into a common waterbody. The term watershed is misused when describing only the land immediately around a waterbody or the waterbody itself. The true definition represents a much larger area than most people normally consider. The Osoyoos Lake watershed is 7,880 km^2.

Watersheds are where much of the hydrologic cycle occurs and play a crucial role in the purification of water. Although no "new" water is ever made, it is continuously recycled as it moves through watersheds and other hydrologic compartments. The quality of the water resource is largely determined by a watershed's capacity to buffer impacts and absorb pollution.

Every component of a watershed (vegetation, soil, wildlife, etc.) has an important function in maintaining good water quality and a healthy aquatic environment. It is a common misconception that detrimental land use practices will not impact water quality if they are kept away from the area immediately surrounding a waterbody. Poor land use practices in a watershed can eventually impact the water quality of the downstream environment.

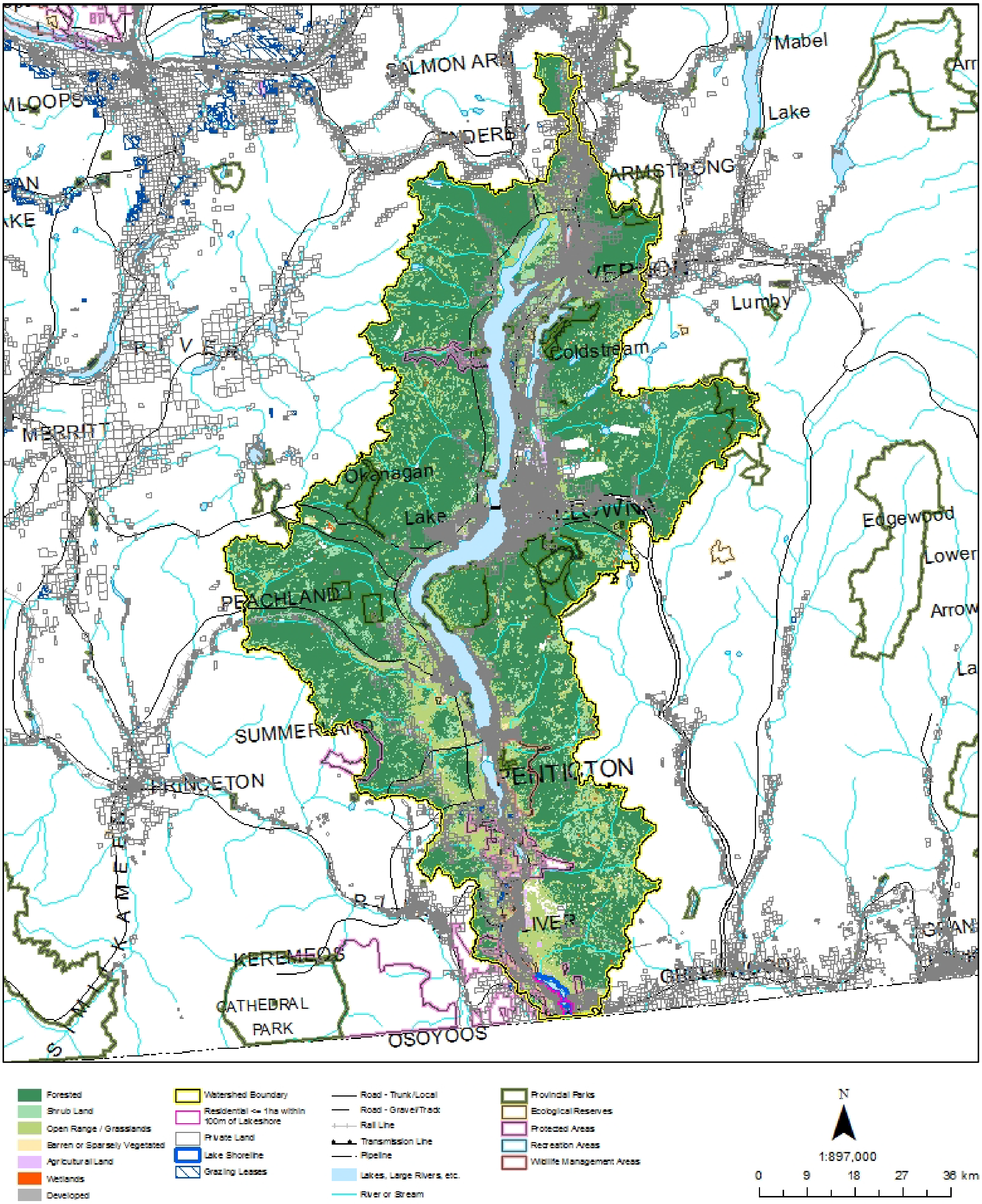
Human activities that impact water bodies range from small but widespread and numerous *non-point* sources throughout the watershed to large *point* sources of concentrated pollution (e.g., waste discharge outfalls, spills, etc.). Undisturbed watersheds have the ability to purify water and repair small amounts of damage from pollution and alterations. However, modifications to the landscape and increased levels of pollution impair this ability.

Osoyoos Lake lies in the traditional territory of the Okanagan Nation. The lake is located in an arid environment at the southern end of the Okanagan River Basin and extends across the Canada-US border into Washington. The town of Osoyoos is located at the south end of the north basin and around the central basin. The lake is 16 km long, has a surface area of 23 km^2, a perimeter of 47.9 km, a volume of 397 Mm^3, and lies at an elevation of 276 m. The maximum depth of the lake is 63 m (in the north basin), and the average basin depths are 21 m, 7 m, and 10 m for the north, central, and south basins, respectively. The Okanagan River flows into the lake at the north end and flows out of the lake at the south end. Inkaneep Creek also flows into the lake at the northeast corner of the north basin (Jensen et al., 2012). The average water residence time for the entire volume of Osoyoos Lake has been estimated at approximately 0.7 years (Pinsent & Stockner, 1974).

Native fish species in Osoyoos Lake include black crappie (*Pomoxis nigromaculatus*), black catfish (*Ameiurus melas*), largescale sucker (*Catostomus macrocheilus*), kokanee salmon (*Oncorhynchus nerka*), lake whitefish (*Coregonus clupeaformis*), mountain whitefish (*Prosopium williamsoni*), northern pikeminnow (*Ptychocheilus oregonensis*), rainbow trout (*Oncorhynchus mykiss*), and prickly sculpin (*Cottus asper*) (BCLSS, 2013). Invasive species in Osoyoos Lake include common carp (*Cyprinus carpio*), goldfish (*Carassius auratus*), largemouth bass (*Micropterus salmoides*), smallmouth bass (*Micropterus dolomieu*), yellow perch (*Perca flavescens*), and pumpkinseed (*Lepomis gibbosus*) (BCLSS, 2013). Western and winged floater mussels and western ridged mussels have also been observed (BCLSS, 2013). The lake was stocked with rainbow trout in the past but has not been stocked in recent years (FIDQ, 2021). Osoyoos Lake is important habitat for anadromous fish, those that spend most of their lives in the sea and migrate to fresh water to breed (Jensen et al., 2012).

Much of the Osoyoos Lake shoreline is developed, and the lake's primary water uses are for recreation, irrigation, and domestic water supply. The map below shows the Osoyoos Lake watershed and its associated land uses which includes forested (47%), forest cover openings (17%), open range/grasslands (17%), shrub land (6%), water (6%), developed (2%), agricultural land (2%), barren/sparsely vegetated (1%), and wetlands (0.3%).

Osoyoos Lake Land Use Map



Map provided by Ministry of Forests, Lands, Natural Resource Operations and Rural Development, 2020.

Non-Point Source Pollution and Osoyoos Lake

Point source pollution originates from municipal or industrial effluent outfalls. Other pollution sources exist over broader areas and may be hard to isolate as distinct effluents. These are referred to as non-point sources of pollution (NPS). Shoreline modification, urban stormwater runoff, onsite septic systems, agriculture, and forestry are common contributors to NPS pollution. One of the most detrimental effects of NPS pollution is phosphorus loading to water bodies. The amount of total phosphorus (TP) in a lake can be greatly influenced by human activities. If local soils and vegetation do not retain this phosphorus, it will enter watercourses where it will become available for algal production.

Stormwater Runoff

Lawn and garden fertilizer, sediment eroded from modified shorelines or infill projects, oil and fuel leaks from vehicles, snowmobiles and boats, road salt, and litter can all be washed by rain and snowmelt from properties and streets into watercourses. Phosphorus and sediment are of greatest concern, providing nutrients and/or a rooting medium for aquatic plants and algae. Paved surfaces prevent water infiltration to soils, and are potential sources of hydrocarbon and metal contamination, which can runoff into lakes during storm events.

Boating

Oil and fuel leaks are the main water quality concerns of boat operation on lakes. However, boating activities can also cause shoreline erosion from large wakes and churn up sediment and nutrients in shallow water from propeller wash. Other problems include the spread of aquatic invasive plants/animals and the dumping of litter.

Forestry

Timber harvesting can include clear cutting, road building, and land disturbances, which alter water flow and the ability for nutrients to remain stored (sequestered) in soil, potentially increasing sediment and phosphorus inputs to water bodies.

Atmospheric Deposition

Gases and particulates released to the atmosphere from combustion sources such as motor vehicle emissions, slash burning, and industrial sources contain nitrogen, sulphur, and metal compounds which eventually settle to the ground as dust or fall to the earth in rain and snow. These contaminants can fall directly into a waterbody, filter slowly into groundwater, or be washed into surface waters with runoff.

Onsite Septic Systems and Grey Water

Onsite septic systems can effectively treat human wastewater and wash water (grey water) as long as they are properly located, designed, installed, and maintained. When these systems fail, they can become significant sources of nutrients and pathogens to water bodies. Poorly maintained pit privies, used for the disposal of human waste and grey water, can also be significant contributors. Properly located and maintained septic tanks do not pose a threat to the environment, however, mismanaged or poorly located tanks have the potential to result in a health hazard and/or excessive nutrient loading.

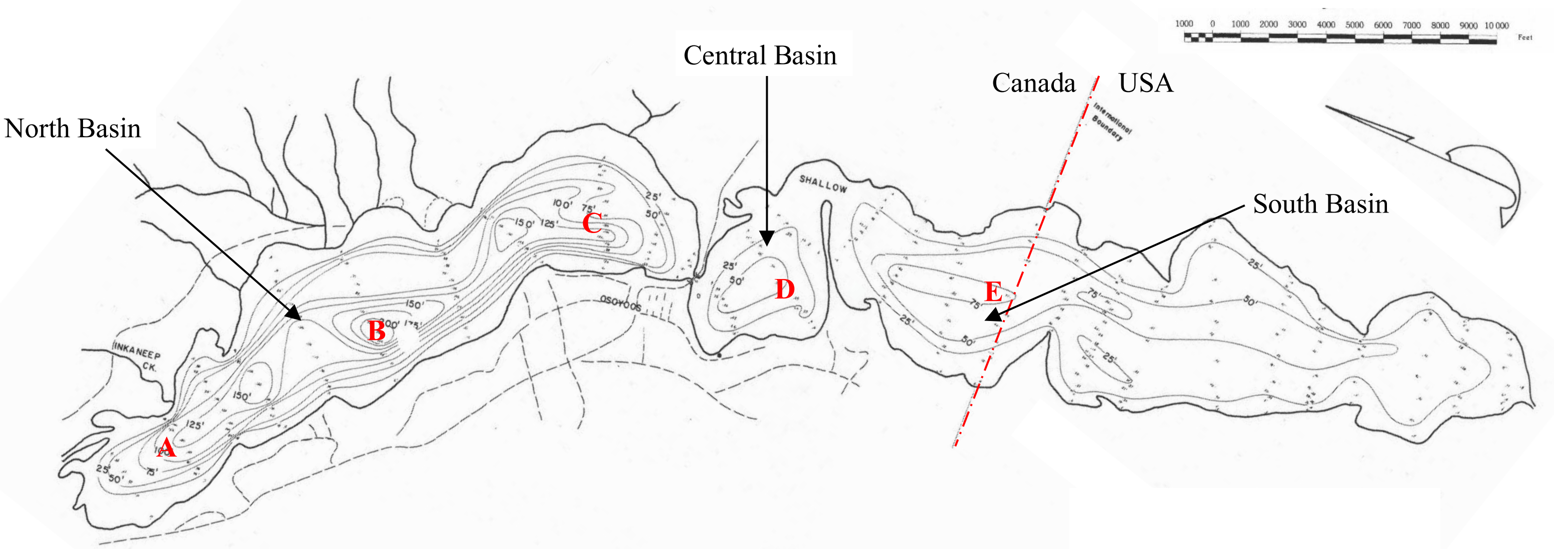
Agriculture

Agricultural production of crops and livestock, along with mixed farming activities, can alter water flow and increase sediment and chemical/bacterial/parasitic input into water bodies. Potential sources of nutrients (nitrogen & phosphorus) include chemical fertilizers, manure, and improperly situated winter-feeding areas. Significant amounts of total phosphorus can be transported by sediment inputs when riparian areas are not well maintained near agricultural activities and become degraded. The Code of Practice for Agricultural Environmental Management outlines requirements to minimize the impacts of agriculture on local waterways, including the distances structures and agricultural activities should be kept away from a watercourse (BC ENV, 2020).

Internal Nutrient Loading

Lake sediments themselves can be a major source of phosphorus. Deep-water oxygen can become depleted (i.e., anoxic), causing a chemical shift in bottom sediments. This shift can cause sediment to release phosphorus to overlying waters. This *internal loading* of phosphorus can be natural but is often the result of external phosphorus addition through NPS entering the lake over a long time period. Lakes displaying internal loading have elevated algal levels and generally lack recreational appeal. Internal nutrient loading can be a significant source of nutrients to the overlying water and is very difficult and complicated to manage/remediate.

Osoyoos Lake Bathymetric Map



Sampling sites (left to right): (A) North End, (B) Packing House/Monashee, (C) White Sands, (D) Central Basin, (E) South Basin

Lake Characteristics

Area: 23 km^2
Max Depth: 63 m
Mean Depth: 14 m
Shoreline Perimeter: 47.9km
Elevation: 276 m

Map obtained from FISS (lake surveyed 1966, revised in 1971). Not to be used for navigational purposes.

What’s Going on Inside Osoyoos Lake?

Temperature

Lakes show a variety of annual temperature patterns based on their location and depth. Most interior BC lakes form layers (stratify), with the coldest water near the bottom. Because colder water is denser, it resists mixing into the warmer, upper layer for much of the summer. When the warmer oxygen rich surface water distinctly separates from the cold oxygen poor water in the deeper parts of the lake, it is said to create a thermocline, a region of rapid temperature change between the two layers.

In spring and fall, these lakes usually mix from top to bottom (overturn) as wind energy overcomes the reduced temperature and density differences between surface and bottom waters. In the winter, lakes re-stratify under ice with the densest water (4°C) near the bottom. Because these types of lakes turn over twice per year, they are called dimictic lakes. These are the most common type of lake in BC.

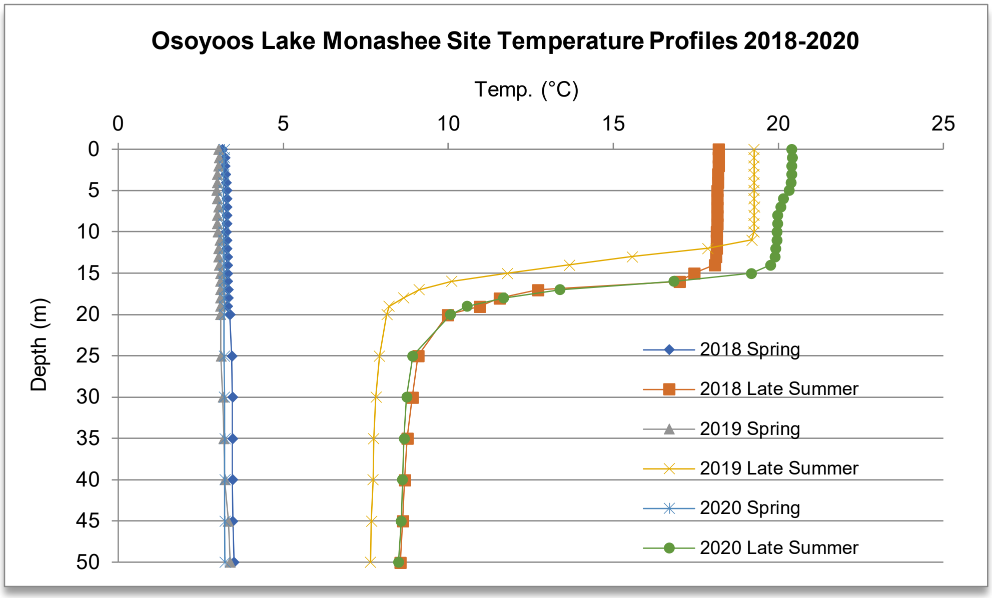
Coastal lakes in BC are more often termed warm monomictic lakes because they turn over once per year. These lakes have temperatures that do not fall below 4°C. Warm monomictic lakes generally do not freeze and circulate freely in the winter at or above 4°C and stratify only in the summer. Osoyoos Lake is classified as a dimictic lake.

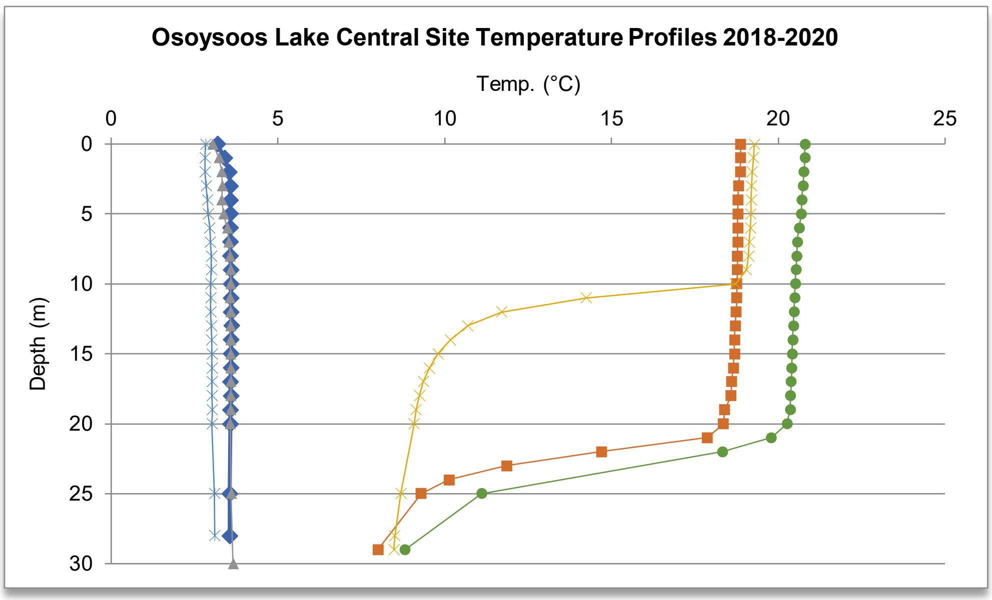
Ice-on and ice-off dates for BC lakes are important data for climate change research. By comparing these dates to climate change trends, we can examine how lakes are being affected. The north basin of Osoyoos Lake does not always completely freeze over, whereas the central and south basins freeze more regularly (Sokal, 2021). Unfortunately, there is limited information available on freezing trends for the lake.

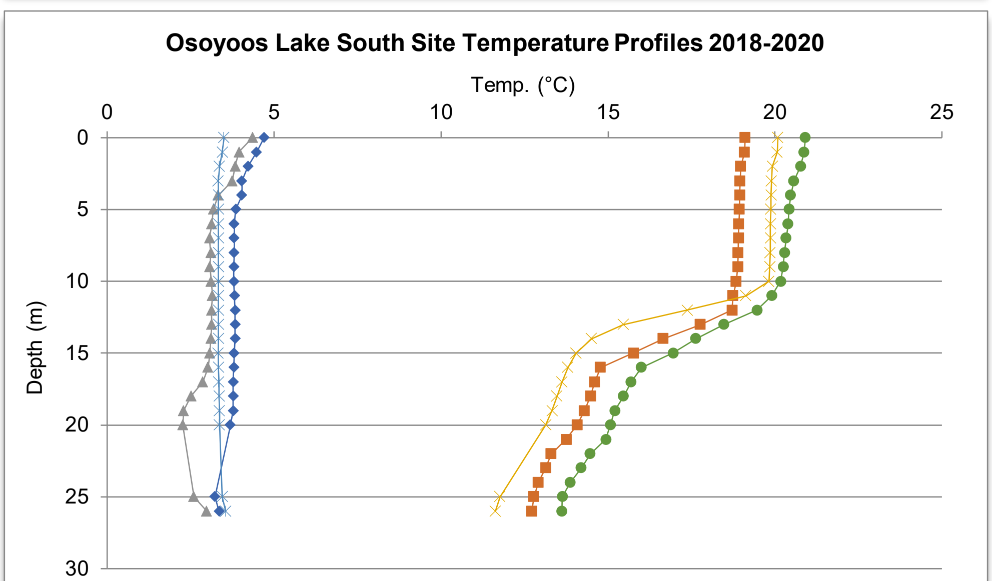
Surface temperature (T) readings serve as an important ecological indicator. By measuring surface temperature, we can record and compare readings from season to season and year to year. Surface temperatures are graphed with Secchi depth in the Clarity section below.

Temperature stratification patterns are also very important to lake water quality. They determine much of the seasonal oxygen, phosphorus, and algal conditions. When abundant, algae can create problems for lake users. The Osoyoos Lake Water Quality Society collected temperature profiles at five sites approximately every two weeks throughout the monitoring season. Spring and late summer temperature profiles were collected by ENV at three sites under the BC Lake Monitoring Network. The Osoyoos Lake spring and late summer temperature profiles for the Monashee (North basin), Central, and South sites for 2018-2020 are shown below. Spring profiles were taken March 21, 2018, April 1, 2019, and March 18, 2020. Late summer profiles were taken September 13, 2018, September 19, 2019, and September 10, 2020.

Spring overturn profiles show that all sites were thermally mixed at the time of sampling. The late summer temperature profiles for 2018-2020 indicate that Osoyoos Lake was stratified at the time of sampling. At the Monashee site, the thermocline is evident between approximately 10 m-20 m in 2018 and 15 m-20 m in 2019 and 2020. At the Central site, the thermocline is evident between 10 m-15 m in 2018 and 20 m-25 m in 2019 and 2020. At the South site, the thermocline is evident from 10 m-14 m in 2018 and 12 m-16 m in 2019 and 2020


Osoyoos Lake Monashee Site Temperature Profiles 2018-2020
Temp. (°C)
0
5
10
15
20
25
Depth (m)
0
5
10
15
20
25
30
35
40
45
50
2018 Spring
2018 Late Summer
2019 Spring
2019 Late Summer
2020 Spring
2020 Late Summer


Osoysoos Lake Central Site Temperature Profiles 2018-2020
Temp. (°C)
0
5
10
15
20
25
Depth (m)
0
5
10
15
20
25
30


Osoyoos Lake South Site Temperature Profiles 2018-2020
Temp. (°C)
0
5
10
15
20
25
Depth (m)
0
5
10
15
20
25
30

Dissolved Oxygen

Dissolved oxygen (DO) is essential to aquatic life in lakes. Oxygen from the atmosphere dissolves and mixes into the water's surface and is also released from plants and algae during photosynthesis. Oxygen is consumed by respiration of animals and plants, including the decomposition of dead organisms by bacteria. A great deal can be learned about the health of a lake by studying oxygen patterns and levels.

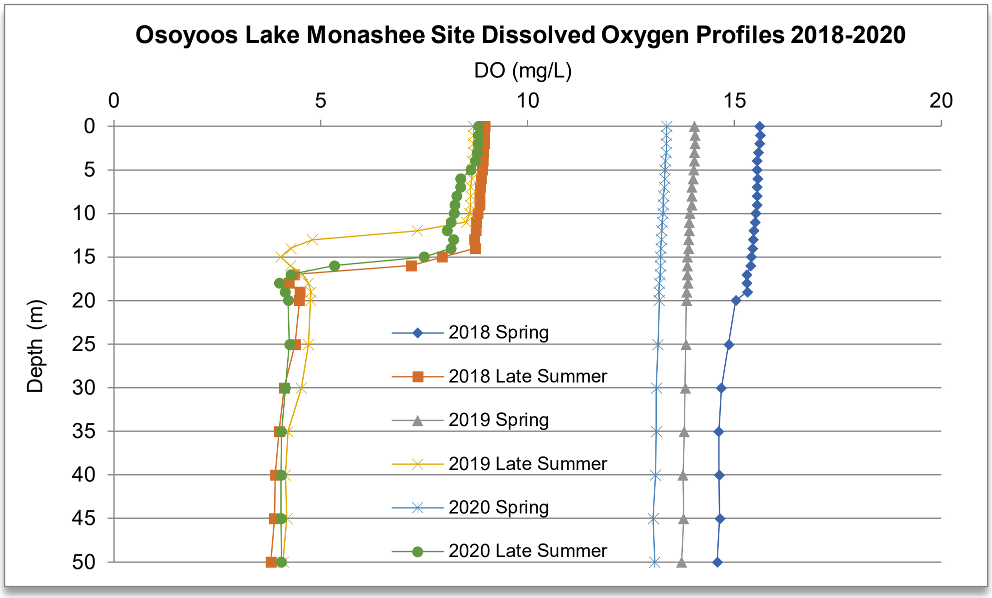
Generally, lakes that are lower in nutrients and algae production will have sufficient dissolved oxygen to support life at all depths through the year. As lakes become more nutrient and algae rich, it leads to increased plant and animal respiration and decay, resulting in more oxygen consumption. This is especially true near the bottom of the lake, where dead organisms can accumulate, and oxygen is depleted more rapidly. Stratified lakes, with low oxygen concentrations in the isolated bottom layer, can impact the behaviours and locations of fish residing within the lake. Fish can become stressed when oxygen concentrations fall below 4 mg/L and begin to show avoidance behaviours at these levels, moving to areas of the lake with higher dissolved oxygen (BC ENV, 1997). Fish kills can occur when decomposing or respiring algae use up the oxygen supply. In summer, this can happen on calm nights after an algal bloom, but most fish kills occur during late winter or at initial spring mixing.

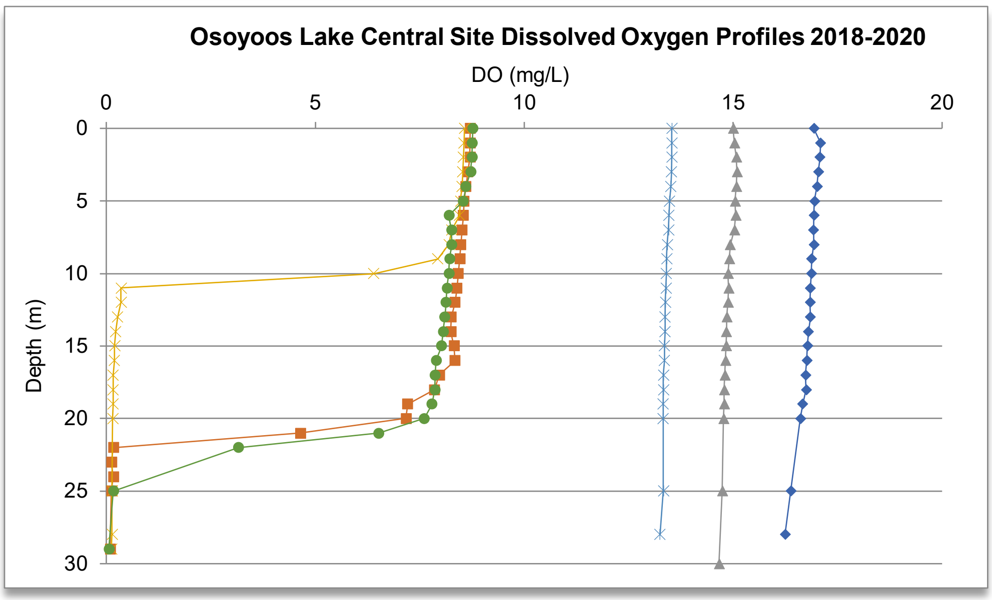
The Osoyoos Lake Water Quality Society collected DO profiles at five sites approximately every two weeks throughout the monitoring season. Spring and late summer DO profiles were collected by ENV at three sites under the BC Lake Monitoring Network. The Osoyoos Lake spring and late summer DO profiles for the Monashee (North), Central, and South sites for 2018-2020 are shown below. Spring profiles were taken March 21, 2018, April 1, 2019, and March 18, 2020. Late summer profiles were taken September 13, 2018, September 19, 2019, and September 10, 2020.

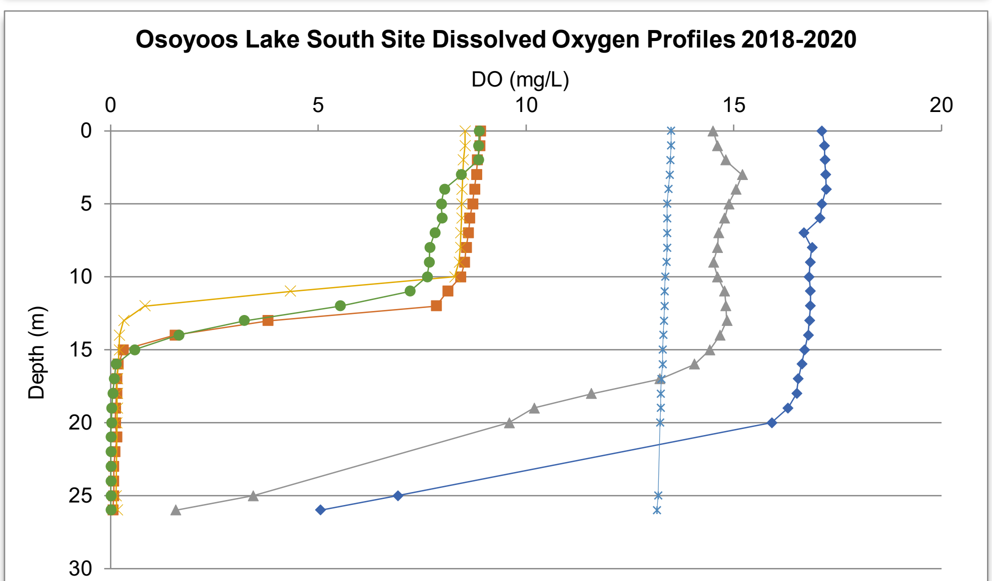
The spring DO profiles show that DO was replenished to bottom waters at the Monashee and Central sites in all years and only in 2020 at the South site. The South site profile shows a sharp decrease in oxygen below 20 m in 2018 and a sharp decrease below 16 m in 2019.

Late summer DO profiles show oxygen depletion in all years at the three sites. However, the Monashee site in the north basin does not show the same extent of depletion as at the Central and South basins. Dissolved oxygen depletion is evident starting at approximately 17 m (2018), 13 m (2019), and 17 m (2020) at the Monashee site; 21 m (2018), 11 m (2019), and 22 m (2020) at the Central site; and 13 m (2018), 11 m (2019), and 13 m (2020) at the South site.

It is important to note that it is significantly shallower in the Central and South basins, which means that there is less initial oxygen mass and therefore it is used up more quickly compared to the deeper North basin (Monashee site) (BCLSS, 2013). Jensen et al. (2012) report that internal loading of phosphorus is most pronounced in the Central and South basins due to these deep water anoxic conditions, which allows for phosphorus to be released from the sediments.


Osoyoos Lake Monashee Site Dissolved Oxygen Profiles 2018-2020
DO (mg/L)
0
5
10
15
20
Depth (m)
0
5
10
15
20
25
30
35
40
45
50
2018 Spring
2018 Late Summer
2019 Spring
2019 Late Summer
2020 Spring
2020 Late Summer


Osoyoos Lake Central Site Dissolved Oxygen Profiles 2018-2020
DO (mg/L)
0
5
10
15
20
Depth (m)
0
5
10
15
20
25
30


Osoyoos Lake South Site Dissolved Oxygen Profiles 2018-2020
DO (mg/L)
0
5
10
15
20
Depth (m)
0
5
10
15
20
25
30

Trophic Status

The term *trophic status* is used to describe a lake's level of productivity and depends on the amount of nutrient available for plant growth, including both floating algae (phytoplankton) and rooted plants (macrophytes). Algae are important to the overall ecology of a lake because they use nutrients to produce organic matter and are consumed by zooplankton, which in turn are food for other organisms, including fish. Macrophytes provide important habitat to many fish species and are the base of littoral zone (shallow water near shore) production.

In most BC lakes, phosphorus is the nutrient in shortest supply relative to need and thus limits the production of aquatic life. When in excess, phosphorus accelerates growth and may artificially age a lake. Total phosphorus in a lake can be greatly influenced by human activities.

Lakes with low levels of phosphorus usually support limited biological production and, thus, contain low concentrations of the photosynthetic pigment chlorophyll *a*, which is found in both algae and aquatic plants. These lakes are called *oligotrophic* and tend to have clear water and sufficient oxygen throughout the year to support fish and other aquatic organisms. *Mesotrophic* lakes have moderate levels of phosphorus and support greater biological production and therefore contain greater concentrations of chlorophyll *a*. Water clarity in mesotrophic lakes is moderate, but there is an increased probability of oxygen depletion in the deepest areas. *Eutrophic* lakes contain even greater concentrations of phosphorus and chlorophyll *and* can experience extended periods of poor water clarity and low oxygen levels.

Mesotrophic and eutrophic lakes experience higher densities of macrophytes and algae. Surface accumulations or 'blooms' of algae may occur during the warmest months, particularly in eutrophic lakes, where lack of water transparency can significantly reduce recreational activities. Mesotrophic to slightly eutrophic lakes support productive fisheries, so are desirable for those seeking good fishing lakes. As a result of higher productivity, these lakes also tend to draw in wildlife and waterfowl in larger numbers.

The trophic status of a lake can be determined by looking at concentrations of different chemical and biological variables. Nordin (1985) defined values for these variables in British Columbia lakes, which are shown in the following table.

	Trophic Categories		
	Oligotrophic	Mesotrophic	Eutrophic
Chlorophyll-a (µg/L)[1]	0 - 2.0	2.0 - 7.0	>7.0
Total Phosphorus (µg/L)[2]	1.0 - 10.0	10.0 - 30.0	>30.0
Total Nitrogen (µg/L)[2]	<100	100 - 500	500 - 1000
Clarity - Secchi Depth (m)[1]	>6.0	3.0 - 6.0	<3.0

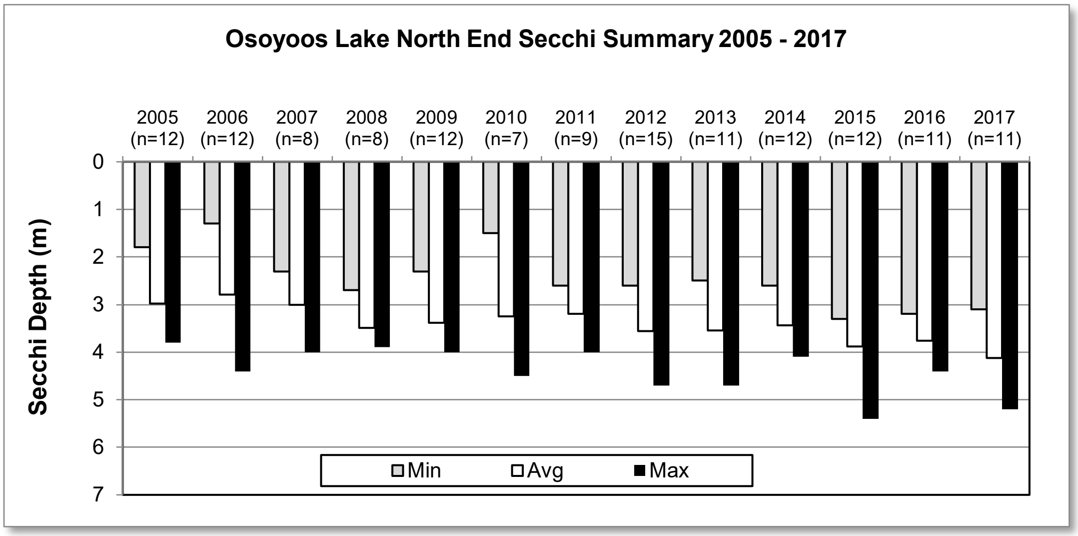
[1]Growing season average, [2]Spring mixed conditions.

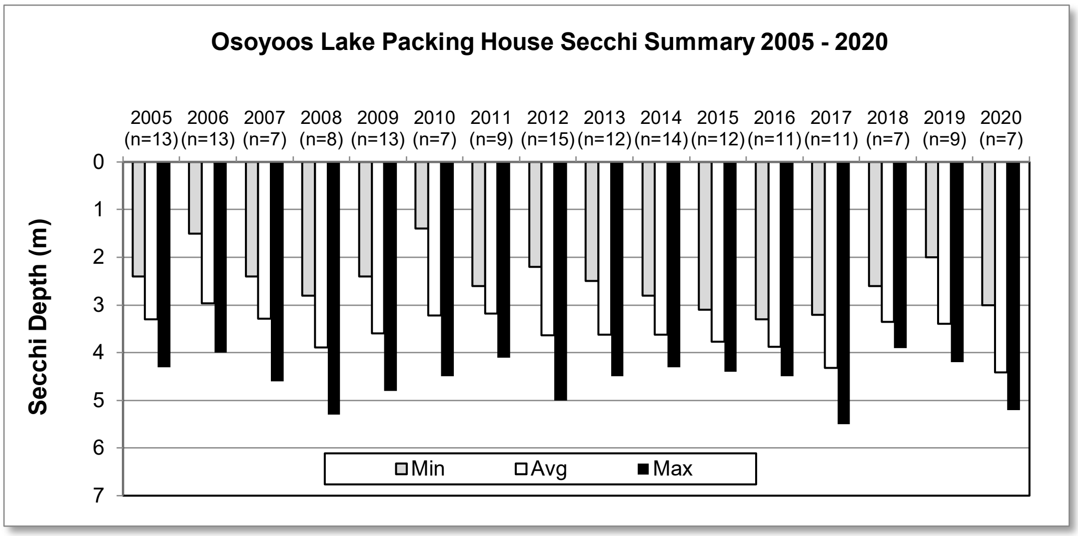
Water Clarity

As mentioned in the previous section, one method of determining productivity is water clarity. Secchi depth is a measure of water clarity and can be used as an indicator of the presence of algal cells in the water column. This can be assessed by using a Secchi disc, a 20 cm diameter black and white disc that measures the depth of light penetration. The disc is lowered into the water until it is no longer visible, and this depth is recorded. The disc is then dropped lower and then pulled up until it becomes visible again. The average of these two readings is known as the Secchi depth.

A deeper Secchi depth suggests clear water and fewer algal cells, while a shallow Secchi depth suggests less clear water, which may be caused by the presence of a large number of algal cells. In years where precipitation is much higher, this relationship can be confounded by additional debris and particulates from overland flow causing shallower Secchi depths.

Secchi depth readings were collected by volunteers between 2005-2020, but the sampling years varied between sampling sites. The following graphs summarize the minimum, average and maximum Secchi readings for the North End (2005-2017), the Packing House (Monashee) and Central Basin sites (2005-2020), and the White Sands and South Basin sites (2005-2009 and 2011-2020) as well as the number of readings (n) per year. It is important to note that the recommended minimum data requirement of 12 evenly-spaced readings from spring through fall was not met for all years, which means that the average Secchi values may not accurately represent the seasonal variation in Osoyoos Lake.


Osoyoos Lake North End Secchi Summary 2005 - 2017
2005 (n=12)
2006 (n=12)
2007 (n=8)
2008 (n=8)
2009 (n=12)
2010 (n=7)
2011 (n=9)
2012 (n=15)
2013 (n=11)
2014 (n=12)
2015 (n=12)
2016 (n=11)
2017 (n=11)
Secchi Depth (m)
0
1
2
3
4
5
6
7
Min
Avg
Max


Osoyoos Lake Packing House Secchi Summary 2005 - 2020
2005 (n=13)
2006 (n=13)
2007 (n=7)
2008 (n=8)
2009 (n=13)
2010 (n=7)
2011 (n=9)
2012 (n=15)
2013 (n=12)
2014 (n=14)
2015 (n=12)
2016 (n=11)
2017 (n=11)
2018 (n=7)
2019 (n=9)
2020 (n=7)
Secchi Depth (m)
0
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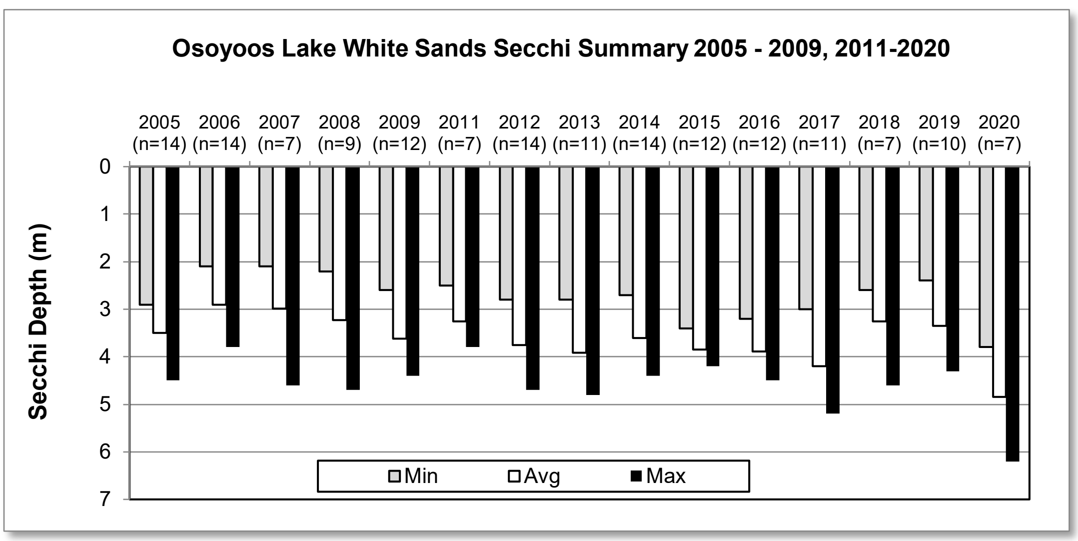
2
3
4
5
6
7
Min
Avg
Max


Osoyoos Lake White Sands Secchi Summary 2005 - 2009, 2011-2020
2005 (n=14)
2006 (n=14)
2007 (n=7)
2008 (n=9)
2009 (n=12)
2011 (n=7)
2012 (n=14)
2013 (n=11)
2014 (n=14)
2015 (n=12)
2016 (n=12)
2017 (n=11)
2018 (n=7)
2019 (n=10)
2020 (n=7)
Secchi Depth (m)
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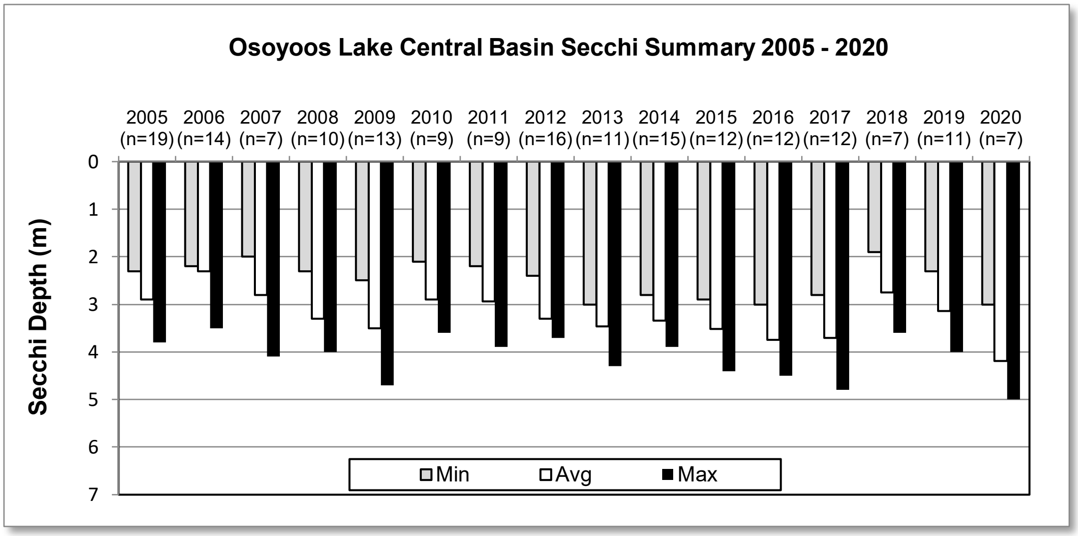
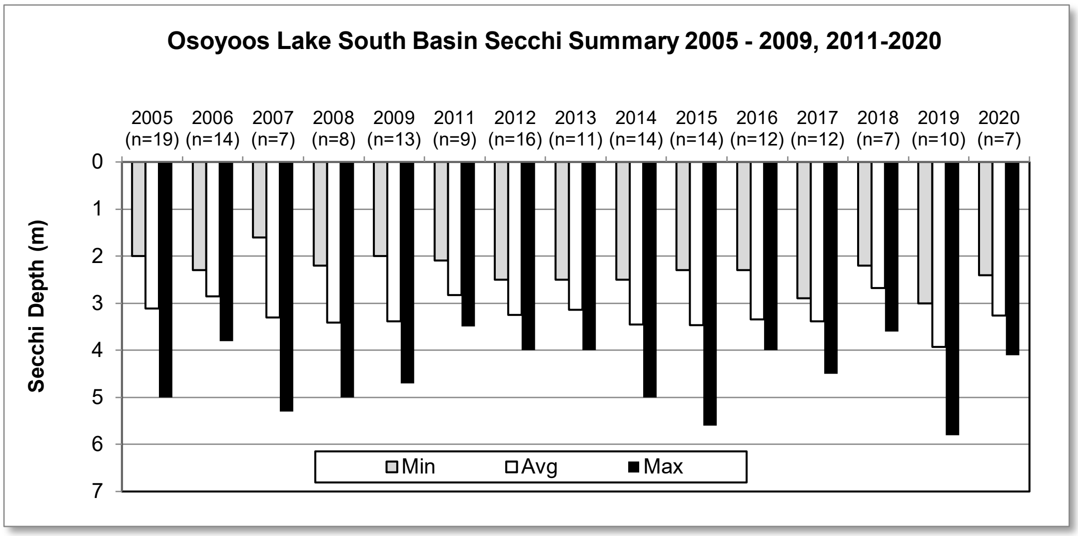
6
7
Min
Avg
Max



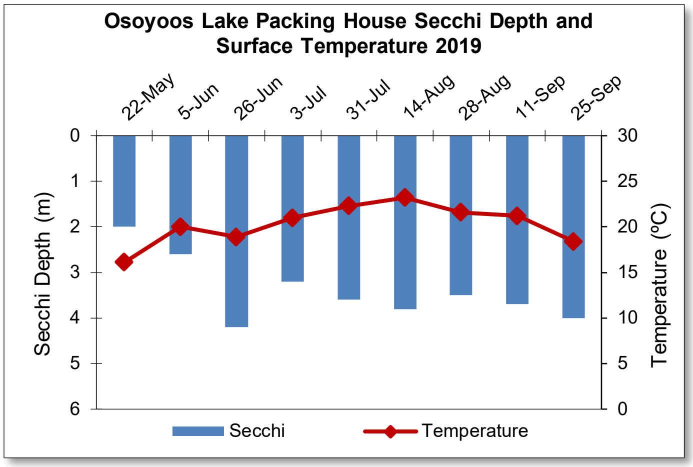


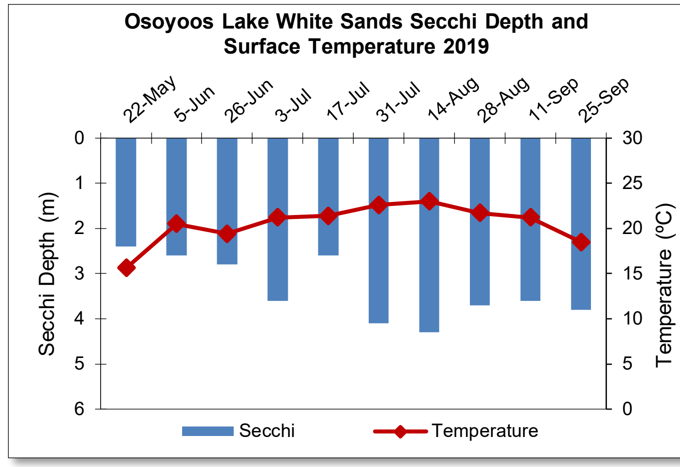
The maximum Secchi reading for the Central site was 5 m (2020) and the minimum was 1.9 m (2018). The maximum reading for the Packing House site was 5.5 m (2017) and the minimum was 1.4 m (2010). The maximum reading for North site was 5.4 m (2015) and the minimum was 1.3 m (2006). The maximum reading for the White Sands site was 6.2 m (2020) and the minimum was 2.1 (2006 & 2007). The maximum reading for the South site was 5.8 m (2019) and the minimum was 1.6 m (2007).

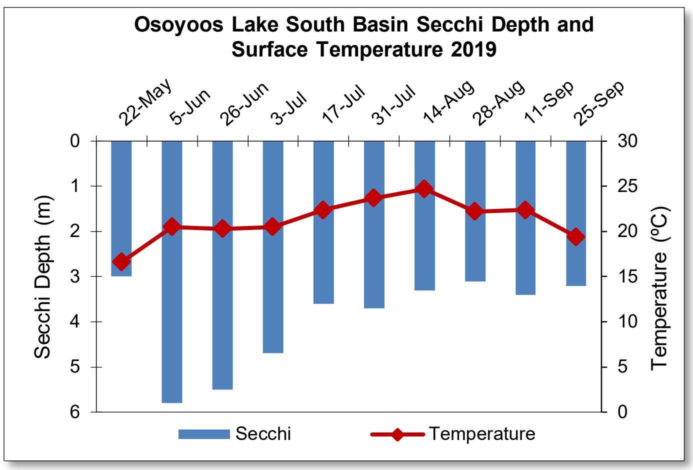
The average Secchi depth measurements are shown in the table below. Based on the average Secchi values from 2005-2020, Osoyoos Lake was exhibiting mesotrophic conditions (Secchi depth 3-6 m) with occasional slightly eutrophic (Secchi depth < 3 m) conditions indicated with green shading (Nordin, 1985).

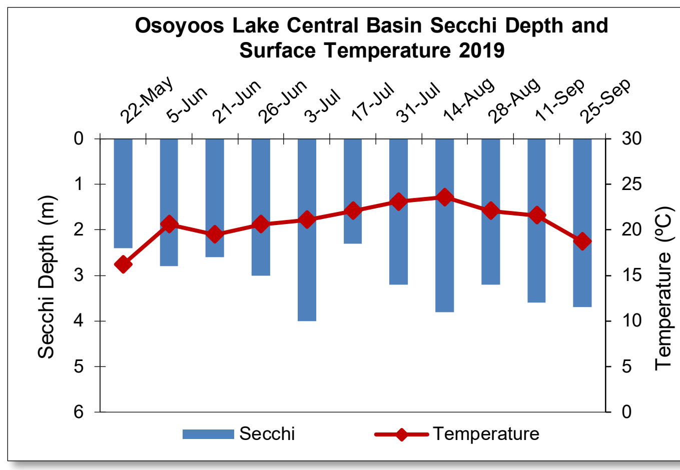
Site	Average Summer Secchi Depth (m)															
	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
North End	3.0	2.8	3.0	3.5	3.4	3.2	3.2	3.6	3.5	3.4	3.9	3.8	4.1	-	-	-
Packing House	3.3	3.0	3.3	3.9	3.6	3.2	3.2	3.6	3.6	3.6	3.8	3.9	4.3	3.4	3.4	4.4
White Sands	3.5	2.9	3.0	3.2	3.6	-	3.3	3.8	3.9	3.6	3.9	3.9	4.2	3.3	3.4	4.8
Central Basin	2.9	2.3	2.8	3.3	3.5	2.9	2.9	3.3	3.5	3.3	3.5	3.8	3.7	2.7	3.1	4.2
South Basin	3.1	2.9	3.3	3.4	3.4	-	2.8	3.3	3.1	3.5	3.5	3.4	3.4	2.7	3.9	3.3

Natural variation and trends in Secchi depth and temperature not only occur between years, but also throughout one season. The graphs below show the seasonal Secchi and temperature measurements at the volunteer sampling sites from 2019. This year was chosen since the number of readings was greater than those of 2018 or 2020, which may be more representative of seasonal variation in Osoyoos Lake.





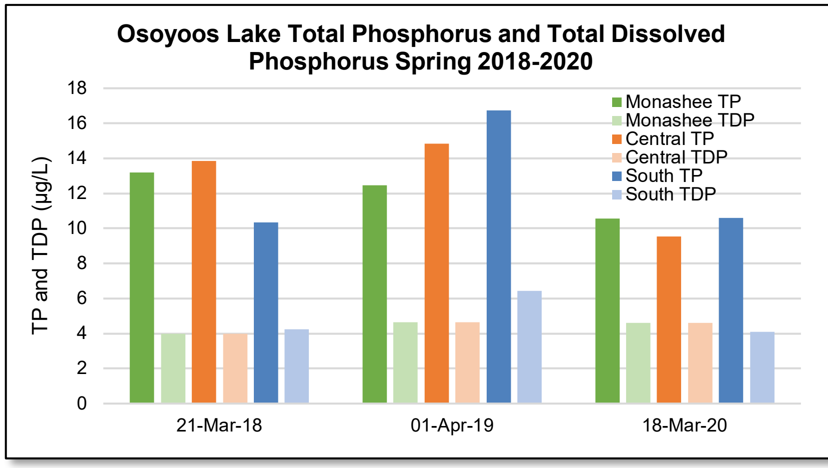




Phosphorus

The trophic status of a lake is characterized, in part, by the spring concentrations of total phosphorus. Phosphorus concentrations measured during spring overturn can be used to predict summer algal productivity. Productivity is dependent on the amount of nutrients (phosphorus and nitrogen) in a lake, which are essential for plant growth, including algae. Algae are important to the overall ecology of a lake because they are the food for zooplankton, which in turn are the food for other organisms, including fish. In most lakes, phosphorus is the nutrient in shortest supply and thus acts to limit the production of aquatic life. When in excess, however, phosphorus accelerates growth and artificially ages a lake. Total phosphorus (TP) in a lake can be greatly influenced by human activities. Measuring total dissolved phosphorus (TDP) is also important as this form is more bioavailable for primary productivity than total phosphorus.

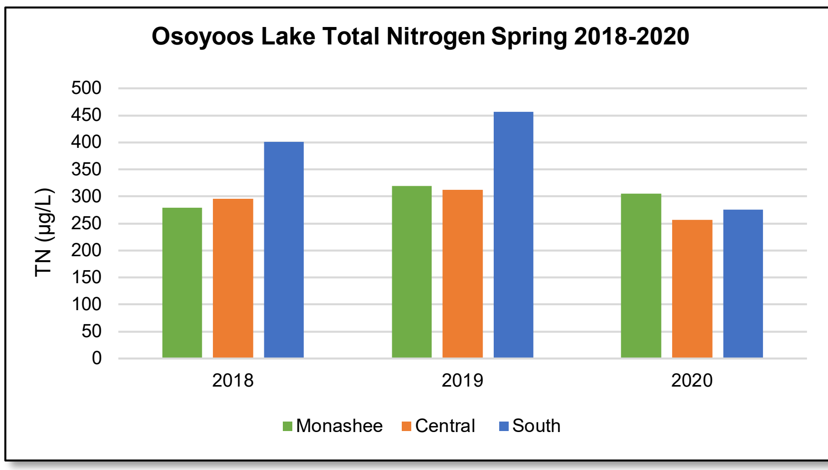
TP and TDP values were averaged from the upper (epilimnion) and lower (hypolimnion) sampling depths since the temperature profiles indicate that the water column was mixed. The figure below shows Osoyoos Lake TP and TDP concentrations for 2018-2020 at the ENV sampling sites.



Spring overturn TP values ranged from 9.55 µg/L at the Central site in 2020 to 16.75 µg/L at the South site in 2019. Spring TP values for 2018-2020 indicate mesotrophic conditions (TP 10-30 µg/L) except for slightly oligotrophic conditions (TP <10 µg/L) at the Central site in 2020 (Nordin, 1985). TDP values are similar between years and basins which is consistent with TP values. There is no apparent increasing or decreasing trend shown in the 2018-2020 graph.

Nitrogen

Nitrogen is the second most important nutrient involved in lake productivity. Nitrogen in water is present in several forms including organic nitrogen, and inorganic forms of nitrogen (i.e., ammonia, nitrite, nitrate, nitrogen gas). Generally, major sources of nitrogen compounds are municipal and industrial wastewater, onsite sewage systems, urban and agriculture runoff, atmospheric precipitation, groundwater, and nitrogen fixation. In B.C. lakes, nitrogen is rarely the limiting nutrient for algal growth (phosphorus limitation is much more common). In most lakes, the ratio of nitrogen to phosphorus is well over 15:1, meaning excess nitrogen is present. In lakes where the N:P is less than 5:1, nitrogen becomes the limiting nutrient to algal growth, and can have major impacts on the amount and species of algae present.

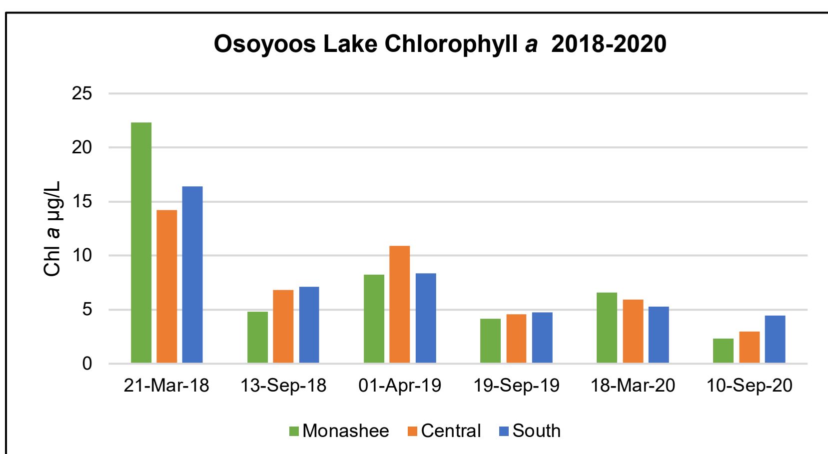


The 2018-2020 spring N:P ratios in Osoyoos Lake ranged between 21:1 and 39:1, suggesting the lake is phosphorus limited.

Spring sampling nitrogen values ranged from 257 µg/L at the Central site in 2020 to 456 µg/L at the South site in 2019, indicating mesotrophic conditions (TN 100-500 µg/L) (Nordin, 1985).

Chlorophyll a

Chlorophyll *a* is the common green pigment found in almost all plants. In lakes, it occurs in plants ranging from algae phytoplankton) to rooted aquatic forms (macrophytes). Chlorophyll captures the light energy that drives the process of photosynthesis. While several chlorophyll pigments exist, chlorophyll *a* is the most common. The concentration of chlorophyll *a* in lake water is an indicator of the abundance of algae present in that same water. The spring and late-summer chlorophyll *a* concentrations are shown in the adjacent figure.



As chlorophyll *a* concentrations were only sampled in the spring and fall by ENV, it is difficult to draw conclusions about the trophic status as single point samples do not account for seasonal variation. In order to determine trophic status using chlorophyll *a*, multiple samples would be required throughout the growing season to calculate mean chlorophyll *a*. However, the available values indicate mesotrophic (chl *a* 2-7 µg/L) conditions except for eutrophic (> 7 µg/L) conditions March 21, 2018 at all 3 sites, September 13, 2018 at the South site, and April 1, 2019 at all 3 sites (Nordin, 1985). Chlorophyll *a* concentrations are higher in the spring than the late-summer, which is a common pattern seen in many B.C. lakes. The elevated values on March 21, 2018 may have been due to a spring algal bloom in the lake.

Aquatic Plants

Aquatic plants are an essential part of a healthy lake. They play an important role in the lifecycle of aquatic insects, provide food and shelter from predators for young fish, and also provide food for waterfowl, beavers, and muskrats.

Factors that affect the type and amount of plants found in a lake include the level of nutrients (i.e., phosphorus), temperature, and introduction of invasive species.

Aquatic plants were surveyed in Osoyoos Lake (Warrington, 1980) and include: *Potamogeton* L., *Lemna* L., *Nymphaea* L., *Ceratophyllum* L., *Eleocharis* R. Br., *Potamogeton zosteriformis* Fern., *Potamogeton natans* L., *Potamogeton illinoensis* Morong, *Potamogeton pusillus* L., *Sparganium eurycarpum* Engelm., *Lemna trisulca* L., *Ranunculus flammula* L., *Elodea canadensis* Rich., *Ceratophyllum demersum* L., *Polygonum hydropiper* L., *Rorippa nasturtium-aquaticum* (L.) S. & T., *Typha latifolia* L., *Eleocharis acicularis* (L.) R. & S., *Scirpus americanus* Pers., *Myriophyllum* L., *Utricularia* L., *Elodea* Richard, *Polygonum* L., *Potamogeton pectinatus* L., *Potamogeton praelongus* Wulf., *Potamogeton amplifolius* Tucker., *Potamogeton gramineus* L., *Myriophyllum exalbescens* Fern., *Sparganium angustifolium* Mich., *Spirodela polyrhiza* (L.) Schleid., *Ranunculus aquatilis* L., *Alisma gramineum* Gmel., *Hippuris vulgaris* L., *Heteranthera dubia* (Jacq.) MacMill., *Ruppia maritima* L., *Potentilla palustris* (L.) Scop., *Scirpus lacustris* L., *Ricciocarpus natans* (L.) Corda, *Sparganium* L., *Ranunculus* L., *Alisma* L., *Scirpus* L., *Potamogeton crispus* L., *Potamogeton perfoliatus* L., *Potamogeton nodosu*s Poir., *Potamogeton alpinus* Balbus, *Myriophyllum spicatum* L., *Lemna minor* L., *Utricularia vulgaris* L., *Ranunculus sceleratus* L., *Najas flexilis* (Willd.) R. & S., *Polygonum amphibium* L., *Zannichellia palustris* L., *Marsilea vestita* Hook. & Grev., *Eleocharis palustris* (L.) R. & S., S*cirpus fluviatilis* (Torr.) Gray, and *Riccia fluitans* L..

Aquatic plant species can spread between lakes via boaters. Be sure to check for and remove all organic material and mud from boats, trailers, and equipment (boots, waders, fishing gear). Drain onto land all items that can hold water (buckets, wells, bilge, and ballast), and dry all items before launching into another body of water (ISCBC, 2020).

Should Further Monitoring Be Done on Osoyoos Lake?

Lakes are sentinels of environmental change, and long-term monitoring of water quality trends in BC lakes allows for inter-annual variation to be distinguished from directional change. Understanding these trends can provide insights into the causes of change and support effective watershed management (BC ENV, 2020). Osoyoos Lake is monitored biannually as a part of the B.C. Lake Monitoring Network. Furthermore, a thorough 15 year dataset of Secchi depth and temperature measurements has been established by committed volunteers, which enhances the long-term trend sampling conducted by the province. These data provide key information about the current conditions and changes occurring within Osoyoos Lake and its watershed.

Overall, the data collected in Osoyoos Lake indicates that the water quality has remained relatively stable over the sampling years. Seasonal Secchi depth data and spring total phosphorus concentrations indicate mesotrophic conditions, with parameters occasionally indicating a variation in trophic category. The spring N:P ratios indicate that the lake is a phosphorus limited system.

	Trophic Categories			Monashee			Central			South		
	Oligotrophic	Mesotrophic	Eutrophic	2018	2019	2020	2018	2019	2020	2018	2019	2020
Chlorophyll *a* (µg/L)[1]	0 - 2.0	2.0 - 7.0	>7.0	-	-	-	-	-	-	-	-	-
Total Phosphorus (µg/L)[2]	1.0 - 10.0	10.0 - 30.0	>30.0	13	13	11	14	15	10	10	17	11
Total Nitrogen (µg/L)[2]	<100	100 - 500	500 - 1000	280	319	305	296	312	257	401	456	275
Clarity - Secchi Depth (m)[1]	>6.0	3.0 - 6.0	<3.0	3.4	3.4	4.4	2.7	3.1	4.2	2.7	3.9	3.3

[1]Growing season average, [2]Spring mixed conditions.

Local volunteers are encouraged to continue to record Secchi depth, surface temperature, and dissolved oxygen profiles readings from Osoyoos Lake, with an emphasis on collecting a minimum of 12 evenly spaced readings to complement the long-term data. ENV and BCLSS recommend that volunteers start monitoring in the south end of the lake in April or May and continue monitoring through to mid-October. Volunteer collected data is also important for long term records and can help identify early warning signs should there be a deterioration in water quality from its current state. It is also recommended that volunteers collect ice-on and off information as this data can be important for climate change research.

Tips to Keep Osoyoos Lake Healthy

Yard Maintenance, Landscaping & Gardening

- Minimize the disturbance of shoreline areas by maintaining natural vegetation cover.
- Minimize high-maintenance grassed areas.
- Replant lakeside grassed areas with native vegetation. Do not import fine fill.
- Use paving stones instead of pavement.
- Stop or limit the use of fertilizers and pesticides.
- Do not use fertilizers in areas where the potential for water contamination is high, such as sandy soils, steep slopes, or compacted soils.
- Do not apply fertilizers or pesticides before or during rain due to the likelihood of runoff.
- Hand pull weeds rather than using herbicides.
- Use natural insecticides such as diatomaceous earth. Prune infested vegetation and use natural predators to keep pests in check. Pesticides can kill beneficial and desirable insects, such as lady bugs, as well as pests.
- Compost yard and kitchen waste and use it to boost your garden's health as an alternative to chemical fertilizers.

Agriculture

- Locate confined animal facilities away from waterbodies. Divert incoming water and treat outgoing effluent from these facilities.
- Limit the use of fertilizers and pesticides.
- Construct adequate manure storage facilities.
- Do not spread manure during wet weather, on frozen ground, in low-lying areas prone to flooding, within 3 m of ditches, 5 m of streams, 30 m of wells, or on land where runoff is likely to occur.
- Install barrier fencing to prevent livestock from grazing on streambanks.
- If livestock cross streams, provide graveled or hardened access points.
- Provide alternate watering systems, such as troughs, dugouts, or nose pumps for livestock.
- Maintain or create a buffer zone of vegetation along a streambank, river or lakeshore and avoid planting crops right up to the edge of a waterbody.
- Ranchers are encouraged to have an Environmental Farm Plan for their operation (contact the Ministry of Agriculture).

Onsite Sewage Systems

- Inspect your system yearly, and have the septic tank pumped every 2 to 5 years by a septic service company. Regular pumping is cheaper than having to rebuild a drain-field.
- Use phosphate-free soaps and detergents.
- Do not put toxic chemicals (paints, varnishes, thinners, waste oils, photographic solutions, or pesticides) down the drain because they can kill the bacteria at work in your onsite sewage system and can contaminate waterbodies.
- Conserve water: run the washing machine and dishwasher only when full and use only low flow showerheads and toilets.
- Use biodegradable household cleaners instead of bleach or other hazardous products (which will kill the good bacteria in your system).
- Avoid planting trees or shrubs near the drain-field because their roots can damage or plug the pipes.

Auto Maintenance

- Use a drop cloth if you fix problems yourself.
- Recycle used motor oil, antifreeze, and batteries.
- Use phosphate-free biodegradable products to clean your car. Wash your car over gravel or grassy areas, but not over sewage systems.

Boating

- Do not throw trash overboard or use lakes or other waterbodies as toilets.
- Use biodegradable, phosphate-free cleaners instead of harmful chemicals.
- Conduct major maintenance chores on land.
- Use 4 stroke engines, which are less polluting than 2 stroke engines, whenever possible. Use an electric motor where practical.
- Keep motors well maintained and tuned to prevent fuel and lubricant leaks.
- Use absorbent bilge pads to soak up minor oil and fuel leaks or spills.

- Recycle used lubricating oil and left over paints.
- Clean, Drain, Dry. Clean off all organic material and mud from boat and equipment (boots, waders, fishing gear). Drain onto land all items that can hold water (buckets, wells, bilge, and ballast). Dry all items completely before launching into another body of water (ISCBC, 2020)
- Leading by example is often the best method of improving practices - help educate fellow boaters.

Docks

- Do not use metal drums in dock construction. They rust, sink, and become unwanted debris. Use blue or pink closed cell extruded polystyrene billets or washed plastic barrel floats. All floats should be labeled with the owner's name, phone number, and confirmation that barrels have been properly emptied and washed.
- Untreated cedar is the best choice for dock construction. In some places, pressure-treated wood is banned for waterfront use because it can leach chemicals into the environment.

Who to Contact for More Information

The BC Lake Stewardship Society
1257 Erskine Street Coquitlam, BC V3B 6R3
Phone: 604.474.2441
Email: info@bclss.org
Website: www.bclss.org

Osoyoos Lake Water Quality Society
https://www.osoyooslake.ca/

BC Ministry of Environment and Climate Change Strategy
Kirsten McNeill, Aquatic Stewardship Coordinator
Public Feedback Welcomed
3rd Floor, 1011-4th Ave Prince George, BC, V2L 3H9
Email: volunteerlakes@gov.bc.ca
Website:
https://www2.gov.bc.ca/gov/content/environment/research-monitoring-reporting/monitoring/lake-monitoring/volunteer-lake-monitoring

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Photos: Neil Bousquet, Osoyoos Lake Water Quality Society

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Technical Review by:
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Land Use Map and Statistics:
Josh Doerksen (Ministry of Forests, Lands and Natural Resource Operations)

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