Water Quality Monitoring Program Annual Report 2024

Columbia Lake Stewardship Society

January 29th, 2025

Executive Summary

The Columbia Lake Stewardship Society (CLSS) began monitoring the water quality of Columbia Lake on April 20, 2014. Since then, monitoring has occurred annually while the lake is ice-free. In 2024 the first water quality monitoring event on the lake took place in mid-May and the last monitoring event in early September.

In 2024, monitoring included:

- measurement of selected water quality indicator parameters on the lake on six occasions between mid-May and early September, and approximately monthly sampling of water for chemical analysis,
- measurement of the water quality of Dutch Creek, Hardie Creek, and the small creek that drains from Canal Flats, and
- assessment of water quality on the Columbia River between the provincial park and Fairmont Hotsprings.

The CLSS water quality monitoring program is administered, conducted, and interpreted largely by volunteers under the overall direction of our Program Coordinator. The 2024 water quality program involved many volunteers who had participated in previous years and some volunteers new to the program.

The monitoring program carried out over the ten years on Columbia Lake (2014-2023) has shown that the lake water is suitable for consumption as drinking water, preservation of aquatic life, and recreational purposes (Table 1). In 2024, the parameters CLSS measured were mostly within the normal ranges determined from 2014-2020 data (expressed as UCL and LCL, section 3.1). However, there were some notable observations from the 2024 monitoring program, which are summarized below.

Columbia Lake 2024

- In mid-July, we recorded the highest lake **temperature** in our database since we began monitoring in 2014. The lake average was 24.4°C, exceeding LWA's water quality guideline of 23.0°C (Table 1).
- Between mid-July and the end of July, the **turbidity** of the surface lake water increased notably at three locations.
- As usual, **specific conductance** increased progressively towards the south end of the lake, being lowest at N1 and greatest at S4. Throughout 2024, specific conductance of the lake water tended towards the upper range of expected values (UCL) and at S4 the specific conductance exceeded the UCL in mid-August.
- Measurements of **total phosphorus** indicated that at S1 and S3 (the "middle of the lake") there were *elevated* levels in mid-June which substantially exceeded the 10 μg/L threshold for an oligotrophic lake. These values decreased by mid-July and CLSS recorded 'normal' values of less than 10 μg/L at all locations on the lake for the remainder of the summer.

- From 2020-2024 inclusive, **nitrate** concentrations in the lake have been consistently less than the analytical detection limit (<0.010 mg/L).
- **Iron** levels in the lake are generally very low. However, at S4, the level recorded at the end of July was 290 μg/L. This is very close to the CCME water quality standard (Table 1).
- In 2024, the greatest concentrations of **chloride** were at the south end of the lake, as has been noted in previous years. Further, our measurements in 2024 show that concentrations at S4 were consistently greater than any previously recorded between 2020 and 2023 (see Table 2).

Lake Comparison (BCMoE Data)

- The concentration of **chloride** in Columbia Lake is substantially greater than that in the three other lakes (Lake Windermere, Premier Lake, and Columbia Lake) in both Spring and Fall.
- In Spring, the **specific conductance** is consistently greatest in Lake Windermere. However, by Fall, the specific conductance is frequently lower in Lake Windermere than in the other lakes. Lake Windermere appears to undergo a notable decrease in specific conductance over the summer, whereas Premier Lake and Whiteswan Lake remain relatively constant and Columbia Lake shows a smaller decrease.
- The **turbidity** of the water in Columbia Lake often increased over the summer and was greater in Fall than in Spring, in 2019, 2021, 2022, and 2023. In contrast, the turbidity of the water in Lake Windermere often decreased over the summer and was lower in the Fall than in the Spring in 2017, 2019, 2022, and 2023. This may be related to flow of water into and out of these lakes.

Creeks 2024

- Concentrations of **chloride** and **nitrate** were notably greater in the Canal Flats creek than in Hardie Creek or Dutch Creek (more than 20 X and 5-10 X greater, respectively).

Columbia River 2024

- **Conductivity** is greatest in the Fall, and it is consistently greater downstream than upstream.
- Concentrations of **nitrate** and **chloride** are consistently greater downstream.

While the values for almost all parameters reported here are still well below CCME and Health Canada guidelines (Table 1), small changes observed over the years and subtle patterns across the lake provide us with information which is important in identifying which indicators of lake health to focus upon in our future monitoring programs. This is especially important given events such as the substantial fish kill observed in Columbia Lake in July 2024.

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1.0 Introduction

Columbia Lake, located in the East Kootenay region of British Columbia between the community of Fairmont Hot Springs and the Village of Canal Flats, is the headwater of the Columbia River drainage system. Because Columbia Lake is a headwater lake, the quality of water draining from the lake potentially influences the water quality received downstream.

Columbia Lake is part of the Columbia Wetlands system. These wetlands extend from the south end of Columbia Lake near the Village of Canal Flats to the community of Donald on the north side of the Trans-Canada Highway, 28 kilometers northwest of Golden, BC. Columbia Lake drains into the Columbia River at the north end of the lake. The river then drains into Lake Windermere and from Lake Windermere continues into the Columbia Wetlands north of the Town of Invermere. North of Donald and just beyond the Mica Dam, the Columbia River turns south and drains through the Arrow Lakes system to exit Canada south of Trail, BC.

In response to concerns about future development along the lake and the consequent potential for impact on the quality of the lake's water, the Columbia Lake Management Plan was prepared for the Regional District of East Kootenay and the Village of Canal Flats in 2021. A draft version of that plan has been used to prepare this report.

The Columbia Lake Stewardship Society (CLSS) began monitoring the lake's water quality on April 20, 2014, and has continued the monitoring program while the lake is ice-free every year through to September this year, 2024. In 2024, water quality monitoring of Columbia Lake began on May 13th and ended on September 4th. As part of the 2024 program, CLSS also tested water quality on the Columbia River at the Columbia Lake Provincial Park boundary, near the north end of the lake, and further north near Fairmont Hotsprings. Sampling of the river occurred on four occasions between the 29th May and the 29th September.

This report of CLSS's water quality monitoring program:

- describes the 2024 program;
- summarizes the water quality monitoring results;
- compares the water quality of Columbia Lake with Lake Windermere, Whiteswan Lake, and Premier Lake, using data collected by BCMOE; and
- discusses development of the monitoring program for 2025.

2.0 Monitoring Program

Sections 2.1 through 2.4 describe:

- the purpose of the program and contributions of volunteers to the program during 2024,
- the monitoring program conducted during 2024,
- water quality objectives established by CLSS for the lake, and
- the QA/QC program undertaken by CLSS.

Initially, the water quality monitoring program for Columbia Lake was developed to respond to recommendations contained in the Columbia Lake Management Strategy (Urban Systems, 1997) that indicated a water quality and water level monitoring program should be implemented. In 2014, four water quality monitoring stations were established on the lake. Since 2014, the program has undergone several changes as more is learned about the lake and as different funds become available to support the monitoring program. In particular, the water quality of four streams flowing into the lake has been monitored since 2020. These changes are summarized chronologically, in Appendix A-2, and they include those suggested by the revised Columbia Lake Management plan, which was written in 2021. (CLSS's work on monitoring water levels is described in a separate annual report.)

2.1 Purpose and Acknowledgements

The purpose of the water quality monitoring program conducted by CLSS is to provide baseline water quality information against which the impacts of current and future activities on the lake, and in the surrounding lands that drain into the lake, can be identified. This activity helps to satisfy the CLSS mission statement:

- To act as a citizen-based water stewardship group for Columbia Lake,
- To implement activities which monitor and help maintain the ecological health of Columbia Lake, and
- To communicate and network with others, as required, to achieve these goals.

The CLSS water quality program is, for the most part, administered, implemented and interpreted by volunteers. During 2024, the following volunteers contributed to the water quality monitoring program:

▪ Gina Fryer & Cesar Fuertes	Participation in lake monitoring events
▪ Ed Gillmor	Monitoring in late May and June
▪ Garry Gray	Monitoring in August
▪ Pat Silver	Overall program administration and accounting
▪ Tom Symington	Assistance with report preparation
▪ Bill Thompson	Assistance with report preparation
▪ Rachel Milner	Lake and stream sampling, report preparation and review
▪ Tom Dance & Nancy Wilson	On-lake monitoring, and compilation, graphing, interpretation, and reporting of monitoring results

In the autumn of 2022, CLSS retained the services of Ms. Caily Craig as Executive Director with responsibility to co-ordinate the water quantity and quality monitoring programs as well as the education program within the local communities. Ms. Craig worked on the water quality program throughout 2023 and until September of 2024 when she returned to graduate school to complete her studies.

The program receives funding from the following agencies:

- Columbia Valley Local Conservation Fund
- Columbia Basin Trust
- British Columbia Hydro - Fresh Water Conservation Program
- Regional District of East Kootenay
- Spirits Reach Community Association
- Columere Marina
- Columbia Ridge Community Association
- Columere Park Community Association

Over the years since its inception, advice on the program has also been provided by the Regional District of East Kootenay (RDEK) Suzanne Bayley of the Columbia Wetlands Society Partnership (CWSP); and Rick Nordin and Dave Schindler of the BC Lake Stewardship Society.

The participation of these volunteers, individuals, and agencies is gratefully acknowledged.

2.2 The Monitoring Program Undertaken in 2024

In 2024, the water quality monitoring program undertaken by CLSS encompassed three related sets of data, for Columbia Lake, for three creeks which feed into Columbia Lake; and for the Columbia River.

Columbia Lake

As usual, water monitoring for Columbia Lake in 2024 comprised bi-weekly to monthly collection of various types of information at each of four locations (N1, S1, S3, and S4) along the lake (shown in Figure 1). Monitoring occurred on six occasions between May 13th and September 4th.

i. Observations about cloud cover, water surface disturbance (waves), and air temperature;
ii. Measurements of the depth of water, and the depth of clear water using the Secchi disk;
iii. Measurements of water temperature, turbidity, specific conductance, pH, and concentration of dissolved oxygen;
iv. Water sampling to measure total and dissolved phosphorous, chloride, nitrate, sulphate, iron, and manganese (four sets of samples in 2024); and alkalinity ($CaCO_3$) (one set of samples).

The four regular monitoring locations shown in **Figure 1** are located at:

Station location	Northing	Easting
N1	N50.28769	W115.87126
S1	N50.253929	W115.86256
S3	N50.20107	W115.84820
S4	N50.17533	W115.83442

Creeks Feeding into Columbia Lake

As previously, the monitoring program undertaken in 2024 also included monitoring several creeks which flow into Columbia Lake:

- Dutch Creek, on the northwest side of the bridge over Highway 93;
- Hardie Creek, at the outfall to the lake on the Spirits Reach property;
- A small creek draining north from Canal Flats on the pathway (Figure 1)

In 2024, data was collected at the three creeks on five occasions between May 14th and July 30th, as follows:

i. Measurements of water temperature, specific conductance, turbidity, dissolved oxygen, and pH;

ii. Water sampling, to measure total and dissolved phosphorous, chloride, nitrate, sulphate, iron, manganese; and alkalinity ($CaCO_3$) (July 30th)

iii. Water sampling to measure total and dissolved phosphorous, chloride, nitrate, sulphate, hardness, alkalinity, and total metals (May 29th)

The results of creek monitoring are described in section 3.2.

NOTE: In past years, CLSS has monitored Marion Creek. However, this was not possible in 2024 because of private property and access issues.

The Columbia River

During the summer of 2023, and repeated in 2024, CLSS began a program to establish baseline measurements along the Columbia River for the major water quality indicator parameters (water temperature, specific conductance, turbidity, dissolved oxygen, and pH) and for certain chemical elements and compounds (chloride, sulphate, alkalinity, nitrate, dissolved phosphorus, total phosphorus, iron, and manganese).

The program involves using kayaks to collect water samples and make measurements directly in the water. The samples and measurements were taken just upstream of the convenient “put-in” spot on the Columbia River, off Columbia River Drive by the boundary of the Columbia Lake Provincial Park; and at the “take-out,” a downstream location on Wills Road/River Drive in Fairmont Hotsprings. Figure 1 shows these two locations (red stars).

These locations were selected because they are relatively easily accessed by kayak and are commonly used by recreational users. Further, most of the recreational activity along this reach of the river (kayaks, canoes, and portable floatation devices, a recreational camping area, and a golf course) occurs between the two locations.

- In 2024, water quality indicator parameters (temperature, specific conductance, turbidity, and pH) were measured directly on four occasions: 29th May, 10th June, 22nd July, and 29th September.
- On May 29th and June 10th samples were collected to measure chloride, nitrate, sulphate, hardness (as $CaCO_3$), alkalinity (as $CaCO_3$), phosphorus total and dissolved, and total metals.

The results for Columbia River are summarized in Section 3.3.

Notes on the Monitoring Parameters

Appendix A-1 provides information on how each of the measured parameters in the monitoring program contributes to our understanding of the water quality of Columbia Lake.

Dissolved oxygen was measured using a hand-held meter previously calibrated for dissolved oxygen concentrations. Acquisition of the dissolved oxygen meter was a recommendation made in the 2016 water quality report. Purchase of the equipment was made possible by the grants provided to CLSS by the funding agencies and a monetary contribution by two of our volunteers.

Originally, as much as lake conditions allowed, water temperature and specific conductance were measured at both “shallow” and “deep” depths. Shallow refers to measurements in the upper 0.5 metres of the lake (an arm’s reach below the water surface for practical purposes) while deep refers to measurements made about 0.5 metres from the lake bottom as measured using the Secchi disk. The deep and shallow measurements began in 2016 but were not routinely collected in 2017, 2018, 2019, 2020 and 2021 because the 2016 data revealed no noticeable differences in measurements at the deep and shallow depths.

Caro Analytical of Kelowna provided the analytical services.

NOTE: In prior years, 2021 to 2023, CLSS monitored indicator parameters and collected 14 samples along the north south profile of the lake for analysis of the concentrations of chloride. This profile could not be compiled for 2024 due to funding constraints.

Lake Data

CLSS has a spreadsheet which contains the observations, measurements, and some of the chemical analyses collected during all years of the monitoring program. The spreadsheet is available upon request.

Email: admin@columbialakess.ca

2.3 Water Quality Standards

To identify potentially harmful changes in water quality, collected quantitative water quality information is compared to water quality guidelines established by regulatory agencies.

The draft version (dated November 2021) of the Columbia Lake Management Plan prepared by the Regional District of East Kootenay and the Village of Canal Flats provides a set of public health standards to judge how the quality of the lake water compares to guidelines for the protection of human health. The water quality standards used for comparison are those published by the Government of Canada (2017) in the Guidelines for Drinking Water Quality.

However, these human health guidelines may not be sufficient for the protection of freshwater aquatic life. CLSS notes that several of the total metal concentration guidelines for the protection of aquatic life, as published by the Canadian Council of Ministers of the Environment (CCME), are considerably lower than the guidelines for protection of human health (Health Canada Drinking Water). For example, Table 1 compares the CCME guidelines for concentrations of arsenic, molybdenum, selenium, uranium, and zinc, with the limit published in the Canadian guidelines for protection of human health.

CLSS also notes that the criteria applied by Lake Windermere Ambassadors to evaluate water quality conditions on Lake Windermere include concentrations of dissolved oxygen and phosphorous, and temperature ranges.

The Province of British Columbia has established a variety of guidelines (WQGs) or criteria useful for judging the quality of water used for drinking water and for protection of aquatic life. These guidelines are for broad application on a province-wide basis and do not consider local land uses or ambient lake conditions and thus may be over- or under-protective of a given lake's specific conditions and development pressures.

On a site-by-site basis the province allows that WQGs may be established by:

- Direct adoption of WQGs for each monitoring parameter,
- Establishing the upper limit of background concentration for each monitoring parameter, or
- Deriving a site-specific water quality objective (WQO) based upon data collected at the site.

CLSS does not have the resources to establish guidelines for Columbia Lake using the upper limit of background concentration or site-specific data. Therefore CLSS has combined the human health guidelines, the CCME guidelines for protection of aquatic life, and the additional criteria used by Lake Windermere ambassadors to use as a comparative assessment of water quality objectives for Columbia Lake. These guidelines are shown in Table 1. Table 1 also shows ranges for parameters measured by BCMOE in their annual monitoring program (Range in Columbia Lake) and, lastly, data collected by CLSS from 2014-2021. Table 1 provides criteria from all of these sources, with the highlighted values identifying the concentrations or ranges applied by CLSS to Columbia Lake.

Together, the value ranges given in Table 1 encompass "expected concentrations" for the lake water and provide a relative measure of whether the lake water is worsening over time or is maintaining the pristine water quality that the users of the lake have traditionally been accustomed to. In general, the measured water quality parameters on Columbia Lake are considerably less than the criteria. However, there are occasions in which some of the parameters exceed guidelines. These occasions are noted in the results and are used to guide the development of future monitoring programs.

Figure 1 Monitoring and Sampling Locations

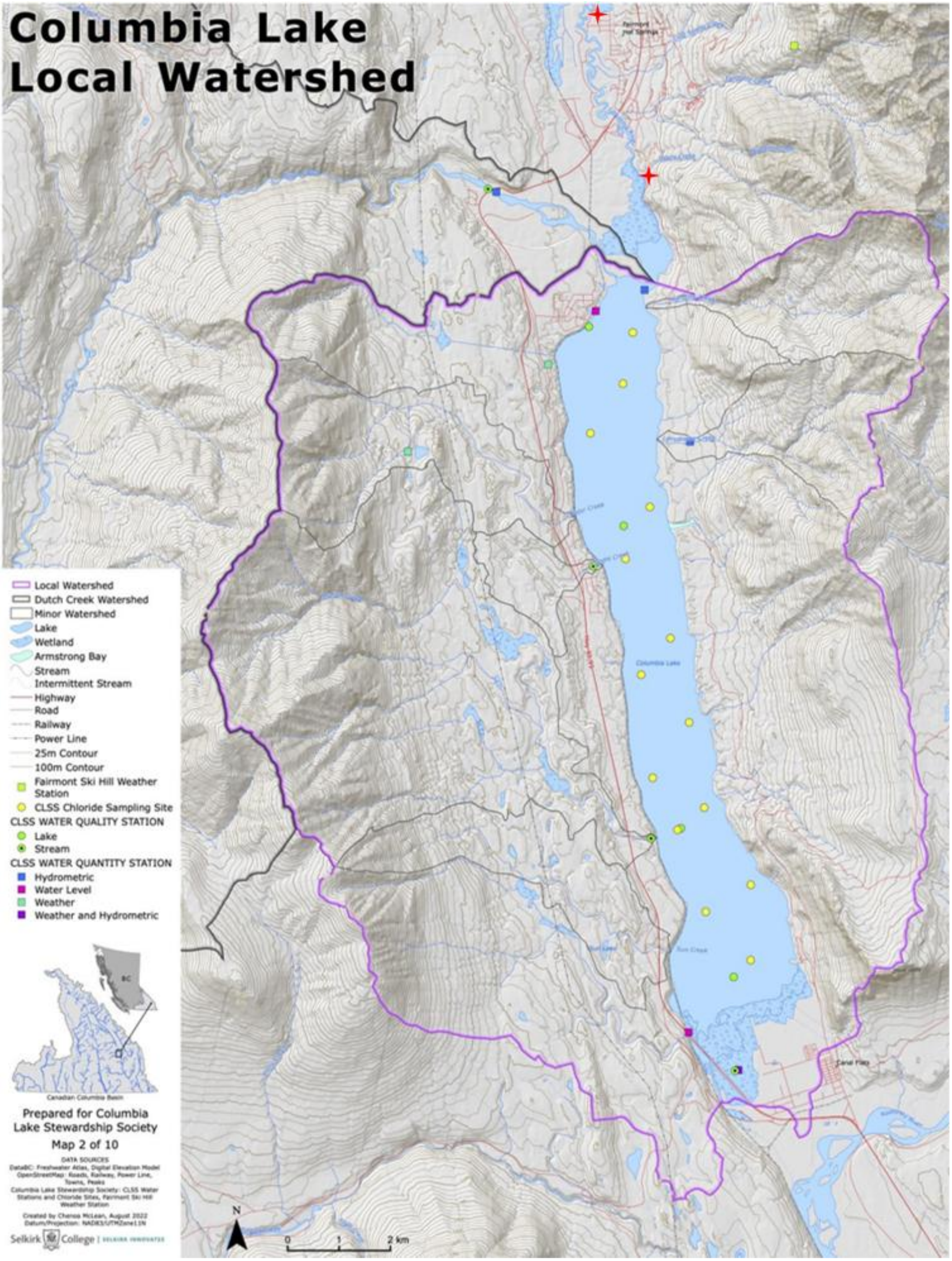


Table 1: Comparative Water Quality Standards

Table 1 Comparative Water Quality Standards for Columbia Lake

Parameter	Measurement Units	Health Canada Drinking Water	CCME[2] for Freshwater Aquatic Life	used by Lake Windmere ambassadors	Range in Columbia Lake[3]	Measured by CLSS[4]
PH		6.5 to 8.5	6.5 to 9.0		8.1 to 8.46	7.3 to 10
Dissolved oxygen	mg/L	--	--	>5 mg/L instantaneous minimum > 8mg/L 30-day mean	8.08 to 10.8	
Specific Conductance	uS/cm	700	--		290 to 345	209 to 459
Phosphorous				0.010 mg/L (maximum)		
Temperature			--	<20°C in June (average) < 25°C in July (average) <23°C in August (average)		
Turbidity	NTU	1	--		0.49 to 0.93	0.5 to 4.3
Chloride[5]	mg/L	--	120		4.36 to 6.44	
Sulphate[5]	mg/L		--		22.4 to 32	
Aluminum total	ug/L	200	--		1.35 to 6.18	
Arsenic total	ug/L	30	5		0.0663 to 1.26	
Boron Total	ug/L	500	1500		5.5 to 7.2	
Chromium total	ug/L	50	--		<0.1	
Copper total	ug/L	1000	--		0.131 to 0.423	
Iron total	ug/L	300	300		2.2 to 18.8	
Manganese total	ug/L	50	430		4.2 to 15.3	
Molybendum total	ug/L	250	73		0.49 to 0.63	
Sodium total	mg/L	200	--		4.89 to 6.79	
Antimony total	ug/L	10	--		0.058 to 0.085	
Selenium total	ug/L	10	1		0.041 to 0.059	
Uranium total	ug/L	100	15		0.661 to 1.06	
Zinc total	ug/L	5000	7		0.47 to 1.31	

Notes:

1 Health Canada Limit as published in the Columbia Lake Management Plan (draft version of November, 2021) Canadian Drinking Water Quality Guidelines, Government of Canada, 2017

2 Canadian Council of Ministers of the Environment

3 Reported by BCMOE for the biannual monitorin program for 2015 through 2021 inclusive

4 As measured by the Columbia Lake Stewardship Society for the bi-monthly monitoring Program 2014 through 2021 inclusive

5 Parameter included in the list because either it is at a concentration in Columbia Lake noticeably different from neighbouring lakes or it is commonly found in the rock and soil surrounding Columbia Lake.

(yellow) water quality guidelines applied by CLSS to Columbia Lake

2.4 QA/QC Program

CLSS uses several quality assurance and quality control measures to improve the reliability of the citizen science information collected by our volunteers. The QA/QC program is currently focused on the collection of reliable field information which requires that:

- each set of volunteers or summer staff is trained in the use of the field equipment by our experienced technical advisors,
- follows the guidance for equipment calibration prior to each monitoring event, and
- when the monitoring events occur over a long day is re-calibrated every four hours.
- field data is checked by comparing to the data collected from prior years for any significant differences and, if beyond the limits established by the upper and lower control limits, is confirmed by a repeated monitoring event as soon as practical.

CLSS has a written procedures manual to guide our volunteers and staff in the use of the equipment, water sample collection methods, care and storage of all samples to maintain sample integrity while being transported to the laboratory for chemical analyses. This manual is reviewed annually and updated as new measuring equipment or monitoring methods are applied to the program.

As funding permits, CLSS would like to use other methods to confirm the reliability of the results of the chemical analysis. Specifically, we intend to collect blank samples for every sampling event, prepare blind duplicate samples and trip blanks for every sampling occasion.

Blank samples are used to determine if the water quality is affected by any sample procedures or equipment. Currently our understanding of the guidance provided by regulatory agencies is that one blank sample is collected for every sampling event. The blank samples would be prepared using distilled water and contained in a laboratory container. The blank samples would be opened at every monitoring location so that any dust or wind-blown debris from the boat could fall into the sample container and alter the water quality measured.

The duplicate samples would be a replica of a single sample and collected in the same way as the sample submitted for chemical analysis. It is called a blind sample because it is not identified using a sample location identification number as is used for the actual sample so that if the concentrations measured differ between the duplicate and the actual sample the difference cannot be corrected by the chemical analyst. Our guidance from regulatory agencies is that a duplicate sample is to be provided for every five samples collected.

Trip blanks are samples prepared using distilled water. The purpose of the trip blank is to determine whether the water quality has been altered during transport from the lake to the chemical laboratory. One trip blank is to be provided in every package of sample container.

For a typical monitoring event CLSS ships only four or five individual samples to the laboratory for analysis. To implement the present program implementing these blank, duplicate and trip samples would require an addition of three samples. Unfortunately, CLSS does not have the financial resources to implement this portion of the QA/QC program but as we expand the lake and stream monitoring program to collect greater than 10 samples per monitoring-event we will begin to have these QA/QC samples added to the program.

3.0 Water Quality Monitoring Results

Respectively, Sections 3.1, 3.2, and 3.3 summarize:

- The results obtained at the four monitoring locations along the lake (N1, S1, S3, and S4),
- The results obtained for Dutch Creek, Hardie Creek, and the creek draining from Canal Flats to the lake, and
- The results from the water quality monitoring along the Columbia River between the Provincial Park and the village of Fairmont.

3.1 Annual Monitoring Program: Columbia Lake

The 2024 annual monitoring program is the eleventh year CLSS has monitored the water quality of Columbia Lake using the indicator parameters of temperature, turbidity, specific conductance, pH and dissolved oxygen.

To illustrate the differences in the values of these parameters from month to month, CLSS compiled the information collected between 2014 and 2020 into a statistical summary for each of the four monitoring locations along the lake. That compilation involved a month-by-month calculation of the mean, the standard deviation, and of 'expected' maximum and minimum values. The expected maximum and minimum values were calculated as the mean plus or minus three times the standard deviation, and these are labelled as upper and lower control limits (UCL and LCL) on graphs of the indicator parameters. Those statistical calculations are available upon request (email: admin@columbialakess.ca). Measurements that exceed either the expected maximum or minimum value identify water quality information that is beyond the normal or expected range, and this may suggest further assessment of the lake's water quality should be considered. Any exceedances are mentioned in the text of this report.

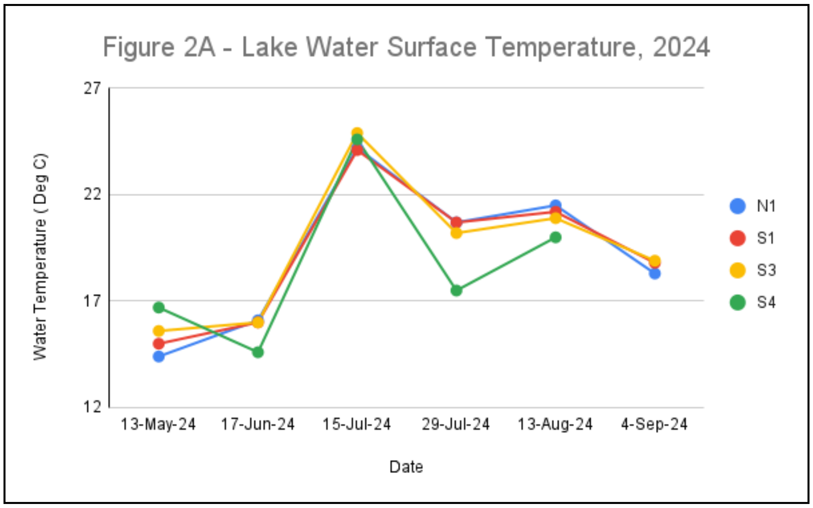
Sections 3.1.1 to 3.1.7 describe the variation in concentration for temperature, Secchi disk depth measurements, turbidity, specific conductance, pH, dissolved oxygen, and total and dissolved phosphorous. In 2020, CLSS added nitrate, iron and manganese, hardness, alkalinity, and chloride to the water quality analyses.

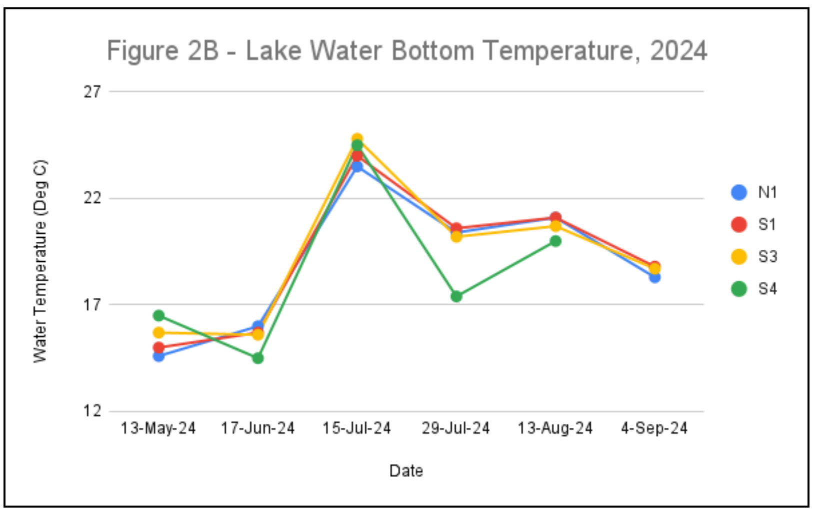
3.1.1 Temperature

Lake temperature is an important ecological condition because the quantity of dissolved oxygen available for fish and aquatic invertebrates declines at higher temperatures, creating a potential environmental stressor. (We understand from conversations at the BC Lake Keepers workshop held at the Columbia Ridge Community Centre in May of 2016 that temperatures greater than 20°C can dramatically stress fish so that fish kills may occur). Further, higher water temperatures increase the rate of degradation of organic matter, consuming dissolved oxygen in the lake water, further increasing the stress on fish and aquatic invertebrates. Figures 2A and 2B plot the temperatures of the lake water measured during 2024, at the surface and bottom depths.

As shown in Figure 2A and B, on July 15, 2024, between 10:20 AM and 11:50 AM, lake temperatures measured at N1, S1, S3, and S4 ranged from 23-25°C. The average temperature taken at these four sites was 24.4°C, and it is likely that higher temperatures were reached later in the day. This measurement exceeds the water quality guideline of 23°C established for Lake Windermere (Table 1). It also marks the highest water temperature recorded in our database since we began monitoring Columbia Lake in 2014.

Figure 2: Lake Temperatures 2024



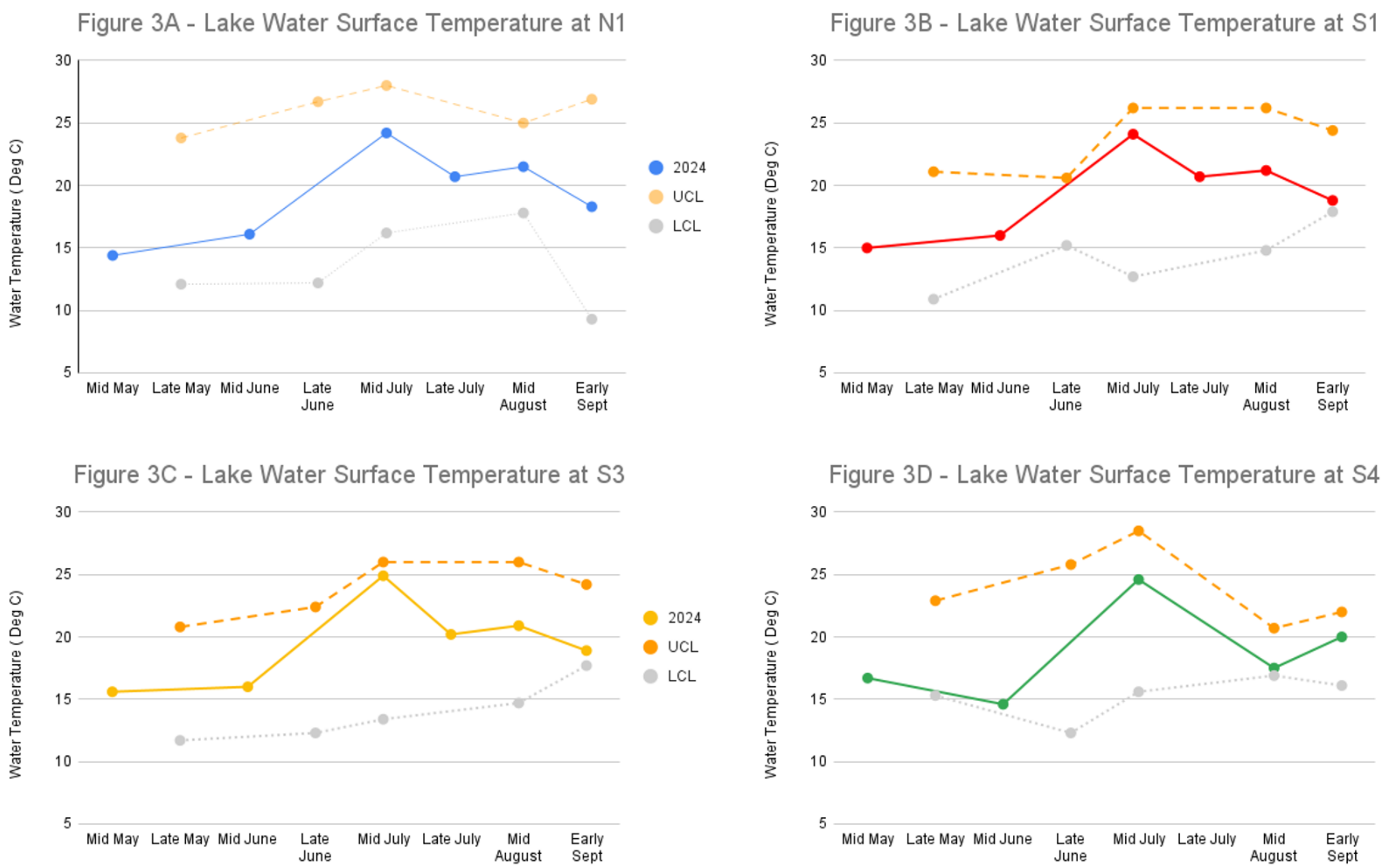


Notably, a substantial fish kill was observed on Columbia Lake in late July of 2024. While we cannot pinpoint the exact cause of the fish deaths, it is likely that the elevated water temperatures and the potential consequent reduction in dissolved oxygen concentrations were significant factors. (Note: The concentrations of dissolved oxygen which CLSS measured on July 15th appeared to be within a normal range. However, the actual concentration of oxygen in the lake water can fluctuate within a 24-hour period and can be affected significantly by the time of day and by location in the lake.)

The minimum temperatures measured in 2024, between approximately 15 and 17°C, were taken during the mid-May monitoring event. There are no noticeable differences (greater than 2°C) in temperature during any monitoring event with the location on the lake. Comparing Figures 2A and 2B illustrates there is no noticeable difference in water temperature with depth at all monitoring locations.

Figure 3, below, compares temperature measurements along the lake in 2024 to the calculated upper and lower control limits (UCL and LCL, see section 3.1). In 2023 (*CLSS Water Quality Report 2023*) the lake temperature exceeded 20°C from the end of June to the end of the monitoring program in mid-August. However, the temperature recorded was steady at all four locations, at around 21°C, for this time period. In contrast, in 2024 water temperatures measured by CLSS were relatively low in mid-June (around 16°C) but showed a distinct peak in mid-July at all locations on the lake (about the time of the observed fish kill). Beyond this date, and to the end of the 2024 monitoring program, water temperatures were lower, at around 20^0. This temperature is more consistent with the lake temperatures observed during prior years.

Figure 3: Lake Temperatures Vs Control Limits



NOTE: Data from a CLSS water depth monitor at Columere marina (Hobolink) confirm that there was a rapid rise in lake temperature in July and that the temperature remained above 22°C for more than two weeks.

3.1.2 Secchi Disk Measurements

Secchi disk measurements are used to qualitatively determine the clarity of the water. Water clarity is an important consideration for lake water quality since it improves the aesthetic appeal of the lake to recreational users and increases the chance of successful predation by birds, terrestrial animals, and fish. Clear water also promotes the photosynthetic processes needed to maintain the ecological health of the lake.

The measurement involves dropping a marked disk into the lake water and determining when the symbols on the disk are no longer visible from the lake's surface. Monitoring the difference between the Secchi depth and lake depth is used to determine changes in the water's clarity.

In 2024 the lake depth and the Secchi depth did not differ substantially in most cases. At N1 and at S4, both depths were the same on all occasions. At S3, on one occasion both depths were the same and on the other three occasions the Secchi depth was only 1-9% less than the lake depth (0.05 - 0.35 m).

The only location where the Secchi depth was notably less than the bottom depth was at S1, the deepest sampling location on the lake. At this location, the Secchi disk depth and lake bottom measurements were identical on one occasion (Sept), but in August, the Secchi depth was 0.4 m less than the lake depth (8% less) and in mid-July the Secchi depth was estimated to be 1.5 m less than the lake depth (29% less).

Note: This observation of increased turbidity at S1 was concurrent with the lake's maximum temperature (3.1.1).

A plot of this information has not been provided.

3.1.3 Turbidity

Turbidity measurements are another means of measuring the clarity (or, in contrast, the cloudiness or murkiness) of the water but, unlike the Secchi disk, these measurements are made in terms of NTUs (Nephelometric Turbidity Units) - a quantifiable measure of turbidity.

The turbidity of lake water is influenced mostly by the growth of phytoplankton and by the quantity of suspended sediments it contains. In the open water zone, the main cause of turbidity increase is the growth of phytoplankton. In contrast, closer to the shoreline suspended sediments are introduced by surface water draining into the lake, by shoreline erosion, and by wave action and recreational activities which disturb the bottom sediments.

Organic matter that decays in the water as it warms up is also a significant contributor to the lake's murkiness. As noted before, the decay of organic matter consumes oxygen, and this may limit the oxygen available to support aquatic life. In many lakes the measured turbidity may also be influenced by some chemical reactions which create insoluble precipitates (carbonates mostly). However, Columbia Lake water has a low mineral content and so these chemical reactions are not as great a contributor to the turbidity as the suspended sediments and organic debris.

Turbidity measurements made during the 2024 monitoring events are plotted in Figure 4. Overall, the turbidity measurements are comparable to those measured in 2023 (CLSS Water Quality Annual Report for 2023), mostly between 0.5 and 1.5. However, Figure 4 shows that, in general, in 2024 the turbidity levels of the lake water did not decline over the summer months. In particular, in 2024 (Figure 4) the turbidity measured at N1 and S4 **increased** between mid-June and the end of July/mid-August, whereas in 2023 the measured turbidity was highest in mid and late May and **decreased** through late June and into August.

Figure 4: Turbidity of Lake Water 2024

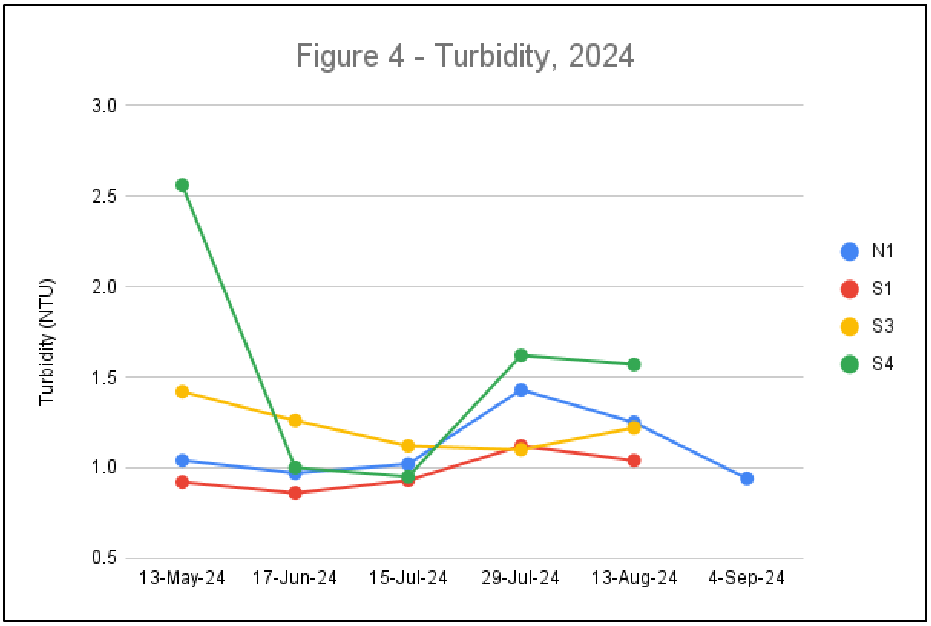
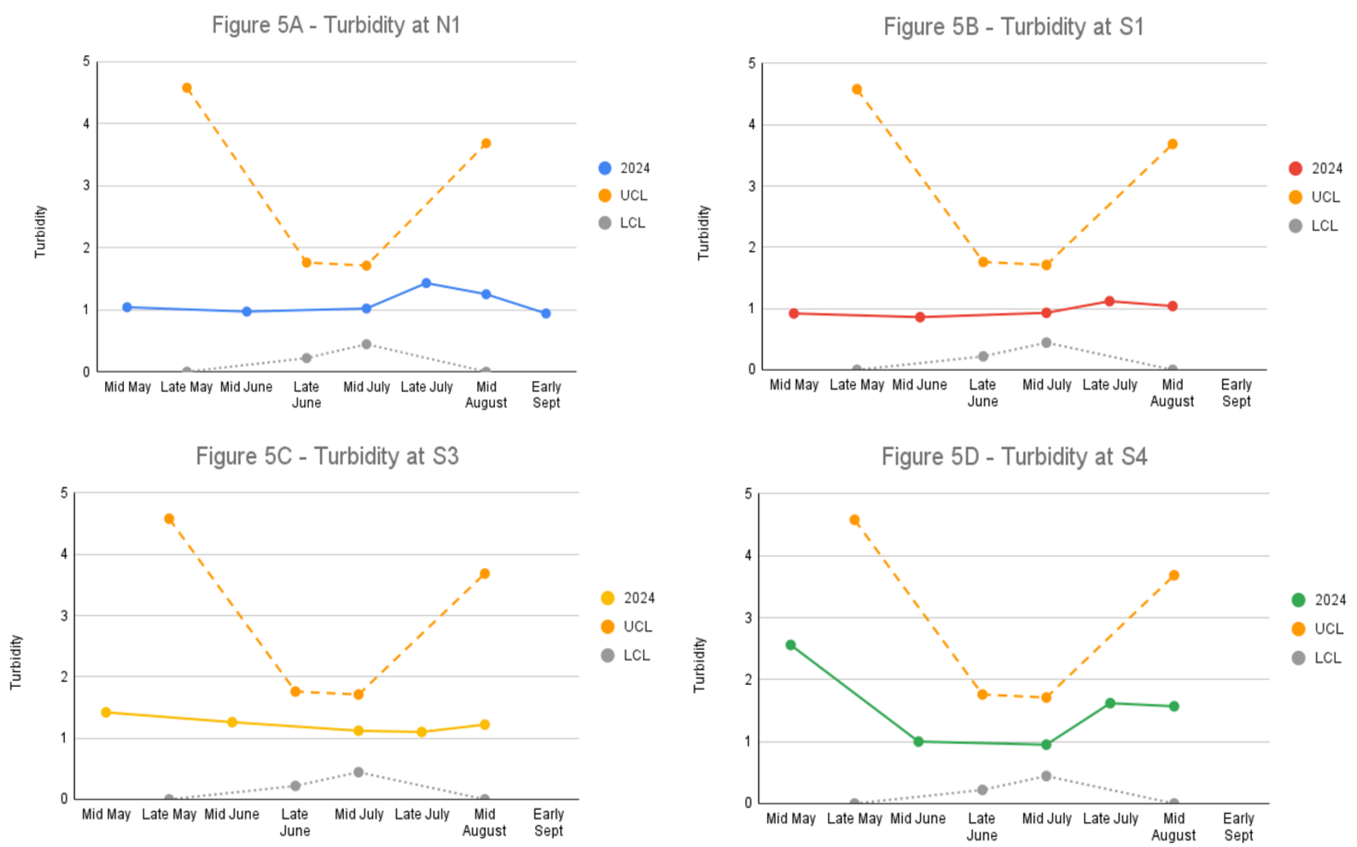


Figure 5 compares the turbidity measurements at each monitoring location on the lake to the calculated upper and lower control limits (UCL and LCL, see section 3.1). The four graphs (Figures 5 A, B, C, and D) show that turbidity in 2024 is comparable to that measured in previous years. All turbidity measurements were less than the UCL.

However, as described at both the north end of the lake (N1) and the south end of the lake (S4) an increase in turbidity was measured in late July to the middle of August. This period coincides with the fish kill on the lake.

The relationship between the growth of phytoplankton and stress on fish is not known, but phytoplankton growth, a significant cause of turbidity changes, requires oxygen. In 2024, the greater turbidity of the water coincided with higher water temperatures (see section 3.1.1) which are known to reduce levels of dissolved oxygen. This supports the suggestion that depleted oxygen levels in the water contributed directly to the fish kill.

Figure 5: Turbidity Vs Control Limits



3.1.4 Specific Conductance

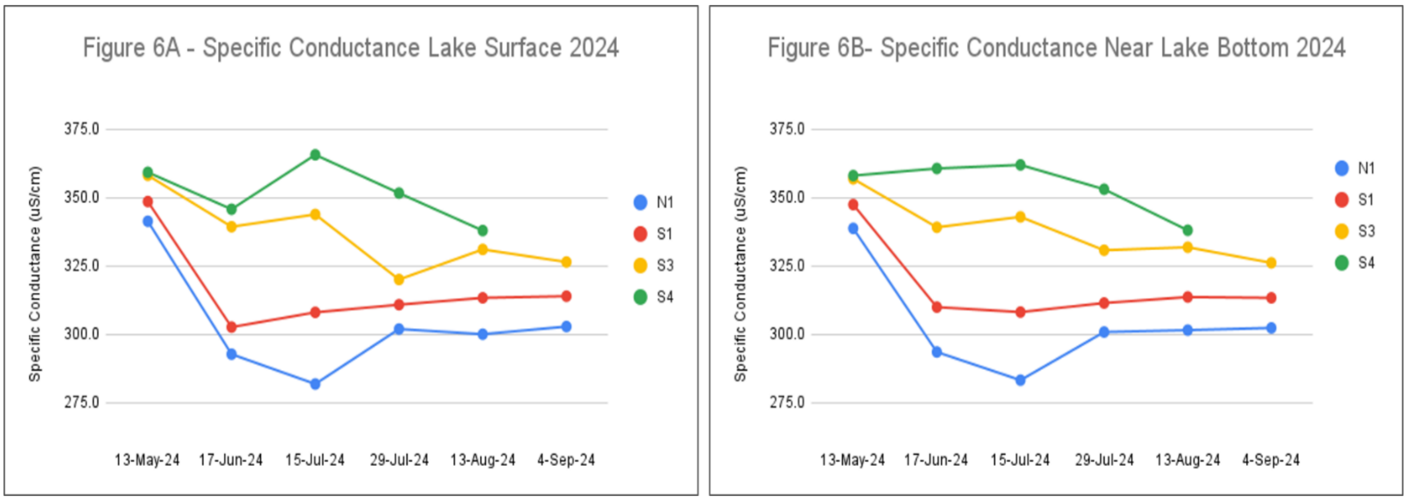
Conductance is a measure of the electrical conductivity of the lake water; an indicator of the quantity of dissolved salts the lake water contains. These dissolved salts consist of both mineral salts dissolved from particulate sediments in the lake, and salts that are carried into the lake by groundwater inflows and surface water drainage. A portion of the conductance of lake water is also due to soluble organic matters that create weak acids as they dissolve (like vinegars) but usually this contribution is considered minor. Conductance is a temperature-dependent measurement, increasing in warmer water. Because of this, most probes correct automatically for temperature and report the specific conductivity, which is the measurement of conductivity standardized to 25^{o}C.

Figure 6 plots the values measured for the specific conductivity during 2024. Figures 6A and 6B show there is no appreciable difference in specific conductance between water samples from the surface and bottom of the lake. Figures 6A and B also show that the greatest values for specific conductance are measured in water at the south end of the lake (at S3 and S4).

Both the small creek draining from the vicinity of Canal Flats (Section 3.3) and Marion Creek drain into the southern end of the lake, and the greater specific conductance recorded in this area of the lake may be associated with drainage from these streams. Also, as reported in 2018 by CLSS volunteers, this section of the lake is understood to be associated with groundwater inflow from beneath Canal Flats. Small sand volcanoes were observed from kayaks by CLSS volunteers at several locations across this end of the lake and along the small creek that drains into the lake. NOTE: The Village of Canal Flats reported in 2024 that the aquifer under the village receives a substantial but, as yet, unmeasured flow of fresh water from the Kootenay River and that this water then flows into Columbia Lake.

These observations suggest groundwater inflow is occurring across the south end of the lake, and this may also contribute to the greater specific conductance.

Figure 6: Specific Conductance of Lake Water



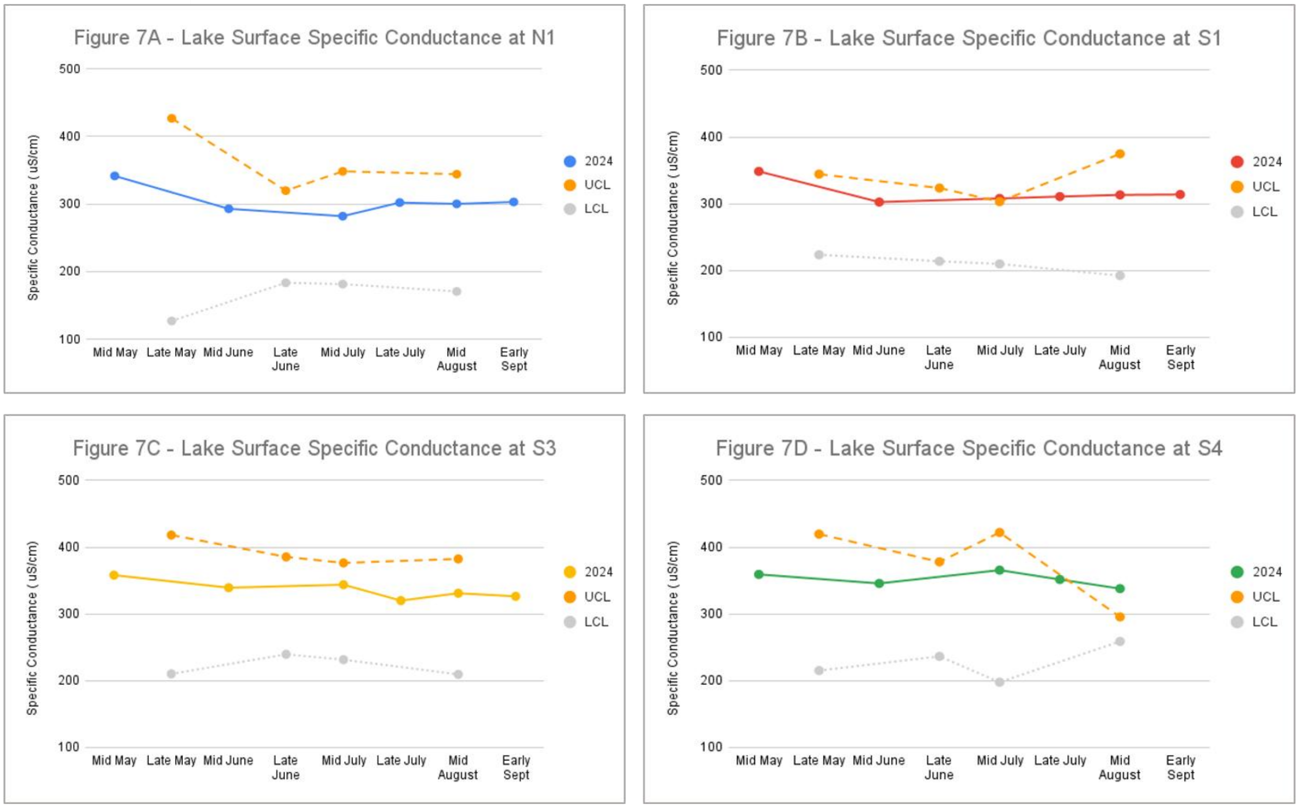
This suggestion is supported by the observation that the greatest specific conductance values are observed at all locations on the lake in the spring and that at this time, when the spring runoff is entering the lake, the values for specific conductance at the north end of the lake (N1 and S1) are closer to the values at the south end of the lake (S3 and S4).

The water quality objective stated in the Columbia Lake Management Plan for specific conductivity is 700uS/cm as established by Health Canada (Table 1). The values for specific conductivity for Columbia Lake are less than this concentration by a factor of two or three.

Figure 7 compares the values for specific conductance measured at each monitoring location on the lake to the calculated upper and lower control limits (UCL and LCL, see section 3.1). Figure 7 shows that in 2024 the specific conductance at S1 was near the upper range of the expected values (7B) and that at S4 (south end of the lake, 7D) the measured specific conductance exceeded the expected values for late July and mid-August.

CLSS's data (2014-2024) shows that specific conductance of the lake water is consistently lower at N1 and S1 than at S3 and S4, especially when the water levels in the creeks are high because of Spring freshet. This may be related to water inflow into the lake from Armstrong Bay and from Dutch Creek. (The specific conductance of the water in Dutch Creek (145-200 µS/cm) is notably less than that of the lake water.)

Figure 7: Specific Conductance of Lake Water Vs Control Limits



3.1.5 Potential of Hydrogen (pH)

Potential of hydrogen (pH) is a measure of the acidity (pH values less than 7) or alkalinity (pH values greater than 7) of water. The pH of water affects the survival and growth of aquatic organisms, and most organisms prefer a pH between 6.5 and 8.5. Values outside this range have a notable impact on the biochemical processes and metabolism of aquatic organisms. The pH of lake water affects the availability of dissolved nutrients like carbonates, phosphate, ammonia, iron, and trace metals, and low pH values can cause release of toxic metals such as lead, mercury, arsenic, and copper from lake sediments because these substances are more soluble at lower pH.

Water suitable for people to drink has a pH between 6.5 and 8.5 (Health Canada, Table 1), and the pH range for fresh water aquatic life considered acceptable by CCME is 6.5-9.0 (Table 1).

The pH values measured in 2024 at each monitoring location on Columbia Lake are shown in Figure 8, below. Generally, the pH values fall within a narrow range, from 8.1 to 8.8 and are similar among the four monitoring locations. Interestingly, the lowest pH values were always recorded at the south end of the lake (S4).

Figure 8: pH of Lake Water

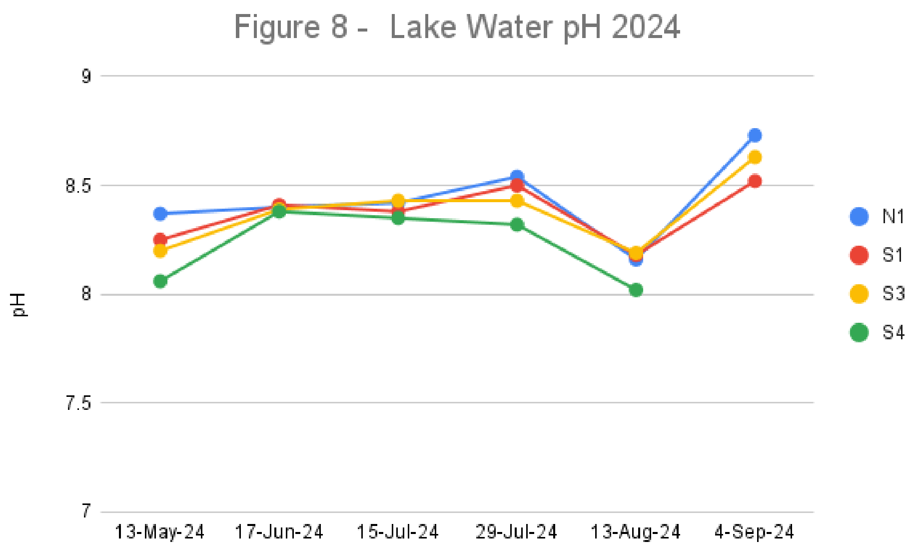
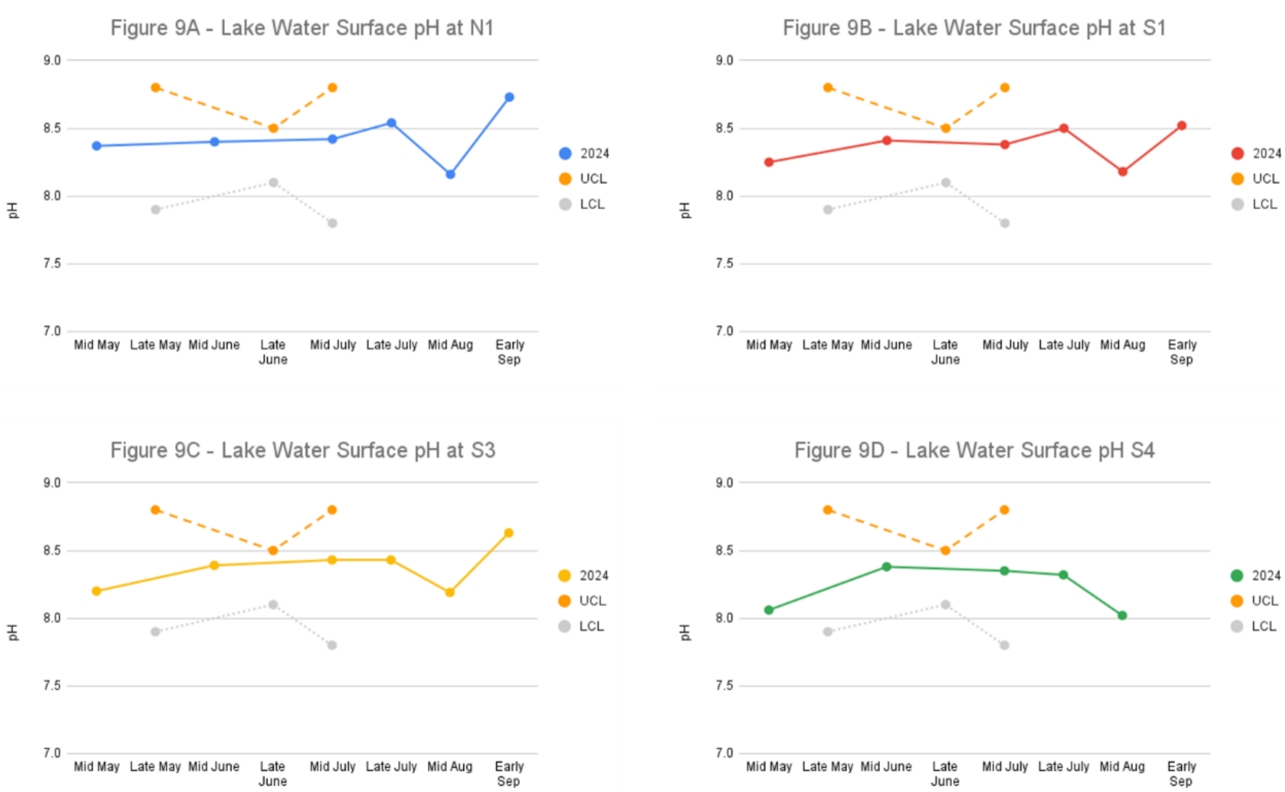


Figure 9 shows the measurements of pH at each monitoring location on the lake in 2024 compared with the calculated upper and lower control limits for pH on Columbia Lake (UCL and LCL, see section 3.1). The four graphs (Figures 9 A, B, C, and D) show that pH values in 2024 were comparable to those measured in previous years, with all measurements within the expected range. Note there are, as yet, no data available for UCL and LCL calculations for August and September.

Figure 9: pH Vs Control Limits



The pH of lake water is affected by a number of variables, including rates of photosynthesis by aquatic organisms (which increases pH during the day by reducing levels of dissolved CO_2), by rain fall (which tends to reduce pH), and by snow melt. Visually, the plots suggest that the lake water increased its pH slightly between May and September at all locations except S4. They also suggest that Columbia Lake is a slightly alkaline lake, the pH consistently falling between approximately 7.8 and 8.7.

3.1.6 Dissolved Oxygen

Oxygen is produced by photosynthesis and much of the dissolved oxygen in lakes is produced by aquatic plants, algae (phytoplankton and periphyton), and cyanobacteria. The other major sources of dissolved oxygen in lake water are 1) diffusion from the air and 2) precipitation falling directly on the lake or introduced as snow melt. Diffusion of oxygen into water from the air (aeration) is enhanced by lake surface disturbances that create turbulence, and by winds which produce waves. Some dissolved oxygen is provided to the lake by the inflow of surface drainage, but groundwater inflow will not contribute substantial amounts of dissolved oxygen.

Dissolved oxygen is required by aquatic species including fish, invertebrates, bacteria, and plants, because all organisms use oxygen in respiration. Even organisms which produce oxygen during photosynthesis consume oxygen during respiration. The amount of dissolved oxygen required varies from organism to organism: bottom feeders such as mussels and worms need minimal amounts (1-6 mg/L), whereas shallow water fish require higher amounts (5-10 mg/L).

The saturation level of oxygen in water is between 8 and 14 mg/L depending upon the water temperature. Oxygen is more readily soluble in cooler water than in warmer water: for example 14 mg/L at water temperatures of 1° C compared with 8 mg/L at water temperatures of 25° C.

Figure 10: Concentration of Dissolved Oxygen

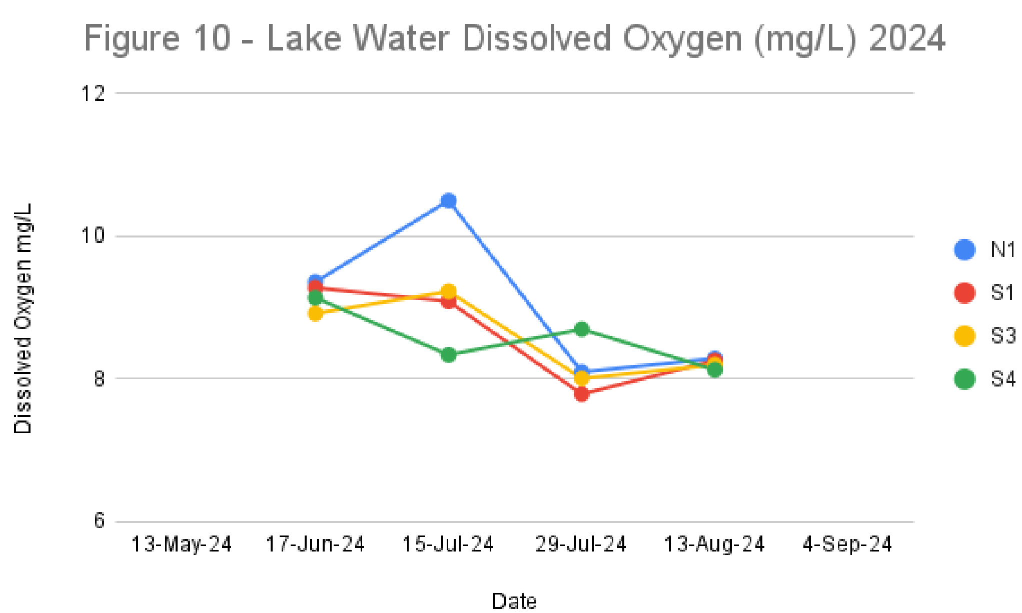
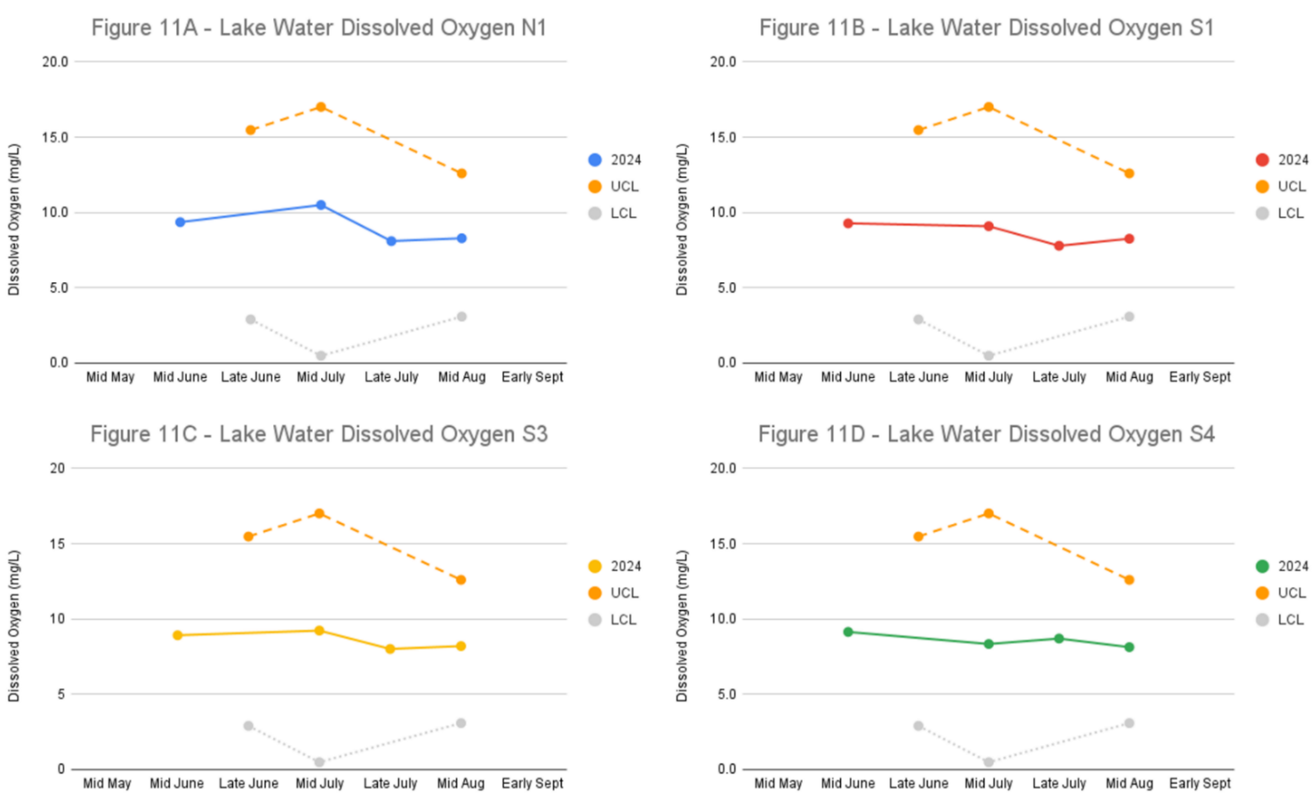


Figure 10 shows the concentrations of dissolved oxygen measured in 2024 at the four monitoring locations along the lake. Between mid-June and mid-August, the dissolved oxygen concentrations in Columbia Lake ranged from a minimum of 7.8 mg/L to a maximum of 10.5 mg/L.

Figure 10 illustrates that the concentrations of dissolved oxygen were generally higher in mid-June than in mid-August. With the exception of one measurement at N1 in mid-July, the dissolved oxygen concentrations generally declined over the monitoring period as the lake water temperature increased. (The average lake water temperature in mid-June was approx. 16°C compared with approx. 21°C in mid-August.)

Figure 11, below, compares the concentrations of dissolved oxygen at the four monitoring location on the lake in 2024 with the calculated upper and lower control limits (UCL and LCL, see section 3.1). As the graphs suggest (Figures 11 A, B, C, and D) the concentrations of dissolved oxygen measured in 2024 are within the expected ranges.

Figure 11: Concentration of Dissolved Oxygen Vs Control Limits



3.1.7 Total and Dissolved Phosphorus

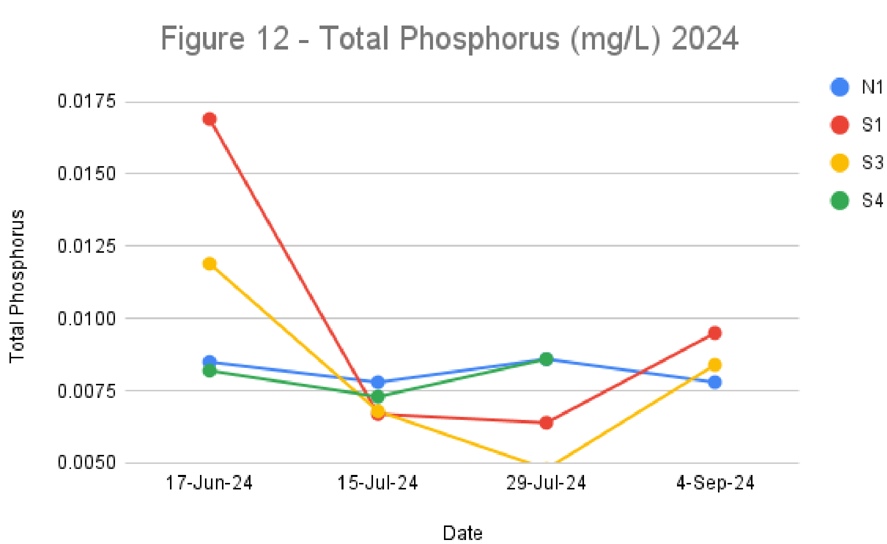
Phosphorous is a nutrient essential for the growth of plants and other photosynthetic organisms in lakes, such as algae (phytoplankton and periphyton). Photosynthetic algae are the principal feed stock of small fish and invertebrates, which in turn become the feedstock of larger fish and aquatic/amphibious vertebrates. Therefore, healthy lake water must contain phosphorous. Phosphates are the usable form in biological systems. Generally, phosphorus is the limiting nutrient in freshwater aquatic systems. Plant and algae growth will cease if phosphorus is unavailable. Natural levels usually range from 0.005 – 0.05 mg/L. LWA uses 0.010 mg/L total phosphorus as a maximum. This is the maximum for a normally **oligotrophic** lake, with slow growth and low productivity.

Phosphorous is provided naturally in lake water by drainage of water courses that contain dissolved mineral salts and organic materials into the lake. Phosphorus is abundant in the earth's crust. Phosphorous may also be introduced into lake water by wastewater discharge and drainage of organic wastes from agricultural lands. This can be a problem because too much phosphorous causes algal blooms, with a subsequent reduction in concentrations of dissolved oxygen, and stagnation of the lake water, an ecological condition not favorable to a healthy lake. Phytoplankton consume oxygen during respiration at night. Also, when they die and settle to the lake bottom they stimulate microbial decay processes which consume oxygen. These factors can cause drastic fluctuations in oxygen levels in the lake water at night.

When measuring phosphorus in a water sample, we actually measure the concentration of total phosphorus and the concentration of dissolved phosphorus. Total phosphorus (TP) is the total concentration of phosphorus in the sample, while dissolved phosphorus (DP) is the concentration of phosphorus remaining in a sample filtered to remove particles. Total phosphorus includes the phosphorous in organic matter like plankton (living and dead), and in suspended sediments. Dissolved phosphorus is the phosphorus remaining in the filtered water. This is the bioavailable fraction which is easily taken up by growing plants and algae.

The total phosphorous concentrations measured by CLSS during the four monitoring events on Columbia Lake in 2024 are plotted in Figure 12.

Figure 12: Total Phosphorus Concentration in Columbia Lake



CCME (2004) Canadian Water Quality Guidelines for the Protection of Aquatic Life states that there are limitations in measurements of biologically available phosphorus (dissolved) and so they recommend TP as the most meaningful measurement of phosphorus.

Changes in total phosphorus in a water sample represent *apparent* gain or loss of phosphorus within the water sample. This could be decreases from phytoplankton death and/or from sedimentation. Sedimentation is apparently normally favoured in freshwater. Increases in total phosphorus represent exogenous sources of phosphorus, such as stirred up sediments, surface run-off, and so on.

Dissolved phosphorus is an indicator that might tell us something about plankton growth, but measurements are limited in their usefulness. They are normally very low anyway, often below the minimum detection level, and so decreases related to plankton growth would be undetectable.

The maximum concentrations of TP measured for 2024 occurred in the mid-June monitoring event. The largest concentrations of total phosphorous were measured in the middle of the lake at S1 and S3. At all locations on the lake the TP levels declined by mid-Jul to less than 0.01 mg/L and remained at that level.

Table 2 includes the TP and DP concentrations measured in 2024.

Comparing the total phosphorous concentration to the concentration used by Lake Windermere of 0.01mg/L (Table 1) to assess water quality, there were only two measurements exceeding this concentration. Both measurements were taken in the middle of the lake (S1 and S3) during the middle of June monitoring event.

CLSS has been collecting dissolved and total phosphorous concentrations since the monitoring program began in 2014. CLSS will be reviewing these data more extensively in 2025 as funding permits. Our measurements for total phosphorus indicate that levels in Columbia Lake are consistently between 6 and 10 μg/L. Canadian trigger ranges for total phosphorus suggest that 4-10 μg/L indicates an oligotrophic lake. Mesotrophic lakes have total phosphorus levels of 10-20 μg/L.

Table 2: Concentrations of Nitrate, Chloride, Sulphate, Phosphorus, and Manganese in Columbia Lake

	Units	MRL	Std (CDWQG)	2024				2023		2022			2021			2020	
N1				6-17-2024	7-15-2024	7-29-2024	9-4-2024	5-29-2023	7-14-2023	5-27-2022	7-20-2022	8-28-2022	6-10-2021	7-22-2021	8-21-2021	05-28-20	07-18-20
Chloride	mg/L	0.1	AO<=250	4.39	4.31	4.97	5.61	4.28	5.12	5.67	3.04	4.12		3.64	4.74	5.7	5.04
Nitrate (as N)	mg/L	0.01	MAC=10	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.01	<0.010	<0.010		<0.010	<0.010	<0.010	<0.010
Sulfate	mg/L	1	AO<=500	27.8	26.3	28.9	31.3	26.1	29.4								
Phosphorus, Total (as P)	mg/L	0.005	N/A	0.0085	0.0078	0.0086	0.0078	0.0124	0.0089	0.0107	0.0069	0.0076	0.0084	0.0127	0.0074	0.0073	0.0082
Phosphorus, Total Dissolved	mg/L	0.005	N/A	0.0064	<0.0050	<0.0050	0.0068	0.0051	<0.0050	0.0055	0.0054	<0.005	0.0076	0.0103	0.0058	0.0039	0.0056
Iron, total	mg/L	0.01	AO<=0.3	0.014	0.018	0.024	0.011		0.013	0.011	<0.010	0.013		0.019	0.018	<0.010	<0.010
Manganese, total	mg/L	0.0002	MAC=0.12	0.00557	0.027	0.0155	0.0169		0.0199	0.0071	0.00215	0.0241		0.0231	0.00969	0.00472	0.0038
S1				6-17-2024	7-15-2024	7-29-2024	9-4-2024	5-29-2023	8-14-2023	5-27-2022	7-20-2022	8-27-2022	6-10-2021	7-22-2021	8-21-2021	05-28-20	07-18-20
Chloride	mg/L	0.1	AO<=250	4.76	4.8	5.26	5.62	4.33	5.36	5.32	3.53	4.48		4	4.97	5.23	4.14
Nitrate (as N)	mg/L	0.01	MAC=10	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010		<0.010	<0.010	<0.010	0.064
Sulfate	mg/L	1	AO<=500	29.1	28.8	29.6	31.6	26.3	31.1								
Phosphorus, Total (as P)	mg/L	0.005	N/A	0.0169	0.0067	0.0064	0.0095	0.0109	0.0118	0.012	0.0069	0.0072	0.0076	0.0127	0.0074	0.0082	0.0077
Phosphorus, Total Dissolved	mg/L	0.005	N/A	0.0062	<0.0050	<0.0050	0.0064	0.0052	0.0087	0.008	<0.005	<0.005	0.0057	0.0103	0.0054	0.0054	0.0065
Iron, total	mg/L	0.01	AO<=0.3	0.011	0.011	0.015	<0.010		<0.010	0.016	<0.010	<0.010		0.03	0.013	<0.010	<0.010
Manganese, total	mg/L	0.0002	MAC=0.12	0.00711	0.0189	0.0165	0.0128		0.0171	0.0087	0.00277	0.0197		0.0172	0.0117	0.00831	0.0108
S3				6-17-2024	7-15-2024	7-29-2024	9-4-2024	5-29-2023	8-14-2023	5-27-2022	7-20-2022	8-27-2022	6-10-2021	7-22-2021	8-21-2021	05-28-20	07-18-20
Chloride	mg/L	0.1	AO<=250	5.96	6.01	6.14	6.11	5.38	6.05	5.97	4.9	6.16		5.04	5.51	5.04	4.74
Nitrate (as N)	mg/L	0.01	MAC=10	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010		<0.010	<0.010	<0.010	<0.010
Sulfate	mg/L	1	AO<=500	33.3	33	32.9	34.2	30.3	34.9								
Phosphorus, Total (as P)	mg/L	0.005	N/A	0.0119	0.0068	<0.0050	0.0084	0.0103	0.0066	0.0095	0.0083	0.0088	0.0106	0.0129	0.0061	0.0072	0.0084
Phosphorus, Total Dissolved	mg/L	0.005	N/A	0.0062	<0.0050	<0.0050	0.0108	0.0055	<0.0050	0.0093	<0.005	<0.005	0.007	0.0119	<0.005	0.0042	0.0064
Iron, total	mg/L	0.01	AO<=0.3	<0.010	<0.010	0.013	<0.010		<0.010	<0.010	<0.010	<0.010		0.014	<0.010	0.015	<0.010
Manganese, total	mg/L	0.0002	MAC=0.12	0.00515	0.00598	0.00843	0.00685		0.00538	0.00524	0.0014	0.0052		0.0063	0.00433	0.0038	0.0078
S4				6-17-2024	7-15-2024	7-29-2024	9-4-2024	5-29-2023	8-14-2023	5-27-2022	7-20-2022	8-27-2022	6-10-2021	7-22-2021	8-21-2021	05-28-20	07-18-20
Chloride	mg/L	0.1	AO<=250	6.69	6.66	6.42		6.13	6.36	6.39	5.97	6.4		5.83	5.96	5.7	5.04
Nitrate (as N)	mg/L	0.01	MAC=10	<0.010	<0.010	<0.010		<0.010	<0.010	<0.010	<0.010	<0.010		<0.010	<0.010	<0.010	<0.010
Sulfate	mg/L	1	AO<=500	36.3	35.1	35.3		33	36.4								
Phosphorus, Total (as P)	mg/L	0.005	N/A	0.0082	0.0073	0.0086		0.0087	0.0093	0.0141	0.0092	0.0106	0.0091	0.0116	0.0079	0.0086	0.0115
Phosphorus, Total Dissolved	mg/L	0.005	N/A	0.0065	0.0064	0.005		0.0054	0.0056	0.0063	0.0053	<0.005	0.0079	0.0101	0.0069	0.004	0.099
Iron, total	mg/L	0.01	AO<=0.3	<0.010	0.011	0.29			0.01	<0.010	<0.010	<0.010		0.029	0.011	<0.010	<0.010
Manganese, total	mg/L	0.0002	MAC=0.12	0.00339	0.00514	0.0115			0.00351	0.00496	0.00101	0.00404		0.00522	0.00365	0.00472	0.0038

3.1.8 Additional Analyses of Lake Water in 2024

During the 2024 monitoring program CLSS collected water samples at each of the four monitoring locations on the lake which were analyzed for levels of nitrate, chloride, sulphate, and iron and manganese. The results of these water quality analyses are in **Table 2**.

Nitrate is a nutrient necessary for aquatic organisms to thrive and is introduced naturally to the lake as dissolved nitrate in rainfall and snowmelt. It is not normally the limiting nutrient for algal growth in lakes, but if nitrate concentrations become too great this may lead to algal blooms, especially where phosphorus is not limited. Algal blooms can lead to excessive oxygen consumption and eutrophication of lake waters. Alternatively, if a lake has limited amounts of phosphorus so that algal growth is limited, excess nitrogen in the water becomes toxic. Nitrate, and especially nitrite and ammonia, are toxic to a variety of invertebrates which form the base of the food chain in the lake. The toxicity of the various forms of excess nitrogen varies with temperature and pH.

Nitrate is frequently a component of runoff from agricultural lands and wastewater systems into lakes, and so measurement of nitrate levels in a lake is a reliable means for detecting possible contributions to the lake from these sources.

Nitrate concentrations were measured at the onset of the program on April 20, 2014 and continued to be measured until May of 2016. All nitrate concentrations were less than the analytical detection limit. Nitrate concentrations were thus not measured in 2017, 2018, or 2019. However, we noted that detectable concentrations of nitrate were found in stream water during the stream sampling program conducted in the early autumn of 2019 (Section 3.3). Based on these measurements we decided to reintroduce the measurement of nitrate in lake water to our annual sampling program. The results provided in **Table 2** show that for 2020-2024 inclusive, nitrate concentrations have been consistently less than the analytical detection limit (<0.010 mg/L).

Iron and manganese were included in the chemical analyses in 2020-2024 to explore increases in turbidity noted in the lake water over the summer months in 2019. The increased turbidity could have been due to increases in phytoplankton growth and/or disturbance of bottom sediments. Bottom sediments can be disturbed through shoreline erosion, sediments from streams draining into the lake, wave action, and recreational activity.

Table 2 shows that in 2024 concentrations of iron above the minimum detection limit (10 μg/L) were measured on several occasions. At N1, the north end of the lake, all four measurements for iron in 2024 exceeded 10 μg/L. However, all concentrations measured were substantially lower than the water quality standards proposed by CCME (Table 1, 300 μg/L). At S4, the south end of the lake, the concentration of iron was consistently at or below the method detection limit, except for July 29th, when the amount of iron measured was 0.29 mg/L or 290 μg/L. This is very close to the CCME water quality standard (Table 1).

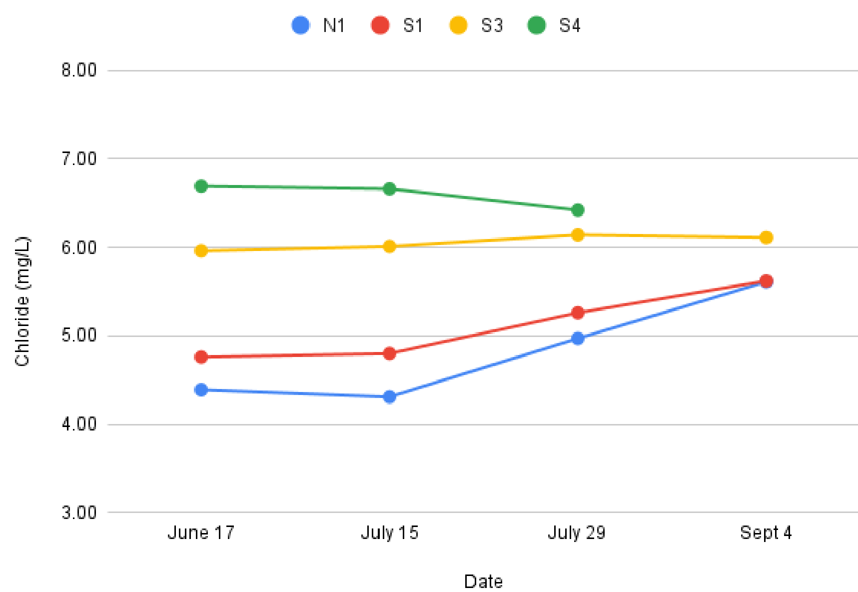
As noted in section 3.1.1, on July 15th we observed the highest temperatures we have ever recorded in Columbia Lake. On this date, the Secchi disc measurements at S3 showed a 28% reduction in apparent lake depth, indicating marked turbidity, and direct measurements indicated notable increases of turbidity from mid-July to the end of July. Dissolved oxygen levels also decreased from mid-July to the end of July, especially notably at N1.

The concentrations of manganese were mostly within the ‘normal’ range we have observed for Columbia Lake (Table 1, 4.2 – 15.3 µg/L).

Chloride was added to the chemical analysis because it was noted in the results of BCMOE’s sampling program that Columbia Lake contained greater concentrations of chloride than other neighboring lakes. Furthermore, analysis of water quality in the small creek draining into the lake from Canal Flats in 2019 showed that the creek had chloride concentrations much greater than those measured in the other streams. CLSS wanted to monitor chloride concentrations in the lake.

The chloride concentrations measured in 2020-2024 (Table 2) show that the greatest concentrations of chloride are at the south end of the lake, at S3 and S4. In 2024, at N1 and S1 the concentration of chloride increases by approx. 20% from the middle of June until late September. In contrast, the levels remain quite steady at S3 and S4 and they are consistently greater. This is illustrated below:

Concentration of Chloride at Four Locations on Columbia Lake by Date in 2024



Overall, at N1, S1, and S3, the chloride concentrations measured in 2024 are similar to those measured in 2020 and 2021. However, at S4 it appears that the average concentration of chloride in the water has increased since 2020, from 5.37 ± 0.47 to 6.59 ± 0.15 mg/L, respectively. While all of these concentrations are much lower than the CCME concentration standard to suggest a water quality concern (Table 1, CCME 120 mg/L), the apparent increase in concentration of chloride at S4 since 2020, near Canal Flats, suggests some need for ongoing monitoring.

This observation is consistent with our finding in 2024 that concentrations of chloride are greater in the Canal Flats creek than in Hardie Creek or Dutch Creek. (Section 3.2)

In 2023, an 'along-the-lake' profile was completed on 18th July, which included measurement of chloride concentrations at 14 locations on the lake, from north to south. The profile showed that concentrations of chloride increase steadily from lowest at the north end to highest at the south end. The profile also showed that, at most of the 14 locations, chloride concentrations in the lake in 2023 were greater than any previously recorded (2019, 2020, 2022). Our measurements of chloride concentrations in 2024 show that concentrations at S4 were consistently greater than any previously recorded between 2020 and 2023 (see Table 2).

Sulphate

Concentrations of sulphate in the lake water increase progressively from north to south (N1<S1<S3<S4). The concentrations at S4, near Canal Flats, were consistently greatest. This observation is consistent with our finding in 2024 that concentrations of sulphate are greater in the Canal Flats creek than in Hardie Creek or Dutch Creek. (Section 3.2)

3.2 Annual Monitoring Program: The Streams

CLSS monitored three streams flowing into the lake during 2024:

Dutch Creek – a high rate of turbulent flow, the creek bed was composed largely of boulders that were not stained with iron oxides, and the water was clear. There was no organic growth along the stream sides.

Hardie Creek - steady and turbulent water flow - the creek bed had gravel-sized material with iron and manganese oxide staining (red to black colored coating) on the gravel particles and the water sampled was clear. There was no organic material along the stream sides.

Canal Flats Creek - steady water flow (no turbulence) - the creek bed was covered in fine-grained grey clay to silt type materials that were easily disturbed and the water became muddy quickly. The water sampled was clear and the stream banks were covered by marshy grasses. At points in 2024, the water level was too low to use the Van dorn apparatus, and there appeared to be more algae than usual (June 10th).

(Marion Creek, monitored by CLSS in prior years, could not be accessed in 2024. Likewise Lansdowne Creek was not monitored in 2024.)

3.2.1 Regular Stream Monitoring Program 2024

CLSS monitored these streams on May 14, May 29, June 10, July 10, and July 30. The water quality measurements made on each stream included: water temperature, specific conductance (conductivity), dissolved oxygen, pH, and turbidity.

The stream measurements for 2024 are summarized in Table 3 and compared with measurements taken in 2023 and 2022. (Measurements taken in 2020 and 2021 were presented in the 2023 Water Quality Annual Report but are not included here.) Some of the stream quality data are compared in Figure 13.

Water Temperature

The temperatures tabulated in Table 4 and plotted in Figure 13A show that the water temperature in Dutch Creek and Hardie Creek generally increased over the summer months in 2024, whereas the water temperature in the Canal Flats creek remained fairly constant, varying by less than one degree C over the summer months. By the end of the summer the water temperature in the Canal Flats creek was lower than the water temperature in both other creeks by approximately 4°C. This observation is in keeping with temperature changes in these creeks measured in previous years (2020-2023).

The low and consistent temperature measurements for the Canal Flats creek are a consequence of the point of measurement being very close to the origin of the spring which we understand to be groundwater discharge from the Canal Flats area. The monitoring locations on all other streams are far down the drainage from the stream's origins and thus the water has had a long time to warm up as it runs over the ground.

The largest variation in water temperature was measured in Dutch Creek, with temperatures ranging from about 6°C in May to about 12°C in late July.

Figure 13: Temperature of Stream Water

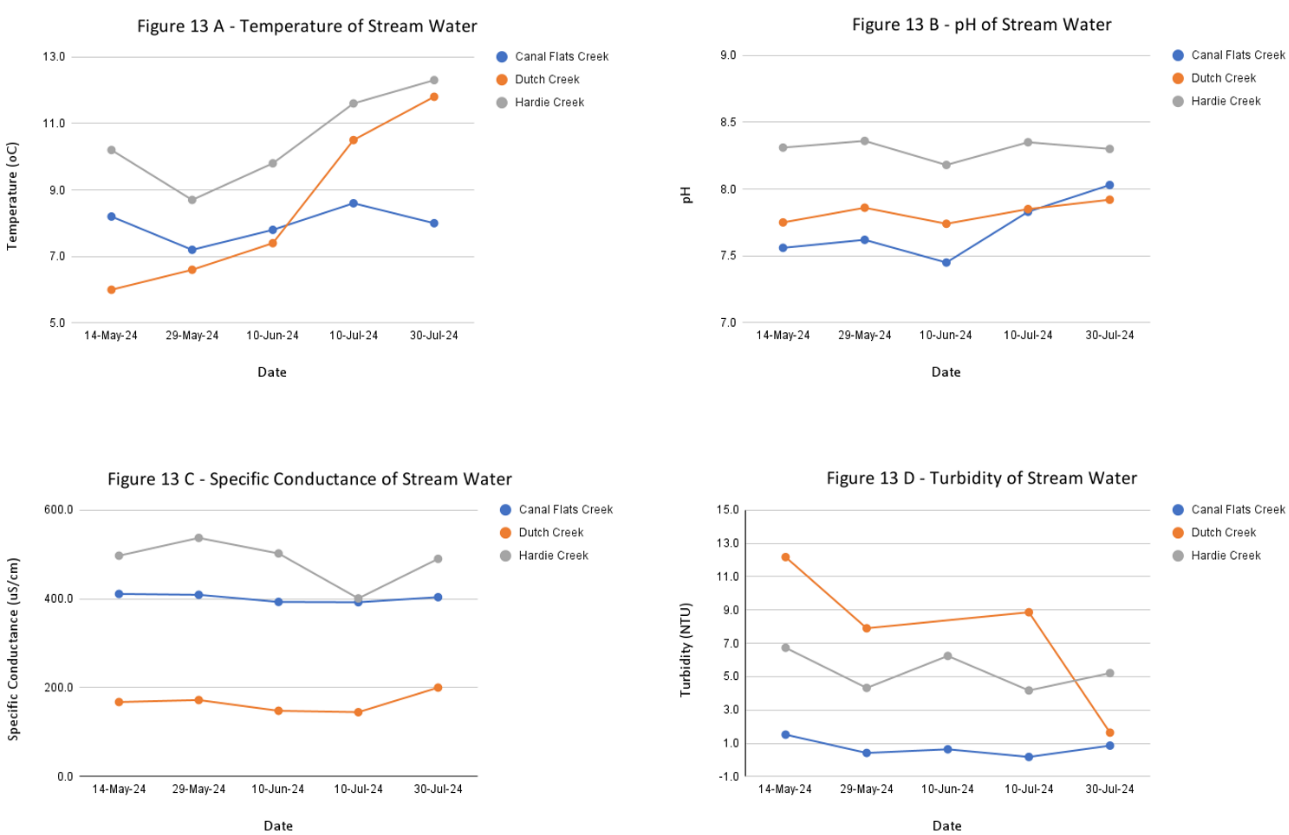


Table 3: Comparison Of Stream Water Quality Measurements in 2024

Stream	Date	Time	Water Temp (°C)	Specific Cond. (µS/cm)	Dissolved Oxygen (mg/L)	pH	Turbidity (NTU)
Canal Flats Creek 2022	10-May-22	11:31 AM	6.9	412.7	9.2	7.6	0.7
	22-Jun-22	9:47 AM	8.2	394.0	11.2	7.9	0.4
	12-Jul-22	12:23 PM	11.1	403.3	8.1	8.2	0.6
	17-Aug-22	1:05 PM	9.4	395.5	10.7	8.5	4.0
2023	15-May-23	1:20 PM	8.0	380.6	10.0	7.9	0.2
	29-May-23	12:26 PM	8.2	394.5	12.2	7.8	0.3
	15-Jun-23	9:45 AM	7.1	401.0	9.4	7.9	0.3
	27-Jun-23	9:19 AM	8.3	392.0	9.3	8.0	0.3
	25-Jul-23	11:10 AM	8.4	389.4	14.8	-	1.0
	14-Aug-23	7:55 AM	7.6	407.7	14.2	-	0.7
2024	14-May-24	11:33 AM	8.2	410.9	9.0	7.6	1.5
	29-May-24	10:00 AM	7.2	409.0	-	7.6	0.4
	10-Jun-24	10:06 AM	7.8	393.0	-	7.5	0.6
	10-Jul-24	10:04 AM	8.6	392.3	-	7.8	0.2
	30-Jul-24	1:40 PM	8.0	403.6	8.8	8.0	0.9
Dutch Creek 2022	10-May-22	1:56 PM	6.7	225.7	11.5	8.4	2.5
	10-May-22	1:56 PM	6.7	225.7	11.5	8.4	2.5
	22-Jun-22	11:55 AM	6.9	139.3	13.1	8.7	39.5
	12-Jul-22	10:15 AM	7.6	132.7	10.7	8.3	17.0
	17-Aug-22	10:57 AM	12.3	181.4	10.9	8.8	1.2
2023	15-May-23	9:30 AM	5.5	134.5	11.5	8.0	18.7
	29-May-23	7:39 AM	7.0	136.4	12	7.3	15.4
	15-Jun-23	8:30 AM	7.5	150.1	10.3	7.8	8.1
	27-Jun-23	8:00 AM	10.6	168.9	11.5	8.0	1.6
	25-Jul-23	8:46 AM	12.9	201.0	14.2	-	3.0
	14-Aug-23	2:12 PM	16.8	214.0	10.2	-	1.9
2024	14-May-24	9:45 AM	6.0	167.8	11.4	7.8	12.2
	29-May-24	8:15 AM	6.6	172.3	-	7.9	7.9
	10-Jun-24	8:30 AM	7.4	148.1	-	7.7	79.3**
	10-Jul-24	8:40 AM	10.5	145.0	-	7.9	8.9
	30-Jul-24	11:50 AM	11.8	200.2	9.9	7.9	1.6
Hardie Creek 2022	10-May-22	1:12 PM	7.9	507.0	13.2	8.5	1.7
	10-May-22	1:12 PM	7.9	507.0	13.2	8.5	1.7
	22-Jun-22	11:20 AM	11.1	507.0	12.5	8.5	1.7
	12-Jul-22	11:03 AM	10.5	492.0	11.7	8.3	4.4
	17-Aug-22	11:42 AM	11.3	474.0	10.6	8.7	2.6
2023	15-May-23	11:15 AM	9.8	503.0	12.8	8.5	1.4
	29-May-23	8:20 AM	9.9	546.0	9.6	8.4	1.4
	15-Jun-23	9:05 AM	10.1	600.0	11.3	8.5	3.3
	27-Jun-23	8:40 AM	11.1	531.0	11.1	8.5	1.4
	25-Jul-23	9:35 AM	12.3	503.0	15.2	-	3.2
	14-Aug-23	1:40 PM	13.4	479.0	9.0	-	2.2
2024	14-May-24	10:37 AM	10.2	497.0	-	8.3	6.7
	29-May-24	9:06 AM	8.7	537.0	-	8.4	4.3
	10-Jun-24	9:18 AM	9.8	502.0	-	8.2	6.2
	10-Jul-24	9:15 AM	11.6	400.9	-	8.4	4.2
	30-Jul-24	12:30 PM	12.3	489.9	9.6	8.3	5.2

pH

The pH of the stream water ranged from 7.5 to 8.4. Figure 13B shows that the lowest pH values were measured in the Canal Flats creek and the highest pH values were measured in Hardie Creek. All of the pH values measured are within the range of pH for good water quality (Table 2).

Specific Conductance

The lowest values for the specific conductance (Figure 13C) in the range of 145 to 200 μS/cm were measured in Dutch Creek: the stream with the greatest flow rate of the three that CLSS monitored. In contrast the water in Hardie Creek and the Canal Flats creek had specific conductance values (approx. 400-500 μS/cm) that were more than twice those in Dutch Creek, with Hardie Creek consistently having the greatest specific conductance. The specific conductance values in all three creeks were much less than the Health Canada guideline (Table 1) of 700 μS/cm.

Turbidity

For 2024, the turbidity values measured on the creeks ranged between 0.2 and 12.2 NTU's (Figure 13D). An unusual value of 79.3 NTU's was measured on Dutch Creek in mid- May which was associated with a very high flow rate in the creek. This was not graphed. Dutch Creek showed the greatest turbidity from May to mid-July. This decreased markedly by the end of July. It is likely that much of this turbidity was related to the Spring run-off, with high water volumes and fast flow rates disturbing sediments on the creek bed.

All of the turbidity measurements made on Dutch Creek and Hardie Creek in 2024 were greater than the value used by Health Canada for drinking water quality guidelines (1 NTU). (The range measured in Columbia Lake in 2024 was mostly <1 to 1.5 NTU's.) Turbidity in fresh water can result from growth of phytoplankton and this is especially likely in Hardie Creek, with its low flow rates and relatively high water temperatures.

The Canal Flats creek had consistently low turbidity which is likely related to its emergence from the aquifer under Canal Flats which is effectively filtered through sand and gravel.

Dissolved oxygen

Dissolved oxygen concentrations ranged from 8.8 – 11.4 mg/L and were greater than 8 mg/L in all three creeks (Table 3). The concentration of dissolved oxygen has not been plotted for 2024 because it was measured only twice at Dutch Creek and the Canal Flats creek, and only once at Hardie Creek. The concentrations that were measured do not differ substantively from the 'normal' values we have measured (2020-2024).

3.2.2 Additional Analyses of Stream Water 2024

On the 29th of May and the 30th of July, 2024, stream samples were also tested for total and dissolved phosphorus, iron, manganese, sulphate, nitrate, and chloride. On the 29th of May, total metals were also measured.

Chloride

As shown in Table 4, chloride concentrations were negligible in Dutch Creek and Hardie Creek, but were nearly 20X greater in the Canal Flats creek. This is in keeping with the relative concentrations of chloride measured on Columbia Lake (section 3.1.8), which are greatest at the south end of the lake, near Canal Flats where the Canal Flats creek enters Columbia Lake. While the concentrations of chloride are well below CDWQG standards for drinking water, they do appear to be increasing at the south end of the lake and this indicates a need for continued monitoring of chloride levels in both the lake and the Canal Flats creek.

Nitrate

Similarly, nitrate levels in Hardie Creek and Dutch Creek are lower than those in the Canal Flats Creek, with concentrations in the Canal Flats creek being about 3.5 times greater. Nitrate concentrations in Columbia Lake were consistently less than the analytical detection limit (<0.010 mg/L). (Section 3.1.8)

Sulphate

Concentrations of sulphate measured in the Canal Flats creek were up to 4 times greater than those measured in Dutch Creek and twice those measured in Hardie Creek. As noted with chloride concentrations, concentrations of sulphate in Columbia Lake increase progressively from north to south, with concentrations being consistently greatest at the south end near the Canal Flats creek. (Section 3.1.8).

Total Phosphorus

Concentrations of total phosphorus were low in all three creeks, remaining close to or below the minimum detection limit.

The greatest value recorded was in Dutch Creek at the end of May (0.012 mg/L). On this date, as noted above, Dutch Creek had very high turbidity relative to the other creeks. This turbidity could partially occur through the mixing of organic phosphates from the creek bed into the creek water, in forms that are adsorbed to inorganic or dead organic particulate matter.

Table 4 Additional Creek Data 2024 – Chloride, Nitrate, Sulphate, Phosphorus, and Metals

				Dutch Creek		Hardie Creek		CF Creek	
			DATE	*2024-05-29*	*2024-07-30*	*2024-05-29*	*2024-07-30*	*2024-05-29*	*2024-07-30*
Analyte	**Units**	**MRL**	**Std (CDWQG)**						
Chloride	mg/L	0.1	AO<=250	0.27	<0.10	0.52	0.37	9.58	9.82
Nitrate (as N)	mg/L	0.01	MAC=10	0.095	0.057	0.026	0.036	0.365	0.271
Sulfate	mg/L	1	AO<=500	10.4	14.5	27.7	17	39.1	41.7
Phosphorus, Total (as P)	mg/L	0.005	N/A	0.012	<0.0050	0.0061	0.0071	<0.0050	<0.0050
Phosphorus, Total Dissolved	mg/L	0.005	N/A	<0.0050		<0.0050		<0.0050	
Aluminum, total	mg/L	0.005	OG<0.1	0.16		0.0194		<0.0050	
Iron, total	mg/L	0.01	AO<=0.3	0.304	0.016	0.027	0.069	<0.010	<0.010
Manganese, total	mg/L	0.0002	MAC=0.12	0.0134	0.00091	0.00187	0.00559	0.00021	0.00051

Iron and Manganese

The total iron measured in Dutch Creek on May 29th, 2024 was 0.304 mg/L. The CDWQG drinking water guidelines and CCME guidelines for fresh water aquatic life both indicate that 0.3 mg/L is the maximum (Table 1). This measurement occurred when the creek water had high turbidity (7.9) and so this measurement may reflect sediment disturbances. This possibility is supported by the observation that the concentrations of manganese and aluminum in Dutch Creek on May 29th, 2024 were also elevated compared with concentrations in Hardie Creek and the Canal Flats creek.

Two months later at the end of July, when the turbidity of the water had decreased from 7.9 to 1.6, the concentration of iron in Dutch Creek was 0.016 mg/L, less than that in Hardie Creek, and the concentration of manganese was at or below that in both Hardie Creek and the Canal Flats Creek.

3.3 Annual Monitoring Program: The Columbia River

CLSS monitored the basic river quality indicator parameters (shown in Table 5) at two locations along the Columbia River on four occasions in 2024. The upstream location is by Columbia River Drive at the boundary of the Columbia Lake Provincial Park. It is a favourite location for putting-in to the river with non-motorized watercraft. The downstream location is on Wills Road/River Drive in Fairmont Hotsprings. Figure 1 shows these two locations (red stars).

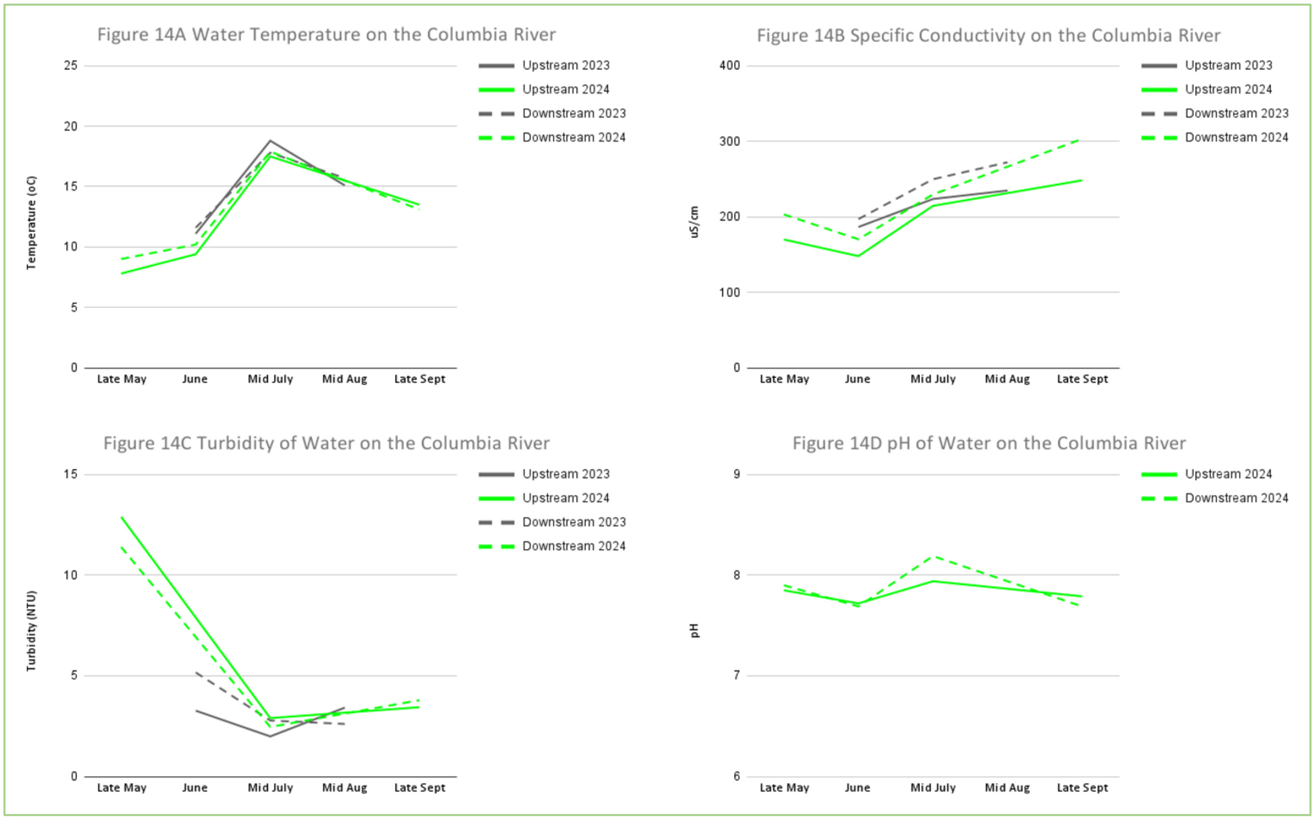
Table 5: Water Quality Data for the Columbia River 2023 and 2024

			Water Temp (°C)	Specific Cond. (uS/cm)	Dissolved Oxygen (mg/L)	pH	Turbidity (NTU)
Upstream	Late May	2023					
	June		11.1	186.5	9.9	8.06	3.27
	Mid July		18.8	223.6	6.3		1.99
	Mid Aug		15.1	234.8	9.4		3.42
	Late Sept						
	Late May	2024	7.8	169.9		7.85	12.9
	June		9.4	147.9		7.72	91.13**
	Mid July		17.5	214.5		7.94	2.9
	Mid August						
	Late Sept		13.5	248.3		7.79	3.44
Downstream	Late May	2023					
	June		11.6	197	9.8	8.03	5.17
	Mid July		17.8	249.8	6.1		2.78
	Mid Aug		15.7	272.2	10.2		2.61
	Late Sept						
	Late May	2024	9	203.2		7.9	11.4
	June		10.2	170.2		7.69	102.1**
	Mid July		17.9	229.7		8.19	2.46
	Mid Aug						
	Late Sept		13.1	303.2		7.69	3.79

The monitoring results are compared to the measurements made in 2024 in Table 5 and are plotted on Figures 14 A, B, C, and D respectively. There was only one measurement of pH on the river in 2023, in early June. The upstream and downstream values recorded were similar to those recorded in early June 2024. In 2024, there were no measures of dissolved oxygen in the river because of problems with the oxygen meter.

The data in Table 5, and the plots, illustrate that water temperature was similar in both years, and did not differ upstream and downstream.

Figure 14 Temperature, Conductivity, Turbidity, and pH on the Columbia River



In both years, specific conductivity was greater downstream than upstream at all times of the summer. Whether or not the observed difference is substantive remains to be determined. Specific conductance is a measure of the dissolved salt content of the water. The upstream and downsteam locations are above and below the Riverside Golf Course which may impact the salt content. In addition, this stretch of the river is used recreationally during the summer by thousands of people “floating” downstream and this may also have some impact. This requires further investigation if the data are to be interpreted meaningfully.

The turbidity of the river water is greatest in the Spring (late May in 2024), reaching its lowest values by late July and remaining at those levels. Interestingly, the values are greater than levels recommended by Health Canada for drinking water quality. In 2024, measurements of turbidity in June were extraordinarily high and have not been plotted in Figure 14C. However, the river was extremely murky at that time and the Spring freshet was underway. We had also observed very high values for turbidity in Dutch Creek around the same time and so these high values likely reflect the impact of the turbulent river flow and high water levels disturbing the river bed sediments.

Additional Data on the Columbia River 2024

In late May (May 29th) and early June (June 10th) samples of river water were collected to measure total and dissolved phosphorus, iron and manganese, sulphate, nitrate, chloride, alkalinity, hardness, and total metals.

The intention was to determine whether there are differences in any of these parameters upstream and downstream which may be related to the river's passage through the golf course and/or to the intense recreational use of the river during the summer.

In 2024, these additional data were only collected at the end of May and in mid-June, whereas in 2023, data was collected early June, mid-July, and mid-August. Currently, we do not have sufficient overlapping time points to compare data from 2024 with 2023. We also do not have enough data to compare any trends over the summer.

In 2023, concentrations of chloride increased over the summer and were consistently greater at the downstream location S2. Concentrations measured in 2024 were also greater at the downstream location on both dates. In 2024, no pattern could be observed for the summer, but if we compare the concentration of chloride in late May-mid-June 2024 with that measured in mid-June 2023, values in 2023 were more than 4X greater.

Concentrations of nitrate were greater at the downstream location on all occasions in both 2023 and 2024.

The most notable finding in 2024 seems to be that concentrations of iron in late May and mid-June (0.307 and 0.157 mg/L) were far higher than those measured in 2023 in mid-June (0.022 mg/L). Also, levels of aluminum in the water increased notably between late May and mid-June at both upstream and downstream locations, as did levels of manganese. These elevated concentrations of metals may reflect sediment disturbance because they are concurrent with the high turbidity of the river in the spring and early summer.

Table 6: Additional Data for Columbia River

				2023 S1			2023 S2			2024 S1		2024 S2	
	Units	MRL	Std (CDWQG)	6/7/2023	7/18/2023	8/15/2023	6/7/2023	7/18/2023	8/15/2023	5/29/24	6/10/2024	5/29/24	6/10/2024
Chloride	mg/L	0.1	AO<=250	0.88	1.33	1.29	1.08	1.66	1.71	0.19	0.11	0.42	0.34
Nitrate (as N)	mg/L	0.01	MAC=10	0.04	0.035	0.056	0.05	0.051	0.086	0.086	0.046	0.091	0.056
Sulfate	mg/L	1	AO<=500	12.7	16.9	23	15.9	32.2	28	10	8.6	15.7	17
Hardness, Total (as CaCO3)	mg/L	0.5								105	93.4	112	104
Alkalinity, Total (as CaCO3)	mg/L	1	N/A	79.5	122	122	83	123	121	79.2	68.9	90	74
Alkalinity, Bicarbonate (as CaCO3)	mg/L	1	N/A	79.5	122	122	83	123	121	79.2	68.9	90	74
Phosphorus, Total (as P)	mg/L	0.005	N/A	0.0051	0.01	0.0106	0.0106	0.0143	0.0072	0.0106	0.0361	0.01	0.043
Phosphorus, Total Dissolved	mg/L	0.005	N/A	<0.0050	0.01	0.0052	<0.0050	0.0082	0.0065	<0.0050	<0.0050	<0.0050	<0.0050
Aluminum, total	mg/L	0.005	OG<0.1							0.165	0.807	0.124	0.797
Iron, total	mg/L	0.01	AO<=0.3	0.022	0.065	0.091	0.031	0.062	0.039	0.307	1.57	0.277	1.62
Manganese, total	mg/L	0.0002	MAC=0.12	0.00583	0.0123	0.00951	0.00543	0.0109	0.00411	0.0166	0.0632	0.0158	0.0638

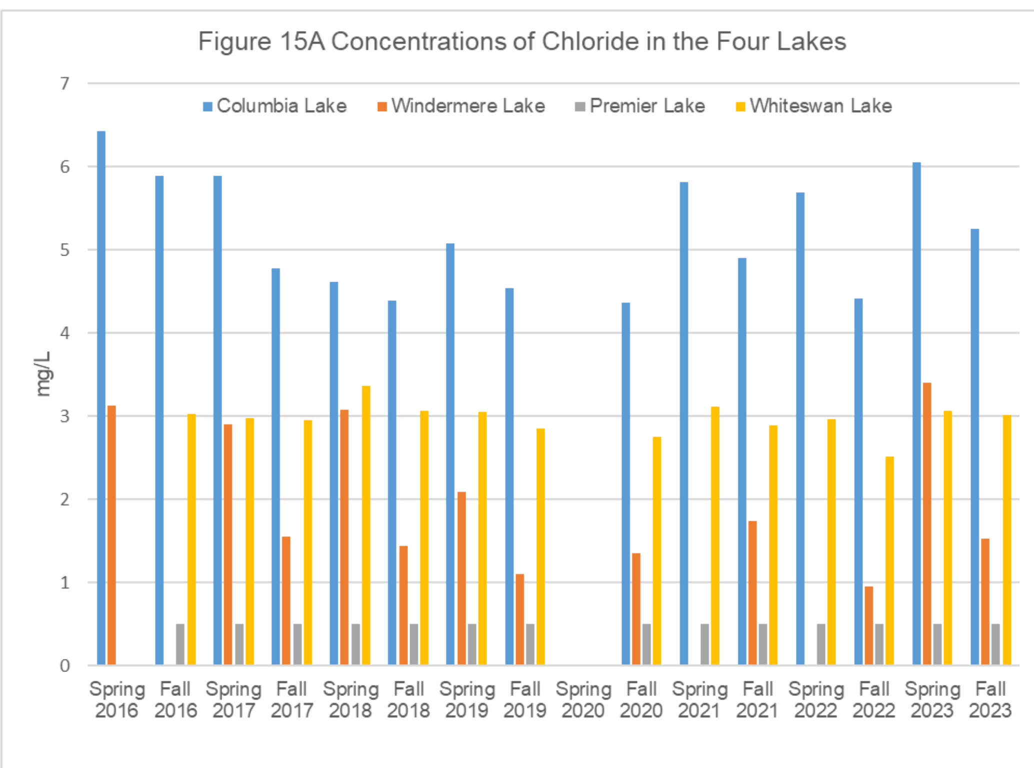
4.0 Comparison to Nearby Lakes

This section of CLSS's water quality report for 2024 compares the measurements for the water quality indicator parameters measured in Columbia Lake with those of three nearby lakes: Lake Windermere, Premier Lake, and Whiteswan Lake.

The comparison is based on data published by BCMOE (British Columbia Ministry of the Environment) on their website. BCMOE has been monitoring the water quality of these four lakes in the spring and late summer each year since 2016. The data available for 2016 through 2023 is used for this comparison (data for 2024 had not yet been placed on the website when this report was prepared in November of 2024.) BCMOE analyses the water samples they collect for an extensive list of parameters (including organic carbon, nutrients, and total and dissolved metals). However, for this report, only concentration of chloride, specific conductance, turbidity, pH, and dissolved oxygen are compared. Figures 15 A, B, C, and D compare the concentration of chloride, the specific conductance, turbidity, and the concentrations of dissolved oxygen, respectively. In general, the values are comparable indicating that Columbia Lake has a very similar water quality to the three nearby lakes, and all four lakes currently have excellent water quality.

Figure 15A: Concentration of Chloride in the Four Lakes

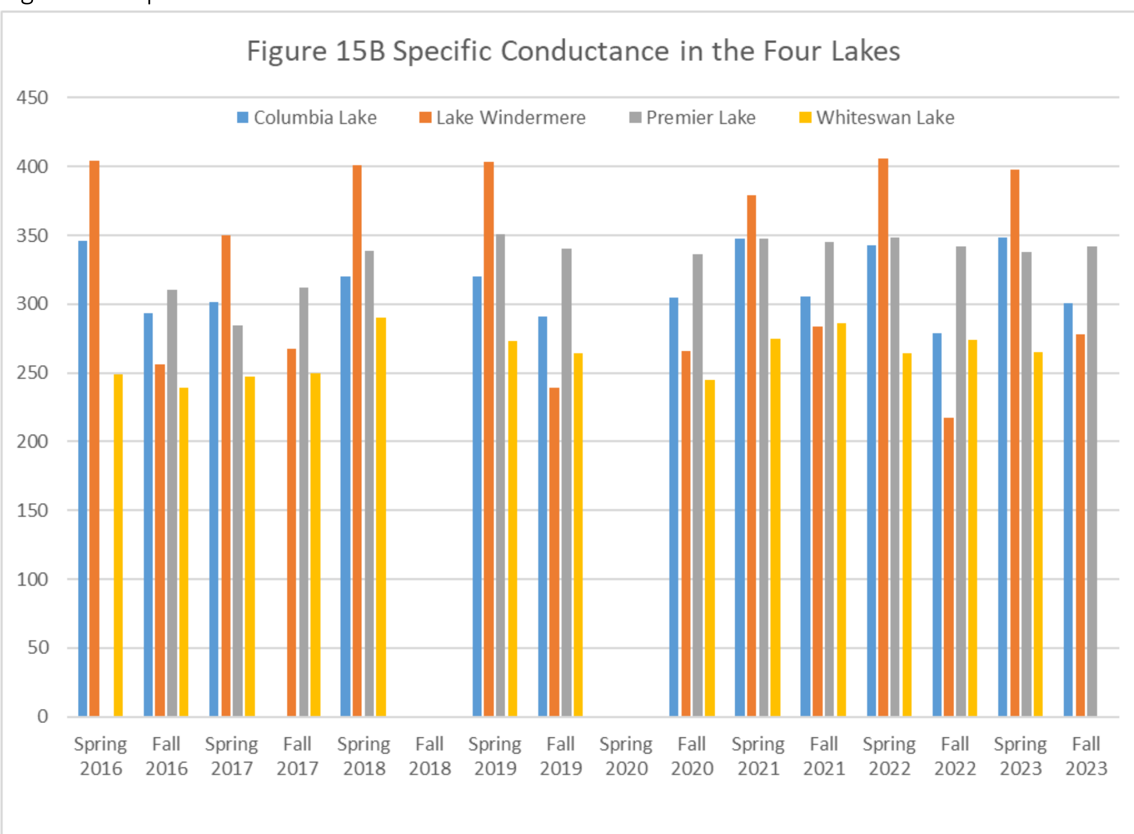
An exception to this general comparison is that Columbia Lake has a much higher concentration of chloride (Figure 15A) than the other lakes. The concentration of chloride in Columbia Lake is often more than double that in the other lakes.



In Premier Lake, the concentration of chloride is typically so low that it is close to the detection limit. Concentrations of chloride in Whiteswan Lake are quite steady, at approx. 3 mg/L, and in Lake Windermere the concentrations of chloride are greatest in Spring (close to levels in Whiteswan Lake) and generally decrease over the summer months.

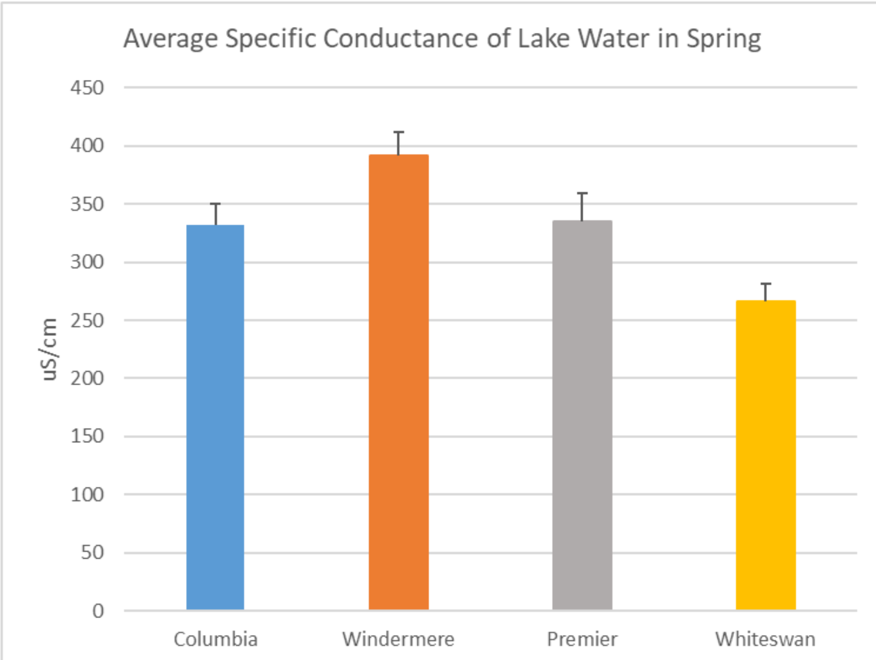
Chloride is a salt and Columbia Lake has no natural source of salt in its drainage basin. Consequently, chloride can only come to the lake from man-made sources. The most common sources of chloride are wastewater disposal, and road salts used for de-icing and dust control. Although the chloride concentrations in Columbia Lake are much lower than the concentrations that would negatively affect the lake water as an aquatic habitat, wildlife drinking water, or human drinking water, and even recreational uses, the greater concentration in Columbia Lake suggest that lake water quality is affected by the use of the surrounding land.

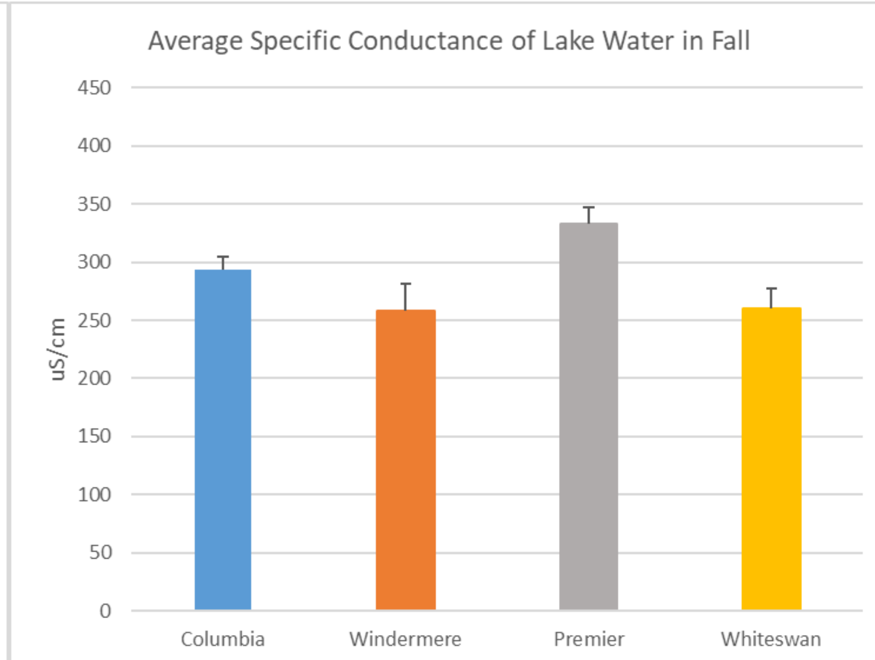
Figure 15B Specific Conductance in the Four Lakes



In Spring, the specific conductance is consistently greatest in Lake Windermere. However, by Fall, the specific conductance is frequently lower in Lake Windermere than in the other lakes. Lake Windermere appears to undergo a notable decrease in specific conductance over the summer, whereas Premier Lake and Whiteswan Lake remain relatively constant and Columbia Lake shows a smaller decrease.

This notable change in specific conductance for Lake Windermere between Spring and Fall is shown in the following graphs:





The decrease in specific conductance on Columbia Lake from Spring to Fall observed by BCMoE is in keeping with CLSS's observations.

The specific conductance on Premier Lake and Whiteswan Lake is consistent from Spring to Fall, with neither lake showing a drop in conductance through the summer. On Premier Lake the conductance tends to be slightly greater than on Whiteswan Lake in both Spring and Fall (approx. 330 vs 260 µS/cm, respectively).

Figure 15C: Turbidity of Water in the Four Lakes

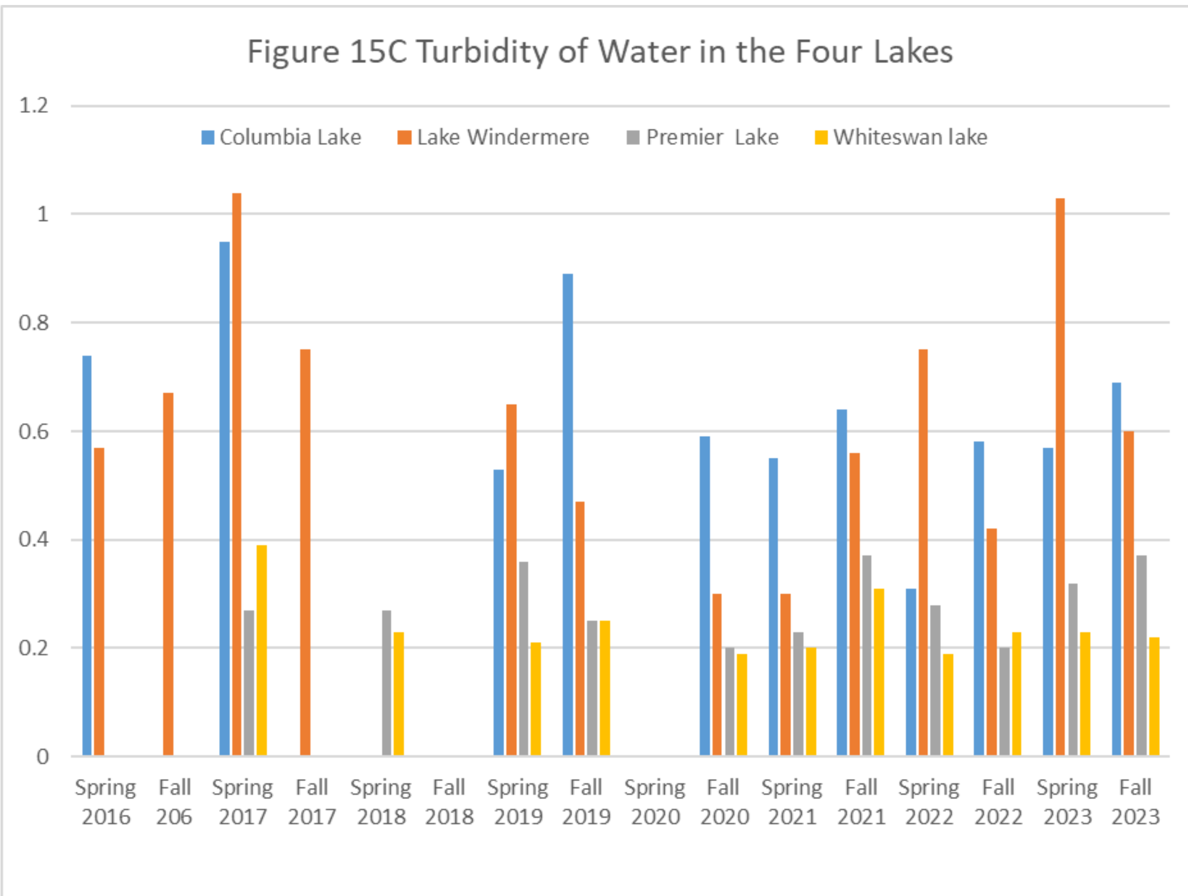


Figure 15C illustrates that Columbia Lake and Lake Windermere have notably greater turbidity than either Premier Lake or Whiteswan Lake, in both Spring and Fall. Whiteswan and Premier Lakes have turbidity values mostly less than 0.3, whereas Columbia Lake and Lake Windermere have values mostly greater than 0.3, frequently greater than 05.

Changes in turbidity of lake water are generally considered to be related to the growth of phytoplankton. However, suspended sediments introduced by wave erosion of shorelines and disturbance of bottom sediments by recreational activity also contribute. Both Lake Windermere and Columbia Lake are more intensely used for recreational activity than Premier Lake and Whiteswan Lake. Whether this contributes to the greater turbidity of the water in these lakes remains to be determined.

It is interesting to note that the turbidity of the water in Columbia Lake often increased over the summer, and was **greater** in Fall than in the Spring in 2019, 2021, 2022, and 2023. In contrast, the turbidity of the water in Lake Windermere often decreased over the summer and was **lower** in the Fall than in the Spring in 2017, 2019, 2022, and 2023. Explanations for this difference in the relatively high turbidity of the water in these lakes remain to be determined.

Note: Both lakes have a significant flow of water through them, from south to north in the summer. However, the flow-through rate is notably greater in Lake Windermere, which is often regarded as a widening of the Columbia River. Also, at certain times of year, especially in the spring, Columbia Lake has some reverse flow, with influx of water from Dutch Creek at its north end, at the Dutch Creek delta.

pH

The pH values measured on the four lakes are consistent and comparable. The average pH (2016-2023) in each lake is between 8.27 in Lake Windermere and 8.53 in Premier Lake, with a SD of only 0.22 – 0.26. The SD for pH values in Whiteswan Lake is slightly greater at 0.43 (n=13) but the average pH is very close to Columbia Lake and Lake Windermere at 8.32.

5.0 Program for 2025

CLSS has been monitoring water quality on Columbia Lake since 2014. We now have a substantial database of various water quality parameters. These data help us appreciate the current water quality conditions in the lake and give us information about specific parameters which may require some focus or more detailed exploration. For example, as noted in this report, there was a substantial fish kill on Columbia Lake in July 2024, and our data on temperature and turbidity of the lake water suggest some possible causative factors. This requires further exploration and we intend to adjust our monitoring program somewhat in 2025 to do this. Specifically, CLSS would like to monitor turbidity and concentrations of dissolved oxygen more closely when the lake temperature rises, along with analyses of possible factors involved in increased turbidity such as sediment disturbances and phytoplankton (over)growth.

Overall, the program in 2025 will continue to include measurement of various water quality parameters (dissolved oxygen, pH, temperature, and turbidity) in Columbia Lake, in some of the streams entering the lake, and on the Columbia River. However, specific details such as frequency of the measurements, locations of measurements, and the specific chemical analyses requested, remain to be determined. The 2025 program will also be based on our data from 2014-2024, and on our interpretations of it. This requires that we complete a thorough review of the data collected from 2014-2024. This process may involve recalculating the lower control and upper control limits (LCL and UCL) which are used as reference points for annual measurements (see section 3.1).

In 2025, CLSS intends to try to collaborate with other groups working on Columbia Lake. As discussed in this report, BCMoE takes various measurements on Columbia Lake each year. We are also aware that the Shuswap Band has ECCC funding for a six-year fisheries program to study Upper Columbia Native Fish Species and they will be doing some water quality work on Columbia Lake. Our intention is to ensure that our work on Columbia Lake in 2025 complements the work of others to ensure the best scientific outcomes possible for all. We are also currently exploring the possibility of participating in the BC Lake Stewardship and Monitoring Program for similar reasons.

Once our data review has been completed, and options for collaborative projects with other groups have been explored, we will finalize our water quality monitoring program plan for 2025.

Appendix A-1: Monitoring Parameters and their Application to Understanding Water Quality Changes

What are the Parameters we Measure and Why are they Important

Ed. Note: The following is a brief description of the parameters that we measure and a comment on their importance. The description is intended to help us understand their relevance in the biological world. It is far from complete and indeed is not even original – most of the material is copied verbatim from two references:

http://water.epa.gov/type/rsl/monitoring/vms50.cfm

http://www.env.gov.bc.ca/wat/wq/wq_guidelines.html

Water Temperature

The rates of biological and chemical processes depend on temperature. Aquatic organisms from microbes to fish are dependent on certain temperature ranges for their optimal health. Optimal temperatures for fish depend on the species: some survive best in colder water, whereas others prefer warmer water. Benthic macroinvertebrates *(Ed. note -includes the immature stages of many flies, beetles, dragonflies, aquatic worms, snails, leeches, etc.)* are also sensitive to temperature and will move in the stream to find their optimal temperature. If temperatures are outside this optimal range for a prolonged period of time, organisms are stressed and can die.

For fish, there are two kinds of limiting temperatures the maximum temperature for short exposures and a weekly average temperature that varies according to the time of year and the life cycle stage of the fish species. Reproductive stages (spawning and embryo development) are the most sensitive stages. The following Table provides optimum temperature criteria for some local species.

Species	Incubation	Rearing	Spawning
Brown Trout	1.0-10.0	6.0-17.6	7.2-12.8
Cutthroat Trout	9.0-12.0	7.0-16.0	9.0-12.0
Rainbow Trout	10.0-12.0	16.0-18.0	10.0-15.5
Mountain Whitefish	less than 6.0	9.0-12.0	less than 6.0
Burbot	4.0-7.0	15.6-18.3	0.6-1.7

Temperature affects the oxygen content of the water (oxygen levels become lower as temperature increases); the rate of photosynthesis by aquatic plants; the metabolic rates of aquatic organisms; and the sensitivity of organisms to toxic wastes, parasites, and diseases.

Causes of temperature change include weather, removal of shading stream bank vegetation, impoundments (a body of water confined by a barrier, such as a dam), urban storm water, and groundwater inflows.

Phosphorus and Nitrogen

Both phosphorus and nitrogen are essential nutrients for the plants and animals that make up the aquatic food web. They are natural parts of aquatic ecosystems.

There are many sources of phosphorus, both natural and human. These include soil and rocks, wastewater treatment plants, runoff from fertilized lawns and cropland, failing septic systems, runoff from animal manure storage areas, disturbed land areas, drained wetlands, water treatment, and commercial cleaning preparations.

Nitrogen and phosphorus support the growth of algae and aquatic plants, which provide food and habitat for fish, shellfish and smaller organisms that live in water. But when too much nitrogen and phosphorus enter the environment - usually from a wide range of human activities - the water can become polluted. Nutrient pollution has impacted many rivers and lakes resulting in serious environmental and human health issues, and impacting the economy.

Too much nitrogen and phosphorus in the water causes algae to grow faster than ecosystems can handle. Significant increases in algae harm water quality, food resources and habitats, and decrease the oxygen that fish and other aquatic life need to survive. Large growths of algae are called algal blooms and they can severely reduce or eliminate oxygen in the water, leading to illnesses in fish and the death of large numbers of fish. Some algal blooms are harmful to humans because they produce elevated toxins and bacterial growth that can make people sick if they come into contact with polluted water, consume tainted fish or shellfish, or drink contaminated water.

Turbidity

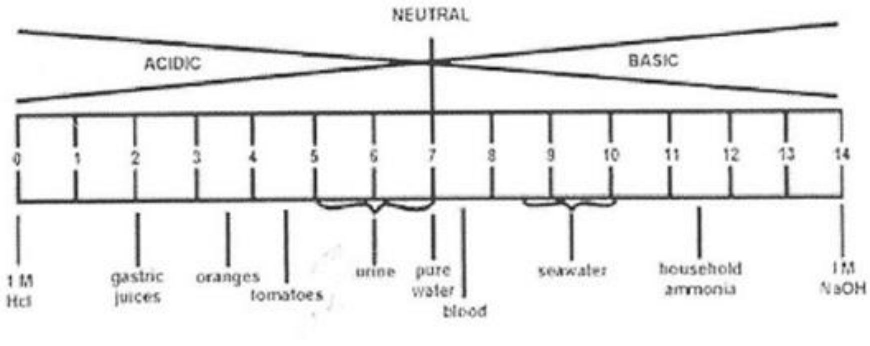
Turbidity is a measure of water clarity or more simply, how much the material suspended in water decreases the passage of light through the water. Suspended materials include soil particles (clay, silt, and sand), algae, plankton, microbes, and other substances. These materials are typically in the size range of 0.004 mm (clay) to 1.0 mm (sand). Turbidity can affect the color of the water.

Higher turbidity increases water temperatures because suspended particles absorb more heat. This, in turn, reduces the concentration of dissolved oxygen (DO) because warm water holds less DO than cold. Higher turbidity also reduces the amount of light penetrating the water, which reduces photosynthesis and the production of DO. Suspended materials can clog fish gills, reducing resistance to disease in fish, lowering growth rates, and affecting egg and larval development. As the particles settle, they can blanket the stream bottom, especially in slower waters, and smother fish eggs and benthic macroinvertebrates. Sources of turbidity include: Soil erosion, Waste discharge, Urban runoff, and Eroding stream banks.

Turbidity can be useful as an indicator of the effects of runoff from construction, agricultural practices, logging activity, discharges, and other sources. Turbidity often increases sharply during a rainfall, especially in developed watersheds, which typically have relatively high proportions of impervious surfaces. The flow of storm water runoff from impervious surfaces rapidly increases stream velocity, which increases the erosion rates of stream banks and channels. Turbidity can also rise sharply during dry weather if earth-disturbing activities are occurring in or near a stream without erosion control practices in place.

pH

pH is a term used to indicate the alkalinity or acidity of a substance as ranked on a scale from 1.0 to 14.0. Acidity increases as the pH gets lower. The following figure presents the pH of some common liquids.



pH affects many chemical and biological processes in the water. For example, different organisms flourish within different ranges of pH. The largest variety of aquatic animals prefers a range of 6.5-8.0. pH outside this range reduces the diversity in the stream because it stresses the physiological systems of most organisms and can reduce reproduction. Low pH can also allow toxic elements and compounds to become mobile and "available" for uptake by aquatic plants and animals. This can produce conditions that are toxic to aquatic life, particularly to sensitive species like rainbow trout. Changes in acidity can be caused by atmospheric deposition (acid rain), surrounding rock, and certain wastewater discharges.

The pH scale is logarithmic. A pH of 7.0 indicates a neutral condition. Distilled water has pH of 7.0. Below 7.0, the water is acidic. When the pH is above 7.0, the water is alkaline, or basic. Since the scale is logarithmic, a drop in the pH by 1.0 unit is equivalent to a 10-fold increase in acidity. So, a water sample with a pH of 5.0 is 10 times as acidic as one with a pH of 6.0, and pH 4.0 is 100 times as acidic as pH 6.0.

Conductivity

Conductivity is a measure of the ability of water to pass an electrical current. Conductivity in water is affected by the presence of inorganic dissolved solids such as chloride, nitrate, sulfate, and phosphate anions (ions that carry a negative charge) or sodium, magnesium, calcium, iron, and aluminum cations (ions that carry a positive charge). Organic compounds like oil, phenol, alcohol, and sugar do not conduct electrical current very well and therefore have a low conductivity when in water. Conductivity is also affected by temperature: the warmer the water, the higher the conductivity. For this reason, conductivity is reported as conductivity at 25 degrees Celsius (25 C).

Conductivity in streams and rivers is affected primarily by the geology of the area through which the water flows. Streams that run through areas with granite bedrock tend to have lower conductivity because granite is composed of more inert materials that do not ionize (dissolve into ionic components) when washed into the water. On the other hand, streams that run through areas with clay soils tend to have higher conductivity because of the presence of materials that ionize when washed into the water. Ground water inflows can have the same effects depending on the bedrock they flow through.

Discharges to streams can change the conductivity depending on their make-up. A failing sewage system would raise the conductivity because of the presence of chloride, phosphate, and nitrate; an oil spill would lower the conductivity.

Conductivity is measured in micromhos per centimeter (µmhos/cm). Distilled water has conductivity in the range of 0.5 to 3 µmhos/cm. The conductivity of rivers in the United States generally ranges from 50 to 1500 µmhos/cm. Studies of inland fresh waters indicate that streams supporting good mixed fisheries have a range between 150 and 500 µhos/cm. Conductivity outside this range could indicate that the water is not suitable for certain species of fish or macroinvertebrates. Industrial waters can range as high as 10,000 µmhos/cm.

Appendix A-2: Historical Development of the Monitoring Program

The water quality monitoring program on Columbia Lake was developed in response to recommendations contained in the Columbia Lake Management Strategy (Urbans Systems, 1997). The monitoring program began in 2014 and has continued while the lake is ice-free until the present day. Since the program's initiation in 2014, several changes to the monitoring program have occurred. These changes are summarized chronologically below.

2014

Four stations for monitoring lake quality were established. These stations are referred to throughout this report as N1, S1, S3, and S4. Their current locations are shown in Figure 1. From north to south along the lake they are now:

Station	Northing	Easting
N1	N50.28769	W115.87126
S1	N50.253929	W115.86256
S3	N50.20107	W115.84820
S4	N50.17533	W115.83442

Water quality monitoring in 2014 confirmed that the lake's condition was consistent with the nearly pristine conditions used as the basis of this management strategy.

2015

In 2015, two changes to the water quality monitoring program were made to better align the program with the management strategy. These changes were the location of two stations:

- Station S4 was moved 2.4 km northward
- Station S3 was moved 1.7 km southward

This new location for S4 placed the site in shallow water.

2016

On January 15, 2016, at location S1, a special investigation of the oxygen distribution in the lake was made by Tracy Flynn and Dave Hubbard. This special investigation has not been repeated in the ensuing years (2017 – 2020) but is brought forward here as a reminder of those factors potentially influencing the lake's water quality.

For that specific investigation, a hole was cut through the ice (January 16th, 2016) and the water temperature and dissolved oxygen concentrations were measured as a function of depth below the lake surface, using handheld instruments.

	Trial One		Trial Two	
Lake Depth (m below base ice)	Temperature (deg C)	Dissolved oxygen (mg/l)	Temperature (deg C)	Dissolved oxygen (mg/l)
0	1.2	15.1	--	--
0.5	1.7	15.1	1.2	14.2
1	2.5	14.4	2.5	13.9
1.5	3.3	13.9	2.7	13.9
2	3.4	13.7	3.3	13
2.5	4.1	13.1	4	12
3	4.3	9.6	4.2	9.5
3.5	4.5	7	4.5	6.9
4	4.7	8.3	4.6	8.1
4.5	4.9	5.4	4.9	5.7
5	4.9	0.7	4.9	0.8

The table shows, as expected, that the water is coldest close to the surface, just below the ice, and increases in temperature with depth. This occurs because the density of water is greatest at 4^{o}C, meaning that water at 4^{o}C sinks while water at 0^{o}C rises. The concentration of dissolved oxygen is greatest at the surface and decreases with depth but remains above the 'normal' minimum for Columbia Lake (Table 1) to at least 4 meters depth.

In Spring, because water has maximum density at 4^{o}C, as the cold surface water warms up (with increasing air temperatures) it sinks. This "falling water" brings greater concentrations of dissolved oxygen from the lake's surface into the deeper water to support growth of aquatic plants and improve fish habitat. As the warmer, denser water falls within the lake, it displaces the now-cooler, less dense water at the bottom of the lake, and the displaced water rises to the surface. The rising water brings with it sedimented inorganic and organic particulates and increases total phosphate concentrations in the surface water. It may also contribute to the elevated turbidity of the lake water that is frequently observed in spring. During the winter, addition of oxygen to the lake water through wave action and inflow of surface water is minimal. Therefore, the concentration of dissolved oxygen near the surface must be dependent upon photosynthetic processes (mostly micro-organisms and phytoplankton). As the water warms up, photosynthetic activity increases along with growth of phytoplankton, and this is also a likely cause of the elevated turbidity observed in the early spring. The principal source of light to support photosynthesis in the lake is diffusion of sunlight through the ice. This evidence that photosynthetic processes continue over the winter indicates that the lake is healthy. In years of heavy snowfall, when the lake surface is covered with a deep layer of snow and less sunlight diffuses through the ice, the dissolved oxygen content of the surface water might become depleted and may lead to a less healthy water body in the spring.

Additional changes to the lake monitoring program were made in 2016 following advice provided to CLSS volunteers at the Lake Keepers workshop sponsored by the BC Lake Stewardship Society and held in conjunction with the May 2016 *Wings Over the Rockies* event. At that workshop, it was learned that dissolved phosphorous might be a more useful indicator of the ecological health of the lake and of contributions to the lake from surface water inflow. Consequently, beginning with the May 2016 event, nitrate was removed from the chemical analysis and dissolved phosphorous was added. In addition, it was suggested that a more useful indicator of lake ecological health was the contrast between deep and shallow water quality. To make this determination, at the deepest sampling location (location S1) two water quality samples, one shallow (about 0.5 m below the water surface) and one deep (about 0.5 m above the bottom of the lake), were collected each month.

These findings and advice prompted CLSS to begin the annual monitoring program as soon as possible each spring to confirm the dissolved oxygen and total and dissolved phosphorous concentrations. The timing of this early monitoring event is largely controlled by the availability of boats provided by our volunteers.

2017

No changes to the monitoring program were made.

2018

During the summer of 2018, a CLSS board member (Mr. Ed Gillmor) compiled information on the groundwater conditions in the vicinity of the south end of Columbia Lake near the village of Canal Flats.

Canal Flats sits on a deposit of granular materials (predominantly sand and gravel) that infills the valley across the south end of Columbia Lake. The valley is confined between the Rocky Mountains to the east and the Purcell Mountains to the west. The Kootenay River flows across and through this valley south of the Village of Canal Flats. Residents of Canal Flats have described to CLSS members that water can be observed and heard to flow within some of the water wells used to provide potable water to the village.

Mr. Gillmor's compilation of the available information is provided in a report entitled "An Estimate of Groundwater's Contribution to Columbia Lake". That report is available on the CLSS website.

The report documents that there is a difference in water level between the Kootenay River and Columbia Lake of some 7 meters, with Columbia Lake lying at a lower elevation than the river. The river and the lake are approximately 1,500 meters apart. Both distances are relatively constant throughout the year. This indicates that a persistent hydraulic gradient exists from the river to the lake, suggesting that the lake is being supplied by water seeping into the lake from the Kootenay River.

This assessment of substantial groundwater inflow at the south end of Columbia Lake, along with observations that there are no other significant streams flowing into the lake except for Dutch Creek at the north end, prompted CLSS to consider whether the lake water changed from south to north. Over the summer months of 2018, a survey of conductivity and turbidity was undertaken by CLSS volunteers Gina Fryer and Lucas and Caesar Fuertes. Every two weeks during the summer of 2018, these volunteers measured conductivity and turbidity at fourteen locations along the lake.

As CLSS reported in 2018, this survey showed that both conductivity and turbidity of the lake water decreased steadily from the south end to the north end of the lake. The results confirmed that the water at the south end of the lake is influenced by the contribution of surface and/or ground water draining into the lake around Canal Flats.

2019

To confirm the differences in water quality along the lake observed in 2018, the survey was repeated in 2019, with concentration of chloride added to the analysis of water quality at the fourteen locations. That survey was undertaken on July 23rd, 2019.

Visual inspections of the outlets of small streams draining into the lake along the west side showed that the shorelines had a different appearance associated with rust and black-stained rocks. Based on this, CLSS decided to initiate an evaluation of the water quality of streams draining into the lake. Over the summer of 2019, Dutch Creek, Hardie Creek, Marion Creek, and the small stream draining from Canal Flats to the lake were monitored on four occasions. Testing was undertaken for specific conductance, temperature, turbidity, pH, and concentration of chloride (on one occasion).

The stream sampling results showed noticeable differences in the quality of surface water among the four creeks.

2020-2024

Since 2020 the monitoring program has remained reasonably consistent, with some variation in such things as the exact timing of sampling on the lake, the specific creeks sampled, and the particular chemical analyses conducted. As far as has been possible the pH, temperature, dissolved oxygen concentration, specific conductance, and turbidity have been measured in all samples from the lake and the creeks, and from the Columbia River since 2023.

In addition, various chemical analyses have been conducted on the water from the lake, the creeks, and the river. These have included total and dissolved phosphorus, iron, manganese, hardness, alkalinity, concentration of chloride, and total metals. These additional analyses are described and reported in the Annual Report for the year in which they were conducted.