Summary of the 2023 Water Quality Monitoring Program for Columbia Lake

Columbia Lake Stewardship Society

May 3, 2024

Executive Summary

The Columbia Lake Stewardship Society (CLSS) began monitoring the water quality of Columbia Lake on April 20, 2014. Monitoring has continued annually while the lake is ice-free. In 2023 the first water quality monitoring event on the lake took place in late May and the last monitoring event in late August. Monitoring included:

- Approximately bi-weekly monitoring of selected water quality indicator parameters and approximately monthly sampling of water for chemical analysis on Columbia Lake and four of its tributaries; Dutch Creek, Hardie Creek, Marion Creek, and Canal Flats Creek
- preparing a profile from fourteen locations along the lake for chloride concentrations

In addition, in 2023 CLSS began a program to monitor water quality along the reach of the Columbia River between the provincial park boundary and Fairmont Hot Springs and collected sediment samples of lake bottom sediments to test for extractable petroleum hydrocarbons and total metals.

The CLSS water quality monitoring program is administered, conducted, and interpreted largely by volunteers under the overall direction of our Executive Director Ms. Caily Craig. The 2023 water quality program involved many volunteers who had participated in previous years and some volunteers new to the program. The 2023 monitoring program was enhanced by assistance received from a summer student made available to the program by a grant received from ECO Canada Summer Internship Program.

Funding for the program was provided by:

- Columbia Valley Local Conservation Fund,
- British Columbia Hydro – Grassroots Grant Program
- Hoodoo Mountain Resort,
- Spirits Reach Community Association,
- Columbia Ridge Community Association, and
- Columere Park Community Association.

The monitoring program carried out over the past nine years on Columbia Lake has shown that the lake water is suitable for consumption as drinking water, preservation of aquatic life and recreational purposes. The trend in concentrations of turbidity that had been observed in previous years was different in 2023.

Columbia Lake contains different concentrations of chloride than the other four neighboring lakes monitored each year by the British Columbia Ministry of the Environment (BCMOE). Different concentrations of chloride are of concern because there are no natural soils or rocks that can contribute chloride to surface water or groundwater draining into the lake.

CLSS intends to proceed in 2024 with a similar monitoring program to that undertaken in 2023.

The program will include:

1. The “Regular” program of bi-weekly measurements of temperature, lake depth, Secchi depths, turbidity, specific conductance, pH and dissolved oxygen at the four locations (N1, S1, S3 and S4),
2. This program will continue monitoring sites on the Columbia River, located between the outlet of Columbia Lake and north of the golf course in Fairmont,
3. Chemical analyses during the regular program in late May and mid-July for total and dissolved phosphorous, total kjeldahl nitrogen, total nitrate, iron and manganese, alkalinity, hardness, and chloride,
4. Monthly monitoring of the three creeks (Dutch Creek, Hardie Creek, and Canal Flats creek) for temperature, turbidity, specific conductance, pH, and dissolved oxygen. Monitoring on Marion Creek will be discontinued due to private landownership.
5. Twice annual (spring and fall) analyses of the creek waters for nitrate, total kjeldahl nitrogen, total and dissolved phosphorous, iron and manganese, alkalinity, hardness, and chloride.
6. As funding permits, CLSS will continue to develop and implement a CABIN monitoring program of stream(s) entering Columbia Lake.

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WATER QUALITY MONITORING PROGRAM SUMMARY FOR 2023

1. 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 Late 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 2023. Water quality monitoring of Columbia Lake began on May 15, 2023, and ended on August 28, 2023. During the 2023 program, CLSS added two additional monitoring events. The first involved monitoring and testing of the water quality of the Columbia River on three occasions during the summer between the provincial park on the north end of the lake and on the river north of the lake to the west of the Fairmont Mountainside Market. The second involved sampling and testing of lake bottom sediments from five locations on the lake.

This summary of the water quality monitoring program:

- describes the 2023 water quality monitoring program,
- summarizes the water quality monitoring results,
- describes the lake sediment sampling program, and
- provides suggestions to improve the monitoring program.

A comparison of the water quality of Columbia Lake to other nearby lakes monitored by British Columbia Ministry of the Environment is in preparation. Information collected for 2022 is incorporated here as Appendix C.

2.0 Monitoring program

Sections 2.1 through 2.4 describe:

- the purpose of the program and contributions of volunteers to the program during 2023,
- the monitoring program conducted during 2023,
- water quality objectives established by CLSS for the lake, and
- the QA/QC program undertaken by CLSS.

CLSS monitors both the water quality of Columbia Lake and the quantity of surface water entering and leaving the lake. The quantity of water flowing into and out of Columbia Lake is reported separately. Initially, the water quality monitoring program of 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 funds are available for the monitoring program. In particular, the water quality of four streams flowing into the lake have been monitored since 2020. Chronologically, these changes are summarized in Appendix A-2 including those suggested by the revised Columbia Lake Management plan written in 2021. C

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 administered, implemented, and interpreted by CLSS staff and volunteers. In 2023, the following volunteers contributed to the water quality monitoring program:

- Ed Gillmor - lake monitoring in late May and June
- Garry Gray - lake monitoring in August
- Amira Elwakeel - stream monitoring in May
- Rachel Milner - stream monitoring
- Pat Silver - overall program administration and accounting
- Tom Symington - assistance with report preparation
- Bill Thompson - assistance with report preparation
- Tom Dance and Nancy Wilson - river monitoring, and compilation, graphing, interpretation and reporting of the monitoring results.

For the 2023 monitoring program, CLSS received a grant from the ECO Canada Summer Internship Program to hire a summer student to assist with the water quality and water quantity monitoring programs and with some of the educational opportunities the society offers. Our summer student Dario Staples participated in the program from May through August of 2023. He has subsequently returned to the University of Dalhousie in Nova Scotia to attend his fourth year of undergraduate studies.

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 and the education program within the local communities.

The program receives funding from the following agencies:

- Columbia Valley Local Conservation Fund,
- British Columbia Hydro – Grassroots Grant Program,
- Spirits Reach Community Association,
- Columere Marina,
- Columbia Ridge Community Association, and
- Columere Park Community Association.

Advice on the program was also 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 During 2023

In 2023, the monitoring program on Columbia Lake undertaken by CLSS involved:

- the “regular” monitoring program comprising approximately bi-weekly measurements of three types of information at the four locations (N1, S1, S3 and S4) along the lake shown on Figure 1:
    - Observations about cloud cover, water surface disturbance (waves), and air temperature,
    - Measurements of:
        - the depth of water at each sampling locations,
        - measurement of water clarity using the Secchi disk,
        - water temperature,

  - turbidity,
  - specific conductance,
  - pH,
  - dissolved oxygen, and
  - total and dissolved phosphorous, Fe, Mn, hardness, and chloride concentrations on three sets of water samples from the lake to help evaluate causes for turbidity increases during the summer months (growth of aquatic vegetation or disturbed bottom sediments);

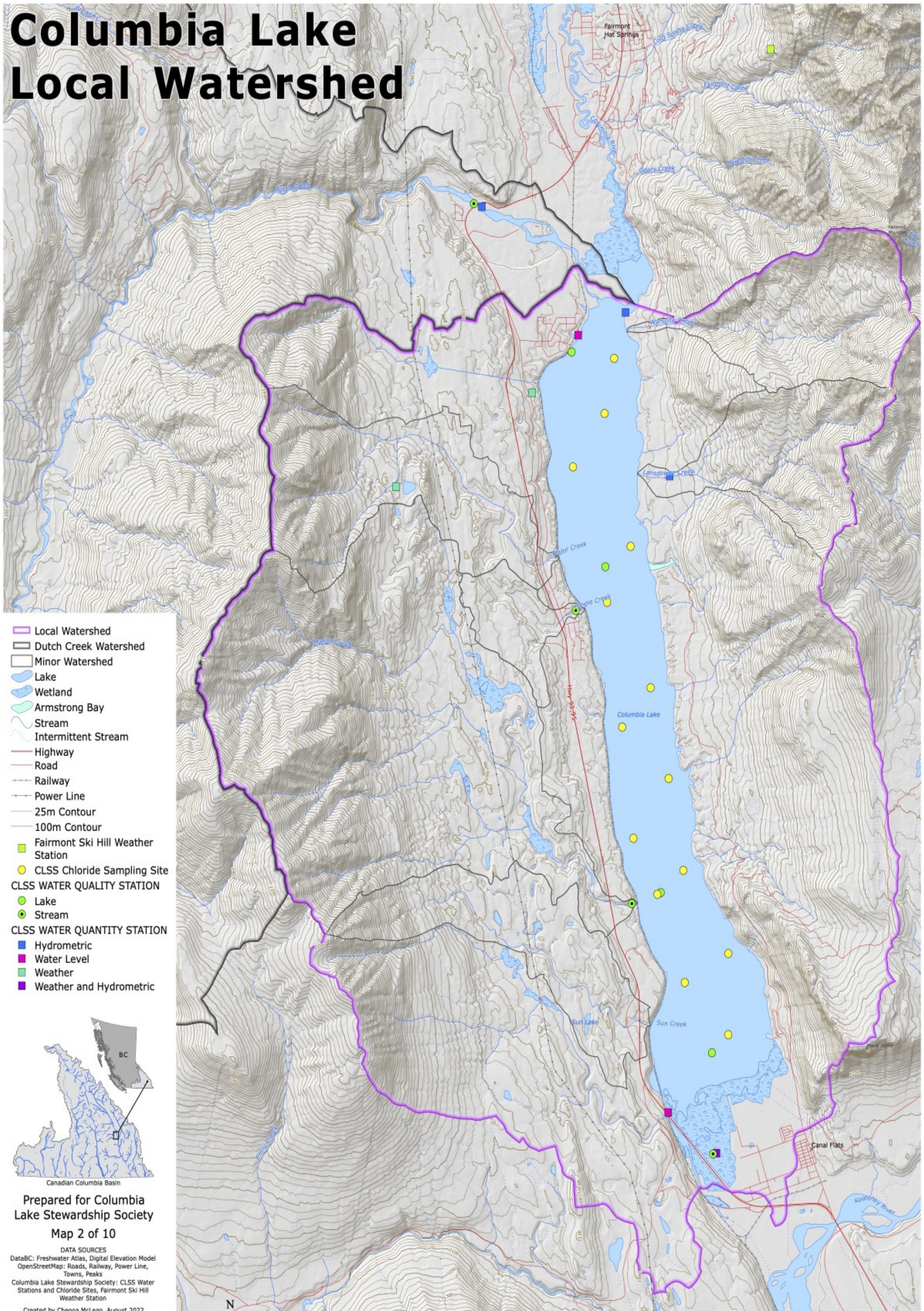
  and

- Measurements of temperature, specific conductance, turbidity, dissolved oxygen and pH on
  - 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;
  - Marion Creek at the outfall to the lake within the provincial picnic area; and
  - A small creek draining north from Canal Flats on the pathway (Figure 1).

The four regular monitoring locations shown on 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

Figure 1– Monitoring and Sampling Locations



Appendix A-1 provides information on how each of the measured parameters 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.

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. This information revealed that the lake had no noticeable differences in parameters between the deep and shallow depths.

In 2023, the regular monitoring program began on May 15 and ended on August 28. Measurements were made as weather permitted on six occasions at approximately biweekly intervals with water samples collected for chemical analyses on May 29, July 18, August 14. Caro Analytical of Kelowna provided the analytical services. The spreadsheet in Appendix B provides the observations, measurements and chemical analysis collected during all seven years of the monitoring program. The results are described in section 3.1.

Monitoring of Dutch Creek, Hardie Creek, Marion Creek and the stream flowing from Canal Flats occurred on May 15, May 29 June 15, June 27, July 25 and August 14. The monitoring results are described in section 3.2.

In addition, on July 18, 2023, CLSS collected 14 samples along the north south profile of the lake for analysis of the concentrations of chloride. This event was like the along the lake profiles obtained from 2020.

Also in 2023, CLSS undertook to special monitoring events to monitor the water quality along the Columbia River and the quality of the lake bottom sediments.

Water quality sampling along the Columbia River

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

The program involved using two one person kayaks to collect water quality samples from the convenient "put-in or the upstream location" along Columbia River Road south of the village of Fairmont and the "take-out or the downstream location" to the west off the Mountainside Market in the meadows of Fairmont. These locations were selected because they were relatively easy access by Kayak and were commonly used by recreational users. Furthermore, most of the recreational activity (recreational use of the river by kayaks, canoes and portable floatation devices, a recreational camping area and a golf course) along this reach of the river occurred between the two locations. Figure 1 shows these two locations.

Water quality measurements for the indicator parameters and samples for chemical analyses were collected on three occasions: in mid June prior to heavy recreational use of the water way, mid July when this section of the river was used heavily and mid-august when the time of most intense use of the river had passed. Measurements of the indicator parameters (temperature, specific conductance, turbidity, dissolved oxygen, and pH were made using portable field equipment by the individual in one the kayaks and recorded by the accompanying individual in the second kayak. Unfortunately, the pH meter measurements were not reliable on the latter two sampling occasions. Likewise, samples were collected in bottles provided by Caro Analytical Labs of Kelowna BC. At the “take-out” locations the samples were placed in insulated containers and packed with a refrigeration pack for storage and shipment to the laboratory.

These results are summarised in Section 3.3.

Lake bottom sediments

In the late summer of 2023, CLSS collected sediment samples from five locations around Columbia Lake to measure concentrations of total extractable petroleum hydrocarbons and heavy metals in the sediments at the bottom of the lake. The sediment sampling program followed a similar program undertaken by Lake Windermere Ambassadors in 2022 when petroleum hydrocarbons and metals exceeding guidelines for the protection of freshwater aquatic life were measured in lake bottom sediments at several locations on Lake Windermere.

For the sediment sampling program, access to the lake came by wading into the lake from the shoreline and collecting the samples in a sterile glass jar. The depth of water was generally to mid thigh and samples were collecting by pushing the jar into the sediments. All sediments were selected to be from similar materials soft organic clays and silts, not predominantly sand and gravel. For shipment to the laboratory for analyses, the samples were decanted from the collection jar into laboratory supplied containers. The collection jars were washed with lake water prior to collecting each sediment sample.

The five locations on the lake were selected to deliberately represent various intensity and variety of recreational activities on the lake.

Site 1 was located at the Canal Flats boat launch at Tilley Memorial Park where we understand boats for fishing and recreation on the lake are frequent over the ice-free days on the lake. This launch site is popular among residents of Canal Flats and recreational visitors to Columbia Lake. The site is the only location for public access for boats to enter the lake. The boat ramp is made of pavement and concrete/gravel and boats are lowered into the lake from the backs of cars and/or trucks.

Site 2 was located at the former boat launch at the southwest corner of Columbia Lake. Access to this boat launch is currently restricted by a gate but we note the gate is frequently cut open. This site is most often used by non-motorized boats (kayaks and canoes). However, this site may have been used by motorized boats by fisherpersons, before the gate was installed but unlikely by water skiers or water surfers due to the shallowness and nearby marsh grasses. The launch area is made of concrete.

Site 3 was located about half along the west shoreline of the lake at the private beach in the community of Spirits Reach where motorized boats are not common and most of the use is by non motorized boats and swimmers. Access to the lake is from the shoreline composed mostly of sand and gravel.

Site 4 was located at the northwest corner of the lake at the Columere Park marina. Boat moorage by residents of the Columere Park community is available at this location and the moorage area is formed by berms and access to the moorage is provide by a paved roadway. We understand that most of the recreational use from this site are for fishing and water sports (water skiing, tubing and wake surfing). The sediment sample was collected from the canal the boats use to enter the lake.

Site 5 was located at the northeast corner of the lake at the Provincial Park beach. Access to this beach requires walking of a trail and there is no motorized watercraft access at this location. This site was selected to represent the conditions at an undisturbed location.

These results are summarized in Section 4.

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 Columbia Lake Management Plan (2022) 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 as published by the Canadian Council of Ministers of the Environment for the protection of aquatic life are considerably lower than the guidelines for human health protection. Arsenic, molybdenum, selenium, uranium and zinc guidelines tabulated in Table 1 are considerably lower than the limit required published by the Canadian guidelines for protection of human health.

CLSS also notes that the criteria applied to evaluate water quality conditions on Lake Windermere by Lake Windermere Ambassadors also uses dissolved oxygen and phosphorous concentrations 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 lake's conditions and development pressures.

On a site-by-site basis the province allows 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 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 and therefore has combined the human health guidelines with the CCME guidelines for protection of aquatic life with those used by Lake Windermere Ambassadors as a comparative measure of the water quality objectives for Columbia Lake.

Table 1 provides these combined criteria with the highlighted values identifying the concentrations or ranges applied by CLSS to Columbia Lake. This table also shows the range in concentrations measured by the annual monitoring program undertaken by BCMOE and the data collected by CLSS. In general, the measured water quality parameters on Columbia Lake are considerably less than the criteria. But there are several occasions when the concentrations of pH, dissolved oxygen and turbidity exceed these guidelines.

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.

🟨 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 and 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 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 can not 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, 3.3 and 3.4 summarize:

- The monitoring results obtained at the four monitoring locations (N1, S1, S3 and S4) along the lake,
- The along the lake profiles prepared by CLSS (although only one set of analyses for chloride was collected by CLSS in 2023),
- The monitoring results obtained for Dutch Creek, Hardie Creek, Marion Creek and the creek draining from Canal Flats to the lake, and
- The results from the water quality events along the Columbia River in Fairmont.

3.1 Annual Monitoring Program

The 2023 annual monitoring program is the tenth 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 concentrations 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 the expected maximum and minimum concentrations. The expected maximum and minimum concentrations were calculated as the mean plus and minus three times the standard deviation and are labelled as upper and lower control limits (UCL and LCL) on graphs of the indicator parameters. Those statistical calculations are provided in Appendix E. Concentrations that exceed either the expected maximum or minimum values identify water quality information that is beyond the normal or expected range and may suggest further assessment of the lake's water quality should be considered. These 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, at higher temperatures, the quantity of dissolved oxygen available for fish and aquatic invertebrates declines and creates 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 20^0C can dramatically stress fish so that fish kills may occur). Further, higher water temperatures increase the rate of degradation of organic matter and potentially creates cloudy, murky, or odorous water. The degradation process also consumes dissolved oxygen from the lake water, further increasing the stress on fish and aquatic invertebrates. Figures 2A and 2B plot the temperatures measured during 2023 at the surface and bottom depths.

Figure 2 – Lake Water Temperature 2023

Figure 2A - Lake Water Surface Temperature, 2023

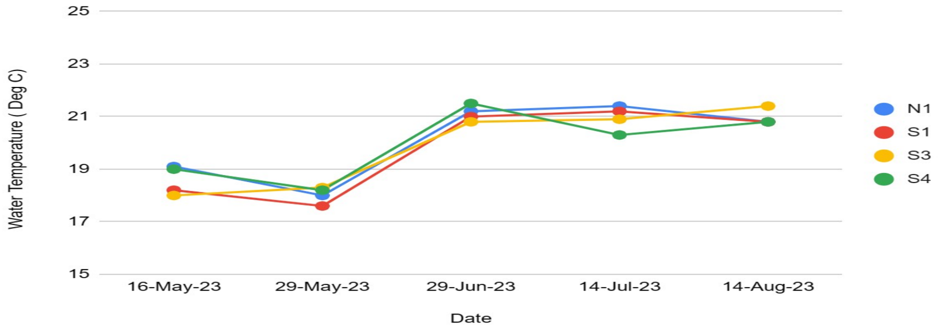
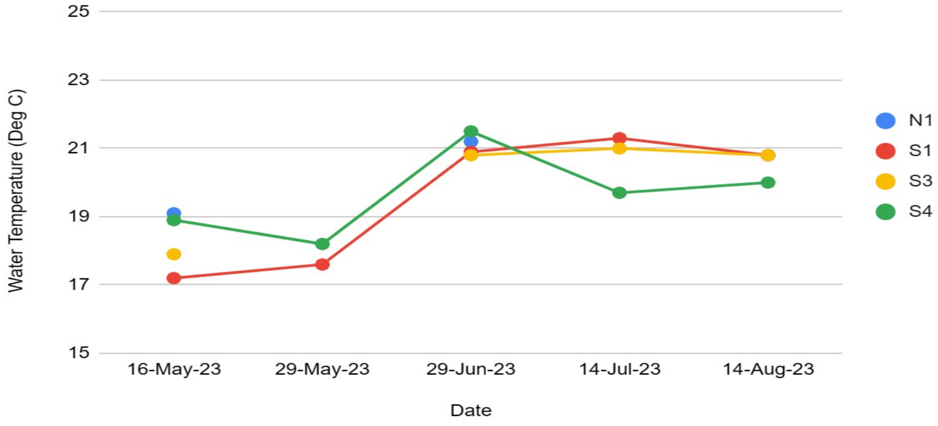


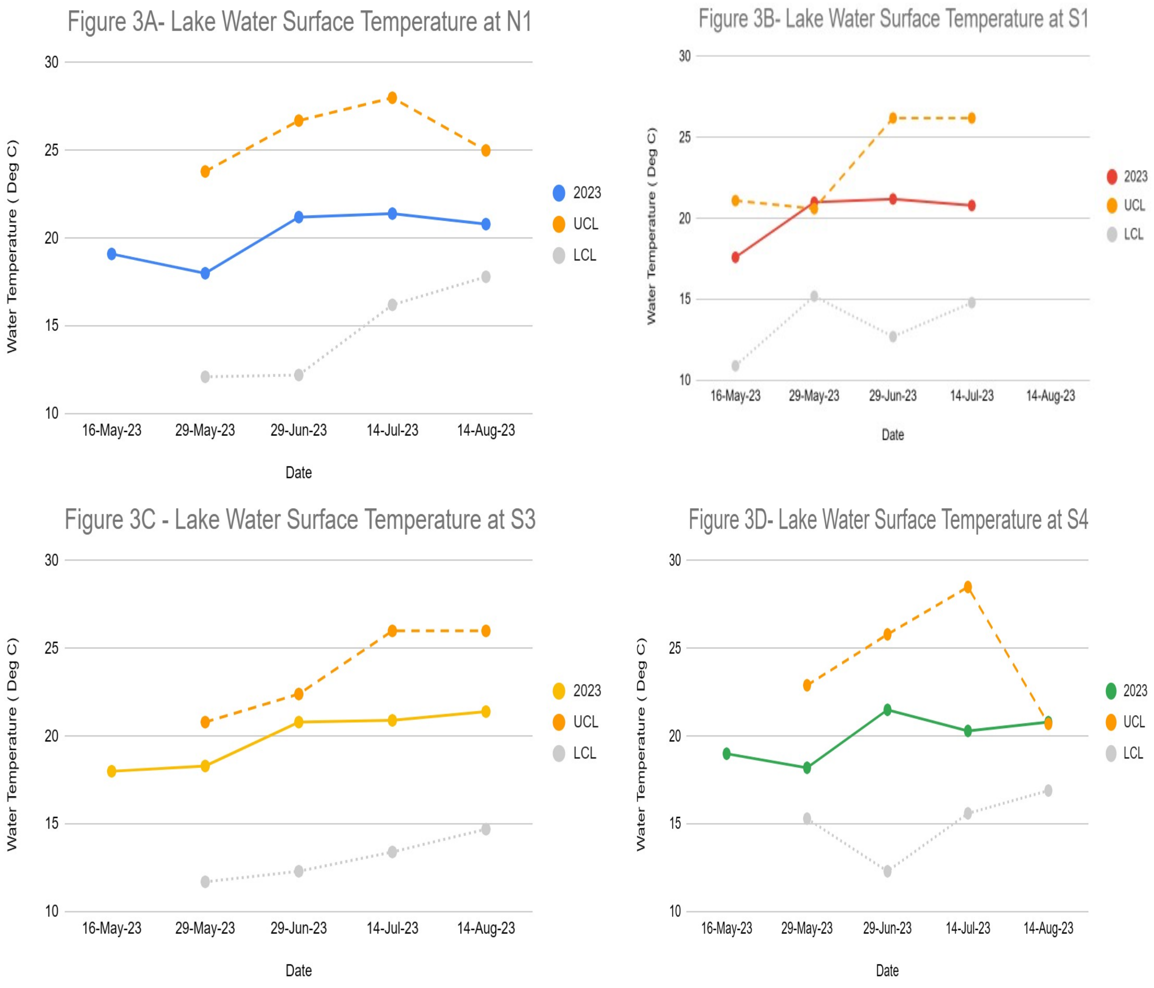
Figure 2B - Lake Water Bottom Temperature, 2023



The minimum temperature measurements in 2023 of between approximately 17 and 19^0 C were measured during the mid and late May monitoring events. The maximum temperatures (greater than 20^0 C) were measured between the late June and the mid-August monitoring events. There are no noticeable differences (greater than 2^{o}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 compares the temperature measurements along the lake in 2023 to the upper and lower temperatures measured between 2014 and 2020. In the prior year 2022, temperatures exceeding the UCL were measured at all locations on the lake in early July. At all four locations on the lake in 2023, however, the lake surface water temperatures exceed 20 from late June until the last monitoring event in mid-August. Also, in 2023 the seasonal decline in water temperature (CLSS annual water quality report for 2022) typically observed to begin in early August was not observed.

Figure 3 – Lake Surface Water Temperature Year to Year Comparison



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 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 not 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.

During the 2023 monitoring events, the lake's surface was frequently too turbulent to allow accurate measurements to be made. A plot of this information has not been provided.

As the collected measurements indicated (Appendix B) the only locations where the Secchi disk was less than the bottom depth occurred at S1, the deepest sampling location on the lake. At this location, the Secchi disk depth and lake bottom measurements generally differed by less than one meter. The Secchi disk measurements made in late May and June of 2017 at S1 differed by more than 1.5 meters.

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 the lake water in the open water zone is influenced mostly by the growth of phytoplankton and the quantity of suspended sediments contained in the lake water. In the open water zone, the main cause of turbidity increase is the growth of phytoplankton. Closer to the shoreline however, suspended sediments are introduced by surface water draining into the lake, shoreline erosion by wave action and disturbance of bottom sediments by wave action and recreational activities. Organic matter that decays in the water as it warms up is also a significant contributor to the lake's murkiness and consumes oxygen as the organic material decays. Decaying organic water consumes oxygen that potentially limits the oxygen available to support aquatic life. The measured turbidity may also be influenced by some chemical reactions that create insoluble precipitates (carbonates mostly) but due to the low mineral content of the Columbia Lake water they are not as great a contributor to the turbidity as the suspended mineral sediments and organic debris.

Turbidity measurements made during the 2023 monitoring events are plotted on Figure 4. The plot demonstrates that the greatest concentrations of turbidity were measured during the mid-May to late-May monitoring event at location N1 on the north end of the lake and at S1 on the southern end of the lake.

Figure 4- Turbidity, 2023

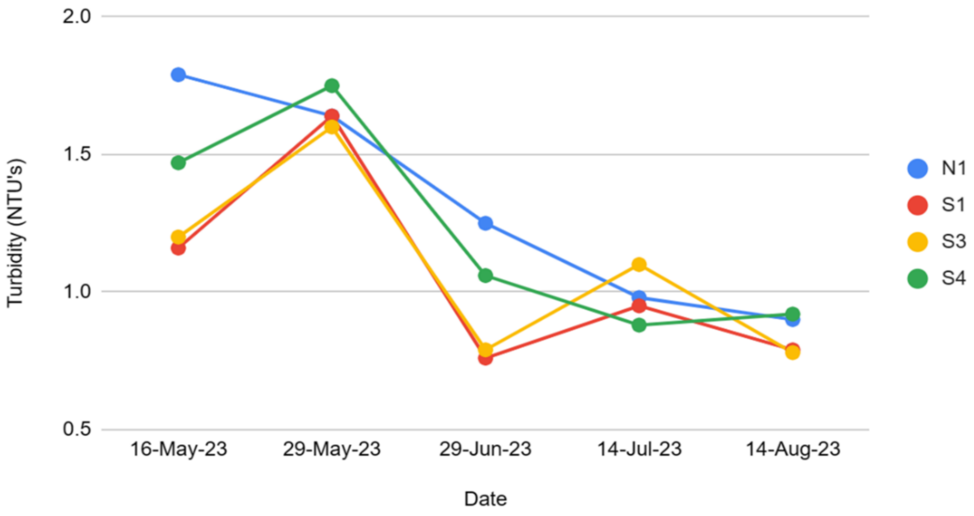


Figure 5 – Turbidity Year to Year Comparison

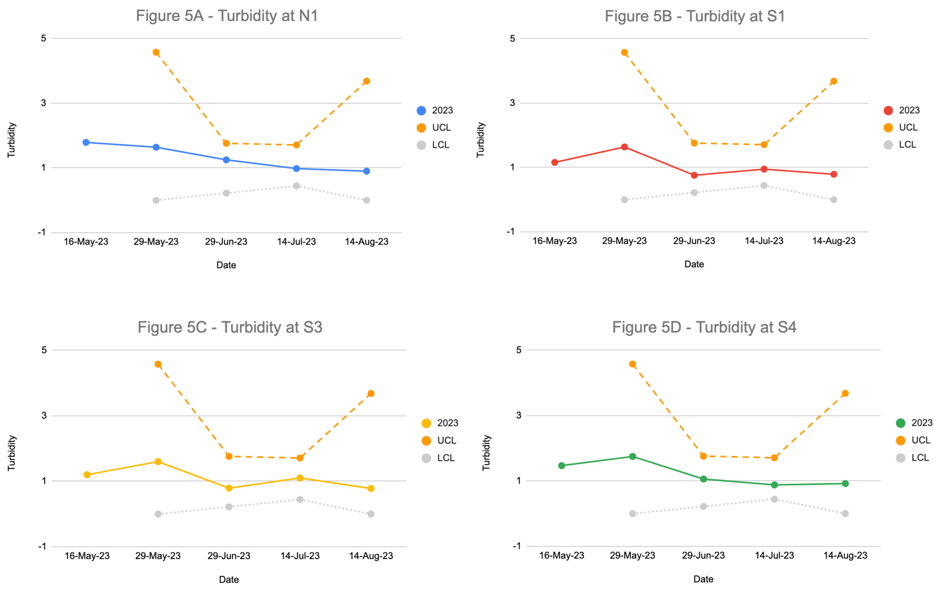


Figure 5 compares the turbidity measurements at each monitoring location on the lake to the control limits established from the range in concentration measured over the previous years. The four graphs (Figures 5 A, B, C and D) show that the trend in turbidity measured over the summer months is comparable to that measured in previous years. The trend is that turbidity concentrations decline from the early spring to late August.

During the 2023 monitoring events all turbidity measurements were less than the UCL.

3.1.4 Specific Conductance

Specific conductance measures the electrical conductivity of the lake water; a measure of the quantity of dissolved salt the lake water contains. These dissolved salts consist of both mineral salts dissolved from particulate sediments in the lake water or that are carried into the lake by groundwater inflows and surface water drainage. A portion of the specific conductance of the 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. Specific conductance is a temperature dependent measurement with higher values measured in warmer water. Most probes correct automatically for the temperature such that the values reported here should not be influenced by temperature changes from month to month.

Figure 6 plots the values measured for the conductivity during 2023. Figures 6a and 6b show there is no appreciable difference in specific conductance concentrations between the surface and bottom of the lake. Figures 6A and B also show that the greatest concentrations for specific conductance are measured in 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. A contribution to the greater concentration of specific conductance in this area of the lake may be associated with drainage from these streams. However, as reported in 2018 by CLSS volunteers, this section of the lake is also 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. These observations suggest groundwater inflow is occurring across the south end of the lake. Therefore, groundwater discharge to the lake at this south end may also be a cause of the greater specific conductance measurements.

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 concentrations for specific conductivity for Columbia are less than this concentration by a factor of three or four.

Figure 6 – Specific Conductance 2023

Figure 6A - Specific Conductance Lake Surface, 2023

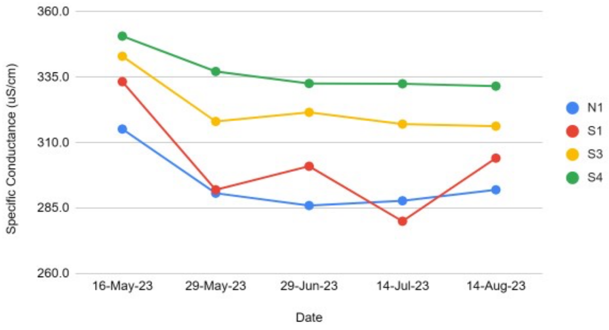


Figure 6B- Specific Conductance Near Lake Bottom, 2023

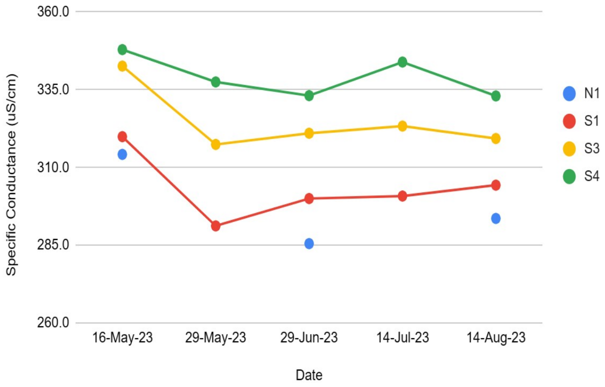
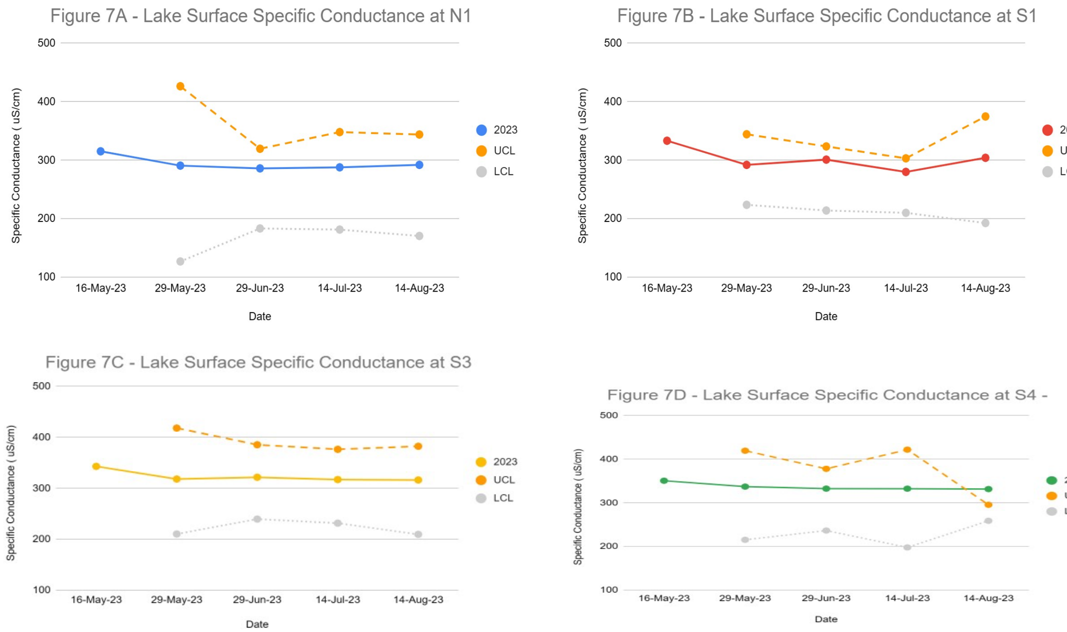


Figure 7 compares the concentrations for specific conductance measured in 2023 to the expected range estimated from between the years 2014 and 2020. These figures demonstrate that the 2023 specific conductance measurements are near the upper range of the expected specific conductance. At the S4 location in the south end of the lake (Figure 7D), the measured specific conductance exceeded the expected value.

Figure 7 – Specific Conductance Year to Year Comparison



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. In water that is too acidic (pH less than 6.5) it is difficult for aquatic organisms to incorporate carbonates into their developing skeletons and water that is too alkaline (pH greater than 8.5) affects the bioavailability of phosphorous and carbonate to aquatic plants also needed for skeletal growth. Water suitable for people to drink has a pH between 6.5 and 8.5 pH units. Table 1 provides a range in pH values of between 6.5 and 9 as published by CCME are suitable for the protection of freshwater aquatic life.

Figure 8 plots the pH values measured at each monitoring location during 2023. Generally, the pH values fall within a narrow range from 7.9 to 8.8 pH units and are similar between the four monitoring locations. Exceptions to this general observation are the pH values measured in late May at N1.

These measured pH values are all within the range established by CCME of 6.5 to 9 for the protection of freshwater aquatic life (Table 1).

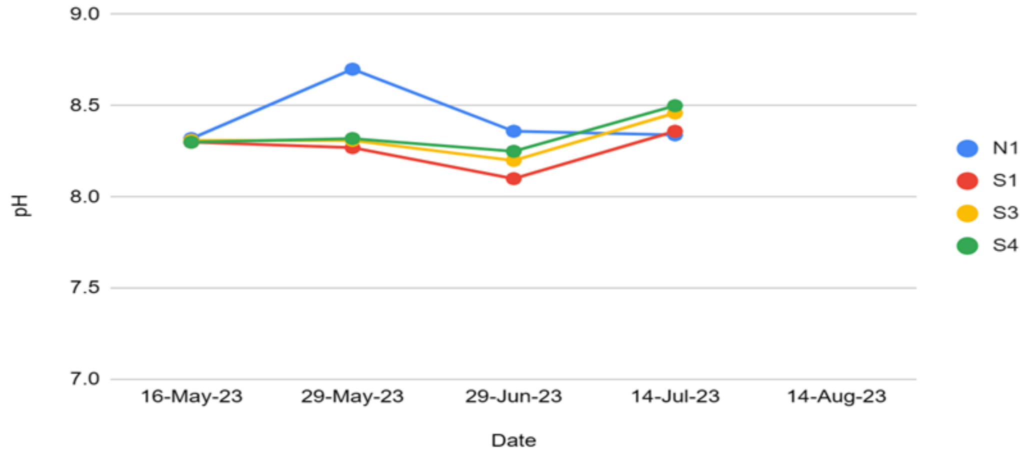


Figure 8 - Lake Water pH 2023

Figure 9 plots the year over year measurements of pH at each of the monitoring locations on the lake. Visually, the plots of the calculated UCL and LCL's suggest that a general increase in pH is observed between April and September. However, in 2023 there was no observable change in pH over the monitoring period. This finding is like that reported in 2021 and 2022. Also, there were no measurements beyond the expected range through the monitoring events in 2023.

Figure 9 – Lake Water pH year to year comparison

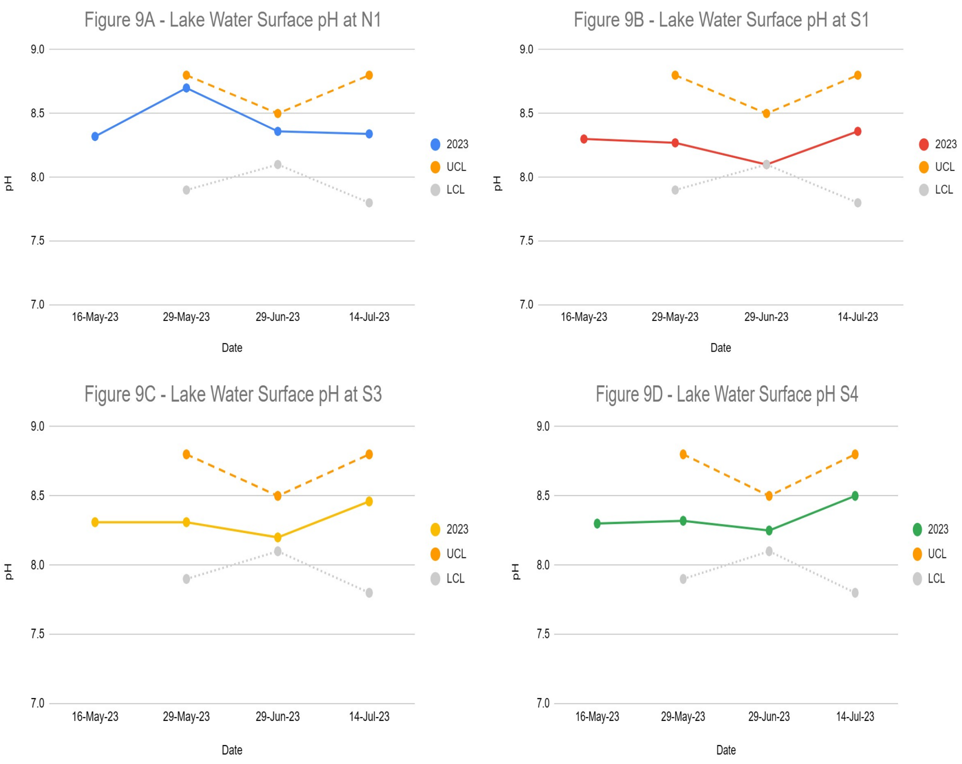


Figure 9A - Lake Water Surface pH at N1

Figure 9B - Lake Water Surface pH at S1

Figure 9C - Lake Water Surface pH at S3

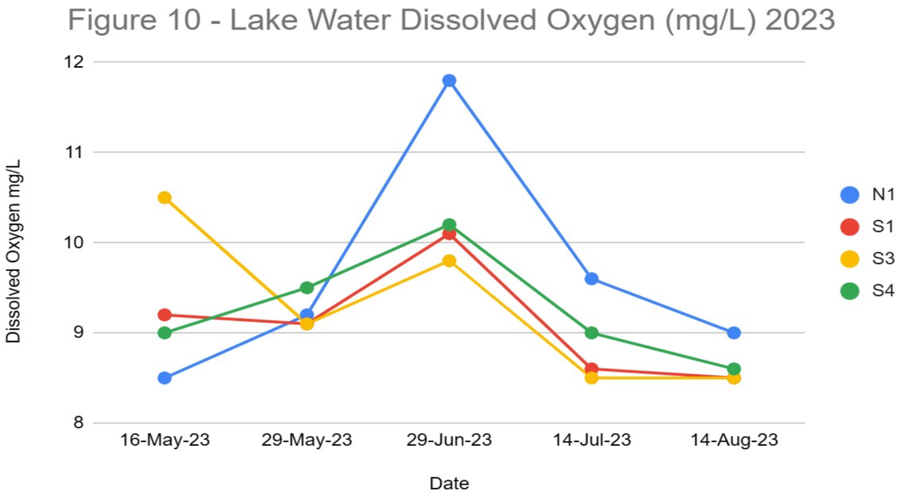
Figure 9D - Lake Water Surface pH S4

3.1.6 Dissolved Oxygen

Water containing dissolved oxygen and carbon dioxide, and which receives sunlight is essential for photosynthetic processes in the lake to occur and allows aquatic and amphibious flora and fauna to thrive. Both carbon dioxide and oxygen are produced by photosynthesis. The only mechanical source of dissolved oxygen is precipitation falling directly on the lake or introduced as snow melt. Lake surface disturbances that create turbulence and waves produced by winds also introduce oxygen to the lake. Some dissolved oxygen is provided to the lake by the inflow of surface drainage, but groundwater inflow will not contribute any noticeable amounts of dissolved oxygen.

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 waters (i.e., 8 mg/L at water temperatures of 25^{o} C and 14 mg/L at water temperatures of 1^{o} C).

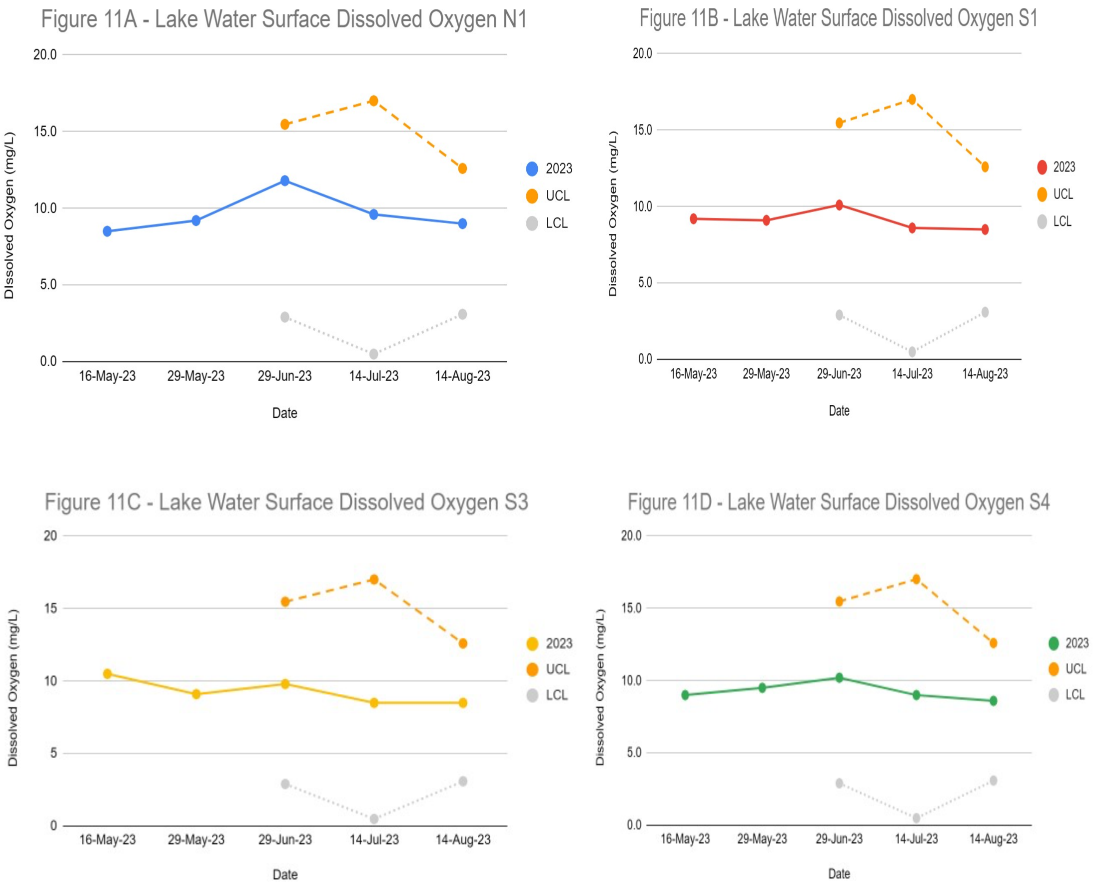
Figure 10 plots the dissolved oxygen concentrations measured in 2023 at the four monitoring locations along the lake. This graph illustrates that for most of the spring and summer, the dissolved oxygen concentrations were greater than 8 mg/L and less than 12 mg/L. Also, the greatest concentrations of dissolved oxygen were measured in mid-June when the lake water was colder. The maximum concentration of dissolved oxygen measured (approximately 11.8 mg/L) was measured during the late June monitoring event. The lowest dissolved oxygen concentrations of about 8.5 mg/L was measured in the middle of May. Table 1 suggests that dissolved oxygen concentrations greater than 5 mg/L are needed to protect freshwater aquatic life.



In general, the dissolved oxygen concentrations increased between May and late June, this observation contrasts that observed in 2022 when the dissolved oxygen concentrations declined from the greater concentration measured in May until the middle of August and increased slightly until the last monitoring event in August of 2022. This pattern of dissolved oxygen patterns follows the pattern of lake surface water temperatures.

Figure 11 compares the year over year measurements of dissolved oxygen. As the graphs on Figures 11 A, B, C, and D suggest, the concentrations of dissolved oxygen measured in 2023, are within the expected ranges measured between 2014 and 2020.

Figure 11 – Dissolved Oxygen – Year to Year Comparison



3.1.7 Total and Dissolved Phosphorous

Phosphorous is a nutrient essential for plant growth. Aquatic plants and particularly microscopic plants are the principal feed stock of phytoplankton which are consumed by small fish and invertebrates and in turn eventually become the feedstock of larger fish and aquatic/amphibious vertebrates. Therefore, healthy lake water must contain phosphorous. However, it is a nutrient that is usually in short supply in freshwater systems. Phosphorous is provided naturally by drainage of water courses that contain dissolved mineral salts and organic materials into the lake. Some phosphorous may also be introduced by wastewater discharge and drainage of organic wastes from agricultural lands. However, too much phosphorous will cause algal blooms, deterioration of oxygen concentrations and stagnation of the lake water, an ecological condition not favorable to a healthy lake.

Phosphorous occurs in both inorganic (derived from the dissolution of minerals in sediments) and organic (derived from decayed organics animal and vegetable) forms. The measure total phosphorous includes both particulate and dissolved phosphorous. Dissolved inorganic phosphorous is the form required for plant growth while animals (including phytoplankton) can use both inorganic and organic forms. This information has been obtained from SEAWA, the South East Alberta Watershed Alliance (2014).

The analyses conducted to date do not distinguish between inorganic and organic phosphorous and perhaps this distinction needs to be investigated in future years as more data on the proportions of total and dissolved phosphorous become available.

The total phosphorous concentrations measured by CLSS during the two monitoring events on Columbia Lake are plotted on Figure 12. The maximum concentrations measured for 2023 occurred in the late May monitoring event when the lake water is beginning to generate algae. At two locations S1 and S4 the concentration of total phosphorous increased over the summer while at the other two locations N1 and S3 the concentration of total phosphorous decreased between mid-May and mid-August.

Figure 12 - Total Phosphorus (mg/L) 2023

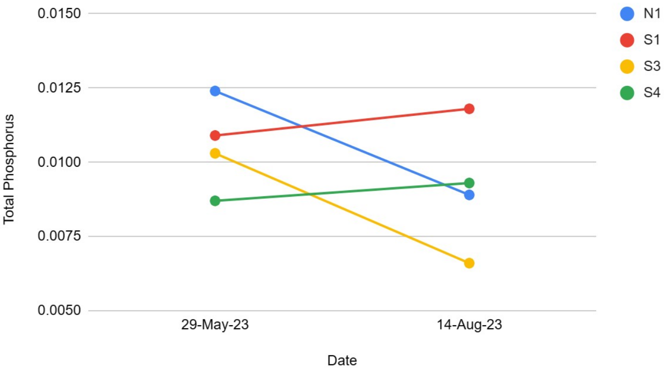


Table 2 contains the total and dissolved concentrations measured in 2023. CLSS understands that the ratio of dissolved phosphorous concentration to total phosphorous concentration may indicate when the phytoplankton growth in the lake is greatest. The growth of phytoplankton is one of the greatest contributors to turbid water and results in murky water. When this ratio is low it means that most of the phosphorous in the water is organic and the phytoplankton content of the water is the greatest. These low ratios occurred in the late spring but generally the total phosphorous concentration was consistent throughout the monitoring period.

Of greater concern, is the comparison of the total phosphorous concentration compared to the concentration used by Lake Windermere of 0.01mg/L (Table 1) to assess water quality. On several occasions during the middle of the summer months the concentration of total phosphorus in Columbia Lake exceeded this maximum value.

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 2024 as funding permits.

3.1.8 Additional analyses in 2023

In 2023 due to funding limits no additional analyses were undertaken at the four monitoring locations on the lake. For the 2023 monitoring program CLSS collected and had analyses undertaken for nitrate, iron and manganese, hardness, and chloride. 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. But if nitrate concentrations become too great to be assimilated into organisms, they can lead to oxygen consumption and eutrophication of lake waters. Nitrate is frequently a component of runoff from agricultural lands and wastewater systems into lakes and is a reliable means of detecting contributions to the lake from these potential 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 not measured in 2017, 2018 or 2019. However, we noted that detectable concentrations of nitrate were measured during the stream sampling program conducted in the early autumn of 2019 (Section 3.3). These measurements suggested that nitrate should be reintroduced to the annual sampling program. The results provided in Table 2 show that for 2020, 2021 and 2022 nitrate concentrations are less than the analytical detection limit.

Iron and manganese, and hardness were added to the chemical analysis to aid in determining whether increases in turbidity noted in the lake water over the summer months in 2019 were due to increases in phytoplankton growth or the disturbance of bottom sediments. Bottom sediments were understood to be disturbed due to increased shoreline erosion, sediments from streams draining into the lake, wave action or recreational activity.

Table 2 shows that concentrations of iron greater than the analytical detection limit in 2022 were measured and N1 in the north end of the lake and the concentrations of both manganese and hardness increased from the south end of the lake to the north end of the lake. All concentrations measured are less than the water quality standards proposed by Table 1.

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 showed that it contained chloride concentrations much greater than that measured in the other streams sampled in 2019. CLSS wanted to learn whether chloride concentrations would increase in the lake.

The chloride concentrations in Table 2 show that the greatest concentrations are in the south end of the lake. The concentrations are much lower than any concentration standard that would suggest a water quality concern. Results of the water quality analyses for 2023 are similar to the concentrations measured in 2022 and 2021.

Table 2 - Comparison of Concentrations for Nitrate, Iron, Manganese, Alkalinity, Hardness and Chloride from South to North

		monitoring location		sampling date											
				29-May-19	22-Jul-19	28-May-20	18-Jul-20	10-Jun-21	22-Jul-21	21-Aug-21	27-May-22	20-Jul-22	28-Aug-22	29-May-23	14-Aug-23
South	Location S4	Total Phosphorous	mg/L			**0.00860**	0.01150	0.0091	0.0116	0.00790	0.0141	0.0092	0.0106	0.0087	0.0093
		Dissolved Phosphorous	mg/L			0.004	0.099	0.0079	0.0101	0.0069	0.0063	0.0053	<0.005	0.0054	0.0056
		nitrate	mg/L			<0.01	<0.01		<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
		iron	mg/L			<0.01	0.015		0.029	0.011	<0.01	<0.01	<0.01		0.01
		managanese	mg/L			0.00472	0.0038		0.00522	0.00365	0.00496	0.00101	0.00404		0.00351
		alkalinity (as $CaCO_3$)	mg/L			173	150								
		hardness (as $CaCO_3$)	mg/L			177	173		188	175	174	174	167		170
		chloride	mg/L			5.7	5.04		5.83	5.96	6.39	5.97	6.4	6.13	6.36
	Location S3	Total Phosphorous	mg/L			0.0072	0.0084	0.0106	0.0129	0.0061	0.0095	0.0083	0.0088	0.013	0.0066
		Dissolved Phosphorous	mg/L			0.0042	0.0064	0.007	0.0119	<0.005	0.0093	<0.005	<0.005	0.0055	<0.005
		nitrate	mg/L			<0.01	<0.01		<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
		iron	mg/L			0.015	<0.01		0.014	<0.01	<0.01	<0.01	<0.01		<0.01
		managanese	mg/L			0.0038	0.0078		0.0063	0.00433	0.00524	0.0014	0.0052		0.00538
		alkalinity (as $CaCO_3$)	mg/L			150	145								
		hardness (as $CaCO_3$)	mg/L			173	169		167	167	174	158	161		161
		chloride	mg/L			5.04	4.74		5.04	5.51	5.97	4.9	6.16	5.38	6.05
	location - S1 Shallov	Total Phosphorous	mg/L	0.0064	0.0089	0.0082	0.0077	0.0076	0.0127	0.0074	0.0102	0.0069	0.0072	0.0109	0.0118
		Dissolved Phosphorous	mg/L	0.0022	0.0037	0.0054	0.0065	0.0057	0.0103	0.0054	0.008	<0.005	<0.005	0.0052	0.0087
		nitrate	mg/L			<0.01	0.064		<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
		iron	mg/L			<0.01	<0.01		0.03	0.013	0.016	<0.01	<0.01		<0.01
		managanese	mg/L			0.00831	0.0108		0.0172	0.0117	0.0087	0.00277	0.0197		
		alkalinity (as $CaCO_3$)	mg/L			164	138								
		hardness (as $CaCO_3$)	mg/L			162	157		154	160	166	138	144		150
		chloride	mg/L			5.23	4.14		4	4.97	5.32	3.53	4.48	4.33	5.36
	Location S1 - deep	Total Phosphorous	mg/L			0.0099	0.0106	0.015	0.0136	0.0081		0.007		0.0119	0.0075
		Dissolved Phosphorous	mg/L			0.0044	0.0066	0.007	0.127	<0.005		<0.005		0.005	>0.005
		nitrate	mg/L			<0.01	<0.01		<0.01	<0.01		<0.01		<0.01	<0.01
		iron	mg/L			0.011	0.014		0.022	0.015		<0.01			0.012
		managanese	mg/L			0.00872	0.0149		0.0185	0.0126		0.00293			0.017
		alkalinity (as $CaCO_3$)	mg/L			166	138								
		hardness (as $CaCO_3$)	mg/L			167	153		154	160		140			
		chloride	mg/L			5.32	4.32		4.03	3.64		3.56		4.37	5.37
North	Location N1	Total Phosphorous	mg/L			0.0073	0.0082	0.0084	0.0127	0.0074	0.0107	0.0069	0.0076	0.0124	0.0089
		Dissolved Phosphorous	mg/L			0.0039	0.0056	0.0076	0.0103	0.0058	0.0055	0.0054	<0.005	0.0051	<0.005
		nitrate	mg/L			<0.01	<0.01		<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
		iron	mg/L			0.032	0.01		0.019	0.018	0.011	<0.01	0.013		0.013
		managanese	mg/L			0.0112	0.0142		0.0231	0.00969	0.0071	0.00215	0.0241		0.0199
		alkalinity (as $CaCO_3$)	mg/L			169	135								
		hardness (as $CaCO_3$)	mg/L			160	146		146	153	161	134	141		149
		chloride	mg/L			4.84	3.67		3.64	4.74	5.67	3.04	4.12	4.28	5.12

3.2 Along the Lake Profile Program

Beginning on July 13 of 2018, CLSS conducted along the lake profiles (south to north) of the water quality indicators, temperature, turbidity, and specific conductance. The program involved monitoring at fourteen locations along the lake within one day as a single “snapshot” of the water quality. The program was initiated because evaluation of the results of the monitoring program at the four locations described in Section 3.1 identified differences in concentrations of the indicator parameters that might occur from the contribution of streams draining into the lake. The results showed that the concentration of turbidity and specific conductance decreased from south to north; a finding that is contrary to the suspicion that evaporation from the lake’s surface over the summer months would cause these concentrations to increase from south to north. The Columbia River at the north end of the lake is the only drainage from the lake.

In 2019, chloride was added to the program because CLSS understood that this simple salt would be the most likely contributor to changes in the specific conductance. Subsequently, CLSS received results of BCMOE’s monitoring of the lake and discovered that Columbia Lake contained concentration of salt that were noticeably greater than other neighboring lakes.

These “Along the Lake Profiles” are described in Appendix D, and the measurements made are tabulated in Table 3, and plotted on Figure 13.

Table 3- Temperature, Turbidity, Specific Conductance and Choride concentrations along Columbia Lake

A) Temperature

	Date								
	2018				2019	2020		2022	2023
Location	13-Jul-18	28-Jul-18	13-Aug-18	22-Aug-18	23-Jul-19	18-Jul-20	18-Aug-20	20-Jul-22	18-Jul-23
1	20.9	21.5	18.8	19	19.6	19.6	20.5		19.9
2	21	21.3	19.7	18.9	19.6	19.7	20.6		20.6
3	20.7	21.4	19.2	18.4	19.5	19.4	20.8		20.6
4	20.9	21.2	20	19.3	19.9	19.3	20.6		21
5	20.7	21.4	20	18.9	19.6	19.2	20.9		21
6	20.7	21.3	20.1	19.5	19.7	19.1	20.6		21.2
7	20.7	21.5	20.5	19.3	20.4	19	21.1		21.4
8	20.9	21.4	20.5	19.7	19.7	19	20.8		21.8
9	20.9	21.5	20.6	19.7	20	18.6	21.1		21.5
10	20.7	21.5	20.1	19.9	19.4	18.8	20.2		21.3
11	21	21.6	20.6	19.8	19.7	19	20.8		21.8
12	20.6	21.6	20.8	20	19.5	18.9	20.6		22.3
13	20.7	21.7	20.6	20	19.3	18.8	20.8		22.2
14	21.2	21.7	19.6	19.6	19.8	18.8	21		22.6

B) Turbidity concentrations (NTU's)

Location	13-Jul-18	28-Jul-18	13-Aug-18	22-Aug-18	23-Jul-19	18-Jul-20	18-Aug-20	20-Jul-22	18-Jul-23
1	1.34	1.92	2.55	1.68	1.22	1.51	2.3		1.53
2	1.98	1.19	2.61	2.34	1.31	1.42	1.66		0.81
3	1.55	1.89	3.33	1.45	1.82	1.24	1.09		0.96
4	1.29	1.64	3.23	1.01	1.34	1.15	0.94		
5	2.72	2.51	2.61	0.87	1.27	0.94	0.79		0.75
6	1.23	1.48	2.39	0.74	1.69	1.03	0.94		0.63
7	1.26	1.81	2.11	1.01	1.12	0.74	0.82		0.93
8	1.09	1.18	2.37	0.93	1.04	0.88	0.66		0.68
9	0.97	1.45	2.38	1.09	1.22	0.69	1.26		0.65
10	1.14	1.17	1.59	0.88	1.08	0.88	1.08		0.77
11	1.04	1.26	1.45	0.89	0.97	0.85	1.06		0.75
12	1.24	1.03	2.35	0.87	0.91	0.81	0.86		0.95
13	1.02	1.69	1.47	1.32	1.64	0.8	0.64		1.16
14	1.18	0.92	1.48	0.83	1.14	0.69	0.92		1.05

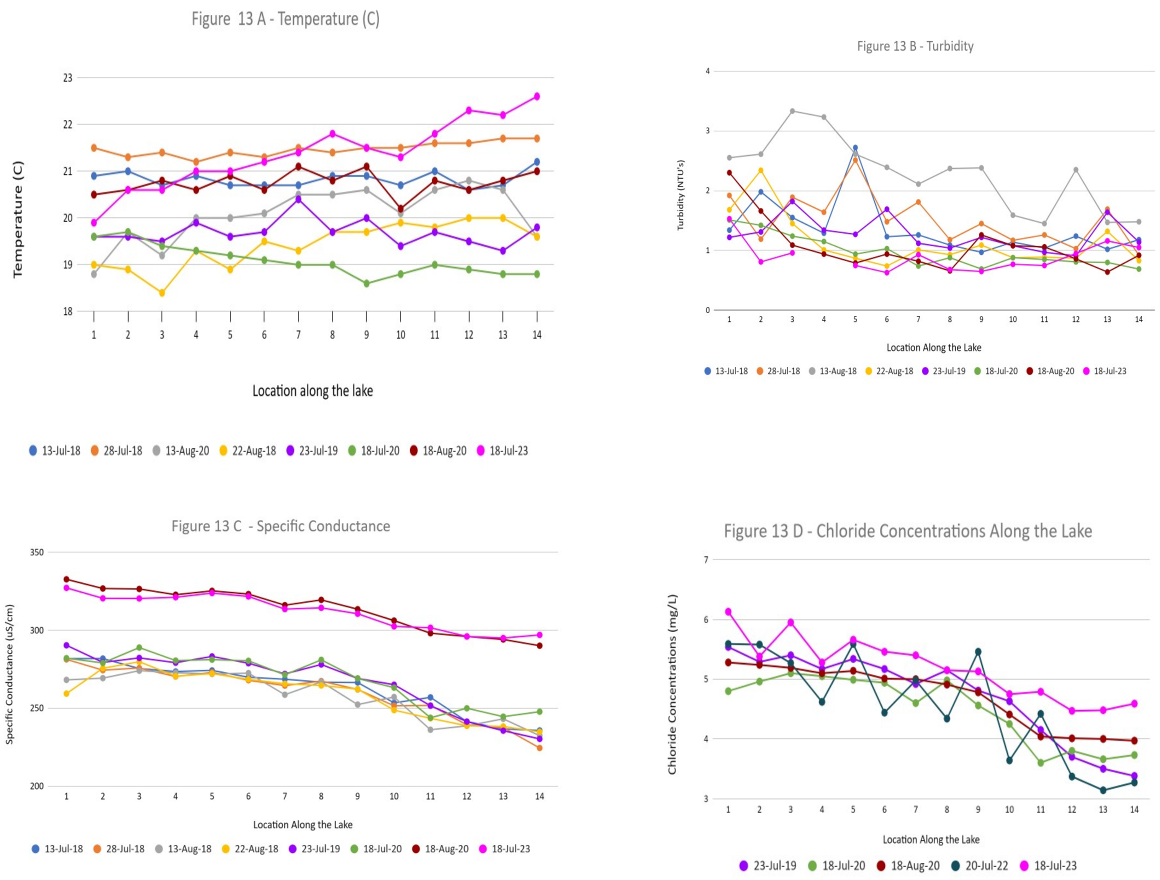
C) Specific Conductance (uS/cm)

Location	13-Jul-18	28-Jul-18	13-Aug-18	22-Aug-18	23-Jul-19	18-Jul-20	18-Aug-20	20-Jul-22	18-Jul-23
1	281.8	281.3	268.2	259.3	290.3	282.1	332.7		327.2
2	281.8	274.4	269.3	275.6	279.4	279	326.8		320.5
3	275.4	275.8	274.1	279.8	282.3	288.9	326.5		320.4
4	273.5	270.3	272.7	270.6	279.2	280.5	322.8		321.2
5	274.2	273	272	272.2	283.2	281.1	325.3		323.9
6	269.9	267.9	272.5	268.5	278.8	280.4	323.2		321.7
7	268.6	264.5	258.6	265.6	272	271.4	316.1		313.6
8	266.7	267.4	266.9	264.6	278	281	319.5		314.4
9	266.5	262	252.3	262.2	269.1	269.1	313.5		310.6
10	253.4	251.5	257.2	248.7	265	263.2	306.2		302.5
11	256.9	251.7	236.1	243.5	251.6	243.8	298.1		301.6
12	241.4	239.3	238.6	238.7	241.4	249.9	296		296
13	236.6	237.6	243.1	238.3	235.5	244.6	294.1		295
14	235.7	224.4	232.4	234.8	230.3	247.7	290.1		297

D) Chloride Concentrations (mg/L

Location	13-Jul-18	28-Jul-18	13-Aug-18	22-Aug-18	23-Jul-19	18-Jul-20	18-Aug-20	20-Jul-22	18-Jul-23
1					5.54	4.8	5.28	5.59	6.13
2					5.29	4.96	5.24	5.58	5.38
3					5.4	5.1	5.19	5.27	5.95
4					5.17	5.05	5.1	4.62	5.28
5					5.34	4.99	5.14	5.59	5.66
6					5.17	4.94	5.01	4.44	5.46
7					4.92	4.6	5	4.98	5.4
8					5.15	4.98	4.91	4.34	5.15
9					4.81	4.56	4.78	5.46	5.13
10					4.63	4.25	4.41	3.64	4.75
11					4.15	3.6	4.04	4.42	4.79
12					3.7	3.8	4.01	3.37	4.47
13					3.5	3.66	4	3.14	4.48
14					3.38	3.73	3.97	3.27	4.59

Figure 13 – Along the Lake Profiles



Funding did not permit data for the north to south profiles to be collected in 2021 prompting CLSS's decision to generate the profiles every other year. In July 2022, one south to north profile was prepared for chloride concentrations only and in 2023 indicator parameters and chloride concentrations were measured at all fourteen locations. These results (Figure 13) show that the specific conductance and chloride concentrations measured at all fourteen locations were greatest measured over the prior 5 years.

This finding is consistent with the stream measurements of the creek draining from Canal Flats (Section 3.3) that show the chloride concentration from this creek has not changed over the period of monitoring by CLSS.

3.3 Stream sampling program

The stream sampling sites monitored by CLSS in 2023 were as follows:

> 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.
>
> Marion Creek - steady and turbulent water flow - the creek bed contained gravel-sized material that had some staining by iron and manganese oxides and the water sampled was clear. There was some fibrous organic material observed along the stream bed.
>
> 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.
>
> Lansdowne Creek- steady water flow, tree sheltered with the stream bed containing mossy rocks.

CLSS monitored these streams on May 15, May 29, June 15, June 27, July 25, and August 14. The water quality measurements made on each stream included water temperature, specific conductance (conductivity), dissolved oxygen, pH, and turbidity. Chloride concentrations were measured on three occasions, the May, July and August events. Sampling of Lansdowne Creek on the east side of the lake was not undertaken in 2023.

The water quality measurements and analyses made during the stream sampling program are summarized in Table 4 and the results compared on Figure 14.

Table 4 - Comparison of Stream Quality Measurments 2023

	Date	Time	Water Temp ( )	Specific Cond. (uS/cm)	Dissolved Oxygen (mg/L)	pH	Turbidity (NTU)	Suspended Sediments (mg/L)	Chloride (mg/L)
A) Dutch Creek	07-Oct-19								0.43
	15-Jun-20	10:00:00 AM	6.3	126.2	11	7.5	20.8		<0.10
	23-Jul-20	10:00:00 AM	10.3	147.2	10.28	8.4	4.09		
	27-Aug-20	1:45:00 PM	12	201.5	10.41	8.2	1.01		
	19-Sep-20	2:25:00 PM	11.9	221	10.5	8.4	0.58		
	17-Jun-21	12:25:00 PM	7.2	141.7	11.9	7.2	3.52		<0.10
	12-Jul-21	1:26:00 PM	13.7	163.9	10.2	8.4	7.58		<0.10
	16-Aug-21	10:05:00 AM	13.1	204.5	10.7	8.38	2.22		<0.10
	10-May-22	1:56:00 PM	6.7	225.7	11.5	8.44	2.53		0.11
	22-Jun-22	11:55:00 AM	6.9	139.3	13.1	8.68	39.5		<0.10
	12-Jul-22	10:15:00 AM	7.6	132.7	10.7	8.31	17		<0.10
	17-Aug-22	10:57:00 AM	12.3	181.4	10.9	8.78	1.17		
	15-May-23	9:30:00	12	134.5	11.5	7.98	18.7		
	29-May-23	7:39:00	7	136.4	12	7.34	15.4		0.14
	15-Jun-23	8:30	7.5	150.1	10.3	7.8	8.1		
	27-Jun-23	8:00	10.6	168.9	11.5	8.02	1.61		
	25-Jul-23	8:46	12.9	201	14.2		2.96		0.1
	14-Aug-23	2:12:00 PM	16.8	214	10.2		1.94		<0.10
B) Hardie Creek	07-Oct-19								
	14-Jun-20		9.2	444	10	8.3	2.47		
	23-Jul-20		11.1	303.8	9.81	8.2	2.85		0.45
	27-Aug-20	1:00:00 PM	10.5	481.3	10.36	8.3	4.09		0.56
	19-Sep-20	11:41:00 AM	10	494	10.5	7.9	7.9		
	14-Mar-21	12:37:00 PM	1.3	543	11.1	8.2	2.34	2.6	0.48
	19-Apr-21	10:30:00 AM	2.7	537	9.2	8.4	2.25	<2.0	0.52
	17-May-21	1:46:00 PM	12.9	508	10.3	8.8	1.29	3.7	0.4
	17-Jun-21	10:00:00 AM	8.2	244	12	8.5	1.47	<4.0	0.35
	12-Jul-21	12:58:00 PM	12.6	487	10.6	8.8	3		0.33
	16-Aug-21	10:57:00 AM	11.4	490	11.7	8.5	3.43		0.31
	10-May-22	1:12:00 PM	7.9	507	13.2	8.54	1.68		0.48
	22-Jun-22	11:20:00 AM	11.1	507	12.5	8.46	1.71		0.4
	12-Jul-22	11:03:00 AM	10.5	492	11.7	8.34	4.43		0.34
	17-Aug-22	11:42:00 AM	11.3	474	10.6	8.67	2.57		
	15-May-23	11:15:00	9.8	503	12.8	8.54	1.37		
	29-May-23	8:20:00	9.9	546	9.6	8.36	1.44		0.64
	15-Jun-23	9:05	10.1	600	11.3	8.53	3.33		
	27-Jun-23	8:40 AM	11.1	531	11.1	8.52	1.36		
	25-Jul-23	9:35 AM	12.3	503	15.2		3.18		0.38
	14-Aug-23	1:40:00 PM	13.4	479	9		2.15		0.37
C) Marion Creek	07-Oct-19								
	15-Jun-20		11.9	283	9.1	8.4			
	23-Jul-20		17.6	344.1	8.7	8.4	4.09		0.4
	27-Aug-20	11:15:00 AM	14.4	354.6	9.82	8	1.56		0.11
	19-Sep-20	2:20:00 PM	13.7	366	10.1	8.3	6.03		
	14-Mar-21	1:03:00 PM	1.3	362.3	10.2	8.1	2.24	<6.7	
	19-Apr-21	9:30:00 AM	5.7	383.3	8.5	8.4	5.61	9.2	
	17-May-21	2:13:00 PM	18	373.5	9.8	8.3	12	15	
	17-Jun-21	10:37:00 AM	14.6	343.5	9.3	8.6	5.93	2	
	12-Jul-21	12:26:00 PM	21	243.1	9.4	8.6	1.24		0.16
	16-Aug-21	10:37:00 AM							
	08-Sep-21	2:04:00 PM	14.1	356.6	5.9	8.6	2.38		
	10-May-22	12:30:00 PM	10.8	385.7	11.7	8.56	7.15		0.42
	22-Jun-22	10:37:00 AM	14.4	326	12.9	8.88	13.9		0.19
	12-Jul-22	11:37:00 AM	15.5	321.3	9	8.3	5.05		0.1
	17-Aug-22	12:24:00 PM	18.6	344.4	9.7	8.6	12.7		
	10-May-22	12:30 PM	10.8	385.7	11.7	8.56	7.15		
	15-May-23	13:00:00	17.1	336.7	8.3	8.43	13.5		
	25-Jul-23	10:17	17.9	352	11		5.36		0.15
	14-Aug-23	1:00:00 PM	17.7	357.7	8.2		3.84		0.18
D) Creek flowing from Canal Flats	14-Jun-20		8.5	341	8.4	7.8	2.01		
	23-Jul-20		8.9	388.6	8.88	8	0.17		9.68
	27-Aug-20	12:05:00 PM	8.8	385.3	9.68	7.8	0.47		8.22
	19-Sep-20	1:40:00 PM	8.2	400.3	9.7	7.4	0.53		
	17-Jun-21	11:05:00 AM	8.5	404.5	15.2	7.9	0.7	<6.7	8.49
	12-Jul-21	11:31 AM	9.1	386.8	9.3	8.4	1.75		8.45
	16-Aug-21	12:00 PM	8.2	394	10.7	8.1	3.16		9.01
	10-May-22	11:31 AM	6.9	412.7	9.2	7.55	0.65		10
	22-Jun-22	9:47 AM	8.2	394	11.2	7.93	0.41		9.96
	12-Jul-22	12:23 PM	11.1	403.3	8.1	8.15	0.62		9.75
	17-Aug-22	1:05 PM	9.4	395.5	10.7	8.5	4		
	15-May-23	13:20:00	8	380.6	10	7.9	0.23		
	29-May-23	12:26:00	8.2	394.5	12.2	7.8	0.26		9.2
	15-Jun-23	9:45	7.1	401	9.4	7.93	0.25		
	27-Jun-23	9:19 AM	8.3	392	9.3	7.98	0.29		
	25-Jul-23	11:10	8.4	389.4	14.8		0.96		9.45
	14-Aug-23	7:55 AM	7.6	407.7	14.2		0.71		10.5
E) Landsdowne Creek	07-Jul-21	1:30 PM	9.1	313.7	12.5	8.9	2.58		

Note: a suspect pH and dissolved oxygen meter did not allow August measurments to be reported.

Figure 14 – Stream Water Comparisons - 2023

Water Temperature

The temperatures tabulated in Table 4 show that the water temperature in each creek generally increases over the summer months. The coolest of the four creeks monitored is the creek that drains from Canal Flats. In 2023 the temperature in this creek ranged from about 7 to 9 degrees C and did not noticeably increase over the summer months as the temperature in the other three creeks. These low temperatures 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 well down the drainage way from the stream's origins.

The warmest of the creeks is Marion Creek. In June of 2023, the water temperature of Marion Creek was measured as 18 degrees.

pH

The pH values ranged from 7.40 to 8.40. These results show that the lowest pH value was measured in Dutch Creek at the north end of the lake. The largest pH was measured in Hardie Creek.

Specific Conductance

The lowest values for the specific conductance in the range of 141 to 225.7 uS/cm were measured in Dutch Creek: the stream with the greatest flow rate of the four that CLSS monitors. In contrast Hardie Creek provided specific conductance concentrations that were noticeable greater than either Marion Creek or the creek draining from Canal Flats. The specific conductance values in all creeks are much less than the Health Canada guideline (Table 1) of 700 uS/cm.

Dissolved oxygen

Dissolved oxygen concentrations were generally greater than 8 pH units in all creeks. Marion Creek provided the lowest value for the pH in the early spring and late spring monitoring events and suggests that additional monitoring (more frequent) for the pH of Marion Creek should be considered to protect the aquatic habitat at the mouth of the creek on Columbia Lake. All creeks except Marion creek measured the greatest dissolved oxygen in late July monitoring event.

Turbidity

For 2023, the turbidity values measured on the creeks ranged between 0.25 and 20.8 NTU's. an unusual value of 20.8 NTU's was measured on Dutch Creek in Mid- May and was associated with a very high flow in the creek. All of the turbidity measurements made on Dutch Creek, Marion Creek and Hardie Creek in 2023 were greater than the value used by Health Canada for water quality guidelines and the range measure in Columbia Lake of less than 1 NTU's. Because much of the turbidity in fresh water is often attributed to aquatic growth, turbidity in these creeks should be continued to be monitored as resources permit more frequently in 2023.

Other parameters

Chloride is a parameter of concern since its primary source is human use of salts.

The concentrations of chloride measured at the four surface water sampling sites in 2023 ranged from less than 0.10 mg/L (the analytical detection limit) in Dutch Creek to 10.5 mg/L in the creek draining from Canal Flats. The other two steams yielded chloride concentrations ranging from 0.15 to o.64 mg/L.

3.3 Water Quality Sampling Along the Columbia River

Table 5 presents the indicator parameters measured during the three sampling events along the Colombia River north of Columbia Lake and compares the upstream to the downstream measurements. The information is plotted on Figure 15. In general, the values for all of the indicator parameters increased between the upstream and downstream locations. Exceptions are for the dissolved oxygen and pH measurements which had essentially the same concentration between the two locations.

Table 6 summarizes the chemical analyses for chloride, sulphate, alkalinity, nitrate, dissolved phosphorous, total phosphorous, iron and manganese. These results are like those for the indicator parameters: the concentrations generally increased between the upstream and downstream locations. The exceptions to this finding are the concentrations of iron and manganese which declined in concentration between the upstream and downstream locations during the mid July and mid august measurements.

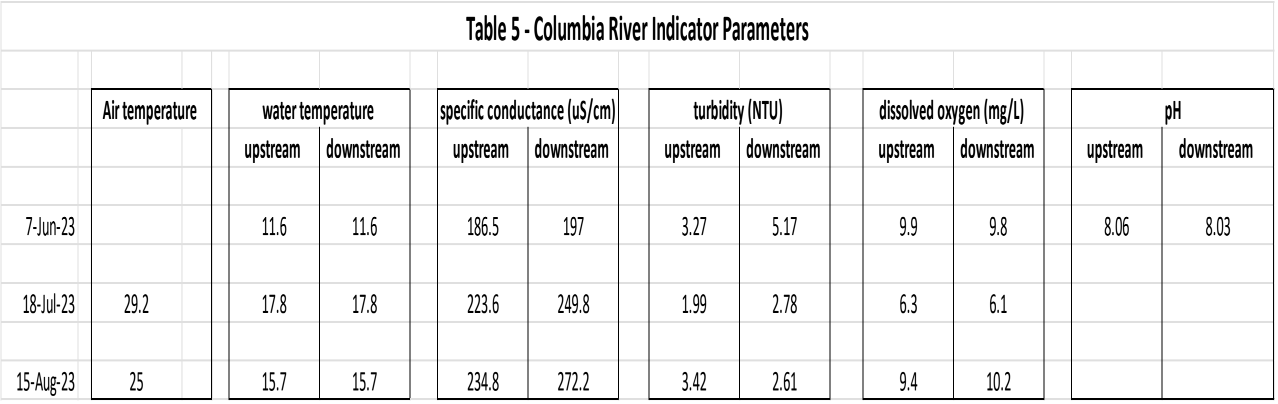
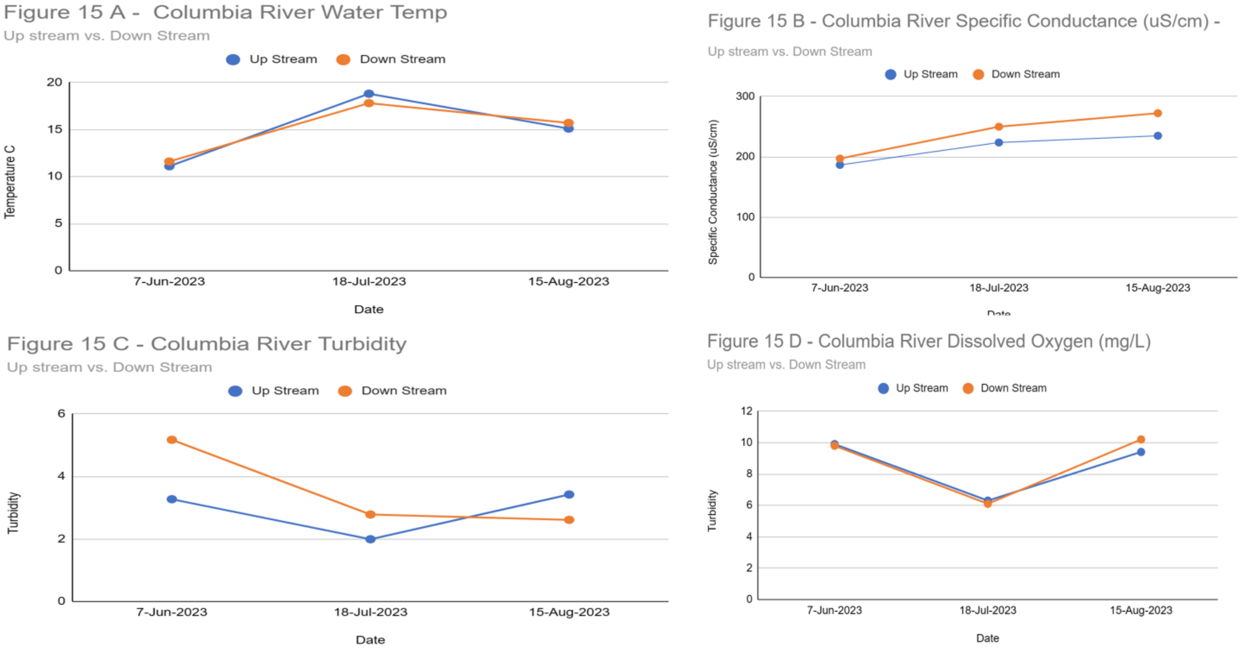


Table 5 - Columbia River Indicator Parameters

	Air temperature	water temperature		specific conductance (uS/cm)		turbidity (NTU)		dissolved oxygen (mg/L)		pH	
		upstream	downstream	upstream	downstream	upstream	downstream	upstream	downstream	upstream	downstream
7-Jun-23		11.6	11.6	186.5	197	3.27	5.17	9.9	9.8	8.06	8.03
18-Jul-23	29.2	17.8	17.8	223.6	249.8	1.99	2.78	6.3	6.1		
15-Aug-23	25	15.7	15.7	234.8	272.2	3.42	2.61	9.4	10.2		

Figure 15 – Columbia River Quality - 2023



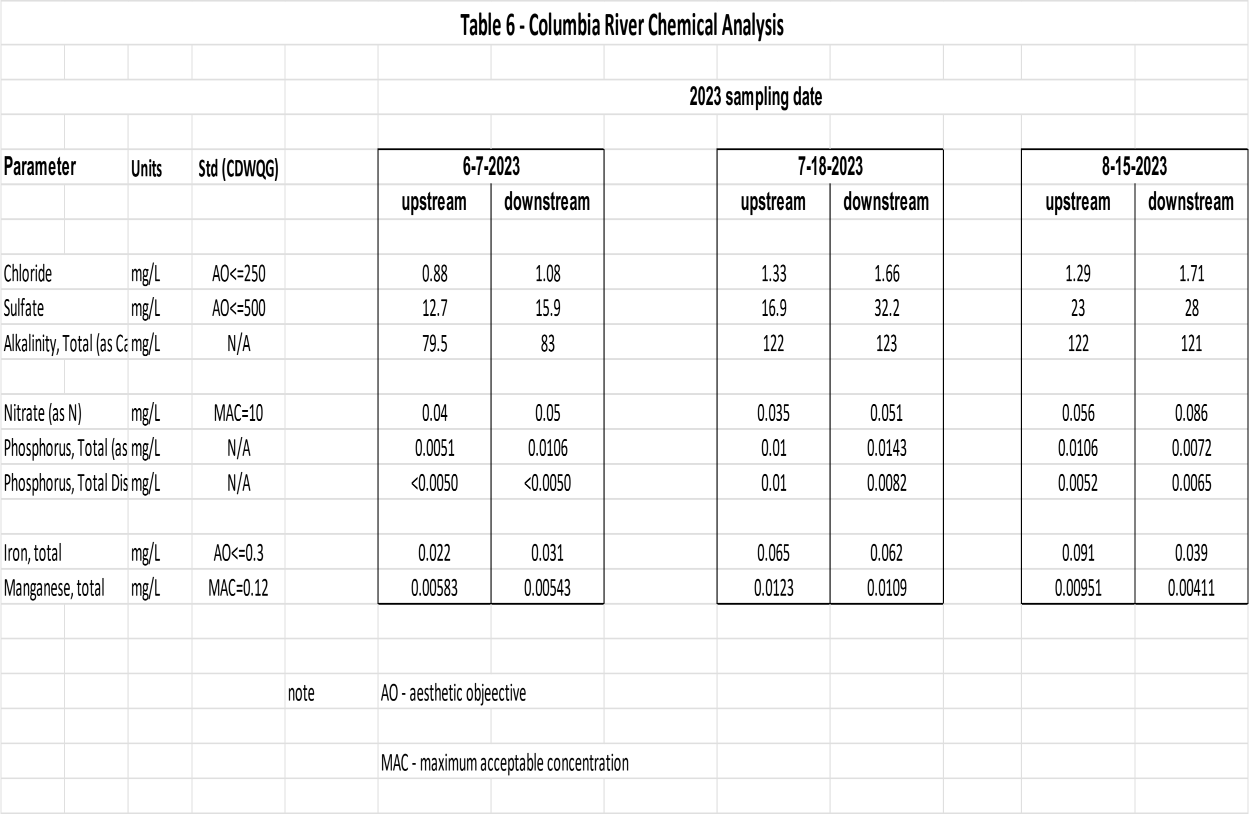


Table 6 - Columbia River Chemical Analysis

			2023 sampling date					
Parameter	Units	Std (CDWQG)	6-7-2023		7-18-2023		8-15-2023	
			upstream	downstream	upstream	downstream	upstream	downstream
Chloride	mg/L	AO<=250	0.88	1.08	1.33	1.66	1.29	1.71
Sulfate	mg/L	AO<=500	12.7	15.9	16.9	32.2	23	28
Alkalinity, Total (as Ca	mg/L	N/A	79.5	83	122	123	122	121
Nitrate (as N)	mg/L	MAC=10	0.04	0.05	0.035	0.051	0.056	0.086
Phosphorus, Total (as	mg/L	N/A	0.0051	0.0106	0.01	0.0143	0.0106	0.0072
Phosphorus, Total Dis	mg/L	N/A	<0.0050	<0.0050	0.01	0.0082	0.0052	0.0065
Iron, total	mg/L	AO<=0.3	0.022	0.031	0.065	0.062	0.091	0.039
Manganese, total	mg/L	MAC=0.12	0.00583	0.00543	0.0123	0.0109	0.00951	0.00411

note AO - aesthetic objective

MAC - maximum acceptable concentration

4.0 Lake Sediment Sampling Program

The sediment sample results are summarized in Table7. The results are organized from left to right by the perceived intensity of recreational activity on the lake (the most intense activity was understood to occur at the Canal Flats boat launch and Columere Park boat moorage and least activity at the Columbia Lake Provincial Park beach. For ease in appreciation of the distribution of hydrocarbons and metals around the lake, table 7 summarizes the analytical results into three categories highest, middle and lowest. These categories were created by using the highest and lowest concentration to calculate an overall concentration range and then splitting that range into three equal ranges.

These data illustrate that there were effective no reliable measured concentrations of hydrocarbons in the EPH 10-19 carbon range (the range that would be associated with diesel fuels and lighter lubricating oils). EPH 19-32 carbon range were measured at three locations on the lake including Canal Flats, Columere Park and the former boat launch in the southwest corner of the lake. Hydrocarbons in this carbon range are associated with oils and greases and waxes (including petroleum hydrocarbons leached from pavements. The sampling method used was not appropriate for testing of the volatile petroleum hydrocarbons (carbon range of LPH 6 to 10) that would be associated with petroleum fuels.

For comparison purposes the acceptable concentrations for metals considered by CCME (the Canadian Council of Ministers of the Environment) to protect freshwater aquatic life have been incorporated within the table. These metals are arsenic, cadmium, chromium, lead and mercury. The arsenic concentration (10.6 mg/kg) measured at the BC Provincial Park location exceeded the recommended guideline concentration (5.9mg/kg).

The three categories of data illustrate that the highest concentrations occurred in the samples obtained from the site assumed to have the least exposure to motorized vessel activities, the Provincial Park (site 5). Conversely the lowest concentrations for the metals were measured in the sample obtained from the beach area at Spirits Reach (Site 4).

This sampling event was the first set of sediment samples collected from Columbia Lake. These results should not be considered an adequate representation of the sediment conditions on the lake without more representative testing and analyses.

Table 7 - Sediment Sampling Results[1]

			Site 1	Site 4	Site 2	Site 3	Site 5
			Canal Flats boat launch	**Columere Park boat launch and moorage**	**SW Columbia Lake former boat launch ramp**	**Spirits Reach beach area**	**BC Provincial Park beach area**
Analyte	**Units**	**CCME Criteria[2]**					
EPHs10-19[3]	mg/kg	N/A	<120	<67	<94	<50	<67
EPHs19-32[3]	mg/kg	N/A	250	220	260	<50	130
Moisture	% wet	N/A	79.4	62.5	73.5	23	62.5
Metals							
Aluminum	mg/kg dry	N/A	4480	5360	4730	3600	4820
Antimony	mg/kg dry	N/A	<0.10	0.22	<0.10	0.46	0.50
Arsenic	mg/kg dry	5.9	5.85	5.15	1.05	4.44	10.6
Barium	mg/kg dry	N/A	200	106	127	49.5	80.7
Beryllium	mg/kg dry	N/A	0.17	0.25	0.19	0.13	0.42
Bismuth	mg/kg dry	N/A	<0.10	0.13	<0.10	<0.10	0.21
Boron	mg/kg dry	N/A	4.7	2.8	5.2	2.3	<2.0
Cadmium	**mg/kg dry**	**0.6**	**0.114**	**0.104**	**0.203**	**0.087**	**0.071**
Chromium	**mg/kg dry**	**37.3**	**7.8**	**9.8**	**10.1**	**6.6**	**9.8**
Cobalt	mg/kg dry	N/A	3.33	7.27	3.94	3.37	10.6
Copper	mg/kg dry	N/A	6.46	11.4	8.68	4.6	20.6
Iron	mg/kg dry	N/A	10200	15300	12100	8600	24500
Lead	**mg/kg dry**	**35**	**8.43**	**13.9**	**11.1**	**9.39**	**11.8**
Lithium	mg/kg dry	N/A	9.2	11.7	10.2	8.13	10.6
Manganese	mg/kg dry	N/A	365	691	240	229	689
Mercury	mg/kg dry	0.17	<0.040	<0.040	<0.040	<0.040	0.068
Molybdenum	mg/kg dry	N/A	0.18	0.16	0.8	0.18	0.28
Nickel	mg/kg dry	N/A	8.07	12	8.87	6.8	22.7
Phosphorus	mg/kg dry	N/A	428	506	526	306	338
Selenium	mg/kg dry	N/A	0.57	<0.20	0.95	<0.20	<0.20
Silver	mg/kg dry	N/A	<0.10	<0.10	<0.10	<0.10	<0.10
Strontium	mg/kg dry	N/A	327	195	351	143	68.5
Sulfur	mg/kg dry	N/A	3760	1440	8000	2830	1850
Tellurium	mg/kg dry	N/A	<0.10	<0.10	<0.10	<0.10	<0.10
Thallium	mg/kg dry	N/A	<0.10	<0.10	<0.10	<0.10	<0.10
Thorium	mg/kg dry	N/A	1.53	3.14	1.59	1.39	2.64
Tin	mg/kg dry	N/A	0.62	0.23	0.54	0.35	0.24
Titanium	mg/kg dry	N/A	20.9	20.3	16.8	15.7	8
Tungsten	mg/kg dry	N/A	<0.20	<0.20	<0.20	<0.20	<0.20
Uranium	mg/kg dry	N/A	0.404	0.347	1.05	0.528	0.779
Vanadium	mg/kg dry	N/A	4.9	6.5	4.9	4.7	9.1
Zinc	mg/kg dry	N/A	36.7	44.4	55.7	37.1	51.2
Zirconium	mg/kg dry	N/A	<2.0	3.4	<2.0	<2.0	3.1
Major Ions							
Calcium	mg/kg dry	N/A	194000	104000	157000	84200	64600
Magnesium	mg/kg dry	N/A	15600	19700	16300	15200	27400
Sodium	mg/kg dry	N/A	97	61	142	<50	61
Potassium	mg/kg dry	N/A	462	465	429	245	646

notes

[1] Sediment Samples Collected on August 29 in the morning.

[2] CCME Sediment Concentrations for Protection of Freshwater Aquatic Life

[3] EPH's - extractable petroleum hydrocarbons 10-19 and 19-32 refers to carbon chain length of aliphatic hycarbons

🟨 higher concentration

🟧 middle concentration

🟩 lower concentration

5.0 Suggested Monitoring Program for 2024

The monitoring program undertaken over the past ten years on Columbia Lake has identified some noticeable differences in concentrations for the indicator parameters between the north and south ends of the lake. CLSS has observed that:

- During the summer months the turbidity concentration decreases. The turbidity concentration is similar from the south end to north end of the lake. A similar decline in values during the summer is observed for the pH and the dissolved oxygen concentrations.
- The specific conductance concentrations are greater in the southern end of the lake.
- Turbidity and total and dissolved phosphorous concentrations from time to time exceed those established by CLSS as water quality standards for Columbia Lake.
- Profiles of concentrations for turbidity, specific conductivity and chloride along the lake at 14 monitoring locations illustrate the concentrations decline from south to north. Whether this trend is due to the inflow of different surface or groundwater sources from one end of the lake to the other cannot be determined. This survey was not completed in 2021 and only once in 2022 due to the limited resources of CLSS. However, CLSS intends to repeat the survey in 2024 as our funding allows. This survey will involve compiling profiles along the lake at the 14 locations: one profile will be undertaken in mid-June and the other in mid-August. The testing will involve measurements of dissolved oxygen, pH, turbidity, specific conductance, lake surface temperature and chloride.
- The concentrations of the elements and compounds differ between the four streams. Most noticeable are the differences in concentration of chloride with the creek draining from Canal Flats containing the greatest concentration of chloride. This difference may in part explain why the lake water to the south also yields greater concentrations of specific conductance and chloride.

CLSS intends to proceed in 2024 with a similar program to that undertaken in 2023. The program will include:

- The “Regular” program of bi-weekly measurements of temperature, lake depth, Secchi depths, turbidity, specific conductance, pH and dissolved oxygen at the four locations on Columbia Lake (N1, S1, S3 and S4).
- Chemical analyses during the regular program in late May and mid-July for total and dissolved phosphorous, total kjeldhl nitrogen, total nitrate, iron, manganese, alkalinity, hardness and chloride.
- Monitoring the distribution of temperature, turbidity, specific conductance and chloride at 14 locations along the lake on two occasions during the summer months (mid-July and mid-August).
- Monthly monitoring of the three creeks, Dutch Creek, Hardie Creek, and Canal Flats Creek for temperature, turbidity, specific conductance, pH and dissolved oxygen.

- Monitoring of the Columbia River in Fairmont for the indicator parameters, and chemical analyses of two sets of water samples for the same parameters measured in 2023.
- Twice per year (spring and fall) analyses of the creek waters for nitrate, total kjeldahl nitrogen, total and dissolved phosphorous, iron, manganese, alkalinity, hardness, and chloride.

In 2024, as funding allows, CLSS also intends to support ecological inventories of the lake by undertaking a CABIN (Canadian Aquatic Biological Network) program as a further means of assessing the health of the lake. CABIN is a set of biological protocols to assess the quality of freshwater systems established by Environment Canada.

Measurement of total petroleum hydrocarbons in lake bottom sediments is a concern for human and ecological health. Additional analyses for hydrocarbons should be undertaken with samples collected using a coring device and chemical analyses for volatile hydrocarbons (benzene, toluene, xylene and ethylbenzene) and Polycyclic Aromatic Hydrocarbons (PAH's). Unfortunately, these measurements come with a high cost, and CLSS lacks the funding necessary to carry out these measurements.

John Thomas Dance, MSc.

Appendix A

A-1 Monitoring parameters and their application to understanding water quality changes.

Note – these pages have been reproduced from another source.

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.

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 2014 however several changes to the monitoring program have occurred. These changes are summarized chronologically as follows.

2014

Four stations for monitoring lake quality conditions were established by this initial program. These stations are referred to throughout this report as N1, S1, S3 and S4. The station locations are shown on Figure 1 and summarized from north to south along the lake as:

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

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Water survey of Canada monitoring station

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 north: and
- 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 and the water temperature and dissolved oxygen concentrations with depth below the lake surface were measured using handheld instruments. Table 1 provides the dissolved oxygen depth profile measured during that investigation.

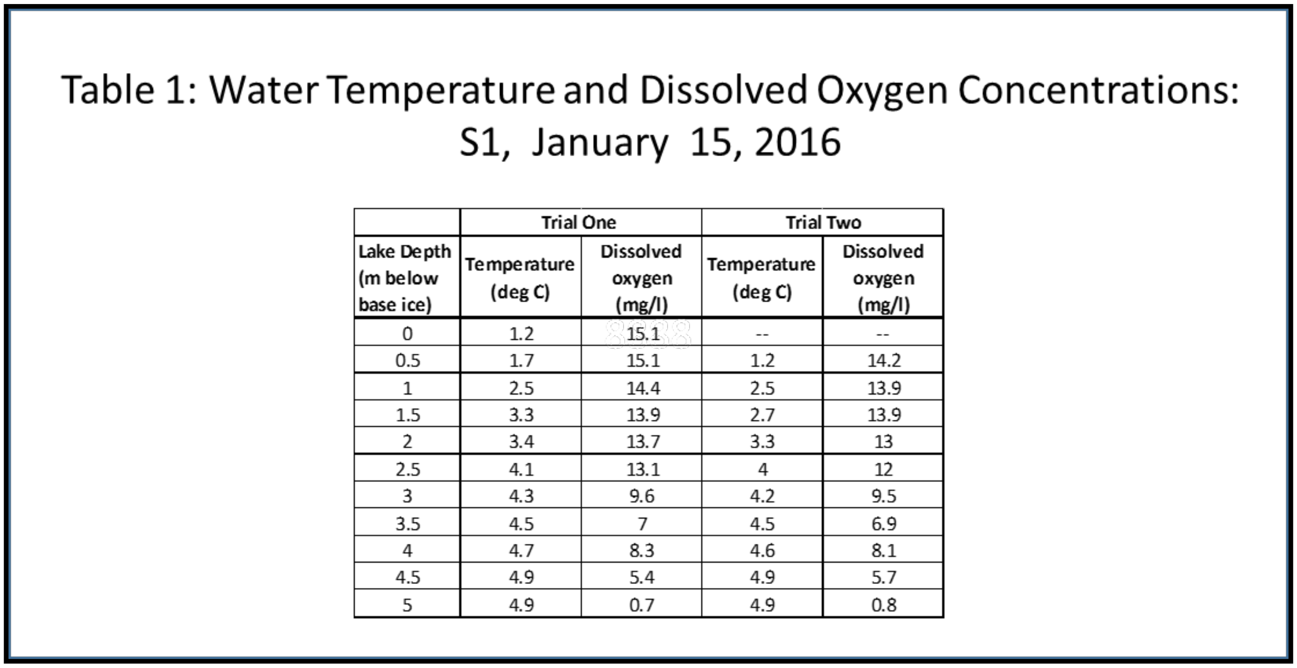

Table 1: Water Temperature and Dissolved Oxygen Concentrations:
S1, January 15, 2016

	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

These data suggest two features about the probable dynamics of the lake and the photosynthetic processes in the lake. First, because water's maximum density occurs at 4° C, as the cold surface water, produced from the ice (at 0^0C), begins to warm up in the spring, it will sink through the water column and rest at the bottom of the lake. 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 shallow and denser water falls within the lake, it displaces the deeper less dense water on the bottom of the lake. The displaced water rises to the surface. The rising water brings with it suspended inorganic and organic particulates and increases the phosphate concentrations in the shallow water as observed in the water quality results described more fully in Section 3.1.7. Second, during the winter, input of oxygen due to wave action and inflow of surface water is minimal and therefore the oxygen concentration at shallow depth must be almost entirely due to photosynthetic processes (mostly micro-organisms and phytoplankton). As the water warms up, photosynthetic activity will increase and is the likely cause of the increases in turbidity observed in the early spring. The principal source of light to support photosynthesis is diffusion through the ice. This evidence that photosynthetic process continues over the winter months indicates the lake is healthy. In years of heavy snowfall, when the lake surface is snow covered 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 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 through this valley to the 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 m with Columbia Lake lying at a lower elevation than the river. The river and the lake are approximately 1500 meters apart. Furthermore, this difference is relatively constant throughout the year. This finding 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 groundwater inflow at the south end of the lake and considering 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 concentrations 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 concentrations at fourteen locations along the lake (Figure 2). The results of this monitoring program are tabulated in Appendix D.

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

2019

To confirm the differences in water quality along the lake found in 2018, the survey was repeated in 2019 with Chloride added to the analyses of water quality at the fourteen locations. That survey was undertaken on July 23, 2019.

Further, visual inspections of the outlets of small streams draining into the lake along the west side, showed that the shorelines had a different appearance that was associated with rust and black stained rocks. 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 chloride (on one occasion).

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

2020

In 2020, the monitoring program on Columbia Lake undertaken by CLSS involved:

- the "regular" monitoring program comprising approximately bi-weekly measurements of three types of information at the four locations (N1, S1, S3 and S4) along the lake shown on Figure 1:
    - Observations about cloud cover, water surface disturbance (waves), and air temperature,
    - Measurements of:

    - the depth of water at each sampling locations,
    - the depth of clear water using the Secchi disk,
    - water temperature,
    - turbidity,
    - specific conductance,
    - pH,
    - dissolved oxygen, and
    - Two sets (May 28 and July 18) of chemical analyses on water samples from the lake for total and dissolved phosphorous as well as, Fe, Mn, hardness, alkalinity, and chloride added to the program for 2020 to help evaluate causes for turbidity increases during the summer months (growth of aquatic vegetation or disturbed bottom sediments.

- Collection of two sets (July 18 and August 18) of south to north measurements of turbidity, conductance, pH and chloride at the 14 locations along the lake shown on the following Figure 2, and
- Four measurements of temperature, specific conductance, turbidity, dissolved oxygen and pH on
    - 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,
    - Marion Creek at the outfall to the lake within the provincial picnic area, and
    - A small creek draining north from Canal Flats on the pathway (Figure 1).

Figure 2 – Location of Monitoring Points For Turbidity and Conductivity Measurements

Not to scale

2021

In 2021, the monitoring program on Columbia Lake undertaken by CLSS was for the most part unchanged from that conducted in 2020 and involved:

- the "regular" monitoring program comprising approximately bi-weekly measurements of three types of information at the four locations (N1, S1, S3 and S4) along the lake shown on Figure 1:
    - Observations about cloud cover, water surface disturbance (waves), and air temperature,
    - Measurements of:
        - the depth of water at each sampling locations,
        - the depth of clear water using the Secchi disk,
        - water temperature,
        - turbidity,
        - specific conductance,

- pH,
- dissolved oxygen, and
- Two sets (May 28 and July 18) of chemical analyses on water samples from the lake for total and dissolved phosphorous as well as, Fe, Mn, hardness, alkalinity, and chloride added to the program for 2020 to help evaluate causes for turbidity increases during the summer months (growth of aquatic vegetation or disturbed bottom sediment.

And

- Four measurements of temperature, specific conductance, turbidity, dissolved oxygen and pH on
    - 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,
    - Marion Creek at the outfall to the lake within the provincial picnic area, and
    - The small creek draining north from Canal Flats on the pathway (Figure 1).

However, north south profiles at the fourteen locations along Columbia Lake for turbidity, specific conductance, pH and chloride were not completed. CLSS opted instead to collect this information every other monitoring year as funding allowed.

Appendix B
Spreadsheet of Collected Water Quality Information

We have provided an electronic version of the spreadsheet instead of reproducing a paper copy here. Several interested parties have asked for the data, and we expected the electronic data would be more useful. Electronic versions of our water quality data can be accessed on the Columbia Basin Water Hub.

Appendix C

Water Quality Information for Columbia Lake, Lake Windermere, Moyie Lake, Premiere Lake and White Swan Lake

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Appendix D – Water Quality Differences Along the Lake

D-1 2018 Summer Survey of the Distribution of Turbidity and Conductivity Concentrations Along Columbia Lake

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D-2 Along the Lake Profiles for the Distribution of Temperature, and Concentrations of Turbidity, Specific Conductance and Chloride from South to North

Temperature and concentrations of turbidity, specific conductance and chloride were measured at fourteen locations along the lake on three occasions over the summer of 2020. These measurements are tabulated in Table D3 along with similar measurements made in 2018 and 2019. The graphs of these parameters are plotted on Figure 13.

These measurements demonstrate that temperature is relatively constant along the lake on any given measurement date. However, concentrations of turbidity, specific conductance and chloride all decrease from the south end of the lake to the north end of the lake.

Appendix E – Statistics for 2014 to 2020

This spreadsheet is saved on the CLSS website http://columbialakess.com/