Summary of the 2021 Water Quality Monitoring Program for Columbia Lake

Columbia Lake Stewardship Society

January 27, 2022

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 2021 the first water quality monitoring event on the lake took place in late May and the last monitoring event in early September. Monitoring included:

- approximately bi-weekly monitoring of selected water quality indicator parameters and approximately monthly sampling of water for chemical- analysis,
- a special water quality sampling program in Hardie Creek undertaken in the late winter and spring, and
- measurement of the water quality of Dutch Creek, Hardie Creek, Marion Creek and the small creek that drains from Canal Flats.

The CLSS water quality monitoring program is administered, conducted, and interpreted largely by volunteers under the overall direction of our Project Director Ms. Leah Downey. The 2021 water quality program involved many volunteers who had participated in previous years and some volunteers new to the program. The 2021 monitoring program was enhanced by assistance received from a summer student made available to the program by a grant received from the Canada Summer Jobs program.

Funding for the program was provided by:

- Columbia Valley Local Conservation Fund Columbia Basin Trust,
- British Columbia Hydro - Fresh Water Conservation Program,
- Regional District of East Kootenay,
- Fairmont Hot Springs Resort Ltd. including the Riverside Golf course and the Fairmont Hot Springs Airport,
- Columbia Ridge Community Association, and
- Columere Park Community Association.

In addition later in the autumn of 2021 CLSS, received sponsorship funds from the Fairmont Market Grocery and Hoodoos Mountain Resort. The contributions by the volunteers, funding agencies and sponsors is gratefully acknowledged.

The monitoring program carried out over the past eight years on Columbia Lake has shown that the lake water is suitable for consumption as drinking water, preservation of aquatic life and recreational purposes. In 2021 the trend in concentrations of turbidity that in previous years increased over the summer months was different. In 2021 turbidity concentrations declined over the summer months

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 2022 with a similar monitoring program to that undertaken in 2021. 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. Chemical analyses during the regular program in late May and mid-July for total and dissolved oxygen, nitrate, iron and manganese, alkalinity, hardness, and chloride,
3. Monthly monitoring of the four creeks (Dutch Creek, Hardie Creek, Marion Creek and the creek draining from Canal Flats) for temperature turbidity, specific conductance, pH and dissolved oxygen, and
4. Twice annual (spring and fall) analyses of the creek waters for nitrate, total and dissolved phosphorous, iron and manganese, alkalinity, hardness, and chloride.

Beginning in 2022 CLSS will begin a CABIN monitoring program to assess the ecological diversity from place to place along the lakeshore. Initial CABIN monitoring program locations will be at the outlets of Dutch Creek, Hardie Creek, Marion Creek, the creek draining from Canal Flats and Lansdowne Creek.

Summary of the 2021 Water Quality Monitoring Program for Columbia Lake

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WATER QUALITY MONITORING PROGRAM SUMMARY For 2021

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 Lake Windermere and from Lake Windermere continues into the Columbia Wetlands north of the town of Invermere. North of Donald and just beyond the Mica Dam, the Columbia River turns south and drains through the Arrow Lakes system to exit Canada south of Trail, BC.

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

The Columbia Lake Stewardship Society (CLSS) began monitoring the lake's water quality on April 20, 2014 and has continued the monitoring program while the lake is ice-free every year through to September 2021. Water quality monitoring of Columbia Lake began on May 31. 2021 and ended September 3, 2021.

This summary of the water quality monitoring program:

- describes the 2021 water quality monitoring program,
- summarizes the water quality monitoring results,
- compares the water quality of Columbia Lake to nearby lakes as monitored and reported by BCMOE, and
- provides suggestions to improve the monitoring program.

2.0 Monitoring Program

Sections 2.1 through 2.5 describe:

- the purpose of the program and contributions of volunteers to the program during 2021,
- the monitoring program conducted during 2021,
- water quality objectives established by CLSS for the lake,
- a special sampling program undertaken by CLSS due to concerns of water quality impacts due to logging in the water shed of Hardie Creek, 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. Water quantity 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. However, since 2014, the program has undergone several changes as more is learned about the lake. Chronologically, these changes are summarized in Appendix A-2.

2.1 Purpose and Acknowledgements

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

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

The CLSS water quality program is, for the most part, administered, implemented, and interpreted by volunteers. In 2021, the following volunteers contributed to the water quality monitoring program:

- Tracy Flynn - monitoring on the lake in early May
- Gina Fryer and Cesar Fuertes - participation in lake monitoring events
- Ed Gillmor - monitoring in late May and June
- Garry Gray - monitoring in August and September
- Dianne Jeffrey - monitoring assistance in July and August
- Dave and Donna Rae - assistance with on-the-lake training
- Pat Silver - overall program administration and accounting

- Barb and Kevin Stromquist - monitoring in June and July
- Tom Symington - assistance with report preparation
- Bill Thompson - assistance with report preparation
- Tom Dance and Nancy Wilson -on the lake monitoring, and compilation, graphing, interpretation and reporting of the monitoring results.

For the 2021 monitoring program, CLSS received a grant from the Canada Summer Jobs 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 Mitchell Aitken participated in the program from May through August of 2021. He has subsequently returned to the University of Calgary to attend his third year of undergraduate studies in engineering.

In the spring of 2021, CLSS retained the services of Ms. Leah Downey as Program Coordinator 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,
- Columbia Basin Trust,
- British Columbia Hydro - Fresh Water Conservation Program,
- Regional District of East Kootenay,
- Fairmont Hot Springs Resort Ltd. (including the Riverside Golf Course and the Fairmont Hot Springs Airport),
- 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.

In late autumn of 2021 CLSS was also provided sponsorship funds from Farimont Market Grocery and HooDoos Mountain Resort. The participation of these volunteers, individuals, sponsor and funding agencies is gratefully acknowledged.

2.2 The Monitoring Program Undertaken During 2021

In 2021, 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
    - 12 sets 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 2021 to help evaluate causes for turbidity increases during the summer months (growth of aquatic vegetation or disturbed bottom sediments;

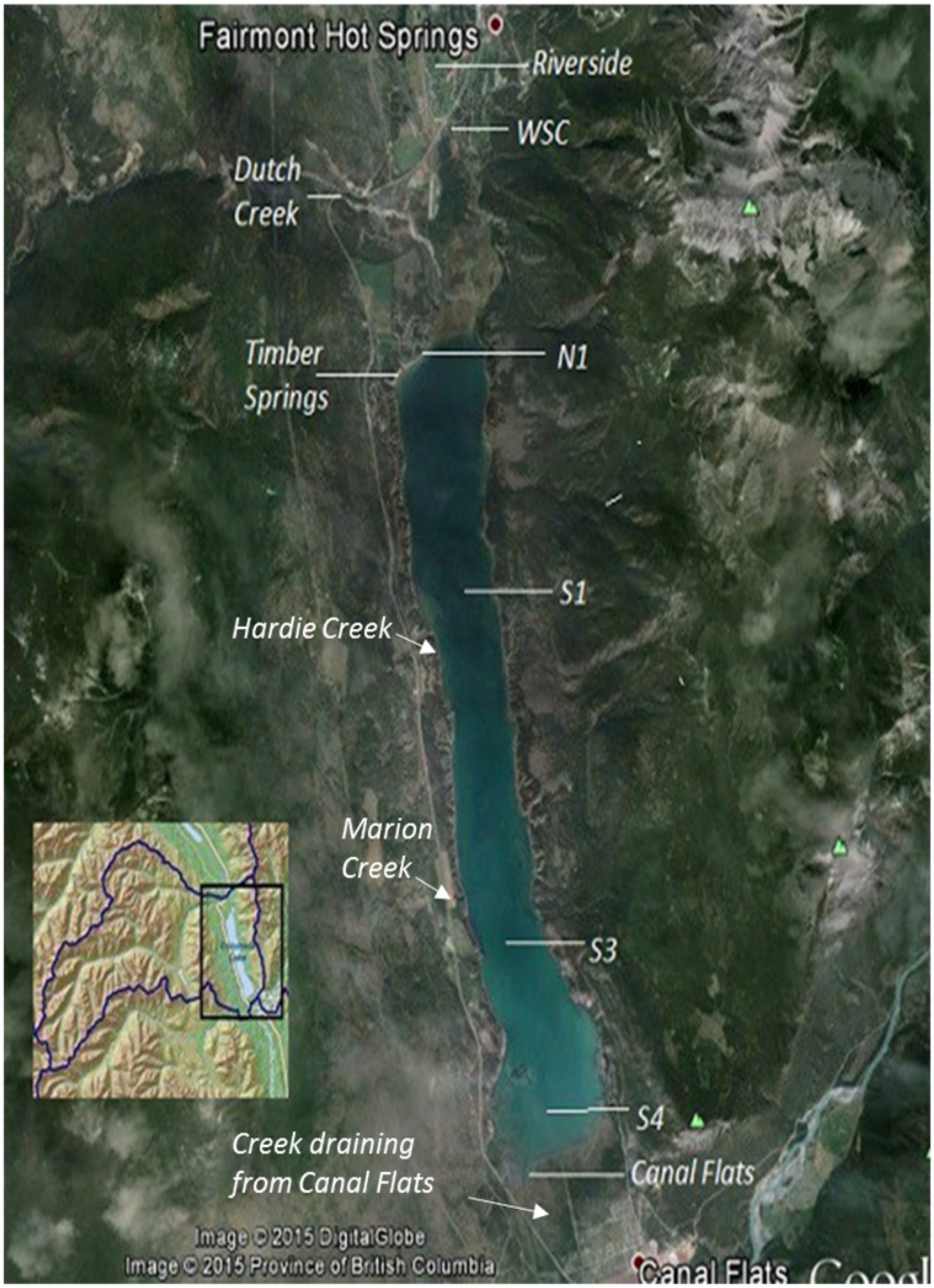
    and

    - Four measurements of temperature, specific conductance, turbidity, dissolved oxygen and pH on the following four creeks:
        - 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).

The four regular monitoring location 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 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 2021, the regular monitoring program began on May 31 and ended on September 5. Measurements were made as weather permitted on six occasions at approximately biweekly intervals with water samples collected for chemical analyses on May 31, July 12 and September 3. 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 June 14, July 23, August 27 and September 19. The monitoring results are described in section 3.2.

2.3 Water Quality Standards

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

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

However, these human health guidelines may not be sufficient for the protection of freshwater aquatic life. CLSS notes that several of the total metal concentration guidelines 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[1]	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 Special Sampling program on Hardie Creek

In the winter of 2021, CLSS became aware of a plan for tree removal over some 200 acres in the Hardie Creek watershed. Hardie Creek drains into Columbia Lake along the western shoreline near the developments of Spirits Reach and Columbia Ridge Estates. The mouth of Hardie Creek is an area designated as a sensitive shoreline in the Columbia Lake Management Plan.

CLSS was concerned that the tree removal would cause the water quality of Hardie Creek to change and potentially affected the shoreline habitat of Columbia Lake. To determine whether water quality changes occurred, CLSS undertook a monthly monitoring program from early March (prior to the start of logging operations) and extending until June (three months past the completion of the tree removal).

Monitoring involved measuring Hardie Creek for:

Water temperature, specific conductance, dissolved oxygen, pH, and turbidity using field equipment, and collecting water quality samples for measurement of suspended sediment, chloride, sulphate, hardness, ammonia, total kjeldahl nitrogen, total and dissolved phosphorous, and total metal concentrations. CLSS then compared these measurements to the changes that might have occurred due to normal seasonal events, CLSS also monitored Marion Creek for water temperature, specific conductance, dissolved oxygen, pH, and turbidity using field equipment, and collected samples for analysis of suspended sediment concentrations.

The results of this special sampling program are described in Section 3.2.

2.5 QA/QC Program

CLSS uses a variety of 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
    - re-calibrates the equipment every four hours when monitoring events occur over the course of a long day of work.
- 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, and the care and storage of all samples to maintain sample integrity while they are 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.

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

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

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

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

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

3.0 Water Quality Monitoring Results

Respectively, Sections 3.1, 3.2 and 3.3 summarize:

- The monitoring results obtained at the four monitoring locations (N1, S1, S3 and S4) along the lake,
- The special water quality sampling program undertaken on Hardie Creek in the late winter and spring of 2021, and
- The monitoring results obtained for Dutch Creek, Hardie Creek, Marion Creek and the creek draining from Canal Flats to the lake.

3.1 Annual Monitoring Program

The 2021 annual monitoring program is the eighth 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 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 on graphs of the indicator parameters. Those statistical calculations are provided in Appendix E.

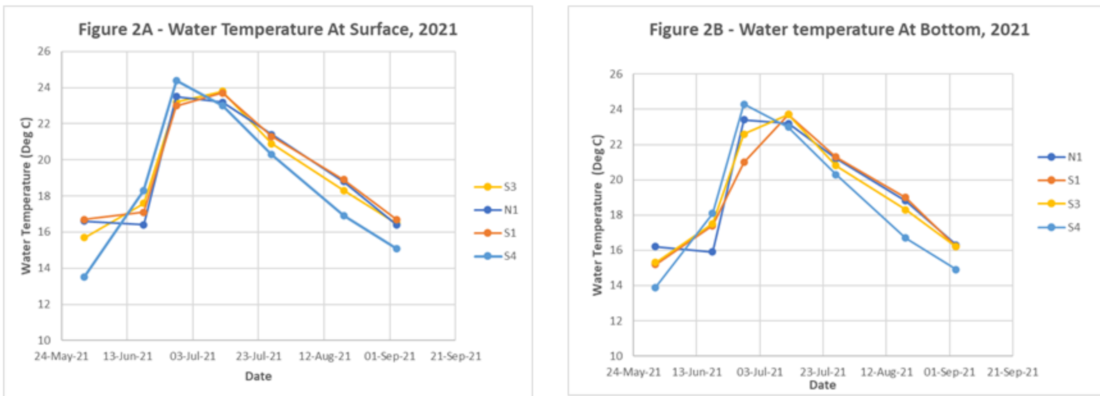
Concentrations that exceed either the expected maximum or minimum values identify water quality information that is beyond the normal or expected range and may suggest further assessment of the lake's water quality should be considered. These exceedances are mentioned in the text of this report.

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. However, these analyses were not repeated in 2021. Section 3.18 summarizes the results for 2020 to support the need for repeating these analyses in 2022.

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 creates potentially 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 2021 at the surface and bottom depths.

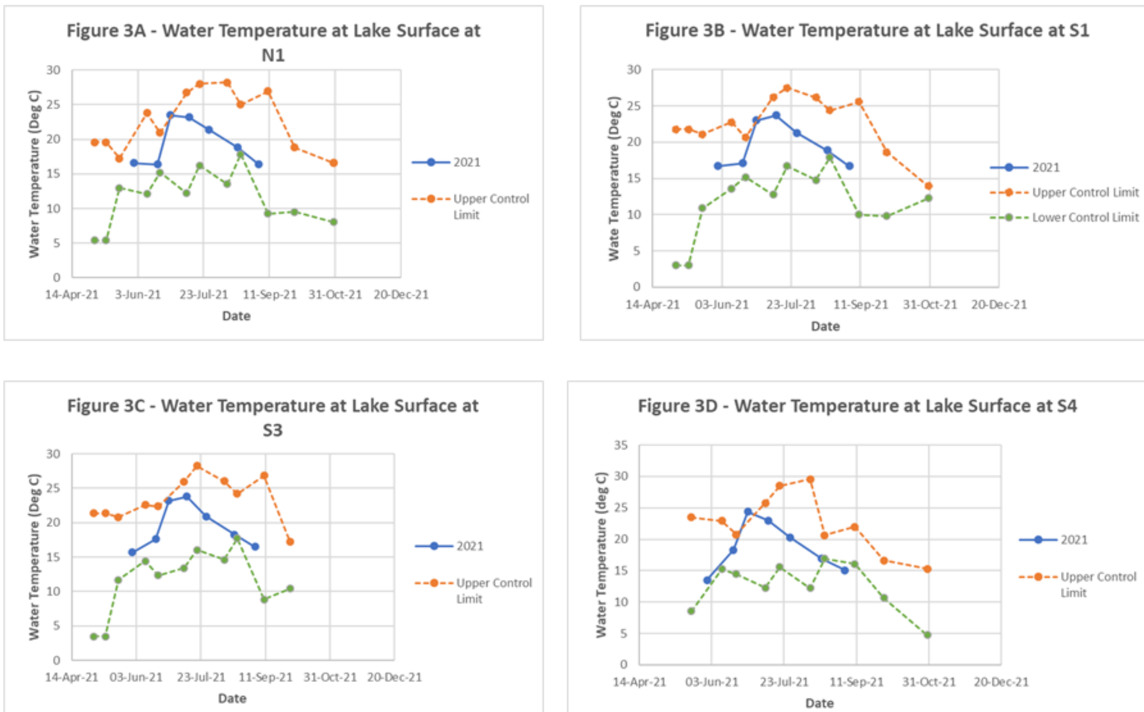
Figure 2 – Lake Water Temperature 2021



The minimum temperature measurements in 2021 of approximately 14^0 C were measured during the first monitoring event in early May. The maximum temperatures (greater than 20^0 C) were measured between the middle of July and the middle of August. There are no noticeable differences (greater than 2^oC) 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 2021 to the upper and lower temperatures measured between 2014 and 2020. In 2021 temperatures exceeding the UCL were measured at all locations on the lake in early July. This observation is consistent with the general observation that July was a very hot month.

Figure 3 - Lake Water Temperature Compared to Control Limits



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 at 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 2020 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 2021 monitoring events are plotted on Figure 4. The plot demonstrates that the greatest concentrations of turbidity were measured during the late spring at N1 and S1 at the north end of the lake and the middle of the lake respectively. At all locations, the turbidity measurements declined throughout the summer months until the middle of August when an increase in the measured turbidity was observed at the north end (N1) and south end (S4) of the lake. This difference is understood to be a result of the increase in phytoplankton growth in the shallower waters at these ends of the lake as the lake temperature increased.

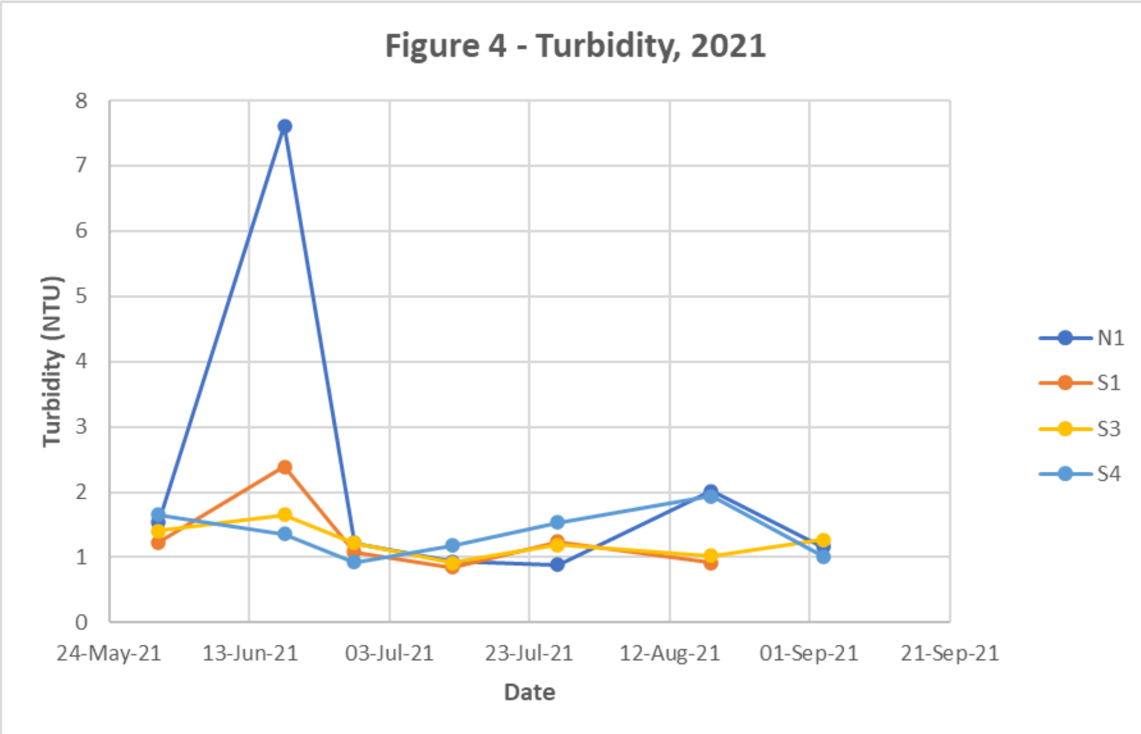
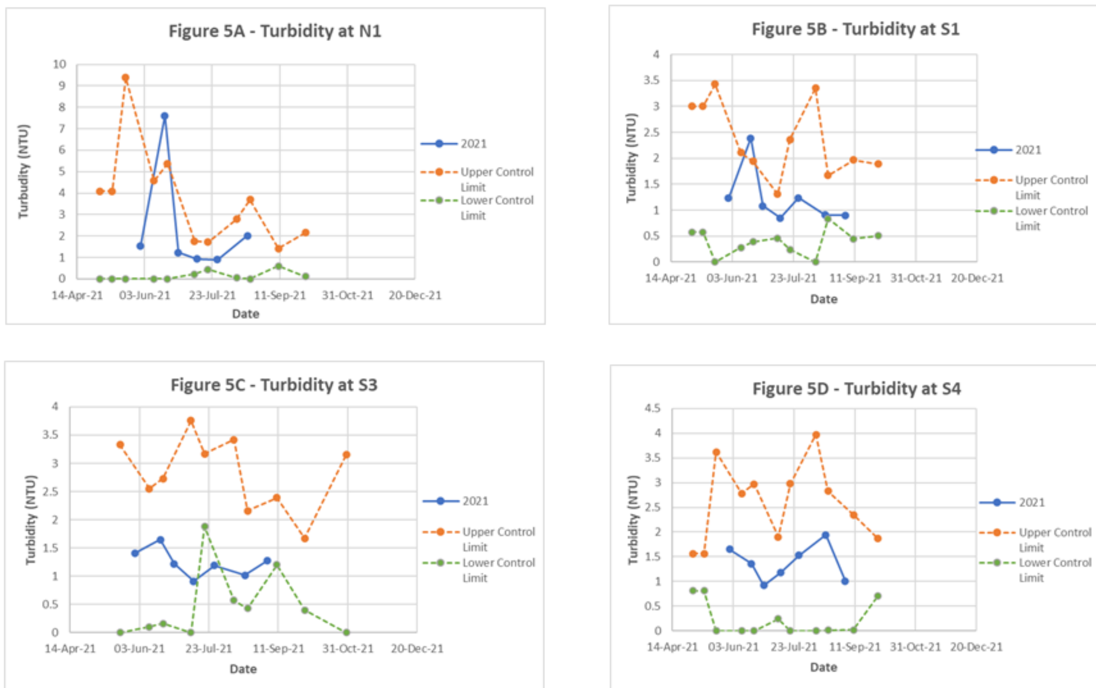


Figure 5 compares the turbidity measurements at each monitoring location on the lake to the control limits established from the range in concentration measured over the previous years. The four graphs (Figures 5 a, b, c, and d) show that the trend in turbidity measured over the summer months is comparable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

Figure 5- Turbidity –
Compared to Control Limits



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 2020. 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 concentration for specific conductance is in the south end of the lake at S3 and S4. Except for the anomalous measurement made at location S4 in late June the plots illustrate that generally the specific conductance concentrations decline from early May to June and then increase slowly over the summer month. This increase is understood to be created by evaporation from the lake surface that increases the salt content of the water. This trend is like that observed in other years (Figure 8).

The exception to this trend is found at location S3 located approximately in the middle of the lake which declines consistently from the first measurement in May to the last monitoring event in September.

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 at several locations across this end of the lake and along the small creek that drains into the lake by CLSS volunteers that 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 conductance is 700uS/cm as established by Health Canada (Table 1). The concentrations for specific conductance for Columbia are less than this concentration by a factor of three or four.

Figure 6 - Specific Conductance

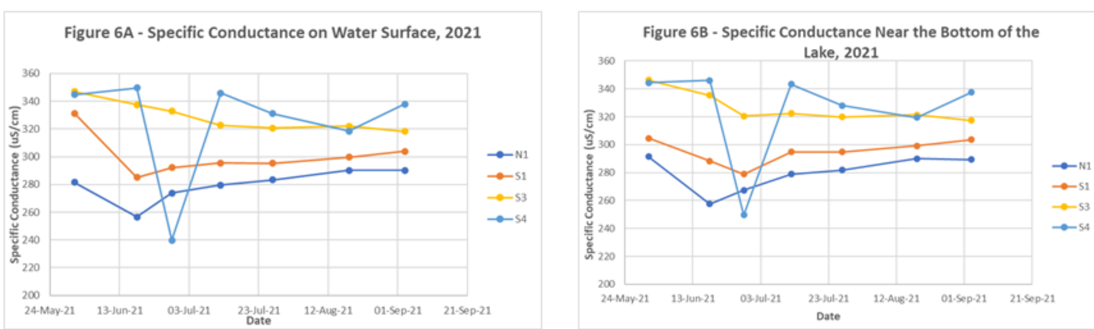
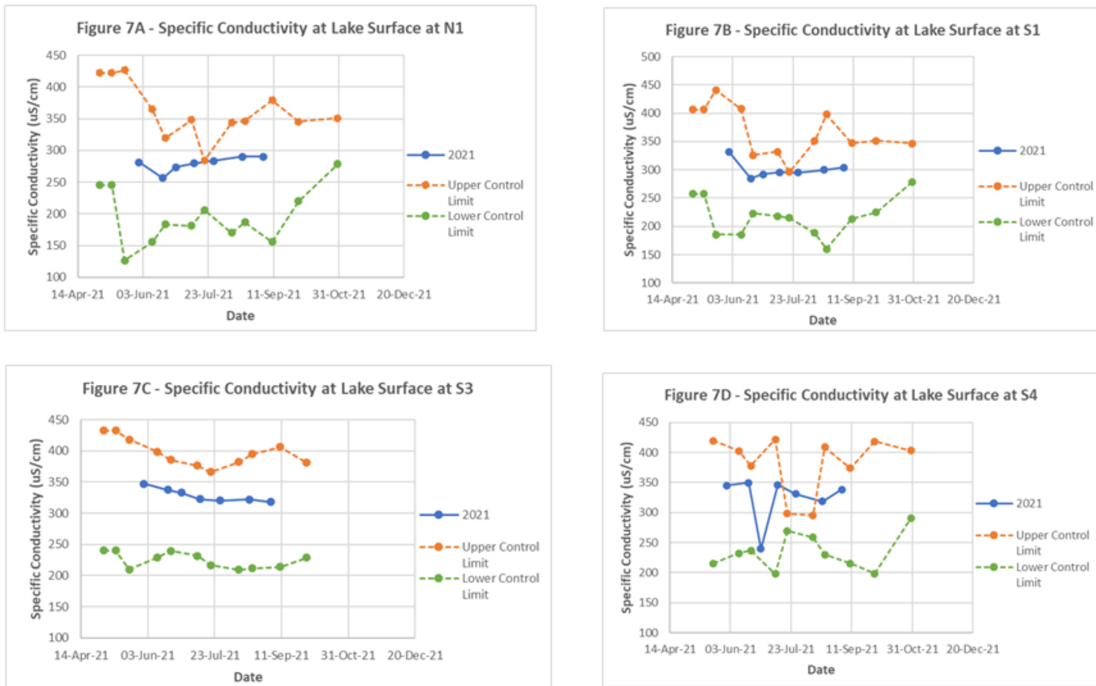


Figure 7 – Specific Conductivity Compared to Control Limits



3.1.5 Potential of hydrogen (pH)

Potential of hydrogen (pH) is a measure of the acidity (pH values less than 7) or alkalinity (pH values greater than 7) of water. 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 2021. Generally, the pH values fall within a narrow range from 8.3 to 8.8 pH units. An exception to this observation was measured in early July at all the monitoring locations when a value of 8.1 was measured. These pH values are all within the range established by CCME of 6.5 to 9 for the protection of freshwater aquatic life (Table 1).

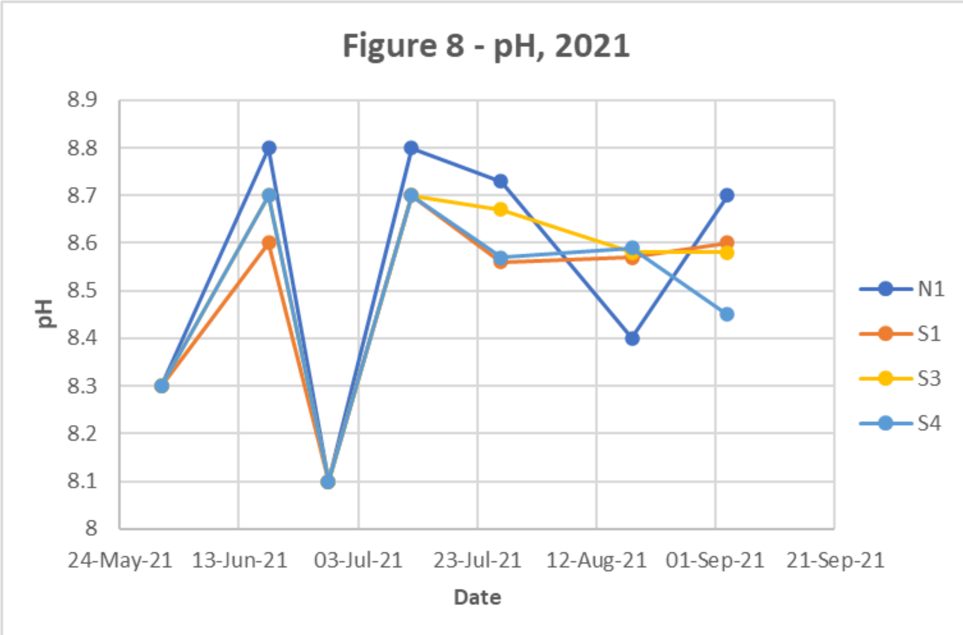
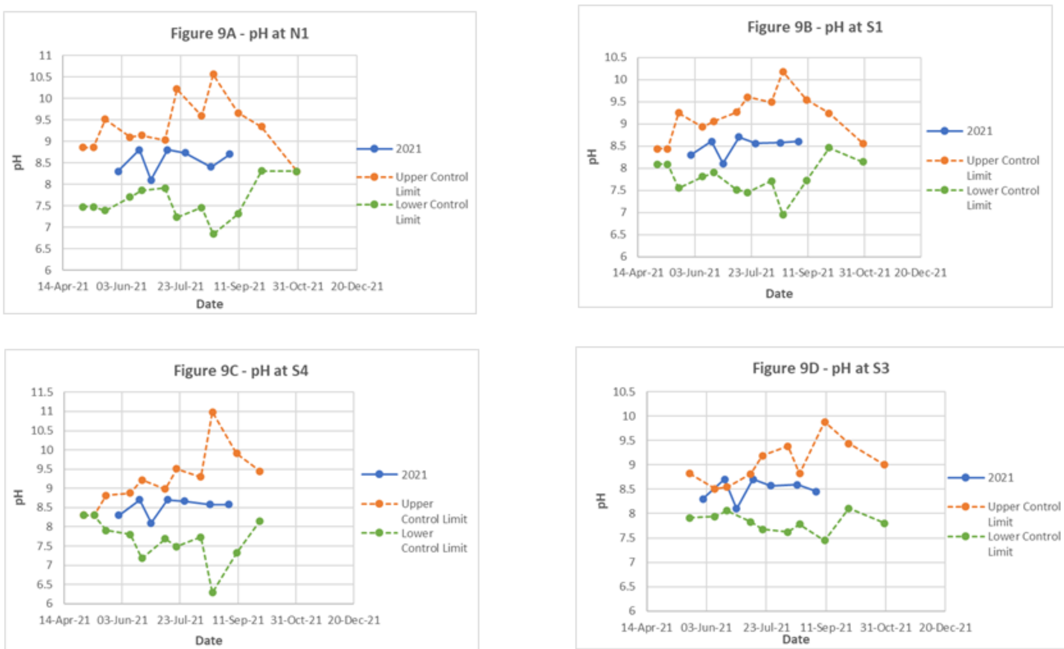


Figure 9 plots the year over year measurements of pH at each of the monitoring locations on the lake. Visually, the plots of the calculated UCL and LCL's suggest that a general increase in pH is observed between April and September. However, in 2021 there was no observable change in pH over the monitoring period.

Figure 9 – pH Compared to Control Limits

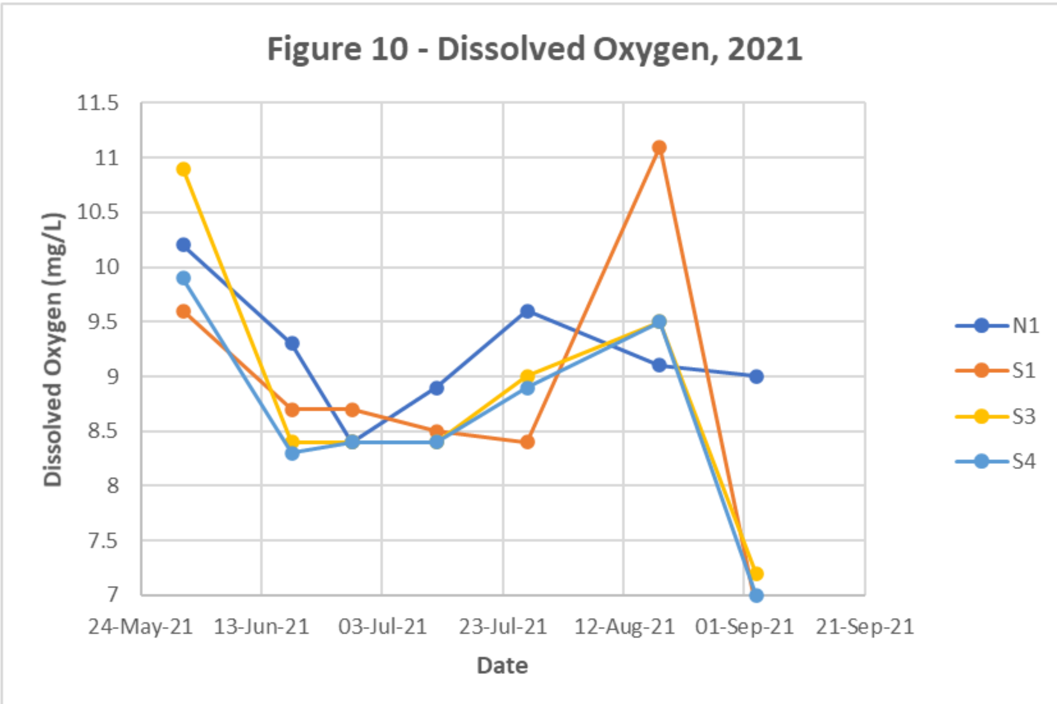


3.1.6 Dissolved Oxygen

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 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).

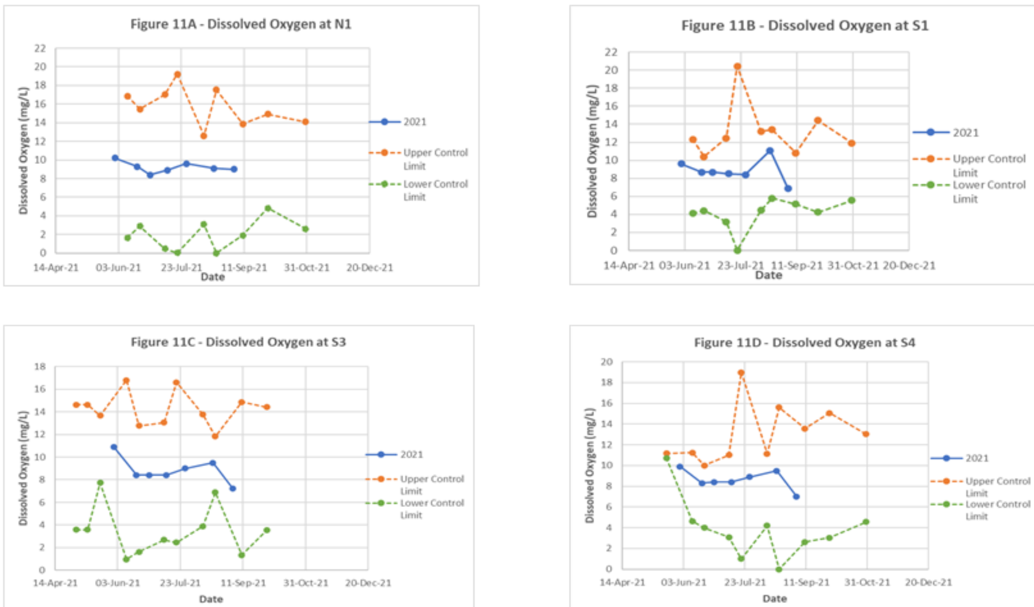
Figure 10 plots the dissolved oxygen concentrations measured in 2021 at the four monitoring locations along the lake. This graph illustrates that for most of the spring and summer, the dissolved oxygen concentrations were greater than 8 mg/L and less than 11 mg/L. Also, the greatest concentrations of dissolved oxygen were measured in the early spring when the lake water was colder. The maximum concentration of dissolved oxygen measured (approximately 11 mg/L) occurred during the August monitoring event at S1 located in the approximate middle of the lake. At S1, S3 and S4, the lowest dissolved oxygen concentration of about 7 mg/L was measured in early September. 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 declined from the greater concentration measured in May until early summer and then the concentrations increased slightly until the autumn monitoring event. 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 2021, are within the6 expected ranges measured over the previous seven years.

Figure 11 – Dissolved Oxygen Compared to Control Limits



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 three monitoring events on Columbia Lake are plotted on Figure 12. The maximum concentrations measured for 2021 occurred in mid-July the hottest period of the summer and are consistent with the findings of prior years. The greatest concentrations occurred at S3 in the spring and mid-summer. The maximum concentration occurred in late summer and was measured at S4, the southernmost monitoring location on the lake.

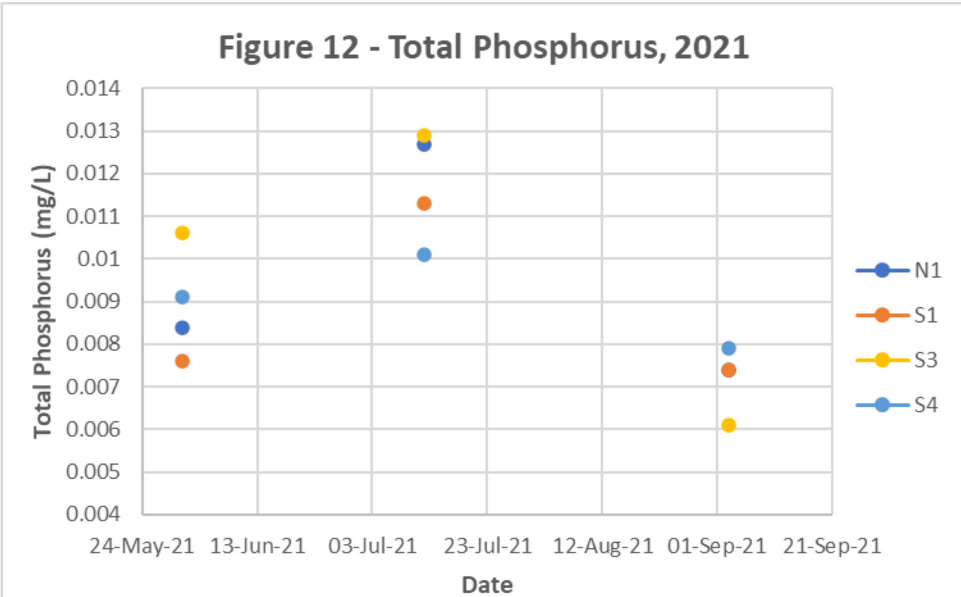


Table 2 contains the total and dissolved concentrations measured since 2019. CLSS understands that the ratio of dissolved phosphorous concentration to total phosphorous concentration may indicate when the phytoplankton growth is greatest. The growth of phytoplankton is one of the greatest contributors 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.

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
South	Location S4	Total Phosphorous	mg/L			0.00860	0.01150	0.0091	0.0116	0.00790
		Dissolved Phosphorous	mg/L			0.004	0.0099	0.0079	0.0101	0.0069
		ratio of DP to TP				0.47	0.86	0.87	0.87	0.87
		nitrate	mg/L			<0.01	<0.01		<0.01	<0.01
		iron	mg/L			<0.01	0.015		0.029	0.011
		managanese	mg/L			0.00472	0.0038		0.00522	0.00365
		alkalinity (as $CaCO_3$)	mg/L			173	150			
		hardness (as $CaCO_3$)	mg/L			177	173		188	175
		chloride	mg/L			5.7	5.04		5.83	5.96
	Location S3	Total Phosphorous	mg/L			0.0072	0.0084	0.0106	0.0129	0.0061
		Dissolved Phosphorous	mg/L			0.0042	0.0064	0.007	0.0119	<0.005
		ratio of DP to TP				0.58	0.76	0.66	0.92	ud
		nitrate	mg/L			<0.01	<0.01		<0.01	<0.01
		iron	mg/L			0.015	<0.01		0.014	<0.01
		managanese	mg/L			0.0038	0.0078		0.0063	0.00433
		alkalinity (as $CaCO_3$)	mg/L			150	145			
		hardness (as $CaCO_3$)	mg/L			173	169		167	167
		chloride	mg/L			5.04	4.74		5.04	5.51
	location - S1 Shallov	Total Phosphorous	mg/L	0.0064	0.0089	0.0082	0.0077	0.0076	0.0127	0.0074
		Dissolved Phosphorous	mg/L	0.0022	0.0037	0.0054	0.0065	0.0057	0.0103	0.0054
		ratio of DP to TP		0.3438	0.4157	0.6585	0.8442	0.7500	0.8110	0.7297
		nitrate	mg/L			<0.01	0.064		<0.01	<0.01
		iron	mg/L			<0.01	<0.01		0.03	0.013
		managanese	mg/L			0.00831	0.0108		0.0172	0.0117
		alkalinity (as $CaCO_3$)	mg/L			164	138			
		hardness (as $CaCO_3$)	mg/L			162	157		154	160
		chloride	mg/L			5.23	4.14		4	4.97
	Location S1 - deep	Total Phosphorous	mg/L			0.0099	0.0106	0.015	0.0136	0.0081
		Dissolved Phosphorous	mg/L			0.0044	0.0066	0.007	0.127	<0.005
		ratio of DP to TP				0.4444	0.6226	0.4667	9.3382	ud
		nitrate	mg/L			<0.01	<0.01		<0.01	<0.01
		iron	mg/L			0.011	0.014		0.022	0.015
		managanese	mg/L			0.00872	0.0149		0.0185	0.0126
		alkalinity (as $CaCO_3$)	mg/L			166	138			
		hardness (as $CaCO_3$)	mg/L			167	153		154	160
		chloride	mg/L			5.32	4.32		4.03	3.64
North	Location N1	Total Phosphorous	mg/L			0.0073	0.0082	0.0084	0.0127	0.0074
		Dissolved Phosphorous	mg/L			0.0039	0.0056	0.0076	0.0103	0.0058
		ratio of DP to TP				0.5342	0.6829	0.9048	0.8110	0.7838
		nitrate	mg/L			<0.01	<0.01		<0.01	<0.01
		iron	mg/L			0.032	0.01		0.019	0.018
		managanese	mg/L			0.0112	0.0142		0.0231	0.00969
		alkalinity (as $CaCO_3$)	mg/L			169	135			
		hardness (as $CaCO_3$)	mg/L			160	146		146	153
		chloride	mg/L			4.84	3.67		3.64	4.74

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.

3.1.8 Additional analyses in 2021

In 2021, during the monthly monitoring program, CLSS collected and had analyses undertaken for nitrate, iron and manganese, alkalinity, 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 note 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. Nitrate concentrations were less than the analytical detection limit in 2020 and 2021.

Iron and manganese, alkalinity 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.

Iron, manganese, alkalinity, and hardness concentrations are tabulated in Table 2. These concentrations are all less than the water quality standards of Table 1.

Chloride was added to the chemical analysis because it was noted in the results of BCMOE's sampling program that Columbia Lakes contained greater concentrations of chloride than other neighbouring 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 of the water quality analyses (May 28, and July 18) are tabulated in Table 2.

3.2 Hardie Creek Sampling Program

The results of the water quality monitoring program of Hardie Creek undertaken by CLSS between March and June of 2022 are summarized in Tables 3 and 4. Table 3 contains the indicator parameters measured on Hardie Creek and compares the results to water quality measurements in prior years and to those measured on Marion Creek during March and June of 2021. Table 4 contains water quality parameters that might be a cause for concern due to the logging operations in the watershed. Both tables highlight the water quality conditions before logging operations began and those that were measured on the three months following completion of the logging operations.

Table 4 shows that there was no substantial difference between the water quality measured before and after the logging work occurred. Further there is no substantial difference between Hardie Creek and Marion Creek except for the larger concentrations for turbidity and suspended sediments measured in Marion Creek in May of 2021. Marion Creek was used as a local comparison for Hardie Creek because it was close to Hardie Creek and not in the watershed used for the logging operations. This noticeable increase in turbidity and suspended solids may be a result of other conditions in the Marion Creek water shed. The turbidity measured in both creeks exceeds the level established for the water quality standards for Columbia Lake in Table 1 as set by Health Canada in the Columbia Lake Management Plan.

Table 3 - Hardie Creek Watershed Testing Program

	Date	Time	Water Temp (C)	Specific Cond. (uS/cm)	Dissolved Oxygen (mg/L)	pH	Turbidity (NTU)	Suspended Sediments (mg/L)	Chloride (mg/L)
A) Dutch Creek	23-Jul-2020		10.3	147.2	10.3	8.4	4.1		0.43
	27-Aug-2020	1:45:00 PM	12.0	201.5	10.4	8.2	1.0		0
	19-Sep-2020	2:45:00 PM	11.9	221.0	10.5	8.4	0.6		
	17-Jun-2021	12:25:00 PM	7.2	141.7	11.9	7.2	3.52	13.3	
B) Hardie Creek	7-Oct-2019								
	14-Jun-2020		9.2	444.0	10	8.3	2.47		
	23-Jul-2020		11.1	303.8	9.81	8.2	2.85		0.45
	27-Aug-2020	1:00:00 PM	10.5	481.3	10.36	8.3	4.09		0.56
	19-Sep-2020	11:41:00 AM	10	494	10.5	7.9	7.9		
	14-Mar-2021	12:37:00 PM	1.3	543	11.1	8.2	2.34	2.6	
	19-Apr-2021	10:30:00 AM	2.7	537	9.2	8.4	2.25	<2.0	
	17-May-21	1:46:00 PM	12.9	508	10.3	8.8	1.29	3.7	
	17-Jun-21	10:00:00 AM	8.2	244	12	8.5	1.47	<4.0	
C) Marion Creek	7-Oct-2019								
	15-Jun-2020		11.9	283.0	9.1	8.4			
	23-Jul-2020		17.6	344.1	8.7	8.4	4.09		0.4
	27-Aug-2020	11:15:00 AM	14.4	354.6	9.82	8	1.56		0.11
	19-Sep-2020	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	
D) creek flowing from Canal Flats	7-Oct-2019								
	14-Jun-2020		8.5	341.0	8.4	7.8	2.01		
	23-Jul-2020		8.9	388.6	8.88	8	0.17		9.68
	27-Aug-2020	12:05:00 PM	8.8	385.3	9.68	7.8	0.47		8.22
	19-Sep-2020	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	

Yellow: after logging

Green: before logging

Table 4 compares the concentrations before and after the logging parameters for a variety of other water quality parameters. Only the ammonia, nitrogen, total phosphorous and dissolved phosphorous concentrations are greater in concentrations after the logging operations than before the work began. However, the period from April to June is when we would expect snowmelt and spring rain to drain from the water shed to the creeks and this increase is understood to be a seasonal and natural occurrence not due to logging operations. The concentrations for the parameters measured do not exceed the maximum acceptable concentration as reported to us by Carol Analytical in their report on the chemical analyses.

Table 4 - Water Quality Analyses for Hardie Creek Spring 2021

Parameter	RDL*	Units		Hardie Creek				Maximum acceptable concentration (MAC)**
			Date sampled	15-Mar-21	19-Apr-21	17-May-21	17-Jun-21	
Anions								
Dissolved Chloride (Cl)	0.5	mg/L		0.48	0.52	0.4	0.35	19.3
Dissolved Sulfate (SO4)	1	mg/L		31.4	27.9	23.4	19.3	500
Calculated parameters								
Hardness	0.5	mg/L		311	319	318	309	None Required
Nutrients								
Ammonia, Total (as N)	0.05	mg/L		0.114	0.156	0.211	0.199	None Required
Nitrogen, Total Kjeldahl	0.05	mg/L		0.315	0.0096	0.0081	<0.0050	*
Phosphorus, Total (as P)	0.005	mg/L		0.0187	<0.0050	0.0068	<0.0050	*
Phosphorus, Total Dissolved	0.005	mg/L		0.0128	<2.0	3.7	<4.0	*
Total metals by ICPMS								
Aluminum, total	0.005	mg/L		<0.0050	<0.0050	<0.0050	0.0131	None Required
Antimony, total	0.0002	mg/L		0.00053	<0.00020	<0.00020	0.00028	0.006
Arsenic, total	0.0005	mg/L		<0.00050	<0.00050	<0.00050	<0.00050	0.01
Barium, total	0.005	mg/L		0.163	0.166	0.183	0.161	2
Beryllium, total	0.0001	mg/L		<0.00010	<0.00010	<0.00010	<0.00010	*
Bismuth, total	0.0001	mg/L		<0.00010	<0.00010	<0.00010	<0.00010	
Boron, total	0.05	mg/L		<0.0500	<0.0500	<0.0500	<0.0500	5.0
Cadmium, total	0.00001	mg/L		<0.000010	<0.000010	<0.000010	<0.000010	0.007
Calcium, total	0.2	mg/L		49.3	50.8	54.8	50.4	None required
Chromium, total	0.0005	mg/L		<0.00050	<0.00050	<0.00050	<0.00050	
Cobalt, total	0.0001	mg/L		<0.00010	<0.00010	<0.00010	<0.00010	*
Copper, total	0.0004	mg/L		0.001	<0.00040	<0.00040	<0.00040	2.0
Iron, total	0.01	mg/L		<0.010	<0.010	<0.010	0.019	None
Lead, total	0.0002	mg/L		<0.00020	<0.00020	<0.00020	<0.00020	0.005
Lithium, total	0.0001	mg/L		0.00454	0.00419	0.00426	0.00396	*
Magnesium, total	0.01	mg/L		45.6	46.5	44.1	44.5	None Required
Manganese, total	0.0002	mg/L		0.00026	0.00045	0.00026	0.00088	0.12
Molybdenum, total	0.0001	mg/L		0.00227	0.0021	0.00225	0.00177	*
Nickel, total	0.0004	mg/L		<0.00040	<0.00040	<0.00040	<0.00040	*
Phosphorus, total	0.05	mg/L		<0.050	<0.050	<0.050	<0.050	*
Potassium, total	0.1	mg/L		1.06	0.92	1.08	0.82	*
Selenium, total	0.0005	mg/L		<0.00050	<0.00050	<0.00050	<0.00050	0.05
Silicon, total	1	mg/L		6.9	7.5	6.6	6.5	*
Silver, total	0.00005	mg/L		<0.000050	<0.000050	<0.000050	<0.000050	None Required
Sodium, total	0.1	mg/L		6	6.64	6.44	5.8	None
Strontium, total	0.001	mg/L		0.16	0.159	0.163	0.146	7
Sulfur, total	3	mg/L		10.9	10.5	8.1	7.1	*
Tellurium, total	0.0005	mg/L		<0.00050	<0.00050	<0.00050	<0.00050	*
Thallium, total	0.00002	mg/L		<0.000020	<0.000020	<0.000020	<0.000020	*
Thorium, total	0.0001	mg/L		<0.00010	<0.00010	<0.00010	<0.00010	*
Tin, total	0.0002	mg/L		0.0127	<0.00020	<0.00020	<0.00020	*
Titanium, total	0.005	mg/L		<0.0050	<0.0050	<0.0050	<0.0050	*
Tungsten, total	0.001	mg/L		<0.0010	<0.0010	<0.0010	<0.0010	*
Uranium, total	0.00002	mg/L		0.00563	0.0055	0.00474	0.0036	0.02
Vanadium, total	0.001	mg/L		<0.0010	<0.0010	<0.0010	<0.0010	*
Zinc, total	0.004	mg/L		0.0101	<0.0040	<0.0040	<0.0040	Not given
Zirconium, total	0.0001	mg/L		<0.00010	<0.00010	<0.00010	<0.00010	*

*reportable detection limit

after logging (yellow)

before logging (green)

** As provided with the analytical results from Caro Analytical

3.3 Stream sampling program

CLSS monitoring the water quality of five streams that feed into Columbia Lake during the 2021 monitoring program. The stream sampling sites 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 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.

In 2021, the water quality measurements made on each stream included water temperature, specific conductance (conductivity), dissolved oxygen, pH and turbidity. Four of the streams, (Dutch Creek, Hardie Creek, Marion Creek and the creek draining from Canal Flats) were monitored on June 17, July 12, and August 16. Lansdowne Creek on the east side of the lake was monitored on July 7.

The water quality measurements and analyses made during the stream sampling program are summarized in Table 5 and the results compared in Figure 13.

Table 5 - Comparison of Stream Quality Measurements 2021

	Date	Time	Water Temp (C)	Specific Cond. (uS/cm)	Dissolved Oxygen (mg/L)	pH	Turbidity (NTU)	Suspended Sediments (mg/L)	Chloride (mg/L)
A) Dutch Creek	23-Jul-2020		10.3	147.2	10.3	8.4	4.1		0.43
	27-Aug-2020	1:45:00 PM	12.0	201.5	10.4	8.2	1.0		0
	19-Sep-2020	2:45:00 PM	11.9	221.0	10.5	8.4	0.6		
	17-Jun-2021	12:25:00 PM	7.2	141.7	11.9	7.2	3.52	13.3	
	12-Jul-2021	1:26:00 PM	13.7	163.9	10.2	8.4	7.6		
	16-Aug-2021	10:05:00 AM	13.1	204.5	10.7	8.4	2.2		
B) Hardie Creek	7-Oct-2019								
	14-Jun-2020		9.2	444.0	10	8.3	2.47		
	23-Jul-2020		11.1	303.8	9.81	8.2	2.85		0.45
	27-Aug-2020	1:00:00 PM	10.5	481.3	10.36	8.3	4.09		0.56
	19-Sep-2020	11:41:00 AM	10	494	10.5	7.9	7.9		
	14-Mar-2021	12:37:00 PM	1.3	543	11.1	8.2	2.34	2.6	
	19-Apr-2021	10:30:00 AM	2.7	537	9.2	8.4	2.25	<2.0	
	17-May-21	1:46:00 PM	12.9	508	10.3	8.8	1.29	3.7	
	17-Jun-21	10:00:00 AM	8.2	244	12	8.5	1.47	<4.0	
	12-Jul-2021	12:58:00 PM	12.6	487	10.6	8.8	3		
	16-Aug-2021	10:57:00 AM	11.4	490	11.7	8.5	3.43		
C) Marion Creek	7-Oct-2019								
	15-Jun-2020		11.9	283.0	9.1	8.4			
	23-Jul-2020		17.6	344.1	8.7	8.4	4.09		0.4
	27-Aug-2020	11:15:00 AM	14.4	354.6	9.82	8	1.56		0.11
	19-Sep-2020	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		
	16-Aug-21	10:37:00 AM							
	08-Sep-21	2:04PM	14.1	356.6	5.9	8.6	2.38		
D) creek flowing from Canal Flats	7-Oct-2019								
	14-Jun-2020		8.5	341.0	8.4	7.8	2.01		
	23-Jul-2020		8.9	388.6	8.88	8	0.17		9.68
	27-Aug-2020	12:05:00 PM	8.8	385.3	9.68	7.8	0.47		8.22
	19-Sep-2020	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	
	12-Jul-21	11:31 AM	9.1	386.8	9.3	8.4	1.75		
	16-Aug-21	12:00 PM	8.2	394	10.7	8.1	3.16		
E) Landsdowne Creek	07-Jul-21	1:30 PM	9.1	313.7	12.5	8.9	2.58		

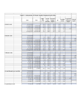


Figure 13 - Stream Water Comparison, 2021

Water Temperature

Over the summer months of 2020 and 2021, the water temperature in Dutch Creek, Hardie Creek and Marion Creek increased from about 7 to 13 degrees. In June of 2021 the water temperature of Marion Creek was measured as 21 degrees. When this measurement was scheduled to be made the flow in Marion Creek was so low that it could not be measured. We suspect that this higher temperature is due to ponded water and not flowing water. However, the creek flow returned by the end of June.

The lowest water temperatures were measured in the creek draining from Canal Flats. 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 origins.

Specific Conductance

The lowest values for the specific conductance in the range of 141 to 221 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 nearly 25% 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 slightly greater than 8 pH units in all creeks except for Marion Creek in September when a pH value of 5.9 was measured. This low value is close to the limit set by Lake Windermere ambassadors of 5 pH units (Table 1) 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.

pH

The pH values ranged from 7.40 to 8.40. These results show that the lowest pH value was measured in Canal Flats at the south end of the lake. The lower pH at this location may be attributed to acidity generated by the decay of organic materials because the stream bank was well grown in and the overall surrounding area is marshy.

Turbidity

For 2021 the turbidity values measured on the creeks was generally in the range of 1.3 to 3.4 NTU's. Unusual values measured of 7.6 and 5.93 NTU's were measured in Dutch Creek on July 12 and on June 17 in Marion Creek. These values are 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 is attributed to aquatic growth in fresh water these creeks should be continued to be monitored for turbidity and as resources permit more frequently in 2022.

Other parameters

In 2020 chloride was measured as part of the regular monitoring program. Chloride is a parameter of concern since its primary source is human use of salts. CLSS resources did not permit Chloride concentrations to be monitored in the creeks in 2021.

The concentrations of chloride measured in the four surface water samples in 2020 ranged from 0.11 mg/L to 8.22 mg/L. The greatest concentration was measured in the creek flowing from Canal Flats. The other three steams yielded chloride concentrations ranging from less than the analytical detection limit (Dutch Creek) to 0.56 (Hardie Creek).

4.0 Comparison to Nearby Lakes

Appendix C contains water quality information tabulated for Columbia Lake, Lake Windermere, Moyie Lake, Premier Lake and Whiteswan Lake using information obtained by CLSS from BCMOE's database. This information consists of biannual water quality results for Columbia Lake, Lake Windermere and Moyie Lake collected by BCMOE from 2015 through to 2021 (Tables C-1, C-2, and C-3 a and b). CLSS also obtained biannual monitoring results from Premier Lake and Whiteswan Lake for 2018, 2019, 2020 and 2021. (Table C-4 and C-5). (We understand that 2018 was the first year that water quality monitoring was conducted on these two lakes.) In 2020 BCMOE collected and analyzed water quality samples from the five lakes in August only.

The tables in Appendix C were prepared by CLSS and not by BCMOE. Any transcription errors are the fault of CLSS.

These data provide a more extensive list of water quality parameters than those monitored in the CLSS annual program. Although an allowance for the differences in geologic setting between the five lakes must be made, this information provides a comparative measure of the water quality of Columbia Lake to the nearby lakes. When reviewing these data, it is important to appreciate that Moyie Lake is much deeper than either Lake Windermere or Columbia Lake. The data in Table 3 is selected for comparable depths of Lake Moyie to that of Lake Windermere and Columbia Lake. Moyie Lake's depth (greater than 30 metres) suggests it may be prone to seasonal stratification and consequently dissolved salts and metals may be distributed differently than in either Lake Windermere or Columbia Lake. For example, when the concentration of conductivity between the five lakes is compared, we note that Moyie Lake concentrations are considerably less than the other lakes.

We cannot make a similar comment about Premier Lake or Whiteswan Lake because depths of these lakes are not known to us.

Table 5 reduces the more extensive list of water quality parameters measured by BCMOE to the range in concentrations measured and contains only those parameters that in one or more lakes differ from the measurements made on the water samples collected from Columbia Lake. There are two parts to Table 5. Table 5A highlights those parameters that have a lower concentration range than that measured for Columbia Lake and Table 5B highlights those concentrations that have a greater concentration range that that measured for Columbia Like. A brief glance at the two tables illustrates that water in Columbia Lake contains greater concentrations for many of the elements and compounds than those measured in the other lakes.

Table 6A - Comparison of Lake Concentrations

A - Lakes with Concentrations Less Than Those Reported for Columbia Lake

Parameter	Units	Columbia Lake Shallow (1 metre)		Columbia Lake Deep (4 metres) *		Lake Windermere (shallow 1 m)		Lake Windermere (Bottom 4 metres)*		Whiteswan Lake		Premier Lake		Moyie Lake north		Moyie Lake south	
		min	max	min	max	min	max	min	max	min	max	min	max	min	max	min	max
Chlorophyll a	ug/L	0.649	1.96			0.245	2.23			0.425	1.36	0.448	2.63	0.397	2.62	0.165	2.02
Field measurements																	
Conductivity	uS/cm	290.9	345.3	301.2	301.2	239.4	404.2			249.6	289.9	338.5	350.9	46.8	62.3	47.2	58.2
Dissolved Oxygen	mg/L	8.08	10.8			6.92	11.6			8.87	10.71	8.52	10.85	8.42	12.04	7.61	12.05
Secchi (H20 clarity)	m	3.18	4.5			2.72	5.3			9.2	9.2	14.2	14.2	3	9.05	3.05	6.4
pH	pH	8.14	8.46			7.88	8.7			7.33	8.95	8.15	9.66	6.26	9.33	6.6	8.4
Temperature	0C	7.8	20.7			8.1	20.7			6.07	18.3	7.4	20.8	3.7	19.9	4.4	20.5
Turbidity	NTU	0.49	0.93	0.55	0.95	0.3	1.04	0.51	1.39	0.19	0.25	0.2	0.41	0.22	1.17	0.2	1.63
Anions																	
Silica	mg/L	2.21	7.83	3.33	8.09	2.56	6.42	2.28	6.91	0.823	3.9	0.87	3.04	3.24	8.81	3.45	8.72
Orthophosphate (p)	mg/L	0.0012	0.0016	0.0012	0.006	0.001	0.0015	<0.001	0.0014			0.0012	0.0012	0.0017	0.0017	0.0018	0.0026
Dissolved Sulphate (SO4)	mg/L	22.4	32	22.9	29.7	25	73.1	25	74.3	3.8	22.4	24.1	26.6	1.82	2.36	1.65	2.36
Dissolved Chloride (Cl)	mg/L	4.36	6.44	4.39	6.43	1.11	3.15	1.11	3.13	2.14	3	<0.5	<0.5	0.081	1.22	0.94	1.5
Calculated parameters																	
Hardness	mg/L	145	193	148	183	115	224	120	223	138	145	173	195.2	19.2	28.4	19.3	27.2
Misc. Organics																	
Total Organic Cargon	mg/L	1.03	3.27	1.79	3.35	1.51	2.64	1.22	2.29	1.25	1.94	2.06	2.56	2.33	3.44	2.44	3.4
Nutrients																	
Total Kjeldahl Nitrogen ((	mg/L	0.164	0.308	0.157	0.239	0.122	0.228	0.123	0.933	0.07	0.119	0.199	0.227	0.061	0.119	0.089	0.185
Dissolved Phosphorous (I	mg/L	0.002	0.0058	0.0031	0.0165	0.0021	0.0048	<0.002	0.0046	0.002	0.0061	0.0017	0.0054	0.0021	0.0032	0.0022	0.042
Nitrate plus nitrite (n)	mg/L	0.002	0.0032			0.003	0.0195	0.0032	0.019	0.0052	0.0052			0.001	0.0728	0.0163	0.0445
Total Nitrogen (N)	mg/L	0.164	0.312	0.157	0.239	0.122	0.228	0.123	0.933	0.0035	0.105	0.199	0.32	0.094	0.178	0.094	0.228
Total Phosphorous (P)	mg/L	0.002	0.0183	0.002	0.0175	0.0022	0.0087	0.003	0.185	0.0023	0.0037	0.00113	0.0065	0.0023	0.0052	0.0021	0.0086
Total metals by ICPMS																	
Aluminium (Al)	ug/L	1.35	6.18	3.13	7.08	1.29	4.49	1.44	4.67	1.16	3.33	1.28	3	12.4	34.8	13	59.8
Antimony (Sb)	ug/L	0.058	0.085	0.068	0.123	0.049	0.073	0.054	0.069	0.081	0.107	0.062	0.072	0.021	0.037	0.034	0.071
Arsenic (As)	ug/L	0.0663	1.26	0.629	1.18	0.535	1.19	0.564	1.23	0.246	0.306	0.373	0.414	0.198	0.24	0.217	0.306
Barium (Ba)	ug/L	67.2	85.7	67.7	81.5	56.7	86.1	56.1	83.6	92.3	112	81.4	94.7	4.91	7.85	5.8	8.66
Boron (B)	ug/L	5.5	7.2	5.6	7.2	5.2	9.4	5.6	8.2								
Cadmium (Cd)	ug/L															0.0252	0.0591
Chromium (Cr)	ug/L					0.14	0.14										
Cobalt (Co)	ug/L	0.015	0.0373	0.0224	0.0407	0.015	0.043	0.014	0.0375	0.0094	0.0228	0.0137	0.022	0.0189	0.0365	0.0206	0.0563
Copper (Cu)	ug/L	0.131	0.423	0.161	0.352	0.123	0.403	0.148	0.24	0.097	1.38	0.076	0.97	0.359	0.646	0.548	2.36
Iron (Fe)	ug/L	2.2	18.8	10.9	18.4	8.7	43.7	10.3	43.9	1.2	4.6	1.1	3.5	13	41.5	18.7	61.3
Lead (Pb)	ug/L	0.008	0.0485	0.0263	0.0514	0.01	0.123	0.0138	0.0742	0.0062	0.024	0.00516	0.0469	0.016	0.0688	1.17	3.68
Lithium (Li)	ug/L	2.52	3.4	2.89	3.32	1.58	3.8	1.7	3.69	1.09	1.25	2.7	2.94				
Manganese (Mn)	ug/L	4.2	15.3	2.11	9.87	5.1	29	5.17	43.5	0.427	2.53	1.12	2.42	1.66	3.61	2.45	4.91
Molybdenum (Mo)	ug/L	0.488	0.614	0.519	0.583	0.515	0.717	0.495	0.604	0.654	0.723	1.09	1.19	0.073	0.113	0.078	0.097
Nickel (Ni)	ug/L	0.05	0.138	0.074	0.142	0.05	0.192	0.068	0.112	0.055	0.091	0.102	0.102	0.093	0.153	0.109	0.196
Selenium (Se)	ug/L	0.041	0.059	0	0	0.044	0.082	0.051	0.055	0.053	0.079	0.077	0.192			0.042	0.042
Strontium (Sr)	ug/L	182	223	167	214	115	373	125	353	98.3	108	164	192	14.9	18.8	15.3	17.9
Thallium (Tl)	ug/L	0.0015	0.0025	0.0029	0.0029	0.0013	0.0057	<0.002	0.0047	<0.002	0.0074			0.003	0.0064	0.0021	0.007
Tin (Sn)	ug/L															0.011	0.011
Uranium (U)	ug/L	0.661	1.06	0.713	1.03	0.02	1.47	0.638	1.27	0.43	0.517	1.33	1.56	0.0661	0.119	0.0624	0.102
Vanadium (V)	ug/L	0.087	0.087	0	0	0.057	0.057										
Zinc (Zn)	ug/L	0.47	1.31	0.93	2.8	0.21	3.02	0.22	3.32	0.17	1.82	0.2	2.17	0.32	2.01	3.45	13.8
Calcium (Ca)	mg/L	25.3	40.4	25	37.9	23	48.9	24	48.9	35	39.4	28	29.5	2.67	8.33	5.55	7.97
Magnesium (Mg)	mg/L	18.5	23.3	18.7	21.8	14	25.6	14.5	24.5	11.2	12.8	25	28.4	1.36	3.44	1.37	1.87
Potassium (K)	mg/L	0.703	0.84	0.673	8	0.151	1	0.418	0.884	0.291	0.354	0.62	0.688	0.423	0.634	0.439	0.618
Sodium (Na)	mg/L	4.89	6.79	5.27	6.51	2.01	4.81	2.09	4.5	1.06	2.57	2.95	3.65	1.36	1.91	1.49	1.92

Concentration range is less than Columbia Lake

Concentration range is greater than Columbia Lake

* not updated with 2021 findings

Table 6B - Comparison of Lake Concentrations

B - Lakes with Concentrations Greater Than Those Reported for Columbia Lake

Parameter	Units	Columbia Lake		Columbia Lake		Lake Windermere		Lake Windermere		Whiteswan Lake		Premier Lake		Moyie Lake north		Moyie Lake south	
		min	max	min	max	min	max	min	max	min	max	min	max	min	max	min	max
Chlorophyll a	ug/L	0.649	1.96			0.245	2.23			0.425	1.36	0.448	2.63	0.397	2.62	0.165	2.02
Field measurements																	
Conductivity	uS/cm	290.9	345.3	301.2	301.2	239.4	404.2			249.6	289.9	338.5	350.9	46.8	62.3	47.2	58.2
Dissolved Oxygen	mg/L	8.08	10.8			6.92	11.6			8.87	10.71	8.52	10.85	8.42	12.04	7.61	12.05
Secchi (H20 clarity)	m	3.18	4.5			2.72	5.3			9.2	9.2	14.2	14.2	3	9.05	3.05	6.4
pH	pH	8.14	8.46			7.88	8.7			7.33	8.95	8.15	9.66	6.26	9.33	6.6	8.4
Temperature	0C	7.8	20.7			8.1	20.7			6.07	18.3	7.4	20.8	3.7	19.9	4.4	20.5
Turbidity	NTU	0.49	0.93	0.55	0.95	0.3	1.04	0.51	1.39	0.19	0.25	0.2	0.41	0.22	1.17	0.2	1.63
Anions																	
Silica	mg/L	2.21	7.83	3.33	8.09	2.56	6.42	2.28	6.91	0.823	3.9	0.87	3.04	3.24	8.81	3.45	8.72
Orthophosphate (p)	mg/L	0.0012	0.0016	0.0012	0.006	0.001	0.0015	<0.001	0.0014			0.0012	0.0012	0.0017	0.0017	0.0018	0.0026
Dissolved Sulphate (S	mg/L	22.4	32	22.9	29.7	25	73.1	25	74.3	3.8	22.4	24.1	26.6	1.82	2.36	1.65	2.36
Dissolved Chloride (C	mg/L	4.36	6.44	4.39	6.43	1.11	3.15	1.11	3.13	2.14	3	<0.5	<0.5	0.081	1.22	0.94	1.5
Calculated parameters																	
Hardness	mg/L	145	193	148	183	115	224	120	223	138	145	173	195.2	19.2	28.4	19.3	27.2
Misc. Organics																	
Total Organic Cargon	mg/L	1.03	3.27	1.79	3.35	1.51	2.64	1.22	2.29	1.25	1.94	2.06	2.56	2.33	3.44	2.44	3.4
Nutrients																	
Total Kjeldahl Nitrog	mg/L	0.164	0.308	0.157	0.239	0.122	0.228	0.123	0.933	0.07	0.119	0.199	0.227	0.061	0.119	0.089	0.185
Dissolved Phosphoro	mg/L	0.002	0.0058	0.0031	0.0165	0.0021	0.0048	<0.002	0.0046	0.002	0.0061	0.0017	0.0054	0.0021	0.0032	0.0022	0.042
Nitrate plus nitrite (n	mg/L	0.002	0.0032			0.003	0.0195	0.0032	0.019	0.0052	0.0052			0.001	0.0728	0.0163	0.0445
Total Nitrogen (N)	mg/L	0.164	0.312	0.157	0.239	0.122	0.228	0.123	0.933	0.0035	0.105	0.199	0.32	0.094	0.178	0.094	0.228
Total Phosphorous (I	mg/L	0.002	0.0183	0.002	0.0175	0.0022	0.0087	0.003	0.185	0.0023	0.0037	0.00113	0.0065	0.0023	0.0052	0.0021	0.0086
Total metals by ICPMS																	
Aluminium (Al)	ug/L	1.35	6.18	3.13	7.08	1.29	4.49	1.44	4.67	1.16	3.33	1.28	3	12.4	34.8	13	59.8
Antimony (Sb)	ug/L	0.058	0.085	0.068	0.123	0.049	0.073	0.054	0.069	0.081	0.107	0.062	0.072	0.021	0.037	0.034	0.071
Arsenic (As)	ug/L	0.0663	1.26	0.629	1.18	0.535	1.19	0.564	1.23	0.246	0.306	0.373	0.414	0.198	0.24	0.217	0.306
Barium (Ba)	ug/L	67.2	85.7	67.7	81.5	56.7	86.1	56.1	83.6	92.3	112	81.4	94.7	4.91	7.85	5.8	8.66
Boron (B)	ug/L	5.5	7.2	5.6	7.2	5.2	9.4	5.6	8.2								
Cadmium (Cd)	ug/L															0.0252	0.0591
Chromium (Cr)	ug/L					0.14	0.14										
Cobalt (Co)	ug/L	0.015	0.0373	0.0224	0.0407	0.015	0.043	0.014	0.0375	0.0094	0.0228	0.0137	0.022	0.0189	0.0365	0.0206	0.0563
Copper (Cu)	ug/L	0.131	0.423	0.161	0.352	0.123	0.403	0.148	0.24	0.097	1.38	0.076	0.97	0.359	0.646	0.548	2.36
Iron (Fe)	ug/L	2.2	18.8	10.9	18.4	8.7	43.7	10.3	43.9	1.2	4.6	1.1	3.5	13	41.5	18.7	61.3
Lead (Pb)	ug/L	0.008	0.0485	0.0263	0.0514	0.01	0.123	0.0138	0.0742	0.0062	0.024	0.00516	0.0469	0.016	0.0688	1.17	3.68
Lithium (Li)	ug/L	2.52	3.4	2.89	3.32	1.58	3.8	1.7	3.69	1.09	1.25	2.7	2.94				
Manganese (Mn)	ug/L	4.2	15.3	2.11	9.87	5.1	29	5.17	43.5	0.427	2.53	1.12	2.42	1.66	3.61	2.45	4.91
Molybdenum (Mo)	ug/L	0.488	0.614	0.519	0.583	0.515	0.717	0.495	0.604	0.654	0.723	1.09	1.19	0.073	0.113	0.078	0.097
Nickel (Ni)	ug/L	0.05	0.138	0.074	0.142	0.05	0.192	0.068	0.112	0.055	0.091	0.102	0.102	0.093	0.153	0.109	0.196
Selenium (Se)	ug/L	0.041	0.059	0	0	0.044	0.082	0.051	0.055	0.053	0.079	0.077	0.192			0.042	0.042
Strontium (Sr)	ug/L	182	223	167	214	115	373	125	353	98.3	108	164	192	14.9	18.8	15.3	17.9
Thallium (Tl)	ug/L	0.0015	0.0025	0.0029	0.0029	0.0013	0.0057	<0.002	0.0047	<0.002	0.0074			0.003	0.0064	0.0021	0.007
Tin (Sn)	ug/L															0.011	0.011
Uranium (U)	ug/L	0.661	1.06	0.713	1.03	0.02	1.47	0.638	1.27	0.43	0.517	1.33	1.56	0.0661	0.119	0.0624	0.102
Vanadium (V)	ug/L	0.087	0.087	0	0	0.057	0.057										
Zinc (Zn)	ug/L	0.47	1.31	0.93	2.8	0.21	3.02	0.22	3.32	0.17	1.82	0.2	2.17	0.32	2.01	3.45	13.8
Calcium (Ca)	mg/L	25.3	40.4	25	37.9	23	48.9	24	48.9	35	39.4	28	29.5	2.67	8.33	5.55	7.97
Magnesium (Mg)	mg/L	18.5	23.3	18.7	21.8	14	25.6	14.5	24.5	11.2	12.8	25	28.4	1.36	3.44	1.37	1.87
Potassium (K)	mg/L	0.703	0.84	0.673	8	0.151	1	0.418	0.884	0.291	0.354	0.62	0.688	0.423	0.634	0.439	0.618
Sodium (Na)	mg/L	4.89	6.79	5.27	6.51	2.01	4.81	2.09	4.5	1.06	2.57	2.95	3.65	1.36	1.91	1.49	1.92

Concentration range is less than Columbia Lake

Concentration range is greater than Columbia Lake

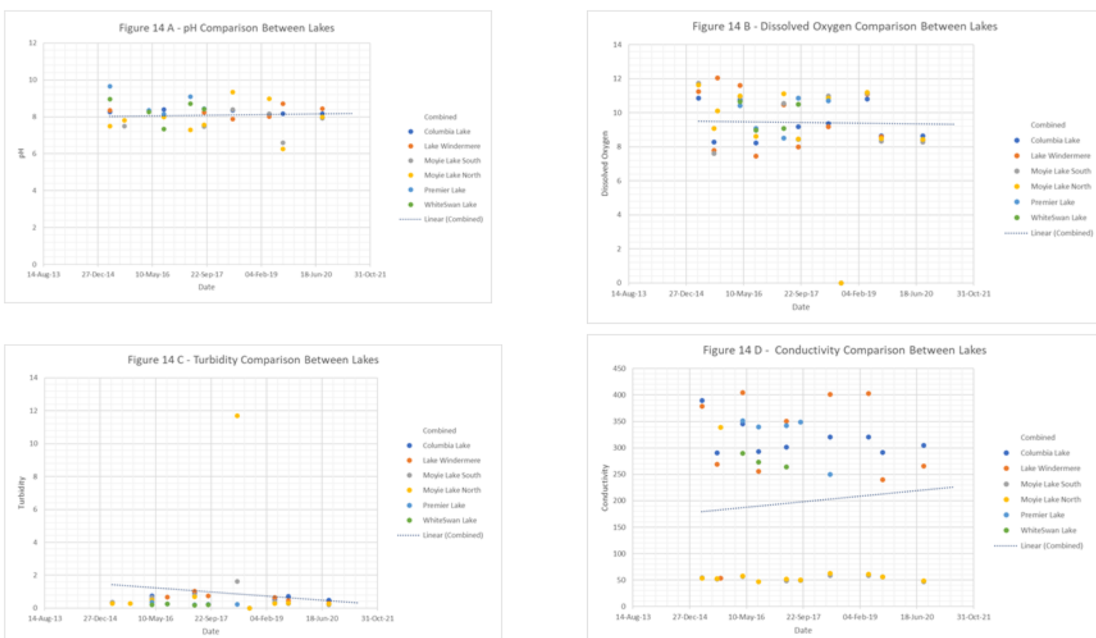
* not updated with 2021 findings

The concentrations of conductivity, turbidity, dissolved SO4, dissolved chloride, hardness, total Kjeldahl nitrogen, total nitrogen, aluminum, antimony, barium, iron, lead, lithium, manganese, strontium, uranium, and sodium are noticeably less (a factor of two or more) than the concentrations measured by BCMOE in Columbia Lake. This comparison should not be inferred to suggest that Columbia Lake has water quality issues but merely to identify parameters that should be monitored more extensively for spatial differences within the lake and for increasing trends that may suggest the beginning of a water quality concern. However, one exception to different geologic condition that should be noted is the comparison of chloride concentrations. There are no naturally occurring sources for chloride in the rocks and soils surrounding any of these five lakes. The only source of chloride is man-made and therefore the greater concentration in Columbia Lake suggests that the lake experiences greater water quality affects from human activity than the other lakes. The greater concentration of sodium measured in Columbia Lake supports this suggestion because sodium chloride is a common salt used by people. Potential sources of chloride salts are wastewater, de-icing salts spread on roads and dust suppression salts used at larger industrial facilities.

For 2021, CLSS has prepared a trend analysis of the concentrations measured for the indicator parameters pH, dissolved oxygen, turbidity and conductivity. These trends are plotted on Figure 14 A, B, C and D respectively. The plotted trend lines for pH and dissolved oxygen (Figures 14 A and B) have a slight slope suggesting that over the period the water quality information has been collected the concentrations of these two parameters remain unchanged. The trend line for the turbidity concentrations however (Figure 14C), although slightly distorted to the high end of the range by an exceptional value for turbidity reported for Moyie Lake shows an overall declining trend for turbidity among the five lakes. Because the major source of turbidity is algae growth, this trend suggests that shallow algae growth in the five lakes has declined overall. The exceptional value for turbidity reported for August will be confirmed in 2022.

The trend for conductivity for the five lakes shows an increasing trend (Figure 14 D). The trend line plotted here includes Moyie Lake which has a much lower concentration than the other four lakes and may be an inappropriate contributor to this trend. However, the overall trend for year to year increases in conductivity concentrations is noted for Columbia Lake. Conductivity is a measure of the dissolved salt contained in the water and is a parameter that needs to be monitored more diligently.

Figure 14 – Comparison Between Lakes



5.0 Suggested Monitoring Program for 2022

The monitoring program undertaken over the past eight 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:

- Over the summer months the turbidity concentration decreases and are similar in concentration from the south end to north end of the lake. A similar trend to declining values is observed in the pH values measured and in the dissolved oxygen concentrations.
- In contrast, the specific conductance concentrations increase over the summer months and 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.
- Further we note that some trends in concentration over the years from 2014 to 2019 were not observed in 2020 and 2021. Turbidity concentrations, for example, were observed to increase over the summer months in the earlier years, but not in 2020 and 2021. Whether this is due to a change due to the hotter summer months in 2021 and 2022, a shorter sampling period or a change in water quality cannot be determined. Trends for the concentrations of other parameters are similar to those in other years.
- Profiles of concentrations for turbidity, specific conductance 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 due to the limited resources of CLSS. However, CLSS intends to repeat the survey in 2022 as our funding allows. This survey will involve two 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.

Columbia Lake also contains different concentrations of chloride than the other four neighbouring lakes monitored each year by BCMOE. Although chloride is not the only element or compound that has a concentration different than that found in the other lakes, it is of concern because there are no natural soils or rocks that can contribute chloride to surface water or groundwater draining into the lake.

Therefore, CLSS intends to proceed in 2022 with a similar program to that undertaken in 2021. 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 (N1, S1, S3 and S4).
- Chemical analyses during the regular program in late May and mid-July for total and dissolved oxygen, nitrate, iron and manganese, alkalinity, hardness and chloride.
- Monitoring the distribution of temperature, turbidity, specific conductance and chloride on two occasions during the summer months (mid-July and mid-August).

- Monthly monitoring of the four creeks, Dutch Creek, Hardie Creek, Marion Creek and the creek draining from Canal Flats for temperature, turbidity, specific conductance, pH and dissolved oxygen.
- Twice per year (spring and fall) analyses of the creek waters for nitrate, total and dissolved phosphorous, iron and manganese, alkalinity, hardness, and chloride.

In addition, in 2022 CLSS intends to begin supporting 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. We will begin this program with our Project Coordinator receiving training through the workshops put on by Environment Canada in British Columbia.

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

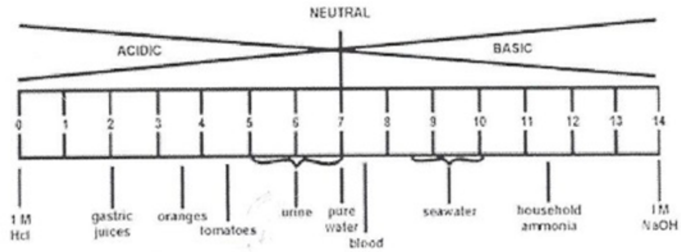
Turbidity is a measure of water clarity or more simply, how much the material suspended in water decreases the passage of light through the water. Suspended materials include soil particles (clay, silt, and sand), algae, plankton, microbes, and other substances. These materials are typically in the size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



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

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

Conductivity

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

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

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

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

Appendix A-2 Historical Development of the Monitoring Program

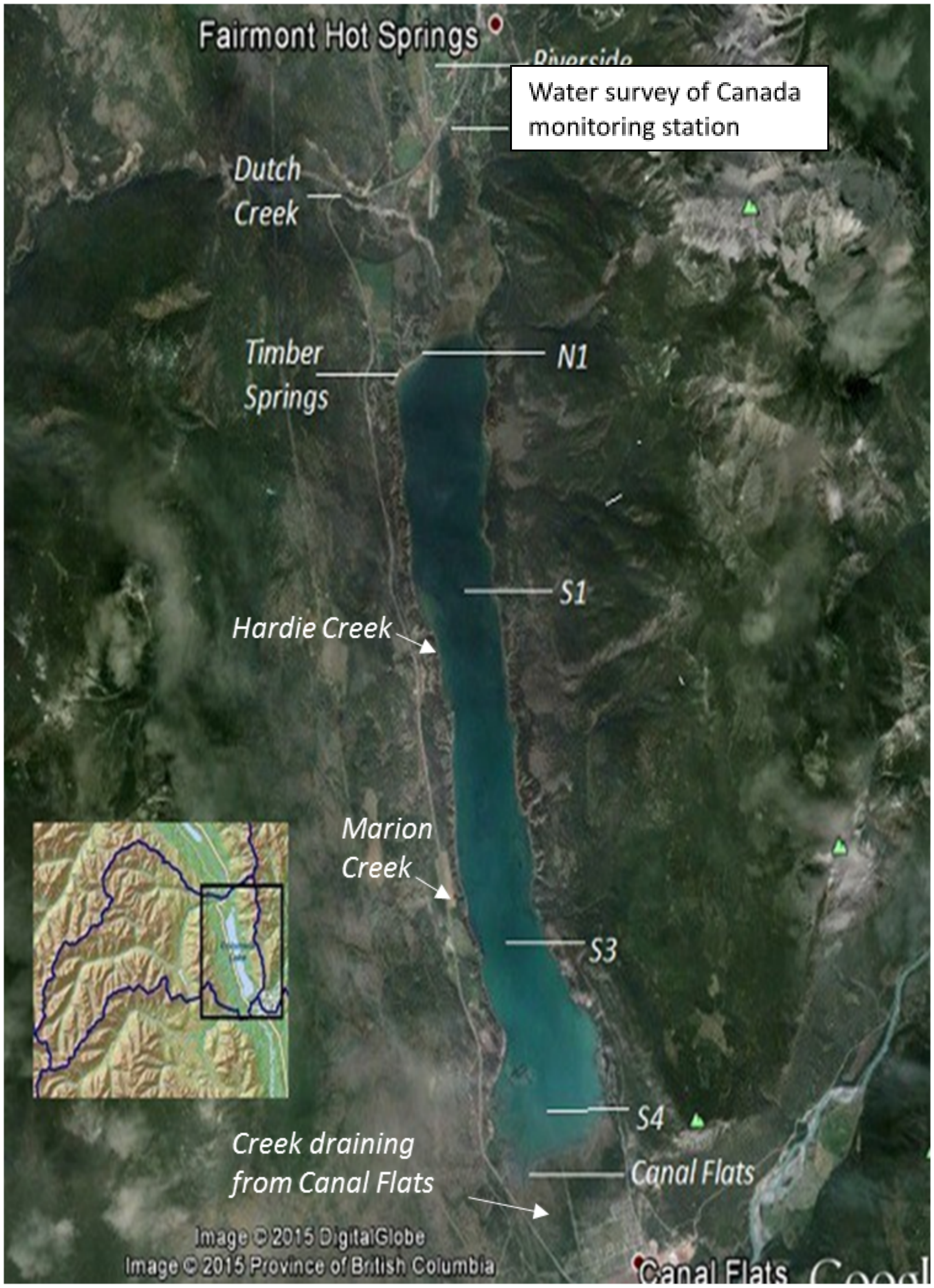
The water quality monitoring program on Columbia Lake was developed in response to recommendations contained in the Columbia Lake Management Strategy (Urbans Systems., 1997). The monitoring program began in 2014 and has continued while the lake is ice free until the present day. Since 2014 however several 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

Figure 1 – Monitoring Locations



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^{o} C, as the cold surface water, produced from the ice (at 0^{0}C), 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

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. The spreadsheet is available on the CLSS website.

Appendix C

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

Table C-1 - Water Quality results for Columbia Lake Surface Samples

January 18, 2022

Parameter	RDL*	Units	Location on the lake	Surface (1 m)	Columbia lake midlake north												Concentration Range	
			Date sampled	15-Apr-15	26-Aug-15	07-Apr-16	24-Aug-16	25-Apr-17	29-Aug-17	16-May-18	04-Sep-18	19-Apr-19	21-Aug-19	17-Aug-20	27-Apr-21	18-Aug-21	minimum	maximum
Chlorophyll a	0.5	ug/L		0.91	1.46	1.33	1.39	1.85	0.856	1.03	1.14	1.96	1.51	0.65	0.649	1.61	0.649	1.96
Chlorophyll a rep	0.5	ug/L		1.28	0.828	1.45	1.97	1.84	0.922									
Field measurements																		
Conductivity	-	uS/cm		339.3	290.9	343.3	298	301.3		320.3		320.3	291	305	345	306	290.9	343.3
Dissolved Oxygen	-	mg/L		10.72	8.27	10.75	8.23	10.49	9.18	9.37		10.8	8.65	8.64	10.45	8.08	8.08	10.8
Secchi (H2O clarity)	-	m		4.5	3.6	4.5	3.6	3.18	4.4	3.9							3.18	4.5
pH	-	pH		8.27			8.4			8.36		8.14	8.17	8.17	8.38	8.46	8.14	8.46
Temperature	-	°C		7.8	18.6	9.26	18.9	10.1	20.3	19.2		8.9	20.7	21	10.6	18.8	7.8	21
Turbidity		NTU				0.74		0.93				0.55	0.72	0.48	0.55	0.64	0.48	0.93
Anions																		
Silica	0.5	mg/L		4.91	7.69	5.97	7.18	4.76	7.83	6.18	6.99	5.12	7.11	5.65	2.21	6.61	2.21	7.83
Orthophosphate (p)	0.001	mg/L		0.0012	<0.001	0.0015	<0.001	<0.001	<0.001	0.0016	0.0016	<0.001	<0.001	0.001	0.001	<0.001	0.001	0.0016
Dissolved Sulphate (SO4)	0.5	mg/L		27.6	22.4	29.7	25.3	29	23.1	27.1	22.9	26.7	25.1	24.1	32	27.5	22.4	32
Dissolved Chloride (Cl)	0.5	mg/L		6.1	5.47	6.44	5.92	5.88	4.78	5.01	4.38	5.09	4.58	4.36	5.72	4.9	4.36	6.44
Calculated parameters																		
Hardness	0.5	mg/L		169	151	193	150	182	151		153	165	156	149	168	145	145	193
Misc. Organics																		
Total Organic Carbon	0.5	mg/L		1.08	2.51	1.95	3.27	2.23	2.71	2.42	2.65	2.05	2.62	2.29	2.08	2.18	1.08	3.27
Nutrients																		
Total Kjeldahl Nitrogen (Calc)	0.02	mg/L		0.23	0.227	0.169	0.226	0.187	0.224	0.164	0.255	0.188	0.256	0.308	0.194	0.21	0.164	0.308
Dissolved Phosphorous (P)	0.002	mg/L		0.0058	0.003	0.002	0.002	0.002	0.0021	0.002	0.0029	0.0025	0.0023	0.0026	0.0045	0.0087	0.002	0.0058
Nitrate plus nitrite (n)	0.002	mg/L		<0.002	0.002	0.0032	0.0032	0.0032	<0.0032	<0.0032	<0.003	<0.003	<0.003	0.0032	0.0032	<0.001	0.002	0.0032
Total Nitrogen (N)	0.02	mg/L		0.23	0.227	0.169	0.226	0.187	0.312	0.164	0.255	0.188	0.256	0.308	0.194	0.234	0.164	0.312
Total Phosphorous (P)	0.002	mg/L		0.0183	0.0043	0.0031	0.0089	0.004	0.0058	0.002	0.0064	0.0046	0.0023	0.0056	0.0045	0.0066	0.002	0.0183
Total metals by ICPMS																		
Aluminium (Al)	0.5	ug/L		6.18		4.23		4.02		13.50		2.08	1.52	3.69	2.06	3.09	1.35	6.18
Antimony (Sb)	0.02	ug/L		0.073		0.065		0.071		0.085		0.06	0.077	0.072	0.058	0.068	0.058	0.085
Arsenic (As)	0.02	ug/L		0.644		0.0663		0.696		0.767		0.621	1.26	1.1	0.671	1.24	0.0663	1.26
Barium (Ba)	0.02	ug/L		74.3		76.5		85.7		71.0		74.8	68.2	70.8	77.8	67.2	67.2	85.7
Beryllium (Be)	0.01	ug/L		<0.01		<0.01		<0.01		<0.02		<0.01	<0.01	<0.01	<0..01	<0.01		
Bismuth (Bi)	0.005	ug/L		<0.005		<0.005		<0.005		<0.001		<0.005	<0.005	<0.005	<0.005	<0.005		
Boron (B)	10	ug/L		<10		<10		<10		5.500		5.9	7.2	6.2	5.7	7.2	5.5	7.2
Cadmium (Cd)	0.005	ug/L		<0.005		<0.005		<0.005		<0.0050		<0.005	<0.005	<0.005	<0.005	<0.005		
Chromium (Cr)	0.1	ug/L		<0.01		<0.1		<0.1		<0.0050		<0.1	<0.1	<0.1	<0.1	<0.1		
Cobalt (Co)	0.005	ug/L		0.027		0.0293		0.0873		0.029		0.024	0.015	<0.001	0.085	0.026	0.015	0.0873
Copper (Cu)	0.05	ug/L		0.259		0.135		0.182		0.423		0.224	0.22	0.131	0.146	0.171	0.131	0.423
Iron (Fe)	1	ug/L		18.8		14.5		13.7		16.400		14.9	2.2	12	9.8	6.4	2.2	18.8
Lead (Pb)	0.005	ug/L		0.0481		0.0384		0.0485		0.041		<0.005	0.008	0.0156	0.0297	0.0283	0.008	0.0485
Lithium (Li)	0.5	ug/L		3.07		3.37		3.4		2.850		3.19	2.94	2.52	3.02	2.81	2.52	3.4
Manganese (Mn)	0.05	ug/L		6.25		9.21		10.3		12.600		7.02	4.2	15.3	9.43	12.2	4.2	15.3
Molybdenum (Mo)	0.05	ug/L		0.514		0.532		0.54		0.614		0.539	0.59	0.492	0.546	0.488	0.488	0.614
Nickel (Ni)	0.02	ug/L		0.138		0.069		0.05		0.126		0.13	0.06	0.061	0.073	0.07	0.05	0.138
Selenium (Se)	0.04	ug/L		<0.04		0.041		<0.04		0.059		<0.04	0.046	<0.04	0.05	<0.04	0.041	0.059
Silver (Ag)	0.005	ug/L		<0.005		<0.005		<0.005		<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	0	0
Strontium (Sr)	0.05	ug/L		217		215		202		195.000		183	183	182	223	215	182	223
Thallium (Tl)	0.002	ug/L		<0.002		<0.002		0.0025		0.002		–	--			<0.002	0.0015	0.0025
Tin (Sn)	0.2	ug/L		<0.2		<0.01		<0.01		<0.01		<0.01	<0.05	<0.002	<0.005	<0.005		
Uranium (U)	0.002	ug/L		1		0.933		1.02		1.060		0.926	0.752	0.685	0.882	0.661	0.661	1.06
Vanadium (V)	0.2	ug/L		<0.2		<0.2		<0.2		0.087		<0.2	<0.2	<0.2	<0.2	<0.2	0.087	0.087
Zinc (Zn)	0.1	ug/L		0.47		0.55		0.509		1.310		0.84	0.5	1.08	0.803	0.76	0.47	1.31
Calcium (Ca)	0.05	mg/L		34.2	26.2	38.8	26.9	37.9	28.6	40.4	25.3	34.9	28.5	29	34.9	27	25.3	40.4
Magnesium (Mg)	0.05	mg/L		20.4	20.7	23.3	20.1	21.3	19.4	19.8	21.8	18.9	20.5	18.5	19.6	18.3	18.3	23.3
Potassium (K)	0.05	mg/L				0.84		0.8		0.834		0.795	0.708	0.74	0.808	0.76	0.703	0.84
Sodium (Na)	0.05	mg/L				6.79		6.71		5.58		6.05	5.47	4.89	5.93	5.71	4.89	6.79

RDL reportable detection limit

Table C-2 - Water Quality results for Lake Windermere Shallow Samples

January 18, 2022

Parameter	RDL*	Units	15-Apr-15	26-Sep-15	07-Apr-16	24-Sep-16	25-Apr-17	29-Aug-17	16-May-18	04-Sep-18	19-Apr-19	20-Aug-19	17-Aug-20	17-May-21	18-Aug-21	Concentration Range minimum	Concentration Range maximum
Location on the lake			Lake Windermere off Timber Ridge Shallow (1 metre)														
Date sampled			15-Apr-15	26-Sep-15	07-Apr-16	24-Sep-16	25-Apr-17	29-Aug-17	16-May-18	04-Sep-18	19-Apr-19	20-Aug-19	17-Aug-20	17-May-21	18-Aug-21	minimum	maximum
Chlorophyll a	0.5	uG/L	0.85	1.83	1.1	1.64	1.14	2.23	1.66	2.07	1.12	1.58	0.281	0.547	0.245	0.245	2.23
Chlorophyll a rep	0.5	uG/L	0.82	1.08	1.27		2.02	2.14									
Field measurements																	
Conductivity	-	uS/cm	389.3	268.9	404.2	256	350.4		401		403.1	239.4	266	379	285	239.4	404.2
Dissolved Oxygen	-	mg/L	10.85	7.79	11.6	7.44	10.47	7.99	9.18		11.1	8.58	8.41	11.24	6.92	6.92	11.6
Secchi (H2O clarity)	-	m	5	4.65	5.3	5.3	2.72	4	3.7		--	--	--	--		2.72	5.3
pH	-	pH	-					8.23	7.88		8.02	8.7	8.45	8.34	7.98	7.88	8.7
Temperature	-	°C	8.4	19.3	9.75	19.8	11.6	20	17.7		8.1	20.7	21	15.9	20.5	8.1	21
Turbidity		NTU			0.57	0.67	1.04	0.75			0.65	0.47	0.3	0.32	0.59	0.3	1.04
Anions																	
Silica	0.5	mg/L	4.48	5.84	5.5	5.8	3.84	6.42	3.71	6.4	4.34	2.65	2.56		5.28	2.56	6.42
Orthophosphate (p)	0.001	mg/L	0.0011	0.001	<0.001	<0.001	<0.001	<0.001	0.0015	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.001	0.0015
Dissolved Sulphate (SO4)	0.5	mg/L	70.8	28.4	71.7	30.5	71.6	31	71.1	32.3	65.8	25	27.8	73.1	28.5	25	73.1
Dissolved Chloride (Cl)	0.5	mg/L	2.9	1.68	3.15	1.45	2.91	1.57	3.04	1.44	2.91	1.11	1.36	3.08	1.75	1.11	3.15
Calculated parameters																	
Hardness	0.5	mg/L	201	148	224	149	209	148		158	197	115	132	183	140	115	224
Misc. Organics																	
Total Organic Carbon	0.5	mg/L	<0.5	1.86	1.63	1.96	1.55	2.36	2.09	1.87	1.51	1.96	1.5		2.64	1.5	2.64
Nutrients																	
Total Kjeldahl Nitrogen (Calc)	0.02	mg/L	0.133	0.193	0.122	0.139	0.133	0.198	0.16	0.228	0.17	0.157	0.169	0.162	0.216	0.122	0.228
Dissolved Phosphorous (P)	0.002	mg/L	0.0083	0.0031	<0.002	<0.002	<0.002	0.0021	0.0038	0.0029	0.0021	0.0048	0.0041	<0.002	0.004	0.0021	0.0048
Nitrate plus nitrite (n)	0.002	mg/L	<0.002	<0.0032	<0.0032	<0.0032	<0.0032	<0.0032	<0.003	<0.003	0.0195	<0.0034	0.0032	<0.0032	<0.0032	0.0032	0.0195
Total Nitrogen (N)	0.02	mg/L	0.133	0.193	0.122	0.139	0.133	0.198	0.16	0.228	0.19	0.157	0.169	0.154	0.1872	0.122	0.228
Total Phosphorous (P)	0.002	mg/L	0.0056	0.0042	0.0033	0.0035	0.0042	0.0022	0.0046	0.0067	0.0049	0.0066	0.0039	<0.002	0.0087	0.0022	0.0087
Total metals by ICPMS																	
Aluminium (Al)	0.5	ug/L	4.33		1.29	1.56	4.17	3.02	4.09		4.49	4.17	2.23	3.23	2.57	1.29	4.49
Antimony (Sb)	0.02	ug/L	0.048		0.05	0.063	0.061	0.073	0.07		0.071	0.062	0.062	0.058	0.059	0.049	0.073
Arsenic (As)	0.02	ug/L	0.672		0.585	1.06	0.634	1.19	0.80		0.585	0.929	1.06	0.704	0.979	0.585	1.19
Barium (Ba)	0.02	ug/L	77.9		83.9	66.8	83.7	67.2	86.10		81.1	56.7	63.9	73.4	70.2	56.7	86.1
Beryllium (Be)	0.01	ug/L	<0.01		<0.01	<0.01	<0.01	<0.01	<0.002		<0.01	<0.01	<0.01	<0.01	<0.01		
Bismuth (Bi)	0.005	ug/L	<0.005		<0.005	<0.005	<0.005	<0.005	<0.001		<0.005	<0.005	<0.005	<0.005	<0.005		
Boron (B)	10/1	ug/L	<10		9.2	5.9	8.2	5.7	8.00		7.8	<0.005	<0.005	9.4	5.2	5.2	9.4
Cadmium (Cd)	0.005	ug/L	<0.005		<0.005	<0.005	<0.005	<0.005	<0.005		<0.005	<0.005	<0.005	<0.005	0.005	0.005	0.005
Chromium (Cr)	0.1	ug/L	<0.1		<0.1	<0.1	<0.1	<0.1	<0.05		0.14	<0.1	<0.1	<0.1	<0.1	0.14	0.14
Cobalt (Co)	0.005	ug/L	0.015		0.0165	0.0161	0.0344	0.0232	0.0274		0.028	0.0259	<0.005	0.043	0.0164	0.015	0.043
Copper (Cu)	0.05	ug/L	0.172		0.123	0.188	0.147	0.179	0.4030		0.287	0.264	0.152	0.142	0.138	0.123	0.403
Iron (Fe)	1	ug/L	43.7		28.9	8.7	24.6	11.6	17.00		34.8	11.1	10.9	11.2	12.4	8.7	43.7
Lead (Pb)	0.005	ug/L	0.0311		0.0192	0.025	0.0589	0.0346	0.0339		0.123	0.038	0.01	0.021	0.0172	0.01	0.123
Lithium (Li)	0.5	ug/L	3.62		3.8	1.91	3.48	2.13	3.63		3.73	1.58	1.7	3.44	1.99	1.58	3.8
Manganese (Mn)	0.05	ug/L	5.1		12.9	29	25.3	26	23.30		9.73	12.3	7.6	22	25.5	5.1	29
Molybdenum (Mo)	0.05	ug/L	0.581		0.515	0.564	0.598	0.574	0.72		0.578	0.549	0.572	0.588	0.541	0.515	0.717
Nickel (Ni)	0.02	ug/L	0.093		0.058	0.083	0.05	0.139	0.19		0.13	0.138	0.083	0.097	0.103	0.05	0.192
Selenium (Se)	0.04	ug/L	<0.04		0.044	0.044	<0.04	0.047	0.08		0.055	0.049	<0.04	0.045	0.048	0.044	0.082
Silver (Ag)	0.005	ug/L	<0.005		<0.005	<0.005	<0.005	<0.005	<0.005		<0.005	<0.005	<0.005	<0.005	<0.005	0	0
Strontium (Sr)	0.05	ug/L	373		340	138	297	143	292		281	115	151	332	155	115	373
Thallium (Tl)	0.002	ug/L	<0.002		<0.002	<0.002	0.0041	0.0027	0.0013		0.0057	<0.002	--	<0.002	<0.002	0.0013	0.0057
Tin (Sn)	0.2/0.01	ug/L	<0.2		<0.01	<0.01	<0.01	<0.01	<0.01		<0.01	<0.05	<0.002	<0.05	<0.05	0	0
Uranium (U)	0.002	ug/L	1.18		1.1	0.726	1.24	0.843	1.47		1.23	0.648	0.647	0.02	0.606	0.02	1.47
Vanadium (V)	0.2	ug/L	<0.2		<0.2	<0.2	<0.2	<0.2	0.06		<0.2	<0.2	<0.2	<0.2	<0.2	0.057	0.057
Zinc (Zn)	0.1	ug/L	0.21		0.26	1.42	3.02	1.09	1.37		1.6	1.85	1.84	1.58	0.72	0.21	3.02
Calcium (Ca)	0.05	mg/L	42.9	33.2	47.7	34.7	45.9	33.9	48.9		46	23	28.8	38.4	31.3	23	48.9
Magnesium (Mg)	0.05	mg/L	22.8	15.9	25.6	15.1	21.5	15.9	24.5		20	14	14.7	14.5	14.9	14	25.6
Potassium (K)	0.05	mg/L			0.964	0.71	0.833	0.708	1.000		0.888	0.418	0.551	0.151	0.713	0.151	1
Sodium (Na)	0.05	mg/L			4.81	2.17	4.06	2.37	4.42		4.59	2.01	2.06	4.46	2.34	2.01	4.81

RDL Reportable Detection Limit

Table C-3a - Water Quality results for South Moyie Lake Shallow Samples

January 18, 2022

Parameter	RDL*	Units	Location on the lake	Moyie Lake, Lower/South Shallow (1 to 10 metres)													Concentration Range	
			Date sampled	2015-04-14	28-Sep-15	06-Apr-16	23-Sep-16	19-Apr-17	23-Aug-17	02-May-19	07-Sep-18	20-Apr-19	22-Aug-19	19-Aug-20	26-Apr-21	01-Sep-21	minimum	maximum
Chlorophyll a	0.5	ug/L		1.51	1.35	2.02	1.19	1.23	1.03	0.52	1.22	1.16	0.985	0.493	0.204	0.165	0.165	2.02
Chlorophyll a rep	0.5	ug/L		2.25	1.54	2.05	1.11	1.14	0.94			-	-					
Field measurements																		
Conductivity	-	uS/cm		53.4	52.2	56.5		48.3	49.6	58.2	-	58.1	55.6	47.2	54.6	49.8	47.2	58.2
Dissolved Oxygen	-	mg/L		12.05	7.61	10.93		10.54	8.43	10.93	-	11.14	8.32	8.28	11.73	8.76	7.61	12.05
Secchi (H2O clarity)	-	m		3.1	6.2	6.1		4.6	6.4	3.05	-	-	-	--	--		3.05	6.4
pH	-	pH			7.5				7.47	8.4	-	8.17	6.6	7.93	7.42	7.08	6.6	8.4
Temperature	-	°C		5.2	18.7	5.27		4.4	20	6.2	-	4.4	19.9	20.5	6	16.9	4.4	20.5
Turbidity		NTU				0.64		0.78		1.63	-	0.38	0.29	0.2	0.36	0.27	0.2	1.63
Anions																		
Silica	0.5	mg/L		7.39	8.12	8.72	7.59	8.32	7.15	8.6	6.99	8.79	8.6	8.45	7.84	8.57	8.45	8.72
Orthophosphate (P)	0.001	mg/L		0.0026	0.0018	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.0018	0.0026
Dissolved Sulphate (SO4)	0.5	mg/L		1.65	2.01	2.25	1.77	2.04	1.83	2.36	1.74	1.84	2.16	1.79	2.18	1.84	1.65	2.36
Dissolved Chloride (Cl)	0.5	mg/L		1.5	1.07	1.34	0.99	1.28	1.14	1.21	1.04	1.26	1.19	0.94	1.24	1.02	0.94	1.5
Calculated parameters																		
Hardness	0.5	mg/L		22.7	23.1	26.3	21.2	27.2	22.1	24.4	20.3	23.1	23.1	19.6	21.7	19.3	19.3	27.2
Misc. Organics																		
Total Organic Carbon	0.5	mg/L		2.52	2.66	2.44	2.85	2.8	3	3.4	2.96	2.72	2.5	3.12	--	2.78	2.44	3.4
Nutrients																		
Total Kjeldahl Nitrogen (Calc)	0.02	mg/L		0.09	0.094	0.089	0.162	0.135	0.1	0.108	0.121	0.093	0.116	0.107	0.124	0.101	0.089	0.135
Dissolved Phosphorous (P)	0.002	mg/L		0.0035	<0.002	<0.002	<0.002	0.0022	<0.002	-	0.042	<0.002	<0.002	<0.002	<0.002	<0.002	0.0022	0.042
Nitrate plus nitrite (N)	0.002	mg/L		0.0322	<0.0032	0.0261	<0.0032	0.0445	<0.0032	0.0365	<0.003	0.0346	<0.003	<0.0032	0.0163	0.0223	0.0163	0.0445
Total Nitrogen (N)	0.02	mg/L		0.122	0.094	0.115	0.161	0.228	0.1	0.144	0.121	0.127	0.113	0.107	0.11	0.101	0.094	0.228
Total Phosphorous (P)	0.002	mg/L		0.0086	0.0021	0.0069	<0.002	<0.002	0.0025	0.0045	0.0024	0.0045	0.0023	<0.002	0.0033	0.0044	0.0021	0.0086
Total metals by ICPMS																		
Aluminium (Al)	0.5	ug/L		38.3		28.3		44.9		58.3		13	18.7	21.1	13	15.6	13	58.3
Antimony (Sb)	0.02	ug/L		0.037		0.038		0.034		0.042		0.071	0.054	0.048	0.054	0.067	0.034	0.071
Arsenic (As)	0.02	ug/L		0.219		0.221		0.217		0.221		0.233	0.306	0.242	0.264	0.259	0.217	0.306
Barium (Ba)	0.02	ug/L		6.57		6.96		6.81		8.66		5.8	6.52	5.92	6.04	5.92	5.8	8.66
Beryllium (Be)	0.01	ug/L		<0.01		<0.01		<0.01		<0.01		<0.01	<0.01	<0.01	<0.01	<0.01		
Bismuth (Bi)	0.005	ug/L		<0.005		<0.005		<0.005		<0.005		<0.005	<0.005	<0.005	<0.005	<0.005		
Boron (B)	10	ug/L		<10		<10		<10		<5		<5	<5	<5	<5	<0.005		
Cadmium (Cd)	0.005	ug/L		0.0318		0.0464		0.0581		0.0581		0.0427	0.0299	<0.003	0.0362	0.0252	0.0252	0.0581
Chromium (Cr)	0.1	ug/L		<0.1		<0.1		<0.1		<0.1		<0.1	<0.1	<0.1	<0.1	<0.1		
Cobalt (Co)	0.005	ug/L		0.0364		0.0292		0.0419		0.0563		0.0256	0.0206	<0.02	0.0208	0.0232	0.0206	0.0563
Copper (Cu)	0.05	ug/L		0.71		0.598		2.36		0.986		0.62	0.612	0.808	0.615	0.548	0.548	2.36
Iron (Fe)	1	ug/L		50.2		36.6		57.1		61.3		27.3	21.3	25.9	23	18.7	18.7	61.3
Lead (Pb)	0.005	ug/L		1.17		1.96		1.73		1.62		2.56	3.68	3.27	2.01	2.32	1.17	3.68
Lithium (Li)	0.5	ug/L		<0.5		<0.5		<0.5		<0.5		<0.5	<0.5	<0.5	<0.5	<0.5		
Manganese (Mn)	0.05	ug/L		2.98		3.69		4.63		4.91		4.63	2.3	2.45	3.42	2.65	2.45	4.91
Molybdenum (Mo)	0.05	ug/L		0.081		0.089		0.078		0.086		0.091	0.097	0.084	0.089	0.091	0.078	0.087
Nickel (Ni)	0.02	ug/L		0.162		0.184		0.173		0.196		0.146	0.159	0.134	0.108	0.122	0.109	0.196
Selenium (Se)	0.04	ug/L		<0.04		<0.04		<0.04		<0.04		<0.04	0.042	<0.04	<0.04	<0.04	0.042	0.042
Silver (Ag)	0.005	ug/L		<0.005		<0.005		<0.005		<0.005		<0.005	<0.005	<0.005	<0.005	<0.005		
Strontium (Sr)	0.05	ug/L		17.7		17.9		15.3		17.5		16.9	16.1	15.6	17.3	16.9	15.3	17.9
Thallium (Tl)	0.002	ug/L		<0.002		0.0022		0.0039		0.007		0.0025	0.0021	<0.002	<0.002	<0.002	0.0021	0.007
Tin (Sn)	0.2/0.01	ug/L		<0.2		<0.01		<0.01		0.011		<0.01	<0.05	<0.05	<0.05	<0.05	0.011	0.011
Uranium (U)	0.002	ug/L		0.0806		0.0763		0.0787		0.102		0.0797	0.0733	0.069	0.0705	0.0624	0.0624	0.102
Vanadium (V)	0.2	ug/L		<0.2		<0.2		<0.2		<0.2		<0.2	<0.2	<0.2	<0.2	<0.2		
Zinc (Zn)	0.1	ug/L		9.31		7.95		13.8		10		6.52	8.83	3.45	7.62	8.77	3.45	13.8
Calcium (Ca)	0.05	mg/L		6.32	6.59	7.45	6.08	7.97	6.34	6.71	5.69	6.54	6.58	5.55	6.13	5.87	5.55	7.97
Magnesium (Mg)	0.05	mg/L		1.68	1.62	1.87	1.48	1.77	1.54	1.81	1.49	1.65	1.64	1.4	1.59	1.37	1.37	1.87
Potassium (K)	0.05	mg/L				0.575		0.613		0.593		0.596	0.489	0.439	0.519	0.489	0.439	0.613
Sodium (Na)	0.05	mg/L				1.89		1.92		1.92		1.73	1.72	1.49	1.66	1.6	1.49	1.92

*RDL Reportable Detection Limit

Table C-3b - Water Quality results for north Moyie Lake Shallow samples

January 18, 2022

Parameter	RDL	Units	Location on the lake / Date sam	Moyie Lake Upper/North Shallow 1 to 10 meter: 14-Apr-15	24-Sep-15	06-Apr-16	23-Sep-16	19-Apr-17	23-Aug-17	02-May-18	07-Sep-18	20-Apr-19	22-Aug-19	19-Aug-20	26-Apr-21	01-Sep-21	Concentration Range minimum	maximum
Chlorophyll a	0.5	ug/L		1.86	2.62	1.79	1.08	0.397	0.884	1.44	0.997	1.52	1.55	0.622	1.09	2.47	0.397	2.62
Chlorophyll a rep	0.5	ug/L		1.46	2.6	1.92	-	1.05	0.92			-	-					
Field measurements																		
Conductivity	-	uS/cm		55	52.3	57.7	47.2	51.6	49.8	62.3	-	61.4	55.8	48.4	53.5	46.8	46.8	62.3
Dissolved Oxygen	-	mg/L		12.04	9.08	10.99	8.6	11.11	8.46	10.85	-	11.18	8.47	8.42	11.63	8.81	8.42	12.04
Secchi (H2O clarity)	-	m		3	8.6	7.6	9.05	4.5	5.85	4.9	-	-	-	-	-		3	9.05
pH	-	pH			7.8		8	7.3	7.56	9.33	-	8.99	6.26	7.99	7.5	7.06	6.26	9.33
Temperature	-	°C		4.3	19.9	4.8	18.9	3.7	19.4	6.8	-	3.7	18.9	19.8	4.5	16.6	3.7	19.9
Turbidity		NTU				0.5		0.69		11.7	-	0.27	0.3	0.25	0.28	0.22	0.22	11.7
Anions																		
Silica	0.5	mg/L		8.1	7.91	8.72	8.26	8.52	8.81	8.58	7.2	7.85	3.8	3.24	7.71	7.23	3.24	8.81
Orthophosphate (p)	0.001	mg/L		<0.001	0.0017	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.0017	0.0017
Dissolved Sulphate (S	0.5	mg/L		1.84	2.01	2.36	2.1	2.22	2.26	2.35	1.83	1.96	2.26	1.82	2.26	1.99	1.82	2.36
Dissolved Chloride (Cl	0.5	mg/L		1	0.91	1.17	1.02	1.22	0.88	1.19	0.89	1.09	1.05	0.81	1.09	0.94	0.81	1.22
Calculated parameters																		
Hardness	0.5	mg/L		23	22.5	25.9	23.9	28.4	22.9	27.4	20.5	23.6	23	19.2	22.9	20.6	19.2	28.4
Misc. Organics																		
Total Organic Carbon	0.5	mg/L		2.55	2.33	2.49	2.68	2.59	3.1	2.97	3.44	2.56	2.69	2.93	2.35	2.6	2.33	3.44
Nutrients																		
Total Kjeldahl Nitroge	0.02	mg/L		0.108	0.094	0.078	0.061	0.114	0.098	0.106	0.119	0.086	0.101	0.118	0.083	0.08	0.061	0.119
Dissolved Phosphoro	0.002	mg/L		0.008	0.0021	<0.002	<0.002	0.0082	0.0025	0.0028	0.0082	<0.002	<0.002	<0.002	<0.002	0.0023	0.0021	0.0082
Nitrate plus nitrite (n)	0.002	mg/L		0.0462	0.082	0.0454	0.0586	0.0632	0.0728	0.0495	0.063	0.056	<0.008	0.001	0.0872	<0.0082	0.001	0.0728
Total Nitrogen (N)	0.02	mg/L		0.149	0.094	0.124	0.114	0.178	0.098	0.155	0.125	0.142	0.104	0.118	0.12	0.1	0.094	0.178
Total Phosphorous (P	0.002	mg/L		0.0083	<0.002	<0.002	<0.002	0.0089	0.0023	0.0052	<0.002	0.0089	0.0046	0.0027	0.0028	0.0026	0.0023	0.0052
Total metals by ICPMS																		
Aluminium (Al)	0.5	ug/L		32.3		26.5		32.4		34.8		17.4	18.7	26.2	12.4	21.7	12.4	34.8
Antimony (Sb)	0.02	ug/L		0.024		0.021		0.022		0.026		0.087	0.026	0.024	0.027	0.021	0.021	0.087
Arsenic (As)	0.02	ug/L		0.213		0.202		0.211		0.21		0.24	0.219	0.198	0.209	0.212	0.198	0.24
Barium (Ba)	0.02	ug/L		6.21		6.15		6.42		7.85		6.69	6.25	4.91	5.8	5.14	4.91	7.85
Beryllium (Be)	0.01	ug/L		<0.010		<0.01		<0.01		<0.01		<0.01	<0.01	<0.01	<0.01	<0.01		
Bismuth (Bi)	0.005	ug/L		<0.005		<0.005		<0.005		<0.005		<0.005	<0.005	<0.005	<0.005	<0.005		
Boron (B)	10	ug/L		<10		<10		<10		<5	<5	<5	<5	<5	<5	<5		
Cadmium (Cd)	0.005	ug/L		<0.005		<0.005		<0.005		<0.005		<0.005	<0.005	<0.005	<0.005	<0.005		
Chromium (Cr)	0.1	ug/L		<0.1		<0.1		<0.1		<0.1		<0.1	<0.1	<0.1	<0.1	<0.1		
Cobalt (Co)	0.005	ug/L		0.0833		0.0267		0.0365		0.0848		0.024	0.0204	<0.002	0.0189	0.468	0.0189	0.468
Copper (Cu)	0.05	ug/L		0.646		0.491		0.359		0.574		0.467	0.519	0.507	0.447	0.389	0.359	0.646
Iron (Fe)	1	ug/L		37.9		28		36.4		41.5		19.7	14.1	17.6	14.7	13	13	41.5
Lead (Pb)	0.005	ug/L		0.0489		0.0856		0.0688		0.0623		0.0346	0.0284	<0.008	0.016	0.0238	0.016	0.0688
Lithium (Li)	0.5	ug/L		<0.5		<0.5		<0.5		<0.5		<0.5	<0.5	<0.5	<0.5	<0.5	0	0
Manganese (Mn)	0.05	ug/L		2.31		2.39		3.09		3.14		3.61	2.04	1.66	1.85	2.99	1.66	3.61
Molybdenum (Mo)	0.05	ug/L		0.094		0.105		0.085		0.113		0.106	0.092	0.073	0.091	0.076	0.073	0.113
Nickel (Ni)	0.02	ug/L		0.144		0.136		0.158		0.152		0.099	0.152	0.125	0.093	0.096	0.093	0.158
Selenium (Se)	0.04	ug/L		<0.040		<0.04		<0.04		<0.04		<0.04	<0.04	<0.04	<0.04	<0.04	0	0
Silver (Ag)	0.005	ug/L		<0.005		<0.005		<0.005		<0.005		<0.005	<0.005	<0.005	<0.005	<0.005	0	0
Strontium	0.05	ug/L		17.9		18.8		16.1		18.6		18	16.4	14.9	18.2	16.2	14.9	18.8
Thallium (Tl)	0.002	ug/L		<0.002		0.008		0.0088		0.0064		0.0048	<0.002	<0.002	<0.002	<0.002	0.008	0.0064
Tin (Sn)	0.2/0.01	ug/L		<0.2		<0.01		<0.01		<0.01		<0.01	<0.05	<0.05	<0.05	<0.05	0	0
Uranium (U)	0.002	ug/L		0.0902		0.0841		0.0969		0.119		0.101	0.077	0.067	0.0746	0.0661	0.0661	0.119
Vanadium (V)	0.2	ug/L		<0.2		<0.2		<0.2		<0.2		<0.2	<0.2	<0.2	<0.2	<0.2	0	0
Zinc (Zn)	0.1	ug/L		0.46		0.32		2.01		1.69		0.51	1.02	1.44	1.04	0.98	0.32	2.01
Calcium (Ca)	0.05	mg/L		6.38	6.43	7.21	6.79	8.33	7.36	7.21	2.67	6.88	6.58	5.45	6.44	5.86	2.67	8.33
Magnesium (Mg)	0.05	mg/L		1.71	1.57	1.92	1.68	1.85	1.83	1.89	3.44	1.67	1.64	1.36	1.62	1.44	1.36	3.44
Potassium (K)	0.05	mg/L				0.589		0.604		0.634		0.594	0.496	0.423	0.547	0.465	0.423	0.634
Sodium (Na)	0.05	mg/L				1.71		1.67		1.91		1.65	1.56	1.36	1.55	1.55	1.36	1.91

Note: After the sampling event in the spring of 2015, all samples collected from the upper Moyie Lake were composite samples collected over the entire depth interval from surface to the bottom of the lake (30 to 40 metres).

Table C-4 - Water Quality results for Premier Lake Deepest Point Shallow samples

January 18, 2022

Parameter	RDL*	Units	Location on the lake	Premier Lake Shallow 1 to 10 meter)							Concentration Range	
			Date sampled	03-May-18	06-Sep-18	01-May-19	23-Aug-19	24-Aug-20	27-Apr-21	01-Aug-21	minimum	maximum
Chlorophyll a	0.5	ug/L		0.864	0.448	2.63	0.748	0.594	1.61	0.941	0.448	2.63
Chlorophyll a rep	0.5	ug/L				-	-					
Field measurements												
Conductivity	-	uS/cm		338.5		350.9	340	342	349	345	338.5	350.9
Dissolved Oxygen	-	mg/L		10.11		10.48	9.08	8.52	10.85		8.52	10.85
Secchi (H2O clarity)	-	m		14.2		-	-				14.2	14.2
pH	-	pH		9.66		8.35	8.15	9.09	8.45	8.56	8.15	9.66
Temperature	-	°C		10.6		7.4	20.8	20.3	8.1	20.4	7.4	20.8
Turbidity		NTU		0.27		0.36	0.25	0.2	0.23	0.41	0.2	0.41
Anions												
Silica	0.5	mg/L		3.04	1.93	1.31	0.87	0.899	3.02	2.09	0.87	3.04
Orthophosphate (p)	0.001	mg/L		0.0012	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.0012	0.0012
Dissolved Sulphate (SO4)	0.5	mg/L		25.4	25.8	26	24.1	25.7	26.6	26.3	24.1	26.6
Dissolved Chloride (Cl)	0.5	mg/L		<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5		
Calculated parameters												
Hardness	0.5	mg/L		179	176	179.6	195.2	189	173	188	173	195.2
Misc. Organics												
Total Organic Carbon	0.5	mg/L		2.19	2.56	2.45	2.4	2.51	2.06	2.46	2.06	2.56
Nutrients												
Total Kjeldahl Nitrogen (Calc)	0.02	mg/L		0.219	0.227	0.208	0.224	0.199	0.205	0.211	0.199	0.227
Dissolved Phosphorous (P)	0.002	mg/L		0.003	0.0054	0.0032	<0.002	0.0032	0.0026	0.0017	0.0017	0.0054
Nitrate plus nitrite (n)	0.002	mg/L		<0.003	<0.003	<0.003	<0.003	<0.003	0.0112	<0.01		
Total Nitrogen (N)	0.02	mg/L		0.219	0.227	0.208	0.224	0.199	0.216	0.32	0.199	0.32
Total Phosphorous (P)	0.002	mg/L		0.0057	0.0032	0.0065	0.0033	0.0045	0.00113	0.0014	0.00113	0.0065
Total metals by ICPMS												
Aluminium (Al)	0.5	ug/L		3		1.28	2.2	1.91	<5	1.46	1.28	3
Antimony (Sb)	0.02	ug/L		0.062		0.064	0.072	0.07	0.065	0.063	0.062	0.072
Arsenic (As)	0.02	ug/L		0.375		0.373	0.414	0.38	0.431	0.388	0.373	0.431
Barium (Ba)	0.02	ug/L		94.7		84.4	86.6	81.40	89	85.3	81.4	94.7
Beryllium (Be)	0.01	ug/L		<0.1		<0.01	<0.01	<0.01	<0.01	<0.01		
Bismuth (Bi)	0.005	ug/L		<0.005		<0.005	<0.005	<0.005	<0.005	<0.005		
Boron (B)	10	ug/L		<5		<5	<5	<5	<5	<5		
Cadmium (Cd)	0.005	ug/L		0.244		<0.005	<0.005	<0.005	<0.005	<0.005		
Chromium (Cr)	0.1	ug/L		<0.1		<0.1	<0.1	<0.1	<0.1	<0.1		
Cobalt (Co)	0.005	ug/L		0.0137		0.0148	0.022	0.0165	0.0175	0.0185	0.0137	0.022
Copper (Cu)	0.05	ug/L		0.97		0.079	0.144	0.12	0.076	0.09	0.076	0.97
Iron (Fe)	1	ug/L		<1.0		1.5	3.5	1.50	<1.0	1.1	1.1	3.5
Lead (Pb)	0.005	ug/L		<0.005		0.00516	0.0469	0.0214	0.0121	0.0078	0.00516	0.0469
Lithium (Li)	0.5	ug/L		2.7		2.73	2.94	2.87	2.84	2.9	2.7	2.94
Manganese (Mn)	0.05	ug/L		1.6		2.42	1.42	1.12	1.73	1.44	1.12	2.42
Molybdenum (Mo)	0.05	ug/L		1.16		1.09	1.19	1.130	1.13	1.12	1.09	1.19
Nickel (Ni)	0.05	ug/L		<0.05		<0.05	0.102	<0.05	<0.05	<0.01	0.102	0.102
Selenium (Se)	0.04	ug/L		0.192		0.084	0.077	0.11	0.114	0.102	0.077	0.192
Silver (Ag)	0.005	ug/L		<0.005		<0.005	<0.005	<0.005	<0.005	<0.005		
Strontium	0.05	ug/L		164		184	192	182.00	182	183	164	192
Thallium (Tl)	0.002	ug/L		<0.002		<0.002	<0.002	<0.002	<0.002	<0.002		
Tin (Sn)	0.2/0.01	ug/L		<0.01		<0.01	<0.05	<0.05	<0.05	<0.05		
Uranium (U)	0.002	ug/L		1.560		1.54	1.41	1.4600	1.42	1.33	1.33	1.56
Vanadium (V)	0.2	ug/L		<0.2		<0.2	<0.2	<0.2	<0.2	<0.2		
Zinc (Zn)	0.1	ug/L		0.460		0.2	2.17	0.68	0.86	0.87	0.2	2.17
Calcium (Ca)	0.05	mg/L		28.7		28.9		29.1	28	29.5	28	29.5
Magnesium (Mg)	0.05	mg/L		26.200		26.1		28.4	25	27.7	25	28.4
Potassium (K)	0.05	mg/L		0.675		0.648	0.62	0.624	0.646	0.688	0.62	0.688
Sodium (Na)	0.05	mg/L		3.19		2.95		3.65	3.15	3.45	2.95	3.65

* RDL Reportable Detection Limit

Table C-5 - Water Quality results for Whiteswan Lake Shallow samples

January 18, 2022

Parameter	RDL*	Units	03-May-18	05-Sep-18	01-May-19	21-Aug-19	18-Aug-20	17-May-21	19-Aug-21	Concentration Range minimum	Concentration Range maximum
Location on the lake: Whiteswan Lake, Shallow 1 to 10 meter)											
Chlorophylla	0.5	ug/L	0.543	0.547	1.36	0.491	0.425	0.688	0.733	0.425	1.36
Chlorophylla rep	0.5	ug/L			-						
Field measurements											
Conductivity	-	uS/cm	249.6		289.9	273.2	264		269	249.6	289.9
Dissolved Oxygen	-	mg/L	10.71		10.66	8.97	9.08	10.5	8.87	8.87	10.71
Secchi(H2O clarity)	-	m	9.2		-	-				9.2	9.2
pH	-	pH	8.95		8.27	7.33	8.72	8.41	8.4	7.33	8.95
Temperature	-	°C	9.3		6.07	17.8	18.3	10.7	17.3	6.07	18.3
Turbidity		NTU	0.23		0.21	0.25	0.19	0.2	0.25	0.19	0.25
Anions											
Silica	0.5	mg/L	3.9		1.55	1.08	0.823	2.92	3.18	0.823	3.9
Orthophosphate (p)	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001		
Dissolved Sulphate (SO4)	0.5	mg/L	3.8	19.5	22.4	19.2	17	21	21.3	3.8	22.4
Dissolved Chloride (Cl)	0.5	mg/L	2.83	2.5	3	2.44	2.14	2.76	2.37	2.14	3
Calculated parameters											
Hardness	0.5	mg/L	145	138	145	143	143	140	138	138	145
Misc. Organics											
Total Organic Carbon	0.5	mg/L	1.56	1.45	1.45	1.94	1.58	1.25	1.8	1.25	1.94
Nutrients											
Total Kjeldahl Nitrogen (Calc)	0.02	mg/L	0.07	0.1	0.105	0.105	0.093	0.107	0.119	0.07	0.119
Dissolved Phosphorous (P)	0.002	mg/L	0.002	0.0035	0.002	<0.002	<0.002	0.0061	<0.002	0.002	0.0061
Nitrate plus nitrite (n)	0.002	mg/L	0.0052	<0.003	<0.003	<0.003	<0.003	<0.0032	<0.001	0.0052	0.0052
Total Nitrogen (N)	0.02	mg/L	0.075	0.1	0.105	0.105	0.093	<0.005	0.0035	0.0035	0.105
Total Phosphorous (P)	0.002	mg/L	0.0025	<0.002	0.0037	<0.002	0.0025	0.0023	0.0035	0.0023	0.0037
Total metals by ICPMS											
Aluminium (Al)	0.5	ug/L	2.37		1.16	3.33	2.68	2.76	1.35	1.16	3.33
Antimony (Sb)	0.02	ug/L	0.107		0.081	0.087	0.082	0.082	0.08	0.081	0.107
Arsenic (As)	0.02	ug/L	0.265		0.246	0.278	0.257	0.294	0.31	0.246	0.306
Barium (Ba)	0.02	ug/L	94.0		92.3	102	97.4	112	103.00	92.3	112
Beryllium (Be)	0.01	ug/L	<0.010		<0.01	<0.01	<0.01	<0.01	<0.01		
Bismuth (Bi)	0.005	ug/L	<0.0050		<0.005	<0.005	<0.005	<0.005	0.10		
Boron (B)	10	ug/L	<5.0		<5	<5	<5	<5	<5	0	0
Cadmium (Cd)	0.005	ug/L	<0.0050		<0.005	<0.005	<0.005	<0.005	<0.005		
Chromium (Cr)	0.1	ug/L	<0.10		<0.1	<0.1	<0.1	<0.1	<0.1		
Cobalt (Co)	0.005	ug/L	0.0122		0.0115	0.0094	<0.001	0.0165	0.0228	0.0094	0.0228
Copper (Cu)	0.05	ug/L	0.2020		0.097	0.368	1.38	1.12	1.12	0.097	1.38
Iron (Fe)	1	ug/L	2.70		4.6	1.3	2	2.4	1.20	1.2	4.6
Lead (Pb)	0.005	ug/L	0.0085		0.0076	0.024	<0.005	0.0062	0.0086	0.0062	0.024
Lithium (Li)	0.5	ug/L	1.250		1.14	1.16	1.09	1.12	1.22	1.09	1.25
Manganese (Mn)	0.05	ug/L	1.320		2.26	0.427	0.888	2.53	2.36	0.427	2.53
Molybdenum (Mo)	0.05	ug/L	0.723		0.7	0.704	0.654	0.716	0.689	0.654	0.723
Nickel (Ni)	0.02	ug/L	0.091		0.076	0.066	0.061	0.055	0.085	0.055	0.091
Selenium (Se)	0.04	ug/L	0.079		0.066	0.063	0.077	0.062	0.05	0.053	0.079
Silver (Ag)	0.005	ug/L	<0.0050		<0.005	<0.005	<0.005	<0.005	<0.005		
Strontium	0.05	ug/L	108		105	107	106	106	98.30	98.3	108
Thallium (Tl)	0.002	ug/L	0.0025		0.0074	<0.002	<0.002	<0.002	0.0024	<0.002	0.0074
Tin (Sn)	0.2/0.01	ug/L	<0.010		<0.01	<0.05	0.082	<0.05	<0.005		
Uranium (U)	0.002	ug/L	0.517		0.508	0.48	0.485	0.455	0.4300	0.48	0.517
Vanadium (V)	0.2	ug/L	<0.20		<0.2	<0.2	<0.2	<0.2	<0.2	0	0
Zinc (Zn)	0.1	ug/L	0.63		0.17	1.82	0.78	1.05	0.91	0.17	1.82
Calcium (Ca)	0.05	mg/L	37.5		39.4	37.1	37.1	35	37.9	35	39.4
Magnesium (Mg)	0.05	mg/L	11.4		11.2	12.2	12.1	12.8	12.1	11.2	12.8
Potassium (K)	0.05	mg/L	0.322		0.291	0.297	0.324	0.354	0.334	0.291	0.354
Sodium (Na)	0.05	mg/L	2.27		2.57	2.13	2.05	0.106	2.28	0.106	2.57

* RDL: Reportable Detection Limit

Appendix D – Water Quality Differences Along the Lake

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

Location (UTM NAD27)			Location#	Date	Turbidity (NTU	perature (Cel	onductivity (us/cm
easting	northing	distance					
583559	5558877	0	1	Friday, July 13, 2018	1.34	20.9	259.7
582686	5559805	1274.09	2	Friday, July 13, 2018	1.98	21	260.3
583561	5560320	1443.00	3	Friday, July 13, 2018	1.55	20.7	252.8
582135	5561373	2873.64	4	Friday, July 13, 2018	1.29	20.9	252.1
582656	5561797	3056.44	5	Friday, July 13, 2018	2.72	20.7	251.7
581654	5562368	3976.95	6	Friday, July 13, 2018	1.23	20.7	247.7
582361	5563429	4707.01	7	Friday, July 13, 2018	1.26	20.7	246.5
581428	5564343	5866.71	8	Friday, July 13, 2018	1.09	20.9	245.8
581999	5565042	6359.31	9	Friday, July 13, 2018	0.97	20.9	245.6
581125	5566561	8060.29	10	Friday, July 13, 2018	1.14	20.7	232.6
581596	5567554	8896.27	11	Friday, July 13, 2018	1.04	21	237.3
580440	5568967	10561.07	12	Friday, July 13, 2018	1.24	20.6	221.1
581074	5569916	11315.24	13	Friday, July 13, 2018	1.02	20.7	217.2
581267	5570895	12234.61	14	Friday, July 13, 2018	1.18	21.2	218.6
11 U 583559E 5558877N	11 U 583559E 5558877N	0	1	Saturday, July 28, 2018	1.92	21.5	262.5
11 U 582686E 5559805N	11 U 582686E 5559805N	1274.09	2	Saturday, July 28, 2018	1.19	21.3	255
11 U 583561E 5560320N	11 U 583561E 5560320N	1443.00	3	Saturday, July 28, 2018	1.89	21.4	256.8
11 U 582135E 5561373N	11 U 582135E 5561373N	2873.64	4	Saturday, July 28, 2018	1.64	21.2	250.7
11 U 582656E 5561797N	11 U 582656E 5561797N	3056.44	5	Saturday, July 28, 2018	2.51	21.4	254.2
11 U 581654E 5562368N	11 U 581654E 5562368N	3976.95	6	Saturday, July 28, 2018	1.48	21.3	249
11 U 582361E 5563429N	11 U 582361E 5563429N	4707.01	7	Saturday, July 28, 2018	1.81	21.5	246.8
11 U 581428E 5564343N	11 U 581428E 5564343N	5866.71	8	Saturday, July 28, 2018	1.18	21.4	249
11 U 581999E 5565042N	11 U 581999E 5565042N	6359.31	9	Saturday, July 28, 2018	1.45	21.5	244.5
11 U 581125E 5566561N	11 U 581125E 5566561N	8060.29	10	Saturday, July 28, 2018	1.17	21.5	234.7
11 U 581596E 5567554N	11 U 581596E 5567554N	8896.27	11	Saturday, July 28, 2018	1.26	21.6	235.4
11 U 580440E 5568967N	11 U 580440E 5568967N	10561.07	12	Saturday, July 28, 2018	1.03	21.6	223.8
11 U 581074E 5569916N	11 U 581074E 5569916N	11315.24	13	Saturday, July 28, 2018	1.69	21.7	222.6
11 U 581267E 5570895N	11 U 581267E 5570895N	12234.61	14	Saturday, July 28, 2018	0.92	21.7	210.3
11 U 583559E 5558877N	11 U 583559E 5558877N		1	Monday, August 13, 2018	2.55	18.8	236.4
11 U 582686E 5559805N	11 U 582686E 5559805N		2	Monday, August 13, 2018	2.61	19.7	242
11 U 583561E 5560320N	11 U 583561E 5560320N		3	Monday, August 13, 2018	3.33	19.2	243.7
11 U 582135E 5561373N	11 U 582135E 5561373N		4	Monday, August 13, 2018	3.23	20	246.7
11 U 582656E 5561797N	11 U 582656E 5561797N		5	Monday, August 13, 2018	2.61	20	246
11 U 581654E 5562368N	11 U 581654E 5562368N		6	Monday, August 13, 2018	2.39	20.1	247
11 U 582361E 5563429N	11 U 582361E 5563429N		7	Monday, August 13, 2018	2.11	20.5	236.4
11 U 581428E 5564343N	11 U 581428E 5564343N		8	Monday, August 13, 2018	2.37	20.5	244
11 U 581999E 5565042N	11 U 581999E 5565042N		9	Monday, August 13, 2018	2.38	20.6	231.1
11 U 581125E 5566561N	11 U 581125E 5566561N		10	Monday, August 13, 2018	1.59	20.1	233.1
11 U 581596E 5567554N	11 U 581596E 5567554N		11	Monday, August 13, 2018	1.45	20.6	216.3
11 U 580440E 5568967N	11 U 580440E 5568967N		12	Monday, August 13, 2018	2.35	20.8	219.5
11 U 581074E 5569916N	11 U 581074E 5569916N		13	Monday, August 13, 2018	1.47	20.6	222.7
11 U 581267E 5570895N	11 U 581267E 5570895N		14	Monday, August 13, 2018	1.48	19.6	208.4
11 U 583559E 5558877N	11 U 583559E 5558877N		1	Wednesday, August 22, 2018	1.68	19	229.6
11 U 582686E 5559805N	11 U 582686E 5559805N		2	Wednesday, August 22, 2018	2.34	18.9	243.5
11 U 583561E 5560320N	11 U 583561E 5560320N		3	Wednesday, August 22, 2018	1.45	18.4	244.5
11 U 582135E 5561373N	11 U 582135E 5561373N		4	Wednesday, August 22, 2018	1.01	19.3	241.1
11 U 582656E 5561797N	11 U 582656E 5561797N		5	Wednesday, August 22, 2018	0.87	18.9	240.5
11 U 581654E 5562368N	11 U 581654E 5562368N		6	Wednesday, August 22, 2018	0.74	19.5	240.3
11 U 582361E 5563429N	11 U 582361E 5563429N		7	Wednesday, August 22, 2018	1.01	19.3	236.7
11 U 581428E 5564343N	11 U 581428E 5564343N		8	Wednesday, August 22, 2018	0.93	19.7	237.8
11 U 581999E 5565042N	11 U 581999E 5565042N		9	Wednesday, August 22, 2018	1.09	19.7	235.7
11 U 581125E 5566561N	11 U 581125E 5566561N		10	Wednesday, August 22, 2018	0.88	19.9	224.5
11 U 581596E 5567554N	11 U 581596E 5567554N		11	Wednesday, August 22, 2018	0.89	19.8	219.3
11 U 580440E 5568967N	11 U 580440E 5568967N		12	Wednesday, August 22, 2018	0.87	20	215.9
11 U 581074E 5569916N	11 U 581074E 5569916N		13	Wednesday, August 22, 2018	1.32	20	215.5
11 U 581267E 5570895N	11 U 581267E 5570895N		14	Wednesday, August 22, 2018	0.83	19.6	210.6

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 14.

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.

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

A) Temperature

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

B) Turbidity concentrations (NTU's)

1	1.34	1.92	2.55	1.68	1.22	1.51	2.3
2	1.98	1.19	2.61	2.34	1.31	1.42	1.66
3	1.55	1.89	3.33	1.45	1.82	1.24	1.09
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
6	1.23	1.48	2.39	0.74	1.69	1.03	0.94
7	1.26	1.81	2.11	1.01	1.12	0.74	0.82
8	1.09	1.18	2.37	0.93	1.04	0.88	0.66
9	0.97	1.45	2.38	1.09	1.22	0.69	1.26
10	1.14	1.17	1.59	0.88	1.08	0.88	1.08
11	1.04	1.26	1.45	0.89	0.97	0.85	1.06
12	1.24	1.03	2.35	0.87	0.91	0.81	0.86
13	1.02	1.69	1.47	1.32	1.64	0.8	0.64
14	1.18	0.92	1.48	0.83	1.14	0.69	0.92

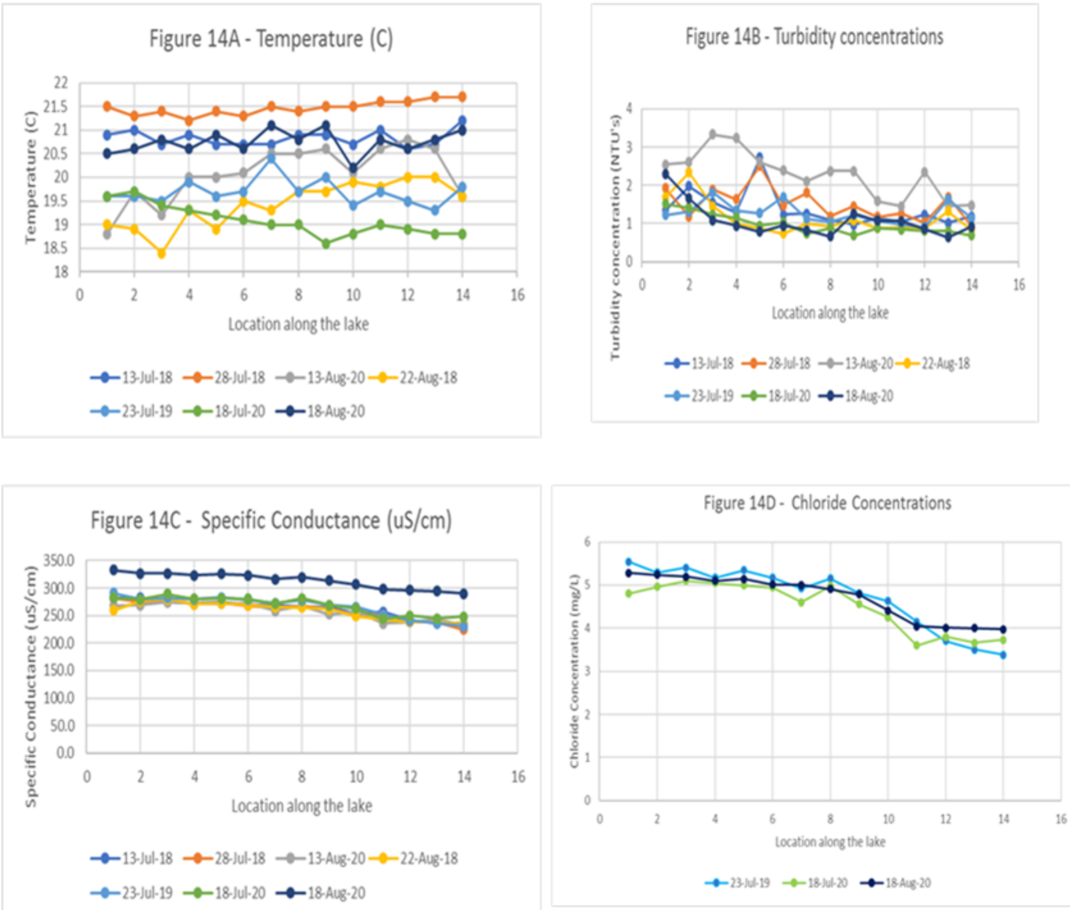
C) Specific Conductance (uS/cm)

1	281.8	281.3	268.2	259.3	290.3	282.1	332.7
2	281.8	274.4	269.3	275.6	279.4	279.0	326.8
3	275.4	275.8	274.1	279.8	282.3	288.9	326.5
4	273.5	270.3	272.7	270.6	279.2	280.5	322.8
5	274.2	273.0	272.0	272.2	283.2	281.1	325.3
6	269.9	267.9	272.5	268.5	278.8	280.4	323.2
7	268.6	264.5	258.6	265.6	272.0	271.4	316.1
8	266.7	267.4	266.9	264.6	278.0	281.0	319.5
9	266.5	262.0	252.3	262.2	269.1	269.1	313.5
10	253.4	251.5	257.2	248.7	265.0	263.2	306.2
11	256.9	251.7	236.1	243.5	251.6	243.8	298.1
12	241.4	239.3	238.6	238.7	241.4	249.9	296.0
13	236.6	237.6	243.1	238.3	235.5	244.6	294.1
14	235.7	224.4	232.4	234.8	230.3	247.7	290.1

D) Chloride Concentrations (mg/L

1					5.54	4.8	5.28
2					5.29	4.96	5.24
3					5.4	5.10	5.19
4					5.17	5.05	5.1
5					5.34	4.99	5.14
6					5.17	4.94	5.01
7					4.92	4.6	5
8					5.15	4.98	4.91
9					4.81	4.56	4.78
10					4.63	4.25	4.41
11					4.15	3.6	4.04
12					3.7	3.8	4.01
13					3.5	3.66	4
14					3.38	3.73	3.97

Figure 14 – Distribution of Temperature, Turbidity, Specific Conductance and Chloride from South to North



Appendix E – Statistics for 2014 to 2020

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