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MISKWABI AREA COMMUNITY ASSOCIATION

WATER QUALITY MONITORING REPORT

PREPARED BY
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WOODLANDS & WATERWAYS EcoWatch

U-LINKS

Miskwabi, Wenona, Negaunee and Long Lakes

Water Quality Monitoring Report Card

Prepared for presentation to the Miskwabi Area Community Association.

Report prepared by U-Links Centre for Community Based Research, as part of the Woodlands and Waterways EcoWatch Program.

With thoughtful review and technical support by Zygoptera Consulting.

This program has been funded in part by the County of Haliburton, Federal and Provincial Grants, Canoe FM, and the Haliburton County Development Corporation.

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Project Overview

Haliburton County is located two hours north of the Greater Toronto Area on a high point of the Canadian Shield, spanning over 4000 square kilometres of broad forests and over 600 lakes$_1$. The geographic landscape of Haliburton County was primarily influenced by glacial melting. These natural amenities attract tourism which in turn drives the local economy.

It is acknowledged that Haliburton County is located on Treaty 20 Michi Saagiig territory and in the traditional territory of the Michi Saagiig and Chippewa Nations, collectively known as the Williams Treaties First Nations$_1$.

Woodlands and Waterways EcoWatch (WWEW) developed a pilot water quality monitoring program to eventually expand to lakes across Haliburton County. In 2022, WWEW and Lake Association citizen scientists sampled water quality parameters from 35 sites on 24 lakes. This program represents a broadscale monitoring objective of having water quality data that is comparable across lakes within the County and with neighbouring regions. The goals of this pilot program are:

- to develop water monitoring protocols and practices specific to the aquatic health concerns in the region.
- to develop and grow a database of water quality measurement for long-term monitoring.

This information will be useful for decision-makers to understand key ecological uncertainties in regards to water quality in efforts to protect the County's freshwater resources.

Stocking Lake, located ~75km North-West from the Miskwabi Lakes (Figure 1), was used as a reference lake for this program. It was selected based on the absence of seasonal and permanent dwellings with the exception of a small collection of cabins used for research. Motorized vehicles are not permitted on the water and shorelines have retained their natural state.

Several limnology experts were consulted during program development, with ongoing technical support from Zygoptera Consulting. This program has been funded in part by the County of Haliburton, Federal and Provincial Grants, Canoe FM, and the Haliburton County Development Corporation, and participating Lake Associations. Many thanks to the Lake Association volunteers who provided sampling support, boat transportation and coordination of association participants as citizen scientists.

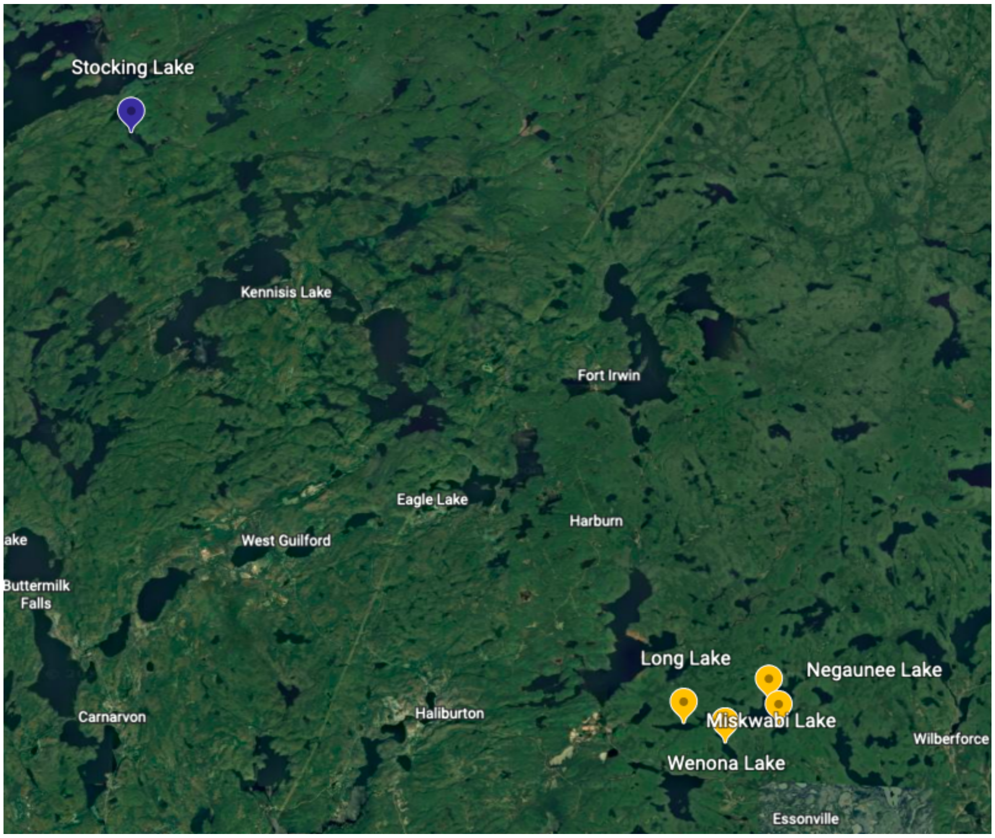


Figure 1: Miskwabi lakes (Miskwabi, Wenona, Long and Negaunee Lakes) (yellow pins) in relation to Stocking Lake (blue pin)

Water Quality Measurements and Methods

SITE LOCATION

Field measurements and samples were collected from Long, Negaunee, Wenona, and Miskwabi Lakes (at five sites: MISK-WQ-01, WENO-WQ-01, WENO-WQ-02, NGAU-WQ-01, LONG-WQ-01) during two sample sessions in 2022, on July 29th and September 20th, 2022. Each sample site was determined as the deepest point in each basin sampled, as they have a better representation of the lake water, with fewer influences from shorelines (Figure 2).

Figure 2: Sample Sites on Long, Negaunee, Wenona and Miskwabi Lakes, 2022

Site Coordinates:

- MISK-WQ-01: 45.0418013, -78.32518
- WENO-WQ-01: 45.03901, -78.35222
- WENO-WQ-02: 45.03199, -78.35854
- NGAU-WQ-01: 45.04090, -78.31955
- LONG-WQ-01: 45.04575, -78.35854

METHODS

To gather vital data and insight necessary to complete this report, industry standard protocols were followed with the use of various monitoring tools in the field to collect measurements. The full protocol is available as a separate document: *Woodlands and Waterways EcoWatch - Lake Sampling Procedures.*

As a part of the program, several on-site water quality measurements were recorded (pH, conductivity, Secchi depth, dissolved oxygen, temperature and alkalinity). Water samples were collected through the water column down to the determined Secchi depth. This allowed the measurement of nutrients present within the entire **photic zone**. Water samples were collected at each site and shipped to the ALS Environmental analysis laboratory based in Waterloo, Ontario. Weather observations were also noted at the start of every sampling event.

To measure alkalinity, test strips were dipped into a surface water sample. Conductivity and pH were measured using an Oakton water meter that was placed into a surface water sample. Dissolved oxygen and temperature were measured at every metre of lake depth (up to 50m) using a YSI probe and cable. All other parameters (ammonia, total Kjeldahl nitrogen, nitrates, nitrites, total phosphorus, and sulfate) were measured at the ALS laboratory using water samples collected in the field.

Parameters Measured

A detailed description of each parameter measured in this program is listed on the following page in Table 1.

Table 1: Chemical water quality parameters descriptions

ALKALINITY	Alkalinity is indicative of a lakes ability to neutralize acids and its sensitivity to acidic inputs [2]	Alkalinity can develop from salts and minerals from **leaching** rocks into lakes, or from wastewater discharge [2]. Recommended limit: 20-200 mg/L. If <10 mg/L = susceptible to acidification [2]
AMMONIA mg/L	Ammonia is a form of nitrogen, formed through the fixation of atmospheric nitrogen and hydrogen [3]	Ammonia can be highly toxic to aquatic life. Common ammonia inputs into freshwater systems include run-off from fertilizers, municipal **effluent** discharges and industry processes [3]. Natural sources can include organic waste breakdown, forest fires, animal waste. Recommended limit: 0.019 mg/L [4]
TOTAL KJELDAHL NITROGEN mg/L	Total Kjeldahl Nitrogen is a measure of total organic nitrogen + ammonia [5]	Some sources of TKN can be from sewage treatment effluent or agricultural run-off [5]. High TKN can lead to eutrophication of lakes or algal blooms [5]. The combination of high TKN values + high TP is especially conducive to algal blooms and **overproduction** [5]
CONDUCTIVITY µS/cm	Conductivity measures the total **ionic strength** of the water, and determines how well an electric current can pass through it [5]	Higher levels of conductivity typically mean it contains more dissolved salts [6]. Conductivity also increases as temperatures increase, due to evaporation of surface water [5]. Pure water has very low conductivity. Lakes can range from very soft water (low salts) = <10 µS, very hard water (high salts) = >1000 µS [6]
PH	pH is a measure of the degree to which water is acidic or basic. On the 0-14 pH scale, 0 = strongly acidic, 14 = highly basic. 7 represents a neutral pH, such as pure water [7]	Most North American freshwater bodies have a pH that ranges from 6.5-8.2, and most fish thrive in water within this range [7]. pH is influenced by local geology (such as the Canadian Shield) and is especially determined by chemistry components like salts, carbonates and various acids [7]

SULFATE mg/L	Sulfate is the most common form of sulfur found in well-oxygenated lakes [8]	Naturally occurring sulfate can be introduced through the breakdown of leaves in the Fall [8], it can also be brought into the lake through acid rain [2]. High levels of sulfate can increase the acidity of a lake, reducing its pH [2]. Recommended limit: >250 mg/L [8]
DISSOLVED OXYGEN mg/L	Dissolved oxygen is the measure of the amount of free oxygen present in the water [9]	Dissolved oxygen has a large influence on aquatic organisms, if outside of the ideal range, it can inhibit aquatic life and affect water quality and is closely related to lake temperature [9]. Range is highly variable
NITRATES, NITRITES mg/L	Nitrates and nitrites are nitrogen compounds that in low concentrations, play an important role in aquatic ecosystem health [2]	If nitrate levels are too high, it can cause algae blooms and **eutrophication** [2]. Elevated levels may be caused by input by pollution (runoff, sewage) and could cause algal growth or eutrophication. Natural surface water levels are typically <1mg/L [2]
TOTAL PHOSPHORUS mg/L	Phosphorus is an abundant mineral and essential aquatic nutrient, key for plant and algae productivity and biomass [2]	In excess, phosphorus can limit biodiversity, harm sensitive species, cause anoxia and lead to eutrophication [2]. Sources can include fertilizers, animal waste, sewage **effluent**. Recommended limit: 0.03 mg/L [2]

Secchi Disk Sampling

Secchi disks are weighted, thin, black and white disks, attached to a line, that gather data based on the visual properties that emerge as they are lowered into the water column. The depth in which the sight of the disk is lost gives insight into water colour, transparency, fluorescence and clarity[10].

The apparent colour is the result of various substances that are either suspended or dissolved in the water column that are typically comprised of three main components: organic particulates (including phytoplankton and zooplankton), inorganic matter (commonly composed of chalk and dissolved minerals) and coloured dissolved organic matter (CDOM)[10].

The results of these components allow for colour comparison correlating to specific water conditions that include the following:

- Colourless – High light penetrations often associated with low nutrient stocks and low rates of biomass primary production.
- Green-blue – Colour tends to be dominated by algae and with moderate levels of dissolved sediment and organic matter.
- Yellow-brown – Waters are subject to high levels of **humification** where CDOM has reached maturity and decomposition of plant remains including aquatic and terrestrial litter has occurred.

The Secchi disk is also used to measure the photic zone, the uppermost layer of water which is penetrated by sunlight. This zone is where plant life can undergo photosynthesis and survive. The depth of this zone is dependent on the amount of suspended matter and particulate[10].

Dissolved Oxygen and Temperature

Dissolved oxygen (DO) is a measure of the amount of oxygen dissolved in the water and available for living organisms, such as fish. Long-term unacknowledged organic matter and nutrient introductions can promote the development of **eutrophication** and algal blooms, leading to reduced DO concentrations effectively suffocating aquatic life. Oxygen is a primary controller of lake chemistry and is thus especially important to measure in lakes[11].

DO is sourced by oxygen transfer from Earth's atmosphere and by photosynthesis (from submerged aquatic vegetation). Aeration from mixing water also promotes oxygen reintroduction, typically at sites containing waterfalls, rapids or during high wind conditions. Temperature is a significant variable affecting DO concentrations, the solubility of oxygen is inversely proportional to temperature so as waters become warmer the DO decreases.

Thermal stratification occurs where a warm water layer remains on top and a cold water layer is below. Due to the density differences in these two layers, there is no mixing and the atmospheric oxygen present in the top layer does not reach the bottom. Due to photosynthesis in the photic zone, DO concentrations remain high throughout the summer, however, the bottom layer can have declines of DO as organisms consume oxygen.

Depending on the amount of biological activity, bottom waters can become **anoxic**, nearly free of dissolved oxygen (<0.5 mg/L). This may lead to fish death and can dramatically affect chemical processes in these waters. Dissolved oxygen levels above 5 mg/L are considered optimal for most aquatic organisms, while fish require levels above 3 mg/L. For coldwater species, such as Lake trout, a minimum of 6 mg/L is needed, along with a temperature below 10°C[11].

Results and Discussion

RECOMMENDED LIMITS

The parameters measured are important indicators of water quality and ecosystem health. However, it is important to note that the individual parameters come together to create a cohesive picture, one parameter alone cannot always tell a story. Individual parameters might fluctuate above or below the recommended limits, and this might be natural and expected over the changing seasons. Other very high or low measurements might be problematic, but cause for concern will be typically established over multiple rounds of sampling and data, and perhaps further investigation.

Total Kjeldahl Nitrogen (TKN) is a measured parameter that does not have an established ideal limit or range as TKN is the sum of total nitrogen[5]. Higher values are considered problematic, and lower values are more ideal. Due to this, it is important to measure regularly and identify trends or spikes. Consistency is key as sudden spikes could indicate an issue[5]. To place some context around this parameter, a trend line can be developed with low versus high concentrations based on collected data during this project.

Similarly, Secchi disk depth does not have a specific contextual range and is dependent on various factors including overall lake depth, shoreline composition and vegetation buffer, local rocks and mineral, organic matter and other natural inputs.

The limits used in this results section have been established by various research institutions, including the Toronto and Region Conservation Authority, the Canadian Councils for Ministers of the Environment (CCME) and the District of Muskoka. These broad range of contexts have allowed us to develop an initial set of water quality limits, but this might not necessarily be relative to your specific lake as these standards are established for either the province of Ontario, or for all of Canada.

RESULTS

Within this project, information was gathered on lake health through in-field observation, the use of various instruments (DO, pH, conductivity), water test strips, and water samples sent to the laboratory for analysis. The results section will provide an overview of the chemical parameters measured and a brief interpretation. The Miskwabi Lakes results are listed in Table 2 with comparison to Stocking Lake results. Please note that several years of data is required to gain a good understanding of the “normal” state of these lakes. Five years of data is suggested to complete a baseline for proper trend analysis.

Table 2: Results from the Miskwabi Lakes in comparison to Stocking Lake and specific parameter limits.

	MISK-WQ-01		LONG-WQ-1		WENO-WQ-01		WENO-WQ-02		NGAU-WQ-01		STOCKING-WQ
	July	Sept	July	Sept	July	Sept	July	Sept	July	Sept	Average
Alkalinity (mg/L)	40	30	40	20	60	80	40	80	60	40	27.5
Ammonia (mg/L)	<0.0050	<0.0050	<0.0050	0.0073	0.0104	0.0067	<0.0050	<0.0050	<0.0050	<0.0050	0.0082
Conductivity (uS/cm)	110.1	67.7	110.2	67.3	130.0	81.3	130.0	80.5	151.2	91.8	14.0
Nitrite (mg/L)*	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Nitrate (mg/L)*	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020
pH	7.33	8.24	7.31	8.26	7.35	8.29	7.29	8.37	7.65	8.43	7.62
Sulfate (mg/L)	5.31	5.51	4.92	5.10	3.27	3.21	3.14	3.22	3.85	3.92	2.28
Total Phosphorus (mg/L)	0.0040	0.0024	0.0044	0.0026	0.0048	0.0039	0.0165	0.0040	0.0045	0.0026	0.0032
Total Kjeldahl Nitrogen (mg/L)	0.217	0.152	0.211	0.187	0.258	0.258	0.252	0.212	0.377	0.245	0.216
Secchi Depth Average (m)	4.25	6.30	4.25	5.25	5.70	5.05	7.50	5.27	4.50	4.05	4.08

PARAMETER	LIMITS
Alkalinity (mg/L)	>10, <200
Ammonia (mg/L)	≤0.019
Conductivity(uS/cm)	<1000 (high salt)
Nitrates/Nitrites (mg/L)	>1
pH	≤6.4(acidic), ≥8.3 (basic)
Total Phosphorus (mg/L)	<0.03
Sulfate (mg/L)	<250

🟨 *exceeding recommended limit*

The Miskwabi lakes are recorded with blue-green hues with moderate levels of humification from plant matter. Secchi depth varies from 4.05m to 7.5m. These tests should be conducted by the same person as results will vary based on the tester's perspective.

The chemistry parameters measured fell within normal limits, with the exception of 3 pH values. These values are indicative of a more *alkaline* lake. However, on other sampling dates these levels are far lower and fall within normal range, indicating seasonal variations.

Ammonia levels across all sites were well below the parameter limit stated in the above table, many sites had negligible levels falling below the limit of reporting. The highest measurement was measured at 0.0104 mg/L at WENO-WQ-01 in July which decreased to 0.0067 mg/L by September. Although ammonia can naturally occur in aquatic environments, elevated concentrations typically result from human activity[4]. The greatest risk of toxic effects of ammonia is with long-term exposure and can increase in the summer and late fall, due to the effects of warm temperatures and extremes in pH caused by high rates of photosynthesis. Levels tend to dilute naturally in water bodies during high flow.

Total phosphorus across all sites were measured to be far below the recommended limit (<0.03 mg/L); the highest measurement was 0.0165 mg/L at WENO-WQ-02 in July which decreased to 0.004 mg/L by September.

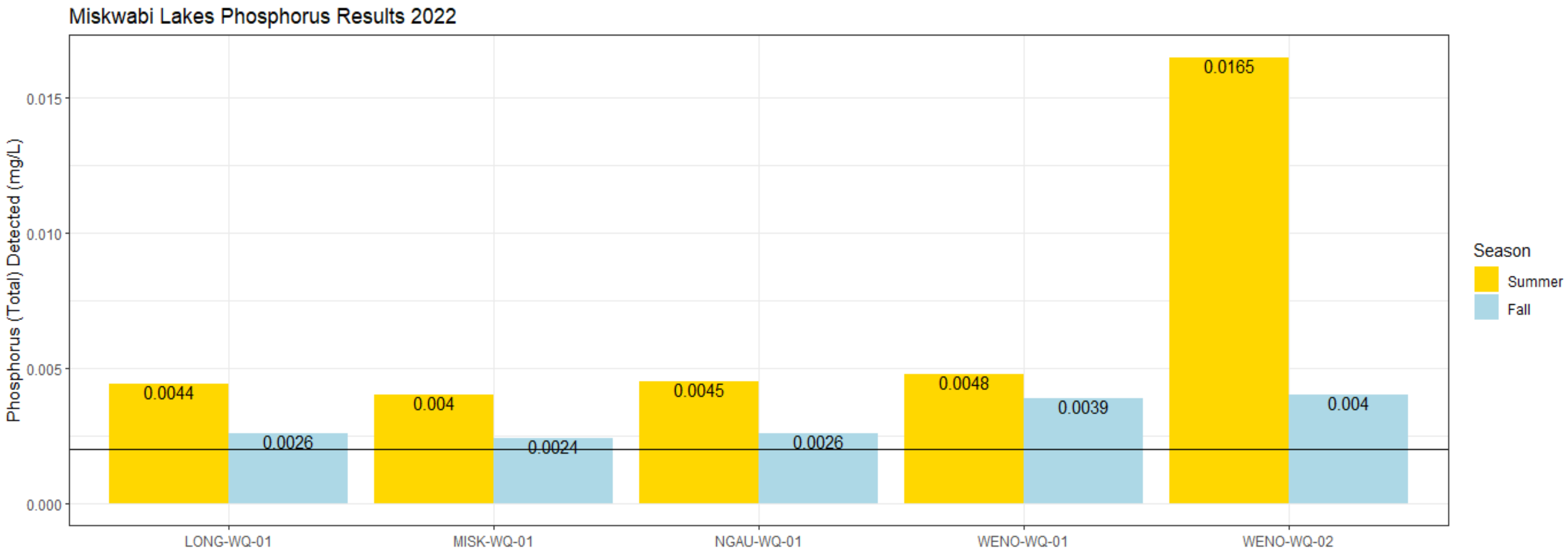


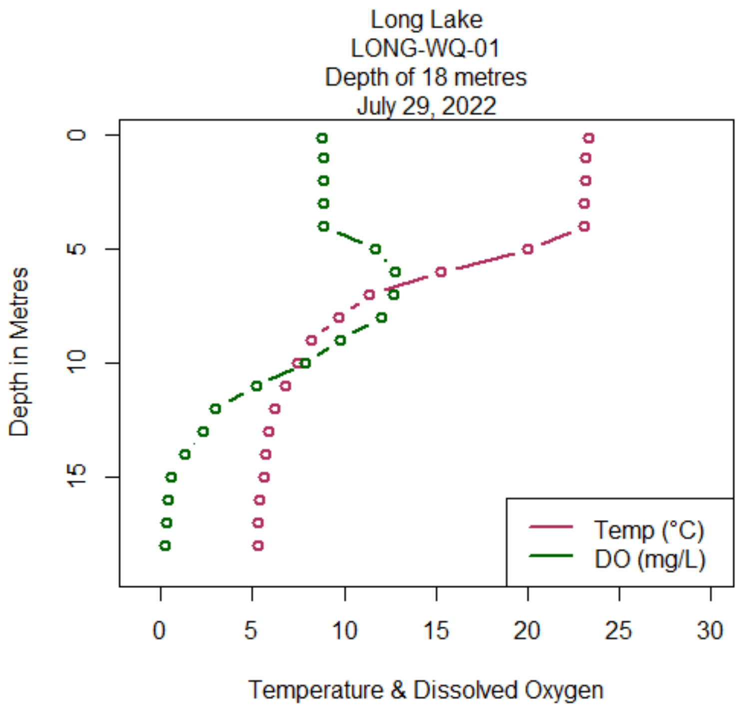
Figure 3: Phosphorus levels on Miskwabi Lake sites. Lab detection limit marked at 0.002 mg/L

Sulfate levels for Miskwabi Lakes were below the recommended limit at Long and Miskwabi lake sites during both summer and fall sampling periods. There was a high of 5.51 mg/l and a low of 2.28 mg/L.

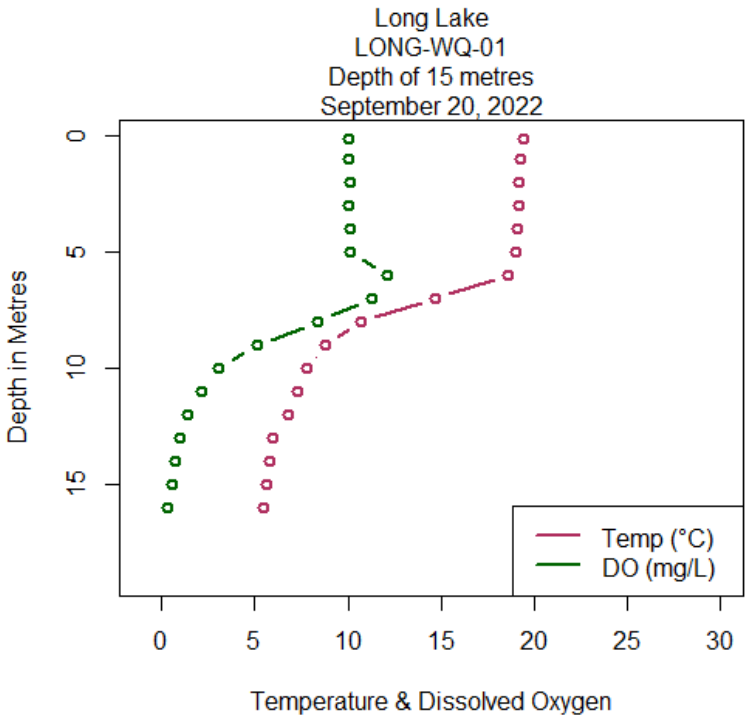
Total Kjeldahl Nitrogen (TKN) was fairly stable with a recorded high of 0.377 mg/L at NGAU-WQ-01 in August and low of 0.152 at MISK-WQ-01 in September.

Dissolved oxygen and temperature profiles are shown below in Figure 4(a-j). They represent the levels of oxygen present and temperature at each metre of depth down to the bottom of each sample site up to 50 m. These profiles give a visual representation of thermal stratification and DO availability to organisms for both sampling events.

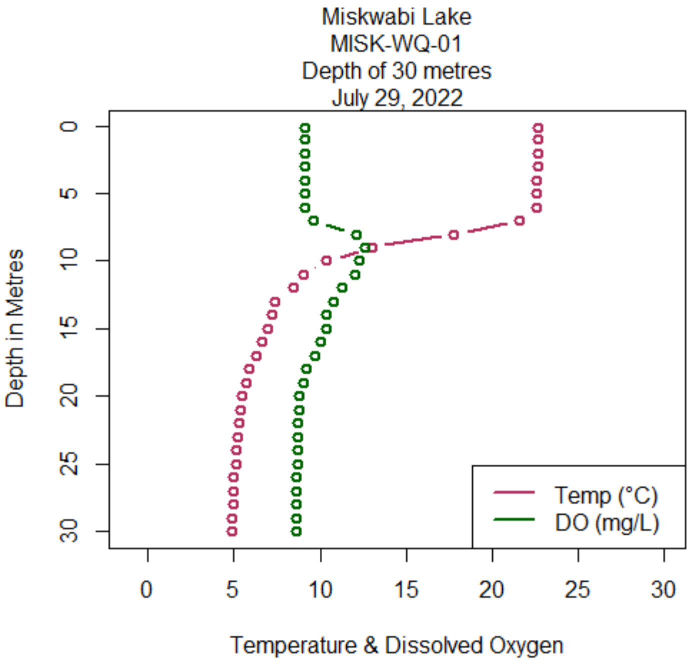
a)



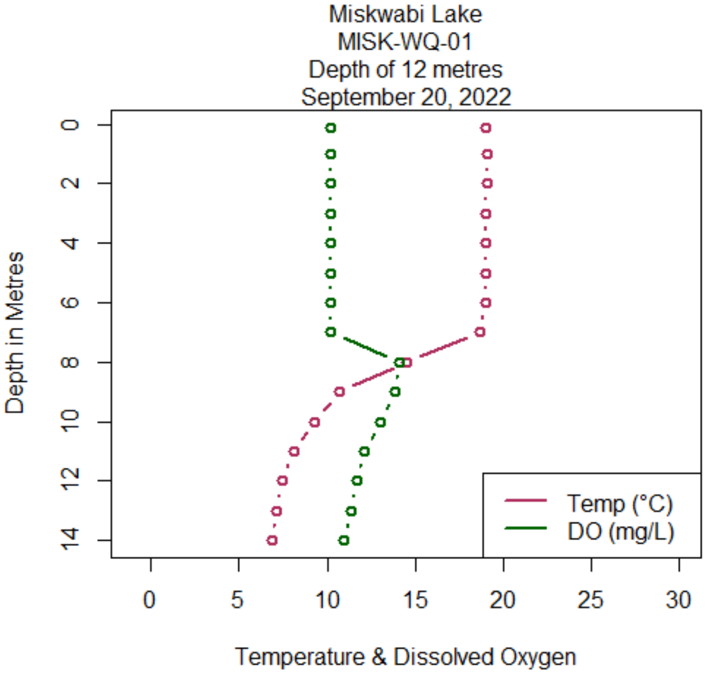
b)



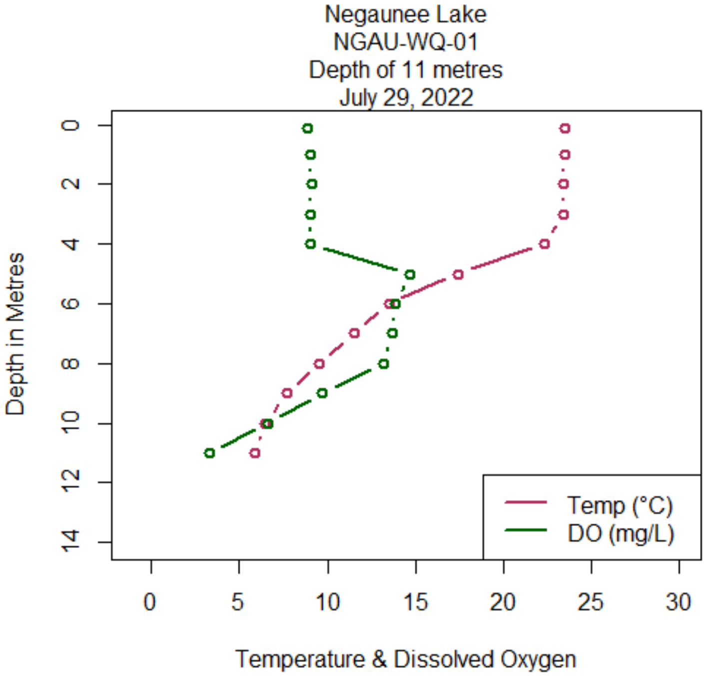
c)


Miskwabi Lake
MISK-WQ-01
Depth of 30 metres
July 29, 2022
Depth in Metres
0
5
10
15
20
25
30
Temperature & Dissolved Oxygen
Temp (°C)
DO (mg/L)

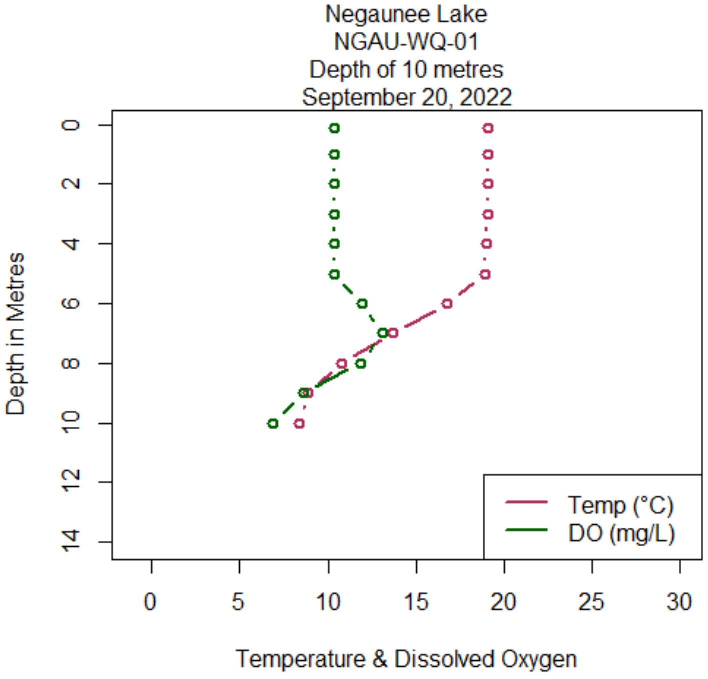
d)


Miskwabi Lake
MISK-WQ-01
Depth of 12 metres
September 20, 2022
Depth in Metres
0
2
4
6
8
10
12
14
0
5
10
15
20
25
30
Temperature & Dissolved Oxygen
Temp (°C)
DO (mg/L)

e)


Negaunee Lake
NGAU-WQ-01
Depth of 11 metres
July 29, 2022
Depth in Metres
0
2
4
6
8
10
12
14
0
5
10
15
20
25
30
Temperature & Dissolved Oxygen
Temp (°C)
DO (mg/L)

f)


Negaunee Lake
NGAU-WQ-01
Depth of 10 metres
September 20, 2022
Depth in Metres
0
2
4
6
8
10
12
14
0
5
10
15
20
25
30
Temperature & Dissolved Oxygen
Temp (°C)
DO (mg/L)

j) k)

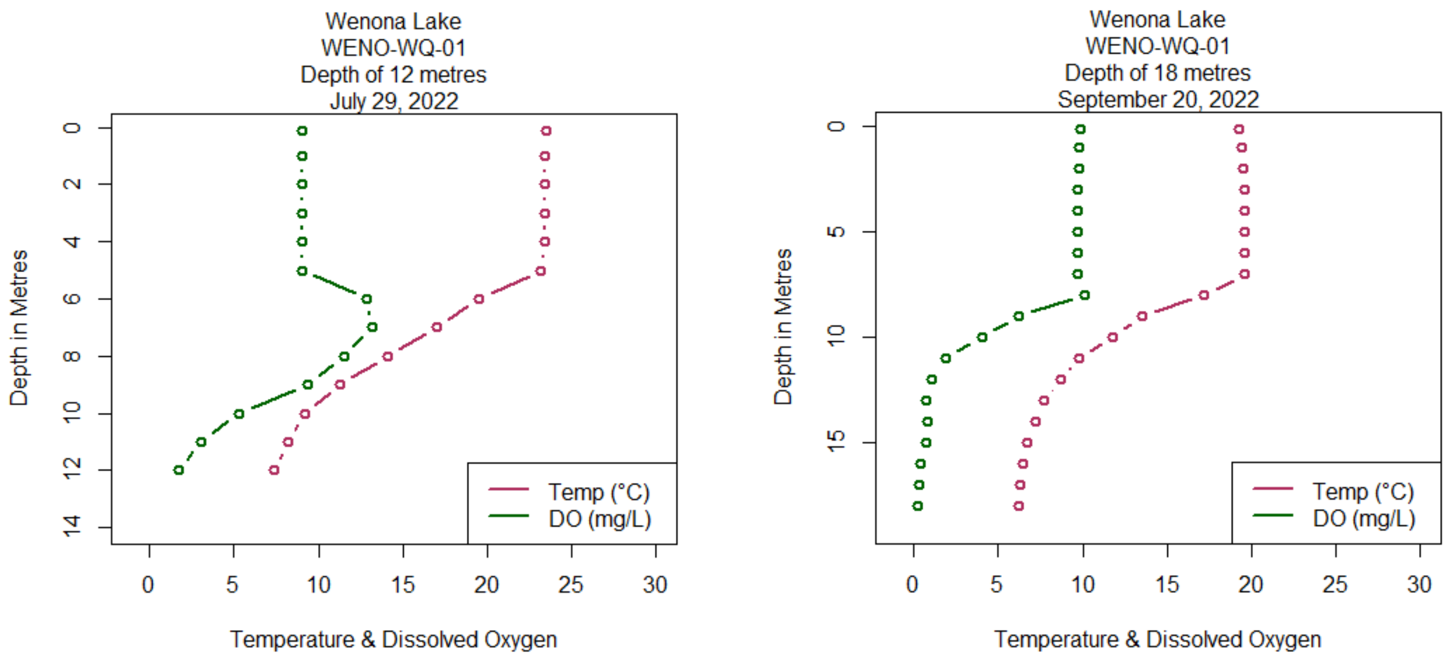


Figure 4 (a-k): Dissolved oxygen & temperatures profiles for all sites

All sites have dissolved oxygen levels around 8.5 mg/L at the surface. Miskwabi and Negaunee Lakes measure DO at depth well above the anoxic limit. Long, and Wenona Lakes eventually reach 0 mg/L near the bottom of the lakes. These shallower basins tend to naturally go anoxic in the fall, as the bottom layer is not large enough to store sufficient DO to support a full season. This variation doesn't necessarily harm the plant or animal life within the lake, as they have adapted to the natural conditions. Continued monitoring is recommended to identify abnormalities.

CYANOBACTERIA: BLUE-GREEN ALGAE

There is growing public concern over **cyanobacteria**, due to an increasing trend in the number of algal blooms in Ontario. Not only do these blooms cause an environmental hazard, impacting water quality, but they also contain toxins harmful to humans and animals. Blooms mostly occur in late summer in warm shallow waters, but have also been recorded in deeper, cooler, **oligotrophic lakes**.

Measurements such as dissolved oxygen and total phosphorus (TP) can provide insight into the probability of cyanobacteria blooms. By regularly measuring these parameters to define a normal range for each lake, unnaturally high temperatures, low DO, and high TP can give early indication of cyanobacteria occurrence.

Anoxic waters can generate a chemical reaction in which phosphorus is released from sediments into the water column, potentially fueling algal growth[12]. This nutrient loading would occur in the late summer/fall months. To anticipate these occurrences, DO/temperature profiles should be taken consistently in the fall to determine the "normal" state of the lake and keep an eye out for unusual anoxic conditions.

Long-term climate warming is a potential contributing factor to recent blooms. The warming of the water column from longer ice-free periods and warmer atmospheric temperatures can provide ideal conditions for eutrophication and rise in bloom occurrences.

Short-term climate variability has also been recorded as a trigger for cyanobacteria blooms. Unusually late ice-out, followed by above average air temperature and low wind speeds (for about 2 weeks) can produce rapid thermal stratification leading to a very short spring **turnover period**[13]. The resulting incomplete oxygen replenishment into the water column at the beginning of summer could lead to anoxia and phosphorus loading over the growing season.

It is important to take note of any unusual weather occurrences that could trigger cyanobacteria growth as well as making sure there are no anthropogenic sources of nutrient loading that could impact water quality. For more information on identifying and reporting blue-green algae blooms visit: ontario.ca/page/blue-green-algae

Trends - Next Steps

As part of this pilot program, compiled historical water quality data from the Lake Partner Program (2002-2022)[14], the Ministry of Environment, Conservation and Park's Water Chemistry data for Lake Trout Lakes (2001-2017)[15], the Ministry of Natural Resources and Forestry's Broadscale Monitoring Water Quality program (2009-2019)[16], and the Lake Health Report completed by the Coalition of Haliburton Property Owners Associations[17] are included. All raw data is provided for your review in an attached excel document. Figure 5 represents the trend of total phosphorus for the LPP's sample site in the centre of Wenona Lake, located at: 45.033889, -78.349167, close to WENO-WQ-02. Data from the WWEW program alongside data from the above-mentioned organizations specific to Wenona Lake is included to show long-term changes in phosphorus levels. Moving forward into 2023, the goal is to have more trend graphs available on additional parameters and lake basins.

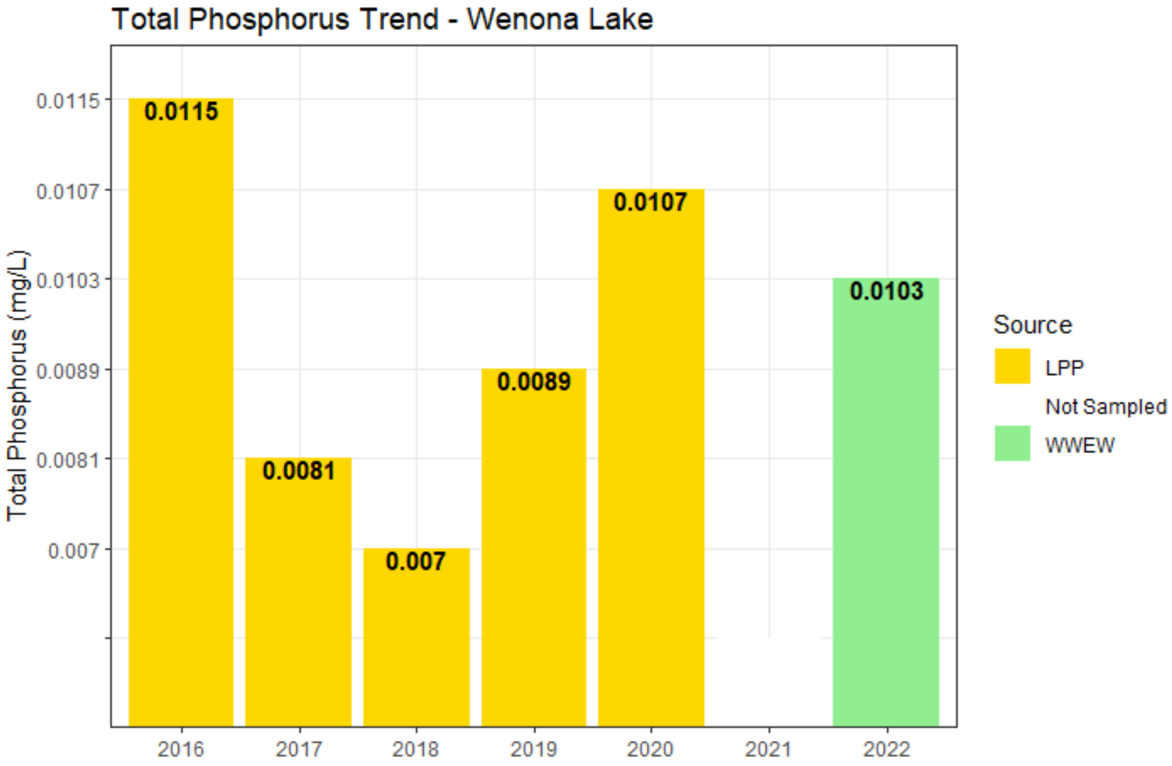


Figure 5: Total Phosphorus Trends for Wenona Lake, sampled close to WENO-WQ-02

Conclusion

The data that WWEW has collected during the pilot 2022 sampling season and subsequent seasons will be significant in identifying trends related to water quality and overall lake health; to increase the knowledge and awareness of current, or potential future hazards is to increase the capacity of intervention and mitigation practices. As stated in the introduction, the goals of this pilot program are to develop water monitoring protocols and practices specific to aquatic concerns in the region and to develop and to grow a database of water quality measurement for long term monitoring.

Challenges within this pilot included measurement for chemical parameters such as nitrate and nitrite concentrations which frequently fell below the limit of reporting for ALS laboratories; for future sampling, WWEW will investigate alternative laboratories and methods for measuring that produce concentration values to be used in comparisons to Stocking Lake and relevant historical data in Haliburton County.

As seen in Table 2, measured parameters are all within normal ranges with the exception of the pH measurements from sample sites on Wenona Lake (WENO-WQ-01, WENO-WQ-02) and Negaunee Lake (NGAU-WQ-01) in the September sample session.

When comparing the MACA Lakes to Stocking Lake it can be seen that overall phosphorus concentrations detected in the MACA Lakes were often greater than the average of 0.0032 mg/L from Stocking Lake. This should be monitored closely due to the large amount of septic systems located around the MACA Lakes.

When comparing total phosphorus data from this year to previous years (sampled by MECP and LPP initiatives) it can be seen that the (averaged) concentration measured in 2022 for Wenona Lake close to site WENO-WQ-02 was 0.0103 mg/L, which is only slightly lower than the 2020 average of 0.0107 mg/L, but higher than the 2018 measurement of 0.007 mg/L. This highlights the fluctuations of TP over the past few years, and especially the noticeable increase since 2018, which seems to have remained relatively consistent at this concentration for the past two years. Unfortunately, there is a data gap from 2021 due to lack of data, which is important to keep in mind while evaluating trends. Several years of consistent data with ongoing support from Lake Association volunteers is required to provide sufficient data to gain a thorough understanding of the health of the MACA Lakes.

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Appendix A - Glossary

Anoxic: the complete absence of oxygen, which occurs in the aforementioned “dead zones”

Cyanobacteria: unicellular, photosynthetic, aquatic bacteria. In ideal conditions, they multiply into extensive growths (blooms)

Effluent: the various types wastewater or liquid byproducts of sewage systems or industry, which often reaches water bodies

Eutrophic lakes (eutrophication): a state that occurs within a lake when nutrient concentrations are high, organic matter increases and decomposes, and the process over-consumes lake oxygen, often leading to “dead zones” where there is a complete lack of oxygen, which is difficult for organisms to survive in

Humification: The process where humic material (organic matter that is decomposing) forms from vegetative matter such as plant remains.

Ionic Strength: Ions are small atoms and ionic strength refers to how many ions there are in the water (concentration). The more ions there are, the greater the ionic strength is. Ionic strength can have negative effects on aquatic life and can decrease their ability to access nutrients, minerals and oxygen in the water

Leaching: the draining away of a chemical or mineral from soil, usually by flowing water

Oligotrophic lakes: lakes with lower concentrations of nutrient concentrations, with higher levels of dissolved oxygen

Overproduction: when excess food is produced and not consumed, leading to high rates of decomposition and high use of oxygen

Photic Zone: the uppermost layer of a body of water that receives sunlight, allowing phytoplankton to perform photosynthesis.

Thermal Stratification: Is the effect when lake water forms individual layers of temperature due to energy intake from the sun; this phenomenon results in three different layers: the epilimnion which is the shallowest and closest to the surface, the hypolimnion which is the deepest and coldest and lastly the metalimnion which is the transition layer between.

Turnover Period: The cooling of lake surfaces makes the water heavier than warm water below in the column causing a mixing effect with cooler water below; this effect can be influenced by wind intensities.

Appendix B - ALS Laboratories Limits of Reporting

The limit of reporting, or laboratory detection limits, are the lowest concentration of an analyte that can be consistently detected with certainty by the lab. Table 3 below summarizes the detection limits from ALS Environmental for the selected study parameters.

Table 3: ALS Environmental analyte detection limits.

Parameter (analyte)	**Detection Limit**
Ammonia	0.0050 mg/L
Nitrate	0.020 mg/L
Nitrite	0.010 mg/L
Sulfate	0.30 mg/L
Total Kjeldahl Nitrogen	0.050 mg/L
Total Phosphorus	0.0020 mg/L

Where a reported less than (<) result is higher than the detection limit, this may be due to primary sample extract/digestate dilution and/or insufficient sample for analysis.

Appendix C - ALS Chemical Analysis Methodology

Table 4: ALS Environmental methodology

Method	ALS Test Description	Lab Location	Matrix	Method Reference	Methodology Description
Anions and Nutrients (Matrix: Water)					
E235.NO2	Nitrite in Water by IC	Waterloo - Environmental	Water	EPA 300.1 (mod)	Inorganic anions are analyzed by Ion Chromatography with conductivity and/or UV detection.
E235.NO3	Nitrate in Water by IC	Waterloo - Environmental	Water	EPA 300.1 (mod)	Inorganic anions are analyzed by Ion Chromatography with conductivity and/or UV detection.
E235.SO4	Sulfate in Water by IC	Waterloo - Environmental	Water	EPA 300.1 (mod)	Inorganic anions are analyzed by Ion Chromatography with conductivity and/or UV detection.
E298	Ammonia by Fluorescence	Waterloo - Environmental	Water	Method Fialab 100, 2018	Ammonia in water is determined by automated continuous flow analysis with membrane diffusion and fluorescence detection, after reaction with OPA (ortho-phthalaldehyde). This method is approved under US EPA 40 CFR Part 136 (May 2021)
E318	Total Kjeldahl Nitrogen by Fluorescence (Low Level)	Waterloo - Environmental	Water	Method Fialab 100, 2018	TKN in water is determined by automated continuous flow analysis with membrane diffusion and fluorescence detection, after reaction with OPA (ortho-phthalaldehyde). This method is approved under US EPA 40 CFR Part 136 (May 2021).
E372-U	Total Phosphorus by Colourimetry (0.002 mg/L)	Waterloo - Environmental	Water	APHA 4500-P E (mod).	Total Phosphorus is determined colourimetrically using a discrete analyzer after heated persulfate digestion of the sample.
Method References					
The analytical methods used by ALS are developed using internationally recognized reference methods (where available), such as those published by US EPA, APHA Standard Methods, ASTM, ISO, Environment Canada, BC MOE, and Ontario MOE. Reference methods may incorporate modifications to improve performance					