2024

KENNISIS LAKE COTTAGE OWNERS ASSOCIATION

WATER QUALITY MONITORING REPORT

PREPARED BY

U-Links Centre for Community-Based Research

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Executive Summary

Haliburton County is located approximately 200 km northeast of the Greater Toronto Area at an elevation of 440 metres above sea level (ASL). This is a point of high elevation on the Canadian Shield, encompassing over 4000 square kilometres of forests and over 600 lakes [1]. The current geographic landscape of Haliburton County was primarily influenced by glacial melting. These natural features attract tourism which drives the local economy.

Acting on information requests from Haliburton County Lake Associations in 2021, Woodlands and Waterways EcoWatch (WWEW), a program of U-Links Centre for Community-Based Research, initiated a pilot water quality monitoring program which has been developed to expand to lakes in Haliburton County. The pilot program started in 2022, and in 2023, WWEW and Lake Association citizen scientists sampled water quality parameters from 37 sites on 25 lakes. In 2024 this program was expanded to include 38 lakes and 60 monitoring locations.

This report and the data presented, serve to add to a collection of data that will reveal trends and can be used to assess the quality of the water and the state of the lakes. This report also displays the results of a metals testing suite including 39 parameters, none of which are shown to be above their guideline limits. Additionally, analysis for phosphorus, nitrogen, and other nutrients was conducted and shows that levels have returned to within guideline limits, following exceedances in previous years. Furthermore, this report also displays a trend of slight declining Secchi depth in the Kennisis Lakes, representing an early indicator of declining lake health, and reaffirming the need for continued water quality monitoring in Haliburton County.

Introduction

Program Overview

Haliburton County is located 200KM north-east of the Greater Toronto Area at an elevation of 325- 440 metres above sea level (ASL), a high elevation point of the Canadian Shield, encompassing over 4000 square kilometres of forests and over 600 lakes [1]. The current geographic landscape of Haliburton County was primarily influenced by glacial melting. These natural amenities attract tourism which 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].

Acting on information requests from Haliburton County Lake Associations in 2021, Woodlands and Waterways EcoWatch (WWEW), a program of U-Links Centre for Community-Based Research, initiated a pilot water quality monitoring project which has been developed to be able to expand to lakes across Haliburton County. For the pilot program, which was completed in 2022 and in 2023, WWEW and Lake Association citizen scientists sampled water quality parameters from 38 sites on 25 lakes (for purposes of this program, Paddy's Bay – on the north shore of Kennisis Lake is a recognized sample location). This program represents a broadscale monitoring objective of having water quality data that is comparable across lakes within Haliburton County and with neighbouring regions.

In 2023, U-Links successfully requested support from Haliburton County to expand its water quality monitoring significantly; growing from 10 participating Lake Associations to 25. Initial outreach to prospective Lake Associations began in February 2024 and by March, the onboarding process was successfully completed. The rapid uptake of this program underscores the high level of interest and engagement among Lake Associations, demonstrating the growing importance of collaborative water quality monitoring in Haliburton County. This expansion reflects both the program's value and its ability to meet the needs of local communities seeking to better understand and manage their aquatic ecosystems.

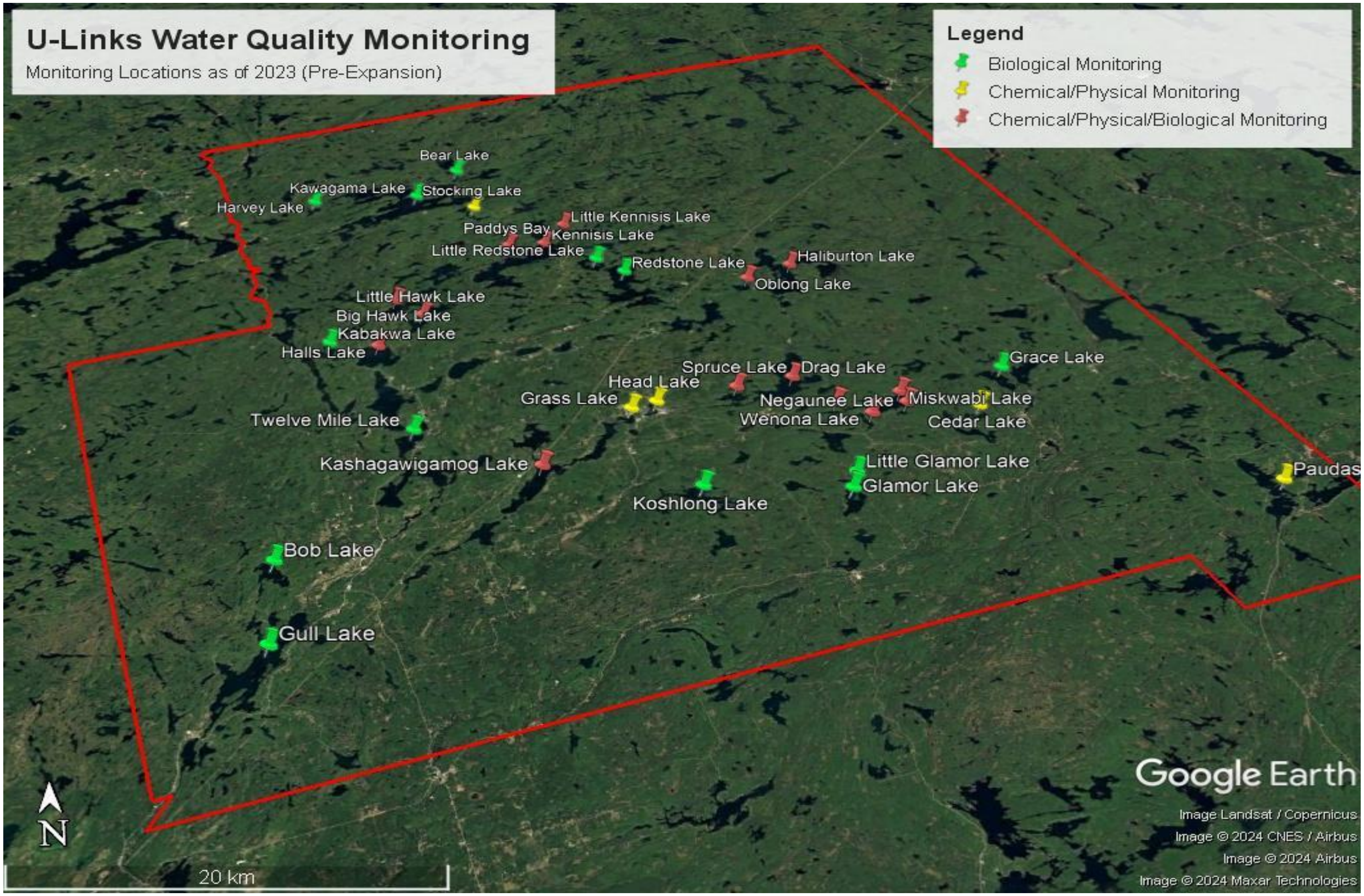


Figure 1: Satellite overview of water quality monitoring undertaken by U-Links/WWEW in 2023 (Previous to 2024 expansion). Green pins represent biological monitoring, yellow pins represent physical/chemical monitoring and red pins represent a lake engaged in both programs.

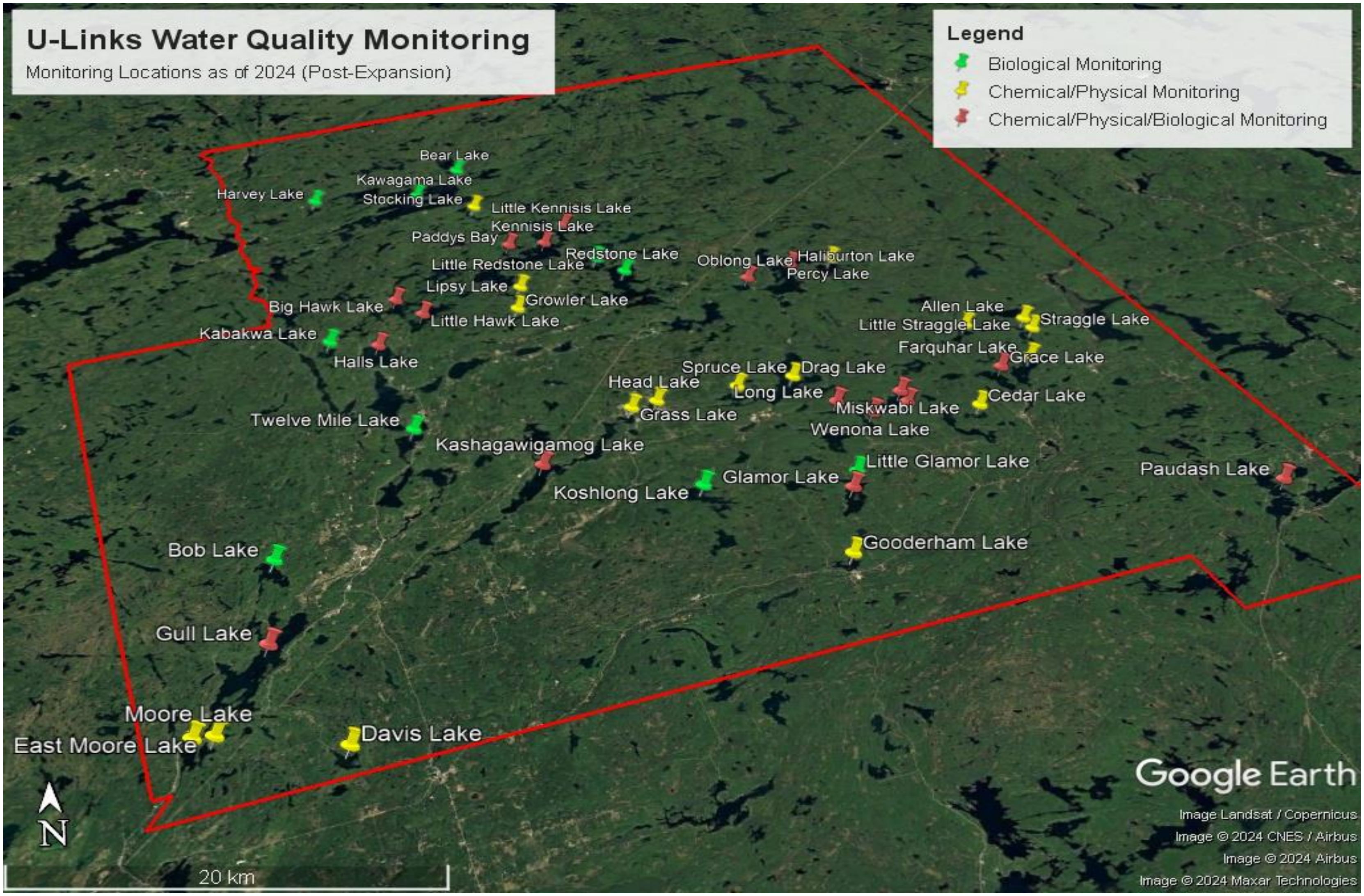


Figure 2: Satellite overview of water quality monitoring by U-Links/WWEW in 2024. (Post 2024 expansion) Green pins represent biological monitoring, yellow pins represent physical/chemical monitoring and red pins represent a lake engaged in both programs.

The goals of this monitoring program are:

- to develop water quality monitoring protocols and practices specific to the aquatic health concerns in the region.
- to develop and grow a database of water quality measurements that will provide long-term information on lake health in Haliburton County.

This information will be useful for decision-makers as they attempt to develop legislation that will ultimately maintain water quality in the County's freshwater resources. The figure below highlights the metrics of data collection and community engagement as of 2024, three years into the program.

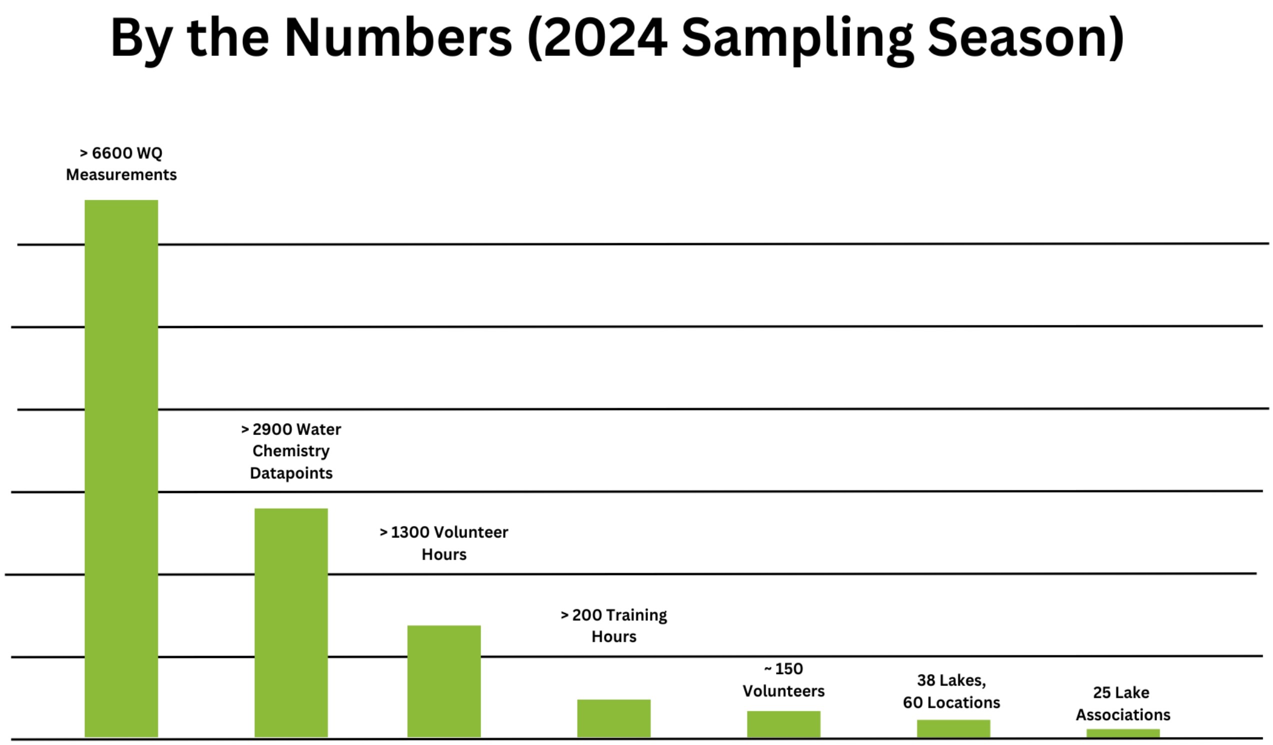


Figure 3: Performance metrics showing the progress this program has made as of the end of 2024 sampling season since the program genesis in 2022.

The Kennisis Lakes (Figure 4), are located ~6km South-East from Stocking Lake, which was used as a reference lake for this program, selected based largely on the absence of seasonal and permanent dwellings except for a small collection of cabins used for research purposes. Motorized vehicles are not permitted on the water and shorelines have retained their natural state.

A Haliburton Water Quality Summit was held in 2022 during program development, where a number of limnology experts were consulted to select and optimize the physical and chemical water quality parameters to measure. This was followed by an additional Haliburton Water Quality Summit in 2024 with many of the same experts from 2022 with the goal to refine protocols. Particulars of amendments are discussed in ‘Sampling Methods’.

This program has been funded in part by the County of Haliburton, grants sourced from Federal and Provincial agencies, Canoe FM, 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.

One objective for 2024/2025 is to include Watershed-centric report cards, as an added deliverable to Lake Associations. This infographic draws inspiration from the Muskoka Watershed Report Card [2] and evaluates 6 indicators: 3 of which measure the health of the lakes and 3 that consider potential threats. The lake health indicators consist of a variety of anions and nutrients (phosphorus, ammonia, nitrate, nitrate, and sulfate), benthic macroinvertebrates (via an array of biotic indices), and calcium/chloride concentrations. Potential threats assessed include interior forest composition (natural, regenerative, and ornamental), climate change, and invasive species.

Report Overview

The *Kennisis Lake Cottage Owners’ Association 2024 Water Quality Report* documents the physical and chemical water quality parameters that were measured on Kennisis Lake, Little Kennisis Lake and Paddy’s Bay in 2024 and provides an update to the 2023 report prepared for the Kennisis Lake Cottage Owners’ Association [3].

This data contained in this report can be used in many ways, such as:

- Evaluating changes over time
- Determining the cumulative health of the watershed
- Creating or apply a lake or watershed plan
- Measuring efficacy of current regulations
- Engaging the community in citizen science and stewardship

Water Quality Measurements and Methods

Site Locations

In our water quality monitoring program, we have strategically selected mid-lake deep basin locations for sampling. This approach is based on the understanding that these central, deeper areas provide a more representative assessment of the lake's overall water quality as they are less influenced by localized factors including: shoreline runoff, human activities and tributary inflows [4]. By focusing on these zones, we aim to minimize the impact of nearshore variables, obtaining data that more accurately reflects the lake's general condition. In 2024, 5 sites across the Kennisis Lakes were sampled seasonally on three occurrences as part of the Woodlands and Waterways EcoWatch – Testing the Waters program. Sampling occurred on March 3rd, May 21st and September 17th, collecting seasonal variation data across the Winter, Spring and Fall.

Site Coordinates

- BIG K-2: 45.204981, -78.664856
- BIG K-4: 45.224608, -78.612922
- LITTLE K-1: 45.249933, -78.597144
- LITTLE K-2: 45.254825, -78.876811
- PADDY BAY: 45.226625, -78.648431

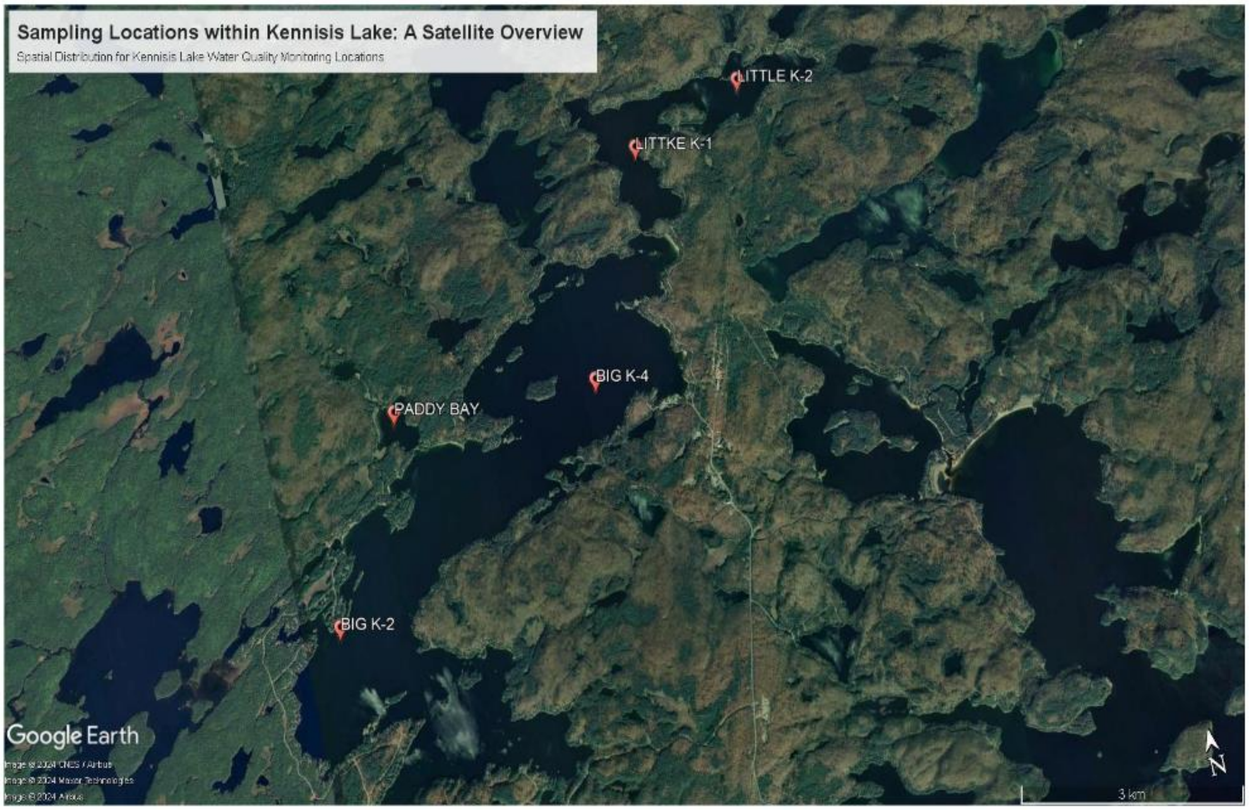


Figure 4: Satellite overview of sampling site location across the Kennisis Lakes (2024).

Sampling Methods

To gather data and gain the insight necessary to complete this report, industry standard sampling protocols were followed with the use of various monitoring tools in the field to collect measurements. The sampling protocols are available as a separate document. *Woodlands and Waterways EcoWatch - Lake Sampling Procedures* [5].

Following suggestions from the 2023 report, two revisions were made to the sampling procedure. Duplicate total phosphorus samples were introduced to rule out sample contamination as the source of spikes in total phosphorus concentrations. Also, in consultation with lake monitoring experts, it was determined to discontinue the detection of nitrite (NO_2) as previous readings continued to fall below the Limit of Reporting (LOR). A thorough breakdown of the ALS Laboratories Limits of Reporting is included in Appendix C.

Parameters Measured

A detailed description of the program's standard parameters is summarized in Table 1 and the following sections.

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 allows for the measurement of nutrients present within the entire **photic zone.** Water samples were collected at each site and shipped to the ALS Environmental Laboratory based in Waterloo, Ontario. Weather observations were also noted at the start of every sampling event.

To measure alkalinity, Water Rangers brand test strips for freshwater were dipped into a surface water sample. Conductivity and pH were measured using an Oakton PCTS-50 multi-meter that was placed into a surface water sample. A depth profile for dissolved oxygen and temperature was produced, measuring in meter intervals of lake depth (up to 50m) using a YSI PRO-ODO device. All other parameters (ammonia, total Kjeldahl nitrogen, nitrates, total phosphorus, and sulfate) were measured at the ALS laboratory using the collected water samples.

An addition to the program was made in 2023 to offer total metals analysis to Lake Associations, providing a baseline measurement of 39 analytes (Listed Total Metals Section, Table 2), allowing for a comparison with the reference lake. This option was offered to lakes onboarded during the expansion as well.

Table 1 – Overview of Key Water Quality Parameters and Their Implications

ALKALINITY	Alkalinity is indicative of a lakes ability to neutralize acids and its sensitivity to acidic inputs [6]	Alkalinity concentrations come from salts and minerals **leaching** from rocks into lakes, or from wastewater discharge [2]. Recommended limit: 20-200 mg/L. If <10 mg/L = the waterbody is susceptible to acidification [6]
AMMONIA	Ammonia is a form of nitrogen, formed through the fixation of atmospheric nitrogen and hydrogen [6]	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 [6]. Natural sources can include organic waste breakdown, forest fires, animal waste. Recommended limit: 0.019 mg/L [7]
CONDUCTIVITY	Conductivity measures the total **ionic strength** of water, and determines how well an electric current can pass through it [6,8]	Higher levels of conductivity typically mean it contains more dissolved salts [6]. Conductivity also increases as temperatures increase, due to evaporation of surface water [6]. Pure water has very low conductivity. Lakes can range from 0-200 μS, with some major rivers reaching >1000 μS [8]
DISSOLVED OXYGEN	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, 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	Nitrates and nitrites are nitrogen compounds that in low concentrations, play an important role in aquatic ecosystem health [6]	If nitrate levels are too high, it can cause algae blooms and **eutrophication** [4]. Elevated levels may be caused by pollution (runoff, sewage). Natural surface water levels are typically <1.0mg/L [9]
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	Most North American freshwater bodies have a pH that ranges from 6.5-8.5, and most fish thrive in water within this range [10]. pH is influenced by local geology (such as the Canadian Shield) and is determined by chemistry components like salts, carbonates and various acids
SULFATE	Sulfate is the most common form of sulfur found in well-oxygenated lakes [6]	Naturally occurring sulfate can be introduced through the breakdown of leaves in the Fall [6], it can also be brought into the lake through acid rain. High levels of sulfate can increase the acidity of a lake, reducing its pH [11]. Recommended limit: <250 mg/L [11]
TOTAL KJELDHAL NITROGEN	Total Kjeldahl Nitrogen is a measure of total organic nitrogen + ammonia [6]	If nitrate levels are too high, it can cause algae blooms and eutrophication [4]. Elevated levels may be caused by input by pollution (runoff, sewage). Natural surface water levels are typically <1.0 mg/L [6]
TOTAL PHOSPHORUS	Phosphorus is an abundant mineral and essential aquatic nutrient, key for plant and algae productivity and biomass [10]	In excess, phosphorus can limit biodiversity, harm sensitive species, cause anoxia and lead to eutrophication. Sources can include fertilizers, animal waste, sewage effluent. Recommended limit: 0.01 mg/L [10]

Secchi Disk Sampling

Secchi disks are weighted, thin, black, and white disks, attached to a line, that gather visual 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 [12].

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) [12].

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 particulates [12].

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 unaddressed 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 [13].

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 cold-water lies 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 exhibit declines in DO as organisms consume oxygen.

Depending upon the amount of biological activity, bottom waters can become **anoxic**, nearly free of dissolved oxygen (<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 minimum levels above 3 mg/L. Anything below 3mg/L is considered **hypoxic** and is largely insufficient to support aquatic life. For cold-water species, such as Lake trout, a minimum of 6 mg/L is needed, along with a temperature below 10℃ [13].

Total Metals

As part of our Water Quality Monitoring Program, we conducted sample collection for a specialized ‘Total Metals Analysis’ package. This optional package, chosen by select Lake Association partners, encompasses the testing of 39 metal analytes [13]. To date, 21 of 25 participating Lake Associations have opted to include this analysis, significantly expanding the availability of total metals data across Haliburton County. Prior to this program, widespread data on metal concentrations in lakes within the Haliburton County region was largely unavailable on a public platform. This enhanced dataset provided an invaluable baseline for understanding metal distributions and potential sources, while also identifying any areas of concern for further investigation.

Table 2 below outlines each analyte included in the analysis, along with a brief description of its relevance to water quality serving as a reference for understanding their method of introduction whether natural or anthropogenic.

Table 2 Parameters included in Total Metals analysis

Metals	Description
ALUMINIUM (Recommended Limit: 0.075mg/L)	Elevated levels of aluminum in freshwater may indicate contamination from industrial processes.
ANTIMONY (Recommended Limit: 0.020mg/L)	Elevated antimony levels in freshwater may result from human activities such as mining and smelting.
ARSENIC (Recommended Limit: 0.0005mg/L)	Arsenic in freshwater can be sourced from both natural sources or human activities such as mining.
BARIUM*** (Recommended Limit: 2mg/L)	Barium concentrations in freshwater are generally low, but elevated levels can arise from industrial discharges.
BERYLLIUM (Recommended Limit: at <75 hardness 0.011mg/L, at >75 hardness 1.1mg/L)	Beryllium in freshwater may indicate contamination from industrial processes with potential toxicity to aquatic life.
BISMUTH (0.01 mg/L)	Bismuth in freshwater is generally low, elevated levels may result from industrial discharges.
BORON (Recommended Limit: 0.2mg/L)	Boron concentrations in freshwater are typically low, but excessive levels may affect aquatic plants and organisms.
CADMIUM (Recommended Limit: 0.1µg/L)	Elevated levels of cadmium in freshwater are often sourced from industrial processes and can be toxic to aquatic life.
CALCIUM*** (Recommended Limit: 1.5mg/L - >20mg/L)	Calcium levels in freshwater are essential for aquatic ecosystems, influencing water hardness and plays a role in nutrient cycling.
CESIUM*** (Recommended Limit: 50Bq/L)	Cesium in freshwater is typically low, but may increase due to nuclear contamination.
CHROMIUM (Recommended Limit: 0.001mg/L for Cr VI and 0.0089mg/L for Cr III)	Elevated chromium levels in freshwater is often sourced from industrial discharge and have negative impacts on aquatic life.
COBALT (Recommended Limit: 0.009mg/L)	Cobalt in freshwater is generally low, elevated levels may indicate contamination from industrial processes.
COPPER (Recommended Limit: 0-20 hardness 0.001mg/L, at >20 hardness limit is 0.005mg/L)	Elevated copper levels in freshwater often originate from industrial discharges or agricultural runoff.

IRON (Recommended Limit: 0.3mg/L)	Iron concentrations in freshwater can vary, excessive levels may lead to aesthetic issues within lakes such as reddish-brown discoloration but are generally non-harmful.
LEAD (Recommended Limit: <30 hardness 0.001mg/L, 30-80 hardness 0.003mg/L, >80 hardness 0.005mg/L)	Elevated levels in freshwater, often from industrial discharges or old plumbing pose serious health risks to aquatic life.
LITHIUM*** (Recommended Limit: 0.070mg/L)	Lithium in freshwater is typically low, but increasing concentrations may be associated with human activities.
MAGNESIUM (No Limit Found)	Magnesium in freshwater contribute to freshwater hardness are are crucial for aquatic organisms.
MANGANESE (Recommended Limit 0.12 mg/L)	Elevated manganese levels in freshwater may arise from natural sources or human activities.
MOLYBDENUM (Recommended Limit: 0.040mg/L)	Molybdenum in freshwater is generally low, increased levels can occur from industrial processes.
NICKEL (Recommended Limit: 0.025mg/L)	Elevated nickel levels in freshwater can occur from industrial discharge and may have adverse effects on water quality.
PHOSPHORUS (Recommended Limit: 0.020mg/L)	Phosphorus concentrations in freshwater influence nutrient levels, with excess phosphorus contributing to eutrophication and water quality issues.
POTASSIUM (No Limit Exists*)	Potassium in freshwater is essential for various biological processes and concentrations are generally within acceptable ranges.
RUBIDIUM (No Limit Found)	Rubidium in freshwater is typically low and is often sourced from industrial discharge which requires monitoring for potential environmental impacts.
SELENIUM (Recommended Limit: 0.010mg/L)	Elevated selenium levels in freshwater are often from natural sources or mining activities and can have toxic effects on aquatic life.
SILICON (No Limit Found)	Silicon concentrations in freshwater are essential for diatoms and other aquatic organisms playing a role in nutrient cycling.
SILVER (Recommended Limit: 0.1μg/L)	Elevated silver levels in freshwater are from industrial discharges and can be toxic to aquatic organisms.

SODIUM **(No Limit Found)**	Sodium in freshwater is naturally sourced but elevated levels may be sourced from human activities.
STRONTIUM **(Recommended Limit: 7mg/L)**	Strontium concentrations in freshwater are generally low, but elevated levels may indicate contamination requiring monitoring for environmental impacts.
SULFUR **(As Sulfate: 250mg/L)**	Sulfur in freshwater is essential for biological processes, elevated levels may result from industrial sources.
TELLURIUM **(Recommended Limit:0.1mg/L)**	Tellurium in freshwater is typically low but elevated levels may occur due to human activities requiring monitoring.
THALLIUM **(Recommended Limit: 0.003mg/L)**	Elevated thallium levels in freshwater result from industrial discharges or natural sources.
THORIUM **(Recommended Limit: 1 Bq/L)**	Thorium concentrations in freshwater are generally low but increased levels may occur from industrial discharges.
TIN **(Recommended Limit: 0.05µg/L)**	Tin in freshwater is typically low, but elevated levels may result from industrial activities requiring monitoring.
TITANIUM **(No Limit Found)**	Titanium concentrations in freshwater are generally low, but elevated levels may occur from industrial discharges requiring monitoring.
TUNGSTEN **(Recommended Limit: 0.030mg/L)**	Tungsten concentrations in freshwater are generally low, but elevated levels may occur from industrial discharges requiring monitoring.
URANIUM **(Recommended Limit: 0.005mg/L)**	Elevated uranium levels in freshwater may result from natural sources or human activities posing potential risks to aquatic life.
VANADIUM **(Recommended Limit: 0.006mg/L)**	Vanadium concentrations in freshwater are generally low, but increased levels may occur from industrial discharges.
ZINC **(Recommended Limit: 0.030mg/L)**	Elevated zinc levels in freshwater, often from industrial discharges, can be toxic to aquatic life.
ZIRCONIUM **(Recommended Limit: 0.004mg/L)**	Zirconium concentrations in freshwater are generally low, with minimal environmental impact under normal conditions.

Results & Discussion

Parameter Guideline Limits

The parameters measured are important indicators of water quality and ecosystem health. However, it is important to note that individual parameters come together to create a cohesive picture as 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 the total nitrogen bound in organic substances plus that nitrogen contained in both ammonia and ammonium [6]. Higher values are considered problematic and lower values are more ideal, the average TKN concentration of Canadian Shield lakes is 0.275 mg/L [14]. Due to this, it is important to measure regularly and identify trends or spikes. Consistency is key as sudden spikes could indicate an issue [6]. To place some context around this parameter, a trend line can be developed with low versus high concentrations based on collected data.

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 Ontario Provincial Water Quality Objectives, the Canadian Councils for Ministers of the Environment (CCME) and the District of Muskoka [7,8,13]. These limits have allowed us to develop an initial set of our own water quality limits which we feel are suitable for the lakes in Haliburton County in general.

When scoring parameters against our identified guideline limits, we utilize a three-tiered threshold system to categorize results:

1. **Within Limit (Good)** – The measured value falls well within the identified guideline range, indicating optional conditions.

2. **Nearing Limit (Fair)** – The measured value is within 10% of the guideline range, signalling a potential for concern [15].
3. **Exceeding Limit (Poor)** – The measured value exceeds the identified guideline range, highlighting a condition that requires attention and/or intervention.

Results

This report provides a detailed assessment of physical and chemical water quality parameters essential for monitoring and maintaining lake health. Table 3 below summarizes the water quality data collected from Kennisis Lakes, covering the program's timeline from its inception in Spring 2022 to the most recent sampling event in Fall 2024. The table encompasses a range of key physical and chemical parameters, offering valuable insights into the lake's ecological state. By analyzing this data, we aim to deepen our understanding of the Kennisis Lakes condition and provide crucial information to support the long-term health of its aquatic ecosystem.

Understanding the 'normal' state of the lake requires a long-term perspective. As we approach the conclusion of the program's third year, we are steadily gaining the ability to identify meaningful patterns and trends. This extended timeframe strengthens the program's reliability, capturing critical seasonal variations and contributing to a more holistic understanding of the lake's ecological dynamics.

Ongoing sampling efforts are vital to building a robust dataset that accurately reflects the variability within the lake's aquatic ecosystem. Continued monitoring in future years will further refine baseline levels, enhancing our capacity to assess the lake's health, resilience, and response to environmental changes over time.

Table 3: Physical and Chemical Parameters for the Kennisis Lakes - 2024 Water Quality Sampling

PARAMETER	LIMITS	LEGEND	
Alkalinity (mg/L)	>10, <200	Exceeding limit (poor)	
Ammonia (mg/L)	<0.019	Nearing limit (fair)	
Conductivity(uS/cm)	<200	Below limit (good)	
Nitrates/Nitrites (mg/L)*	<1.0	No limit available	
pH	≥6.5(acidic), ≤8.5 (basic)		
Total Phosphorus (mg/L)	<0.01		
Sulfate (mg/L)	<250		

	BIG K-2		BIG K-4			LITTLE K-1		LITTLE K-2			PADDY BAY		STOC-WQ-01		
	Spring	Fall	Winter	Spring	Fall	Spring	Fall	WInter	Spring	Fall	Spring	Fall	Winter	Spring	Fall
Alkalinity (mg/L)	35	20	20	40	40	40	40	60	40	40	40	33.3	20	20	40
Ammonia (mg/L)	0.0076	0.0265	0.0198	0.0091	<0.0050	0.0083	0.0054	0.0315	0.0143	0.0207	0.0077	0.0267	0.0151	<0.0050	<0.0050
Conductivity (uS/cm)	22.7	19.8	30.3	23.2	19.0	18.8	17.0	22.5	19.0	16.2	19	33.3	16.1	18.2	35.7
Nitrate (mg/L)*	0.063	<0.020	0.094	0.062	<0.020	0.065	<0.020	0.089	0.054	<0.020	<0.002	<0.020	0.04	<0.020	<0.020
pH	5.83	8.97	8.63	6.06	8.44	5.93	8.32	7.94	6.0	7.79	6.04	8.67	8.34	7.53	8.21
Sulfate (mg/L)	2.2	2.5	2.77	2.34	2.51	1.7	1.85	2.03	1.62	1.78	1.73	1.99	2.05	1.87	1.98
Total Phosphorus (mg/L)	0.003	0.00335	0.00365	0.003	0.0026	0.00415	0.0045	0.0058	0.00415	0.0046	0.00515	0.00375	0.007	0.005	0.005
Total Kjeldahl Nitrogen (mg/L)	0.21	0.205	0.21	0.23	0.201	0.26	0.26	0.28	0.27	0.268	0.275	0.249	0.268	0.31	0.249
Secchi Depth Average (m)	6	6.9	NA	6.85	6.3	3.23	4.0	NA	3.15	4.4	3.5	3.85	2.95	3.3	3.7

pH

pH levels across sites on the Kennisis Lakes illustrate seasonal and site-specific variations over the span of this program. Most values remained within the Canadian freshwater guideline range of 6.5-8.5, reflecting a generally stable and well-buffered system. However, the data highlights more pronounced variability in 2024 compared to previous years, with fluctuations both below and above the guideline limits.

In 2023, pH levels were relatively stable across most sites, with only minor deviations observed, such as in the fall at BIG K-2 and Paddy's Bay (pH values of 6.65 and 6.78, respectively). In 2024, sharper declines were observed in the spring, with all sites dropping below the lower guideline limit. Notably, BIG K-2 reached 5.83, and LITTLE K-1 dropped to 5.49, suggesting localized acidification or increased runoff inputs. By fall 2024, pH levels rebounded, with BIG K-2 and Paddy's Bay surpassing the upper guideline limit (8.97 and 8.67, respectively), likely influenced by late-season stratification or other environmental factors.

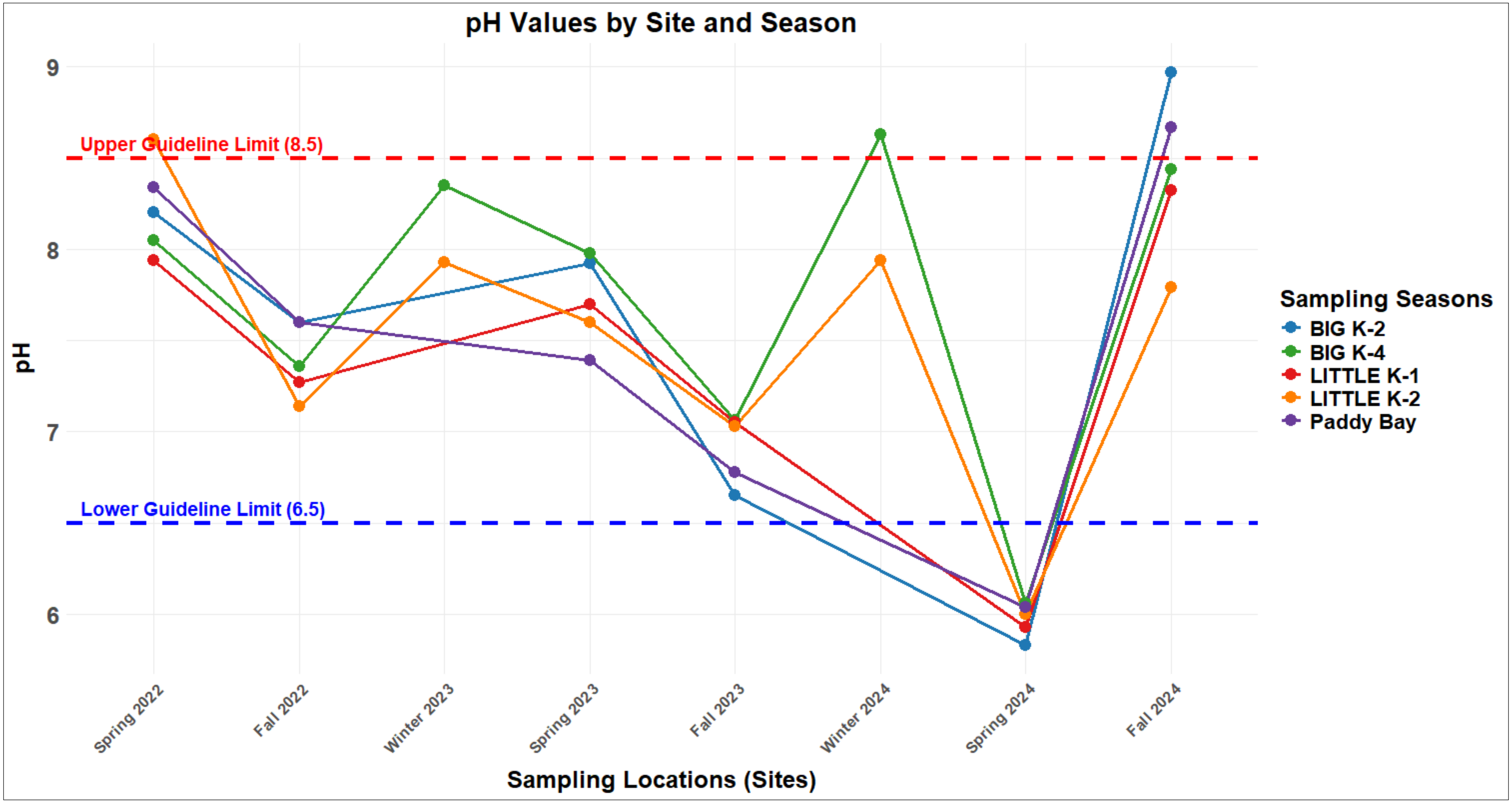


Figure 5 Seasonal and annual pH levels of the Kennisis Lakes (2022-2024), illustrating trends in pH variation across Spring, Fall and Winter.

Nitrogen

Nitrate

Nitrate concentrations across sites on the Kennisis Lakes continue to demonstrate consistent with low-productivity, oligotrophic conditions. In most cases, concentrations remained below the limit of reporting (<LOR) across all seasons, aligning with expectations for lakes with minimal nutrient input. However, notable variations are observed, particularly in 2023 where spices in nitrate were detected at specific sites.

A significant spike occurred with BIG K-2 during spring 2023, with nitrate levels reaching 0.147 mg/L, the highest recorded value over the monitoring program. This spike, while still remaining well below the guideline limit of 1.0 mg/L, likely reflect nutrient flushing from spring snowmelt combined with a delayed turnover due to warmer than average temperatures in preceding seasons. This pattern is supported by the subsequent decline to <LOR in following seasons, indicating the transient nature of this nitrate pulse.

In contrast, nitrate levels in 2024 have remained more stable, with fewer detectable values across all sites and seasons. A minor spike was observed at BIG K-2 and LITTLE K-2 during winter and spring, respectively (both measured at 0.089 mg/L). These values, though lower than the spring 2023 event, may suggest localized nutrient inputs or variability in runoff timing.

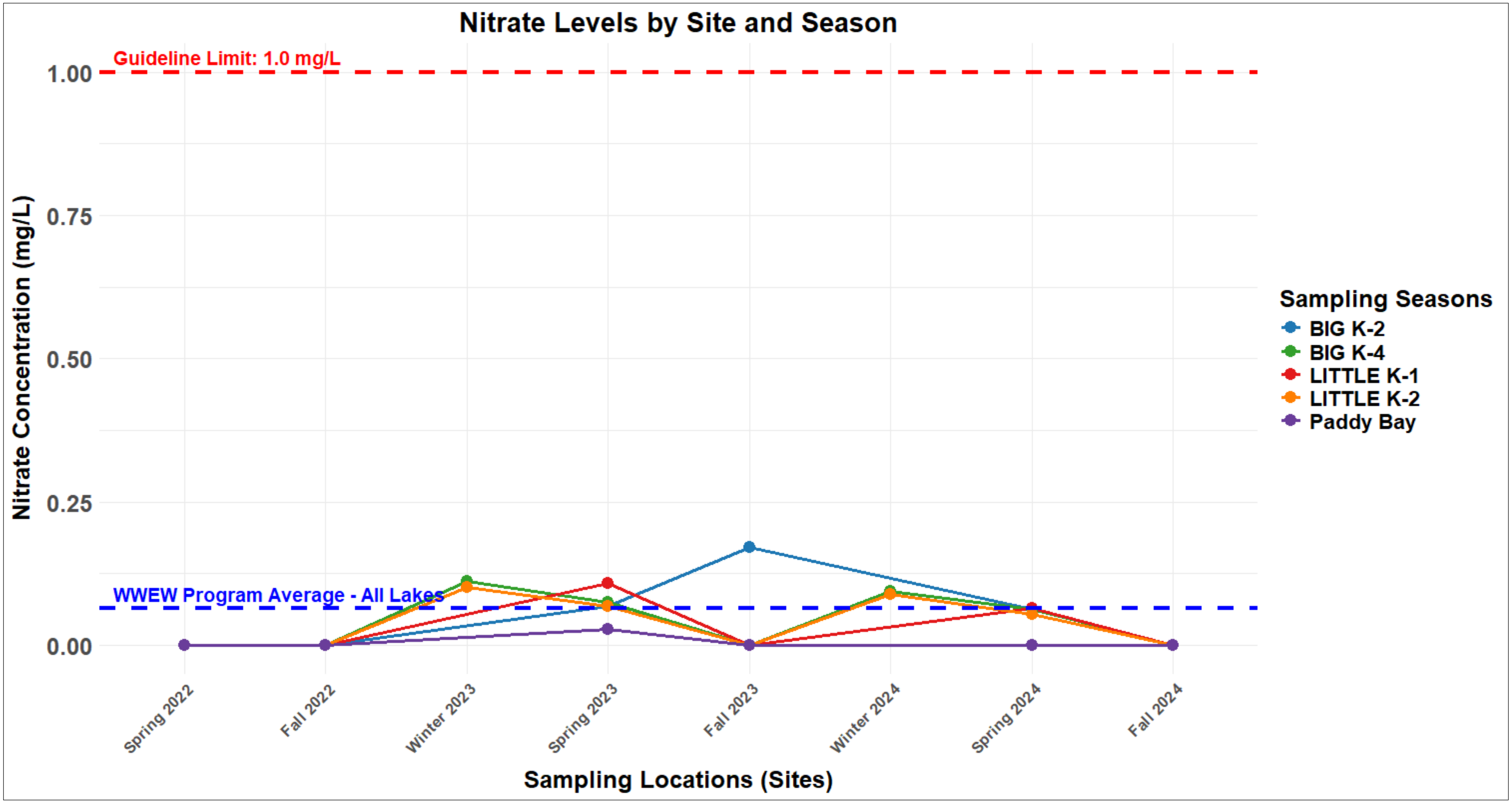


Figure 6 Nitrate concentrations in the Kennisis Lakes by year and season (2022-2024), showing a notable spike in Fall 2023 compared to levels below the limit of reporting (LOR) in other seasons and years.

Total Kjeldahl Nitrogen

Total Kjeldahl Nitrogen (TKN) concentrations across the Kennisis Lakes demonstrated both seasonal and interannual variation, with values fluctuating across sites and years. While levels remained relatively low overall – consistent with oligotrophic nature of the lakes- there are notable patterns and spikes indicating shifts in nitrogen availability.

The lowest recorded TKN concentration was 0.150 mg/L at BIG K-4 in spring 2023, reflecting minimal nitrogen inputs during the early growing season. In contrast, Paddy's Bay recorded the highest concentration of 0.336 during fall 2023, suggesting enhanced nitrogen availability likely driven by sediment release, runoff inputs or reduced biological uptake late in the season. Elevated concentrations during fall 2023 and winter 2024 across several sites, particularly LITTLE K-2 (0.334 mg/L) and Paddy's Bay (0.376mg/L), may reflect a delay of turnover events due to warmer than average conditions and promotes nutrient accumulation in the hypolimnion.

Compared to 2023, concentrations in 2024 appear slightly more variable, with seasonal peaks persisting at several sites during winter and spring. Sites like LITTLE K-1 and Paddy's Bay continue to exhibit higher than average TKN values, while others such as BIG K-4 remain relatively sable across sampling periods.

These observed trends suggest a combination of external influences (e.g. runoff, atmospheric deposition, etc.) and internal processes (e.g. sediment nutrient release and turnover dynamics) contributing to nitrogen availability. While concentrations remain well with acceptable freshwater thresholds, the seasonal spikes highlight the importance of continued monitoring to detect emerging trends that could signal changes in nutrient dynamics across the Kennisis Lakes.

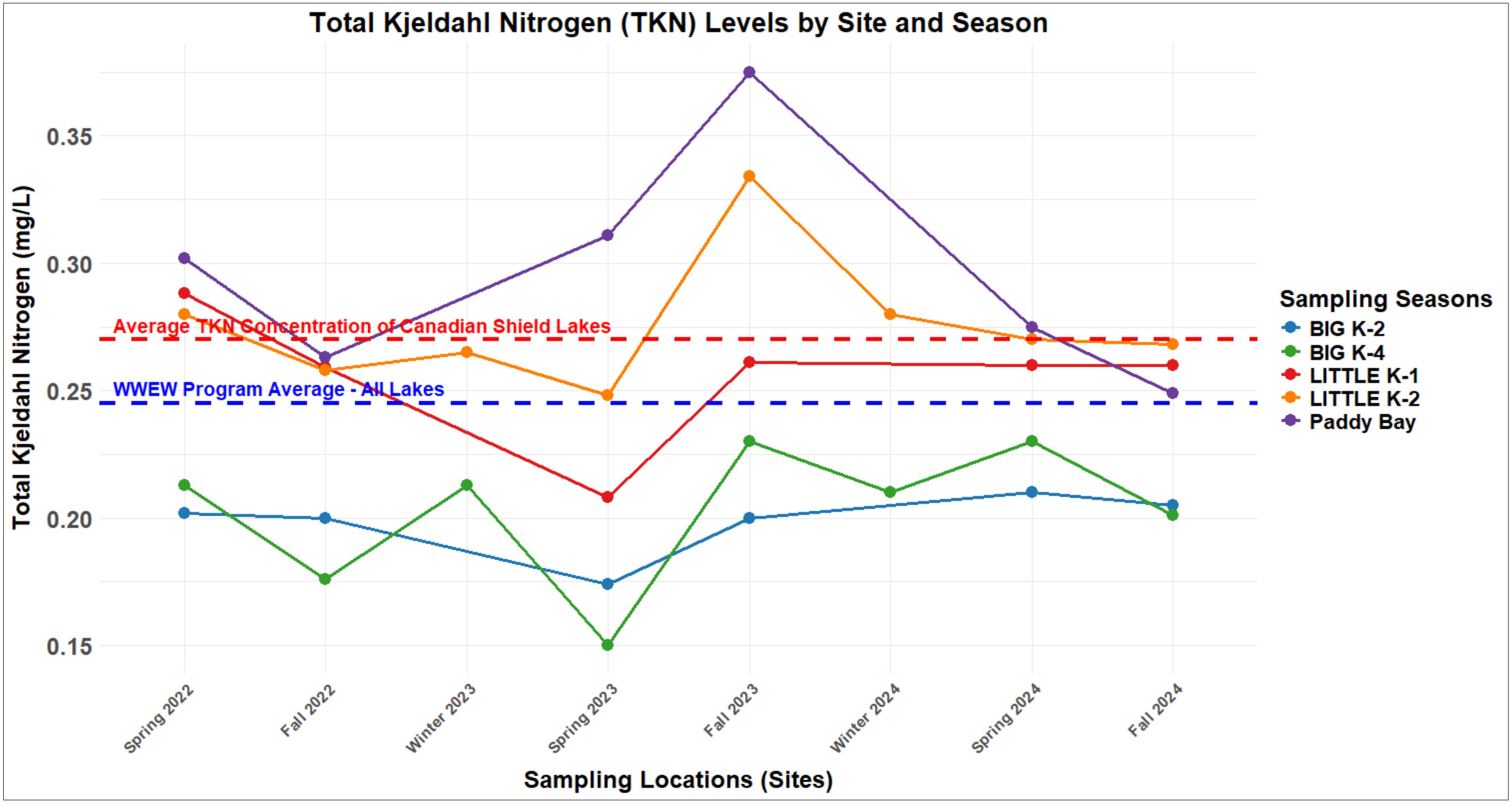


Figure 7 Total Kjeldahl Nitrogen (TKN) concentrations in the Kennisis Lakes by year and season (2022-2024), highlighting seasonal variability and interannual trends, with a notable peak in Fall 2023.

Ammonia

Ammonia concentrations across the Kennisis Lakes throughout this program show several spikes at specific sites. While levels remained below the analysis limit of reporting (<LOR) during early monitoring periods in 2022, subsequent years sampling revealed periodic increases suggesting that influences from sediment release, biological activity and external nutrient inputs are at play.

In 2022, ammonia concentrations were consistently low, with values below detection at select sites and others remaining below the guideline limit of 0.019 mg/L. Minor increases at BIG K-2 and Paddy's Bay in July (0.0128 mg/L and 0.0136 mg/L respectively) though both remained below the guideline limit. By 2023, ammonia levels began to rise with exceedances recorded at BIG K-4 (0.0483 mg/L) in March, followed by another elevated level of 0.0282 mg/L in September. LITTLE K-1 saw the highest ammonia concentration of the monitoring period reaching 0.0540 mg/L in September 2023.

In 2024, ammonia concentrations remained elevated but showed a reduction in magnitude compared to 2023. LITTLE K-2 recorded 0.0315 mg/L in winter 2024, an increase of 2023s fall value (0.0154 mg/L). Paddy's Bay showed a decrease in the spring to 0.077 mg/L however subsequently rose to 0.267 mg/L by the fall.

Overall, ammonia levels across the Kennisis Lakes demonstrate distinct seasonal trends, with winter and fall showing the most pronounced increases. The gradual rise in ammonia concentrations over the three year period highlights the potential influence of variables such as sediment nutrient release, runoff inputs, and changing seasonal conditions on lake nitrogen dynamics. Continued monitoring will be critical to assess whether these patterns persist or intensity, and to understand their implications for lake health and productivity.

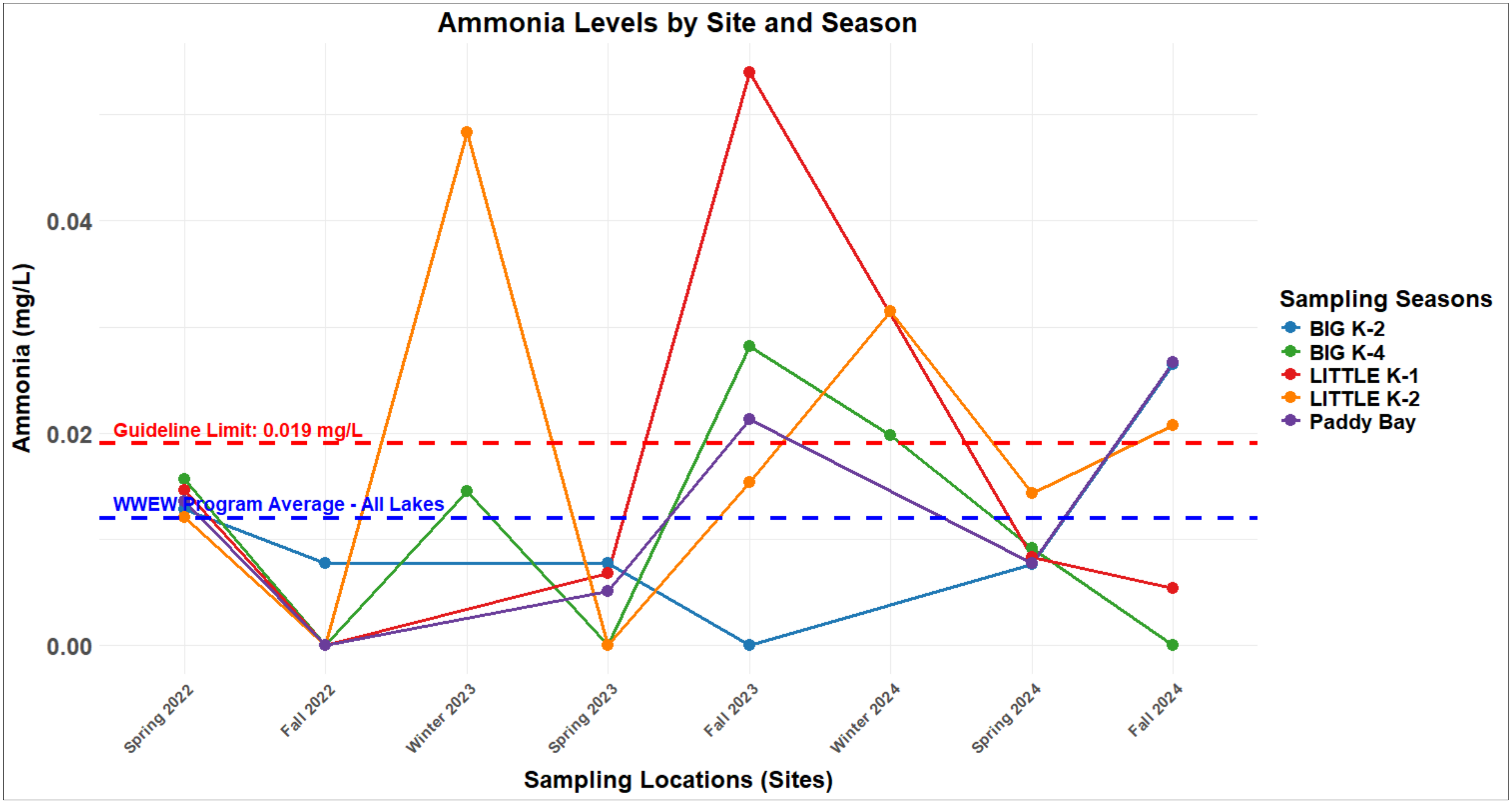


Figure 8 Ammonia concentrations in the Kennisis Lakes by year and season (2022-2024), with a significant peak observed in Fall 2023, the highest recorded value during the monitoring period

Phosphorus

Total Phosphorus (TP) concentrations across the Kennisis Lakes have demonstrated some notable exceedances of the guideline limit of 0.01 mg/L observed during specific periods. While values remained low and consistent with oligotrophic conditions in 2022, later years saw increases at select sites, particularly during spring and fall of 2023.

In spring 2023, the highest recorded concentration was observed at BIG K-4 (0.0441 mg/L), a value significantly exceeding the guideline limit and standing out as an anomaly across the monitoring period. Elevated TP levels were also recorded at LITTLE K-1 (0.0170 mg/L) and BIG K-2 (0.0107 mg/L) during the same season. This pattern aligns with a major external disturbance – the failure of a beaver dam at Bone Lake in August 2023. This event discharged substantial organic debris into Big Kennisis Lake via the Bone Lake Creek outlet, introducing a significant nutrient load. Compounding this, road and creek washouts near Little Kennisis likely contributed additional phosphorus through sediment transport and surface runoff.

In the following months, elevated TP concentrations persisted, particularly at sites such as LITTLE K-2 (0.0092 mg/L) in the fall 2023 and Paddy's Bay (0.0075 mg/L) in winter 2024, highlighting the ongoing influence of the August disturbance. These elevated values also coincide with suspected blue-green algal blooms observed during the same period. The blooms would suggest increased biological activity in response to nutrient enrichment, though sample contamination cannot be ruled out as a factor. As mentioned in the sampling methods, contamination mitigation was a required area for improvement in the program and thus duplicate samples for phosphorus were added to the program.

Comparing across years, 2022 showed a much lower TP concentration across sites. The contrast between 2022 and 2023 highlights the potential role of external nutrient inputs and hydrological disturbances in driving phosphorus variability. In 2024, TP concentrations appear to show signs of recovery, with most sites returning to near-background levels that were seen in 2022, though isolated peaks such as BIG K-2 (0.0107 mg/L) measured in winter 2024 accentuate the need for continued monitoring.

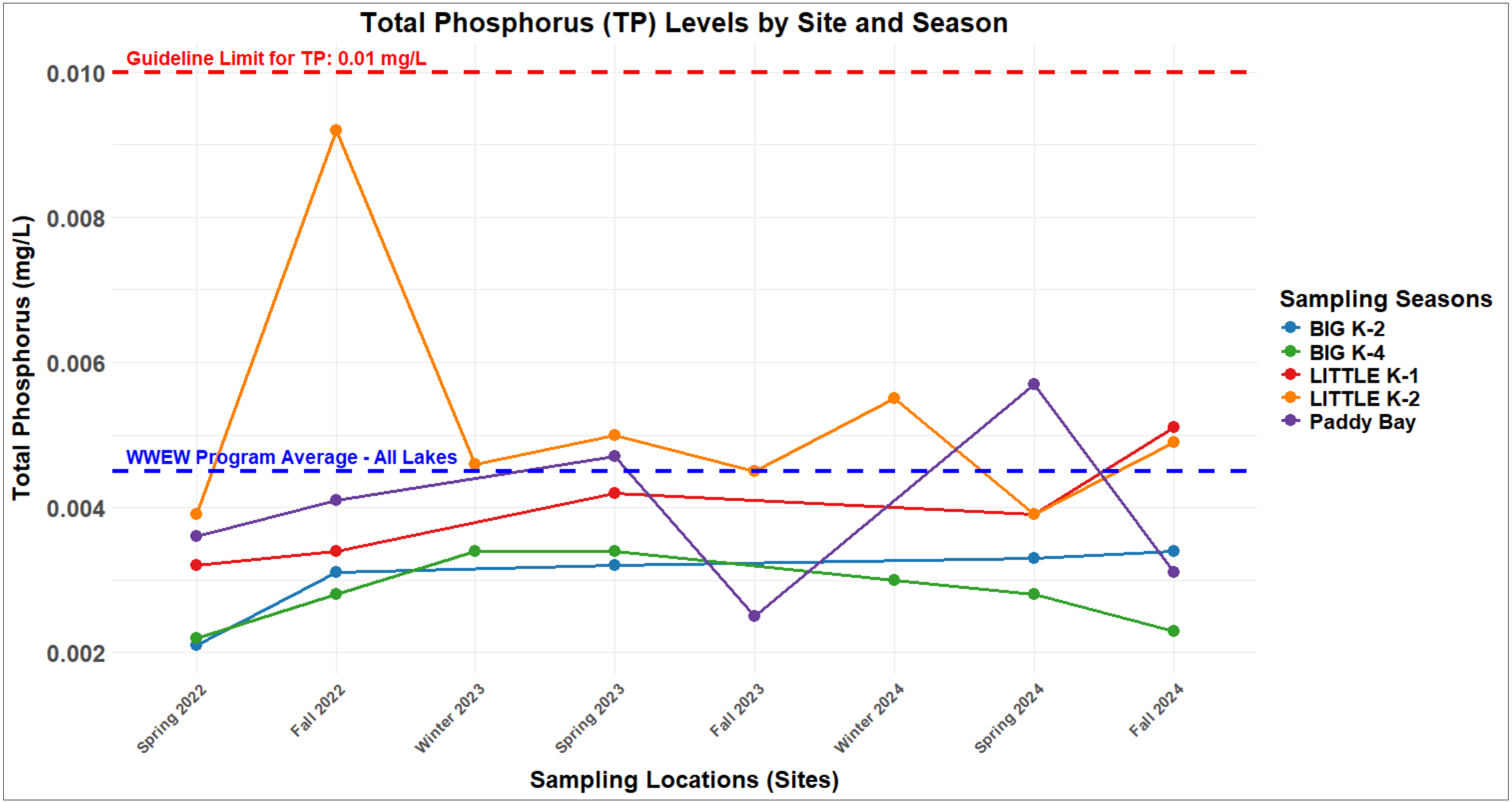


Figure 9 Total Phosphorus (TP) concentrations in the Kennisis Lakes by year and season (2022-2024), showing a gradual increase over time with consistent peaks in Winter 2023 and 2024.

Sulfate

Sulfate concentrations across the Kennisis Lakes show clear seasonal patterns and subtle site specific differences, consistent with sulfur cycling dynamics in freshwater systems. Elevated values during spring sampling periods reflect the mobilization of sulfate through snowmelt-driven runoff, a process where sulfur compounds deposited atmospherically over winter are flushed into lakes [17].

The most pronounced peak occurred in spring 2023 at Big K-4 (3.1 mg/L) surpassing values observed at other sites across years of this program. Similar seasonal increases were recorded in spring 2022 (2.92 mg/L) and Paddy's Bay (2.30 mg/L), highlighting the influences of the years rapid spring melt.

By contrast, sulfate levels showed a decline through the summer and fall months, likely due to reduced runoff, dilution during stratification, and potential update by aquatic organisms [17]. In fall 2023 and winter 2024, sulfate concentrations saw small increases at sites BIG K-4 (2.77 mg/L) and Paddy's Bay (2.5 mg/L).

Spring snowmelt continues to be the primary driver of seasonal sulfate increases across Kennisis Lakes sites. Elevated concentrations at BIG K-4 suggest higher sulfur inputs relative to other sites, while lower levels at LITTLE K-2 pointed to limited external contributions.

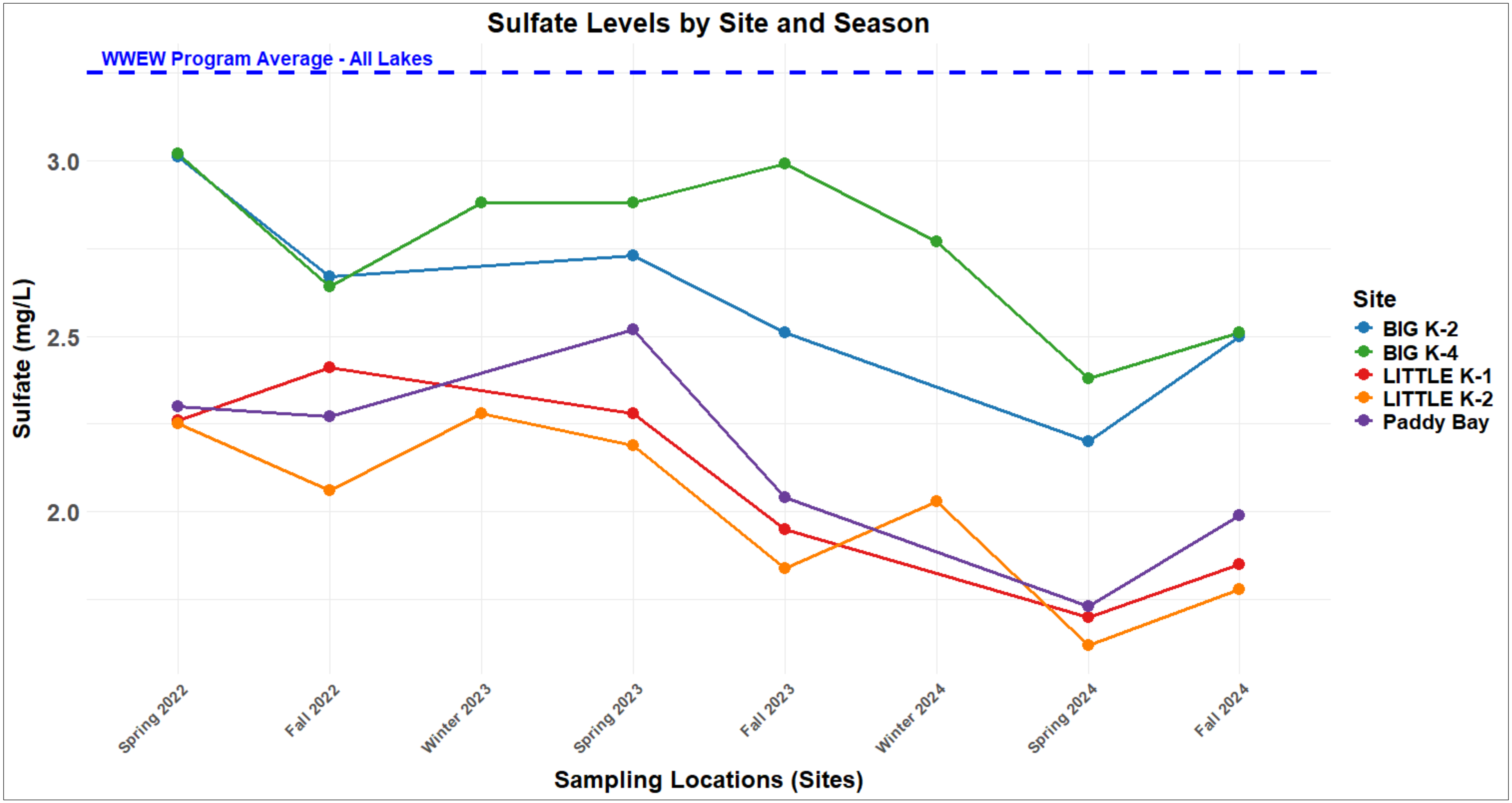


Figure 10 Sulfate concentrations in Kennisis Lakes by year and season (2022-2024), with a notable peak in Spring 2023, representing the highest value during the monitoring period.

Dissolved Oxygen and Temperature

Understanding the intricate components of the water column in lakes is essential for comprehending the distribution of temperature and dissolved oxygen (DO) throughout the aquatic environment Lakes exhibit distinct layers: the epilimnion, which is the warm, upper layer; the metalimnion, characterized by the thermocline and transitional properties; and the hypolimnion, the cold lower layer [10]. These layers play a significant role in regulating the dynamics of DO and temperature within the lake. Seasonal variations in DO levels are closely intertwined with biological activity and environmental conditions [24]. Spring brings upon increased solar radiation, stimulating photosynthesis and drives a surge in oxygen production [24]. This abundance of oxygen persists throughout the summer, particularly in the epilimnion, where continuous photosynthesis and atmospheric diffusion contribute to higher levels of DO [24]. However, the stratification common in temperate lakes during summer creates divergent conditions in the hypolimnion [24]. Comparing this to eutrophic lakes which are characterized by high productivity, oxygen becomes depleted in the lower layers due to isolation from oxygen sources and organism respiration [24]. On the other hand, oligotrophic lakes which have lower algal biomass and deeper light penetration in relation to eutrophic lakes, retain oxygen at depth – benefiting from the enhanced solubility in colder water [24].

Winter presents contrasting challenges however, while oligotrophic lakes remain relatively stable, ice-covered eutrophic lakes may experience drastic declines in DO [24][10]. With limited sunlight penetration through an ice layer and lack of atmospheric contributions, microbial decomposition can quickly deplete oxygen availability, leading to “winter kill” events and exacerbating water quality issues [24][10].

The primary purpose of understanding these profiles are to visually illustrate the phenomenon of thermal stratification and the availability of DO to aquatic organisms, such as lake trout. By examining temperature and DO profiles, the presence and characteristics of these layers can be identified which offer crucial insights into the health and dynamics of lake ecosystems. Figure X shows the typical seasonal changes of DO and temperature for oligotrophic lakes.

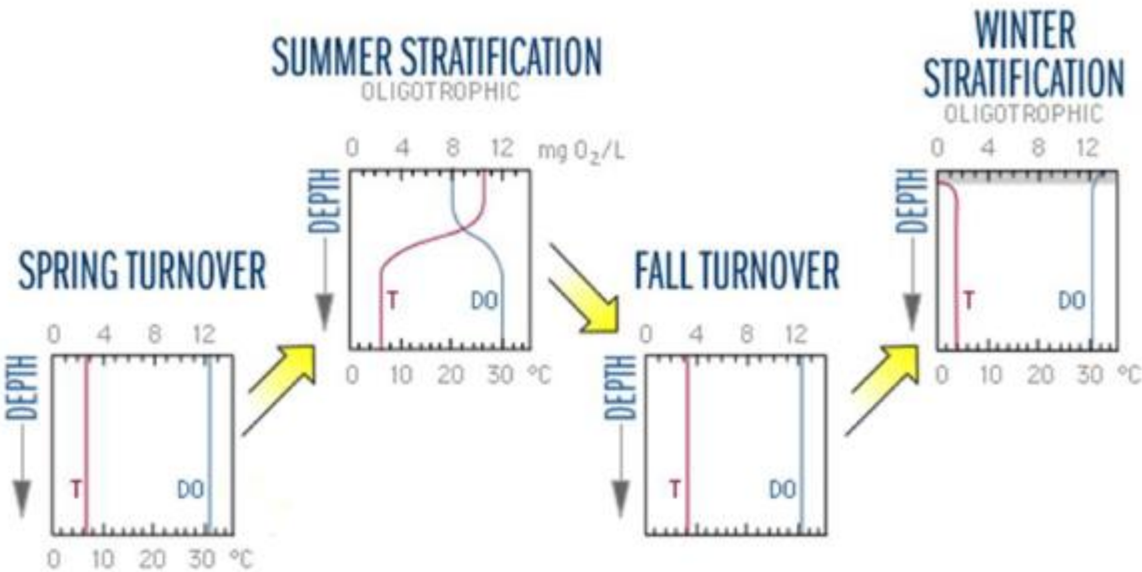


Figure 11 Typical dissolved oxygen and temperature changes across seasons in oligotrophic lakes

In Figures 12(a-j) the dissolved oxygen and temperature profiles collected throughout this program so far are shown below. These profiles offer a comprehensive insight into the distribution of oxygen levels and temperature gradients across varying depths at each of the sampling locations, and across seasons throughout the program (2022-2024). The data here spans from the water surface (0.1 metres) down to a maximum depth of 50 metres, providing a detailed vertical profile of the water column.

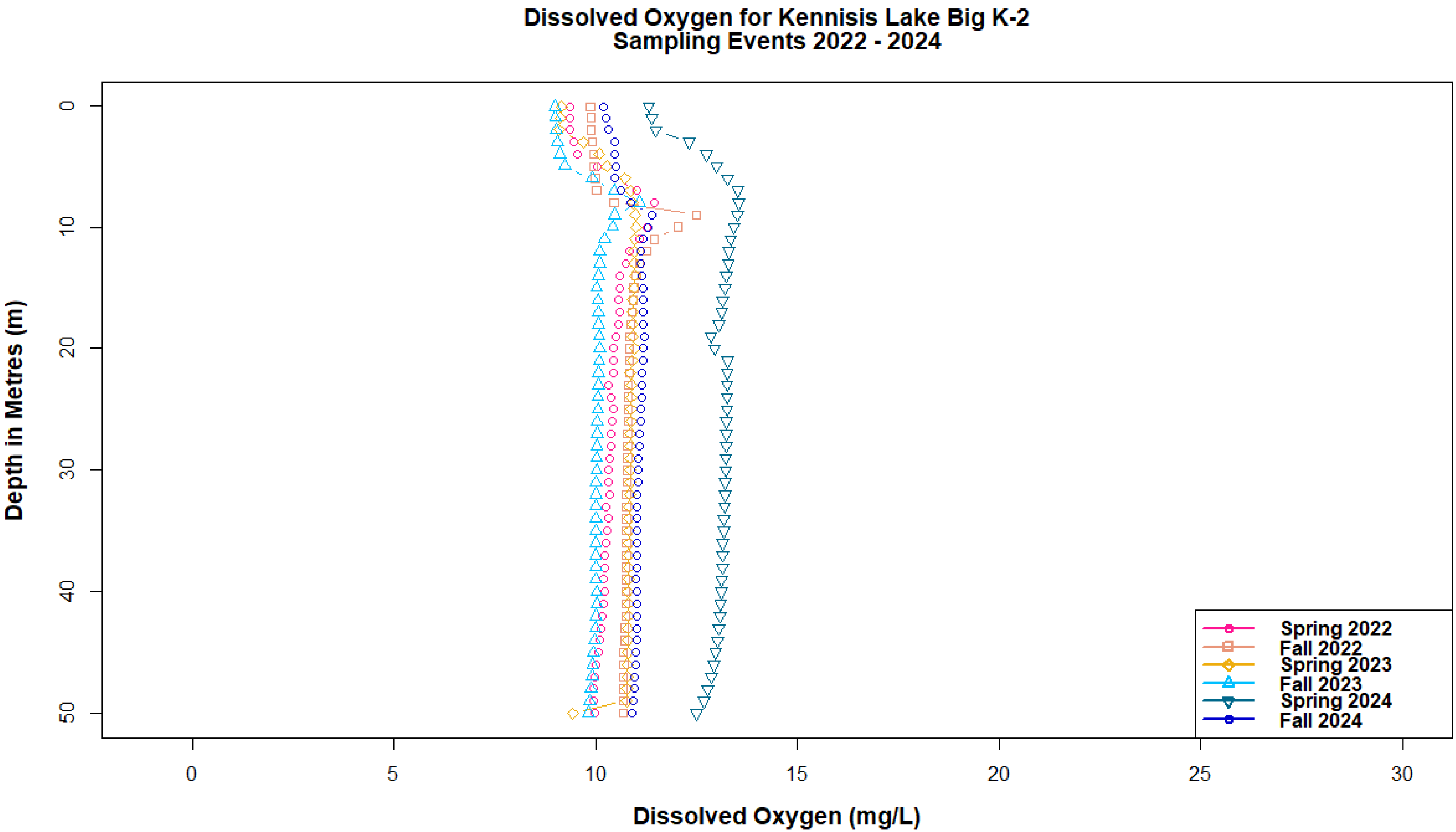


Figure 12a: Dissolved oxygen profiles for site BIG K-2 throughout monitoring program (2022-2024)

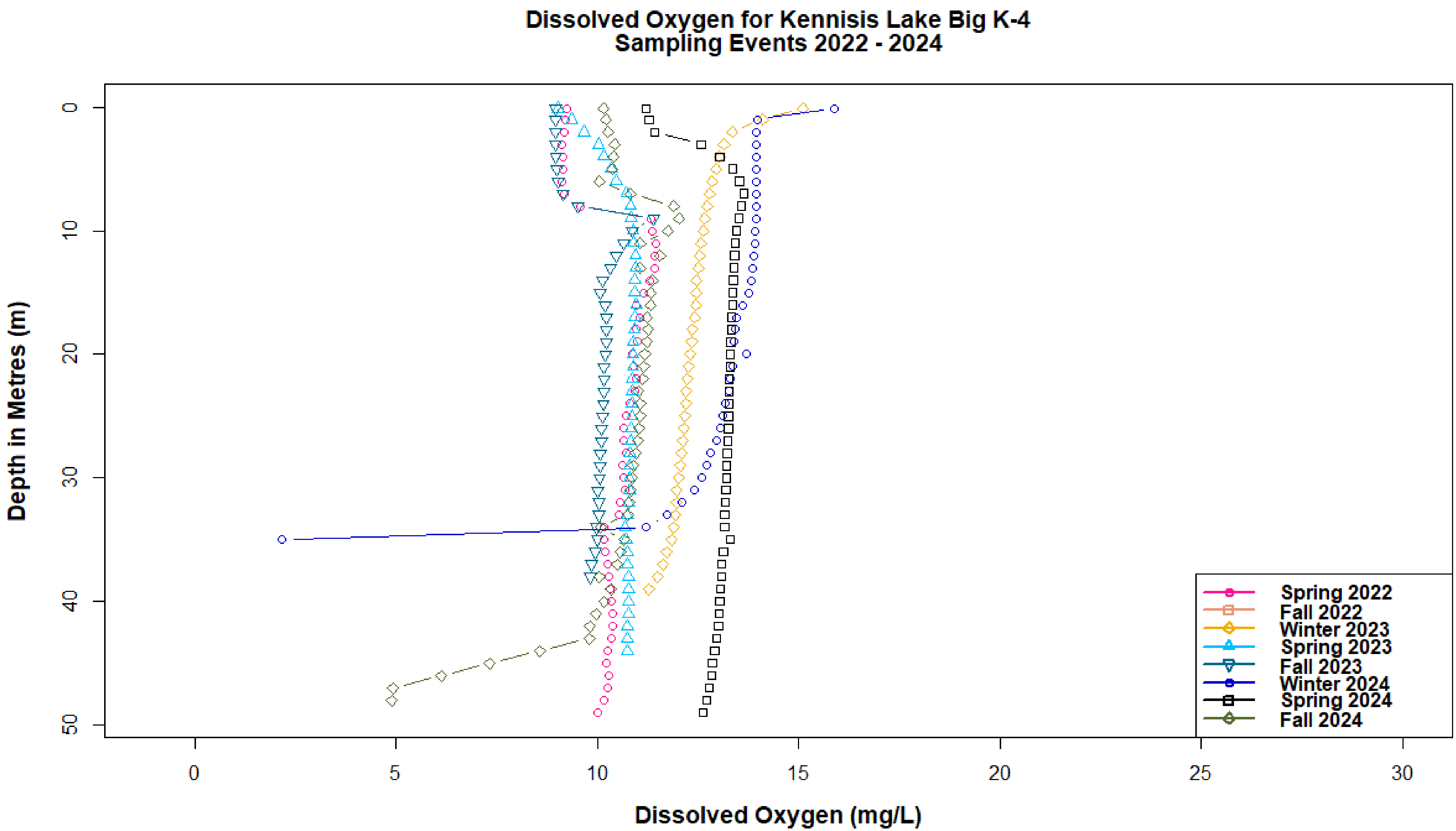


Figure 12b: Dissolved oxygen profiles for site BIG K-4 throughout monitoring program (2022-2024)

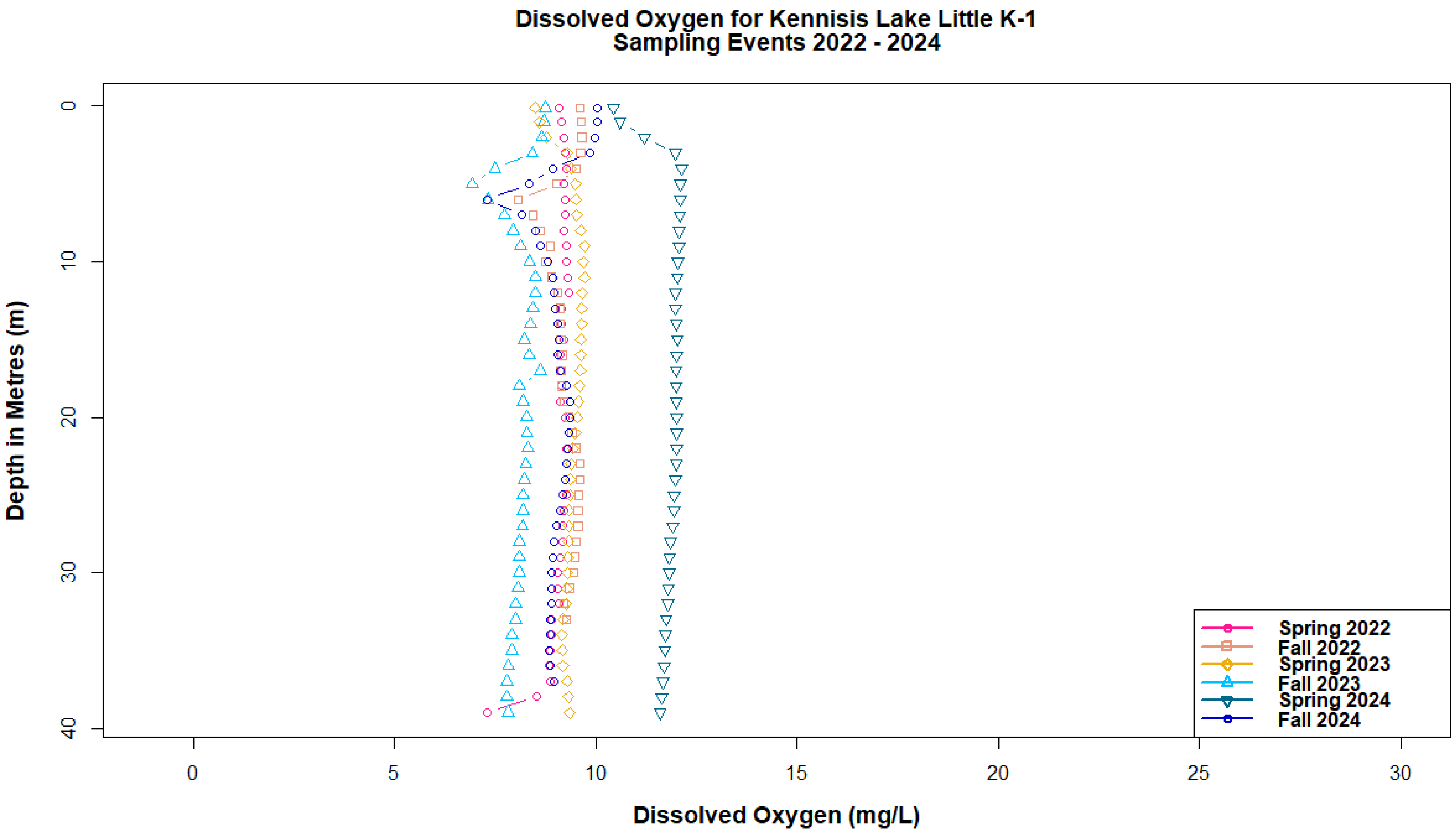


Figure 12c: Dissolved oxygen profiles for site LITTLE K-1 throughout monitoring program (2022-2024)

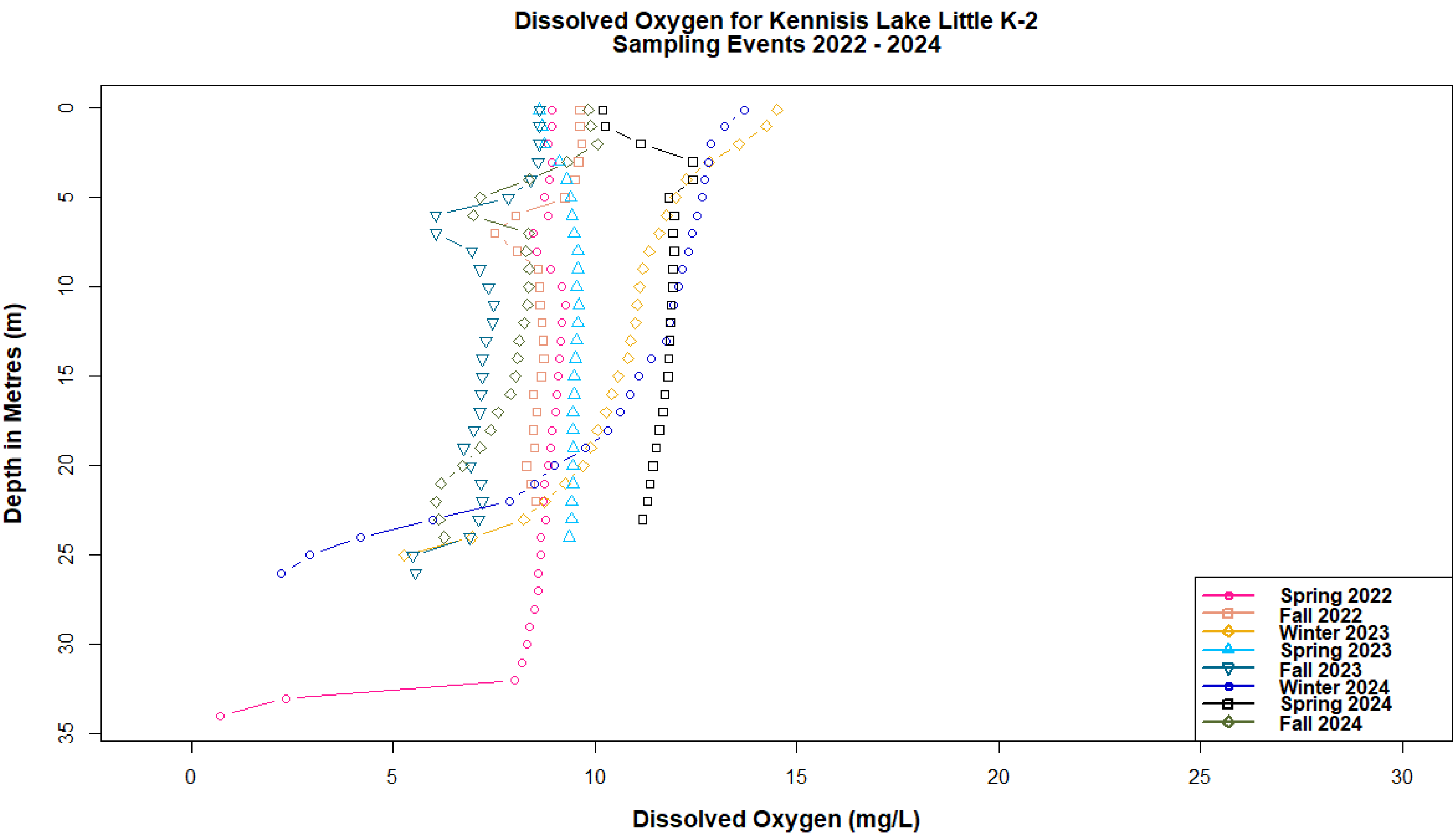


Figure 12d: Dissolved oxygen profiles for site LITTLE K-2 throughout monitoring program (2022-2024)

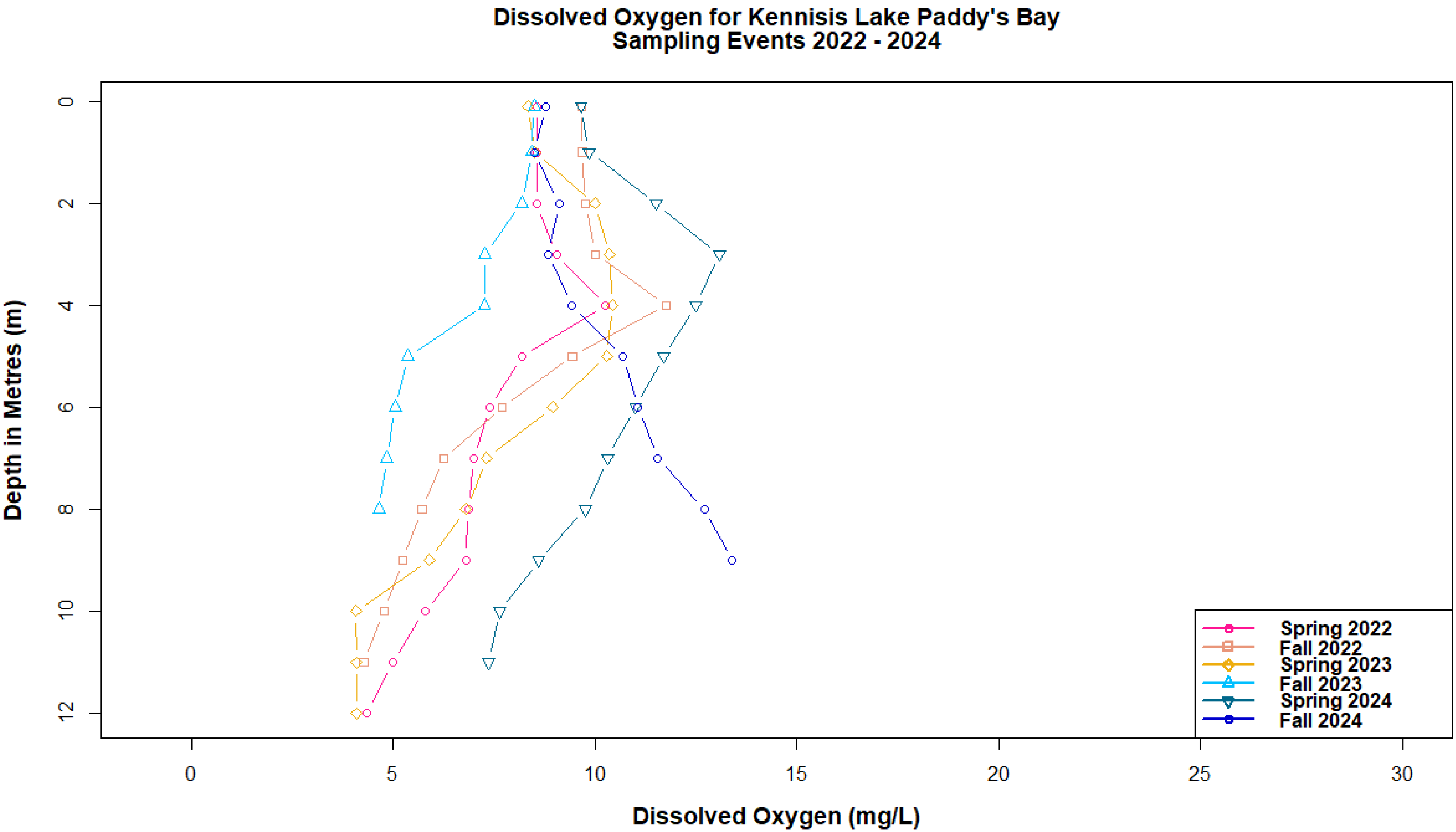


Figure 12e: Dissolved oxygen profiles for site Paddy's Bay throughout monitoring program (2022-2024)

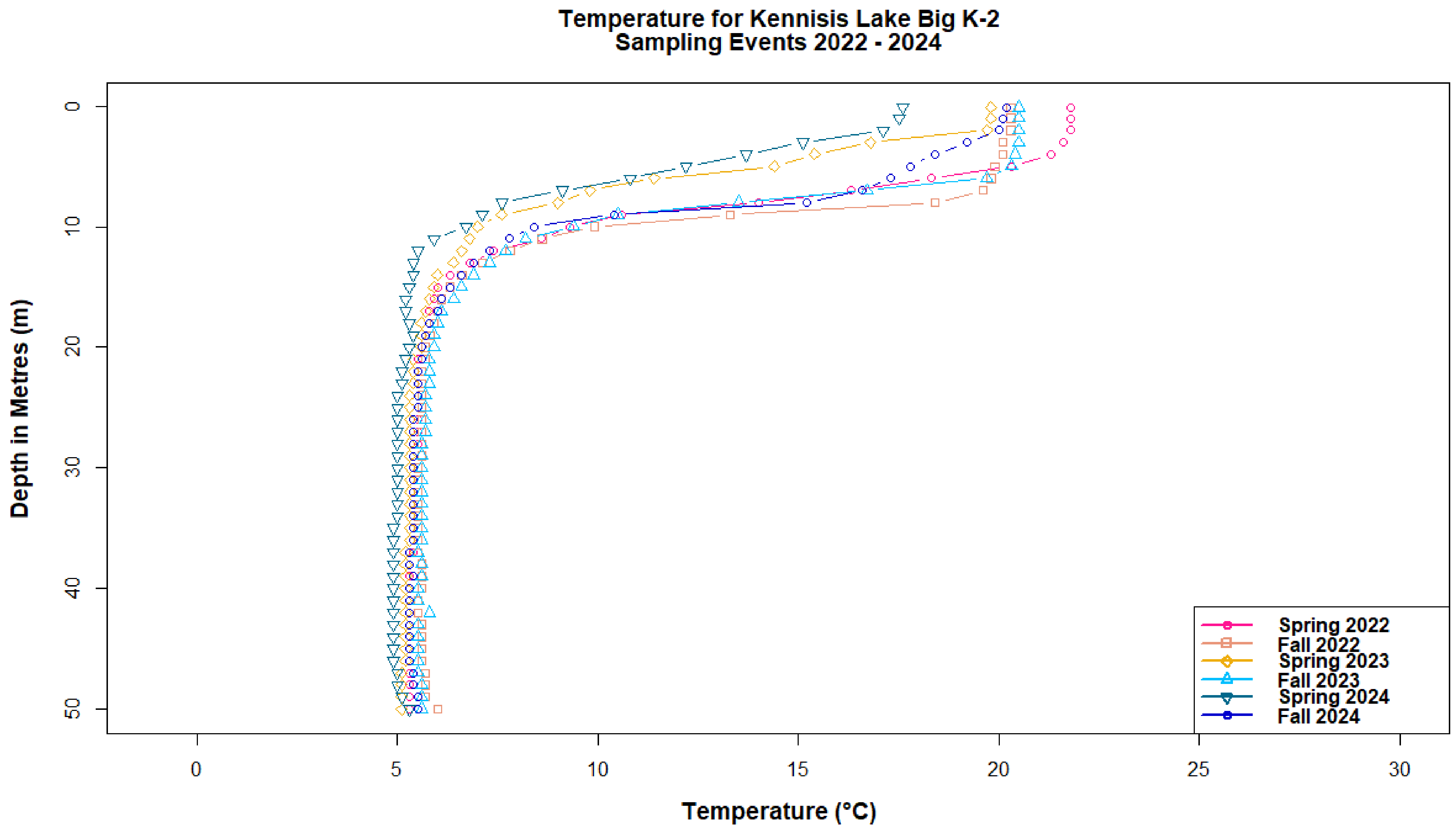


Figure 12f: Temperature profiles for site BIG K-2 throughout monitoring program (2022-2024)

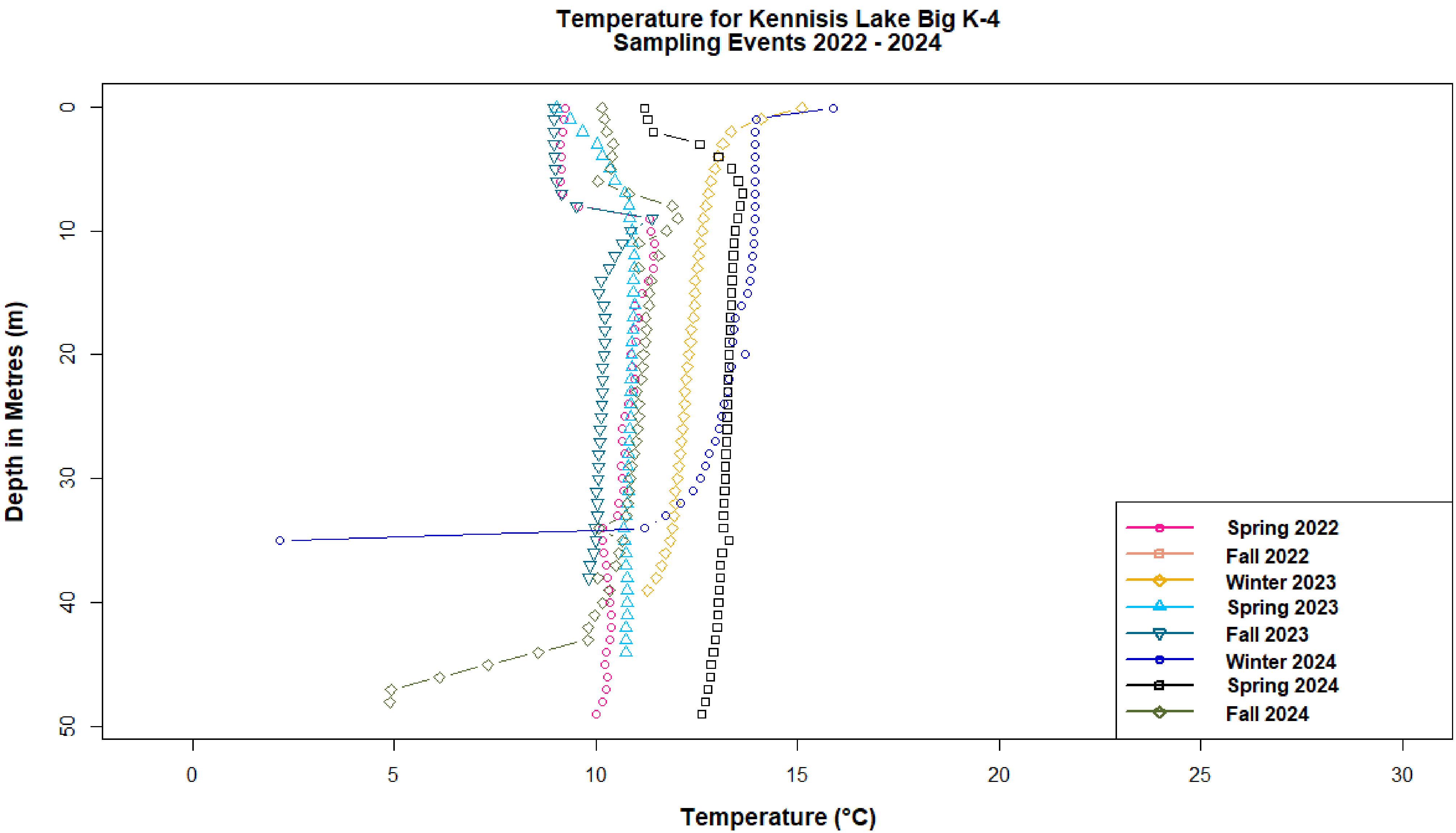


Figure 12g: Temperature profiles for site BIG K-4 throughout monitoring program (2022-2024)

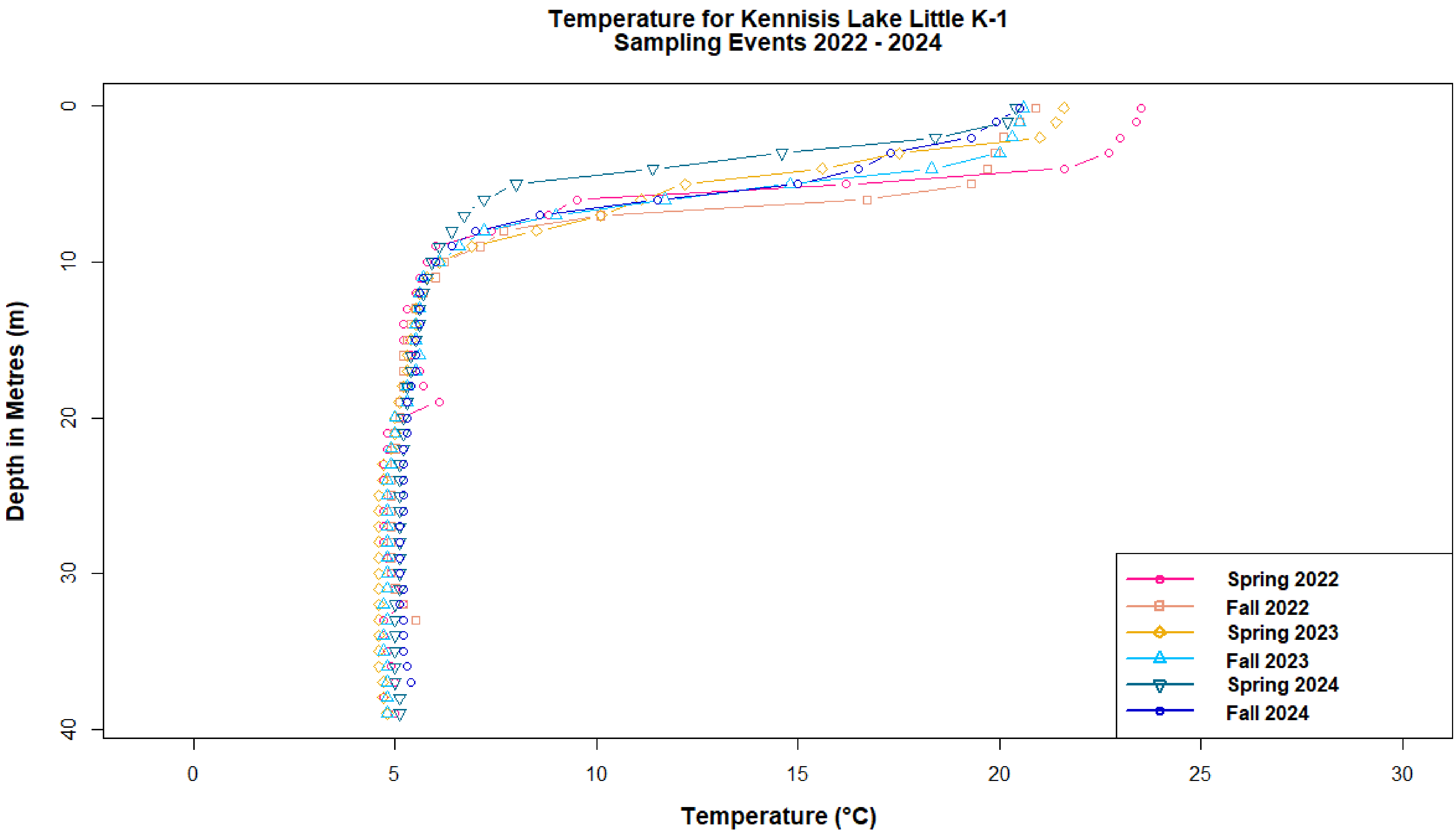


Figure 12h: Temperature profiles for site LITTLE K-1 throughout monitoring program (2022-2024)

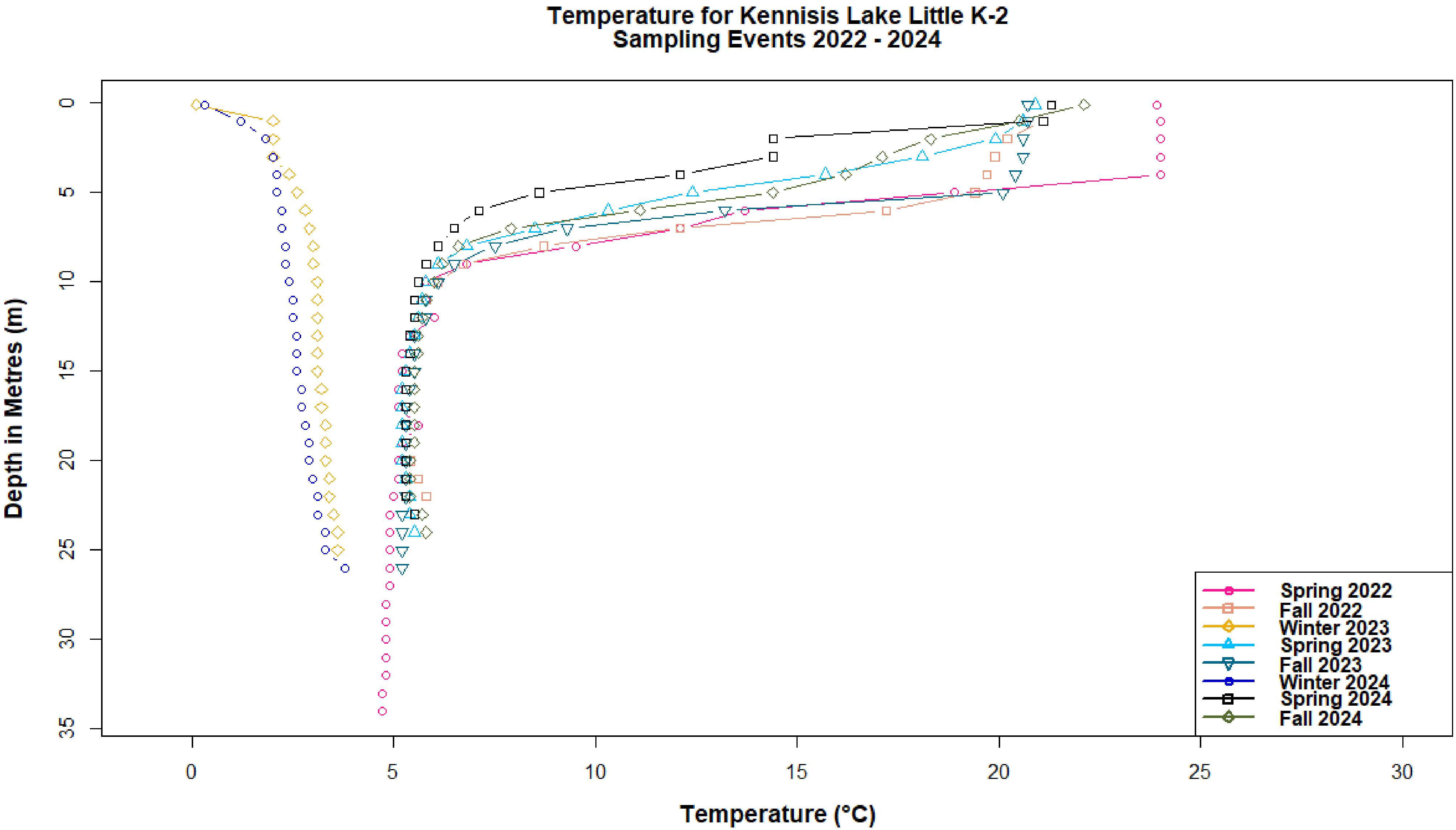


Figure 12i: Temperature profiles for site LITTLE K-2 throughout monitoring program (2022-2024)

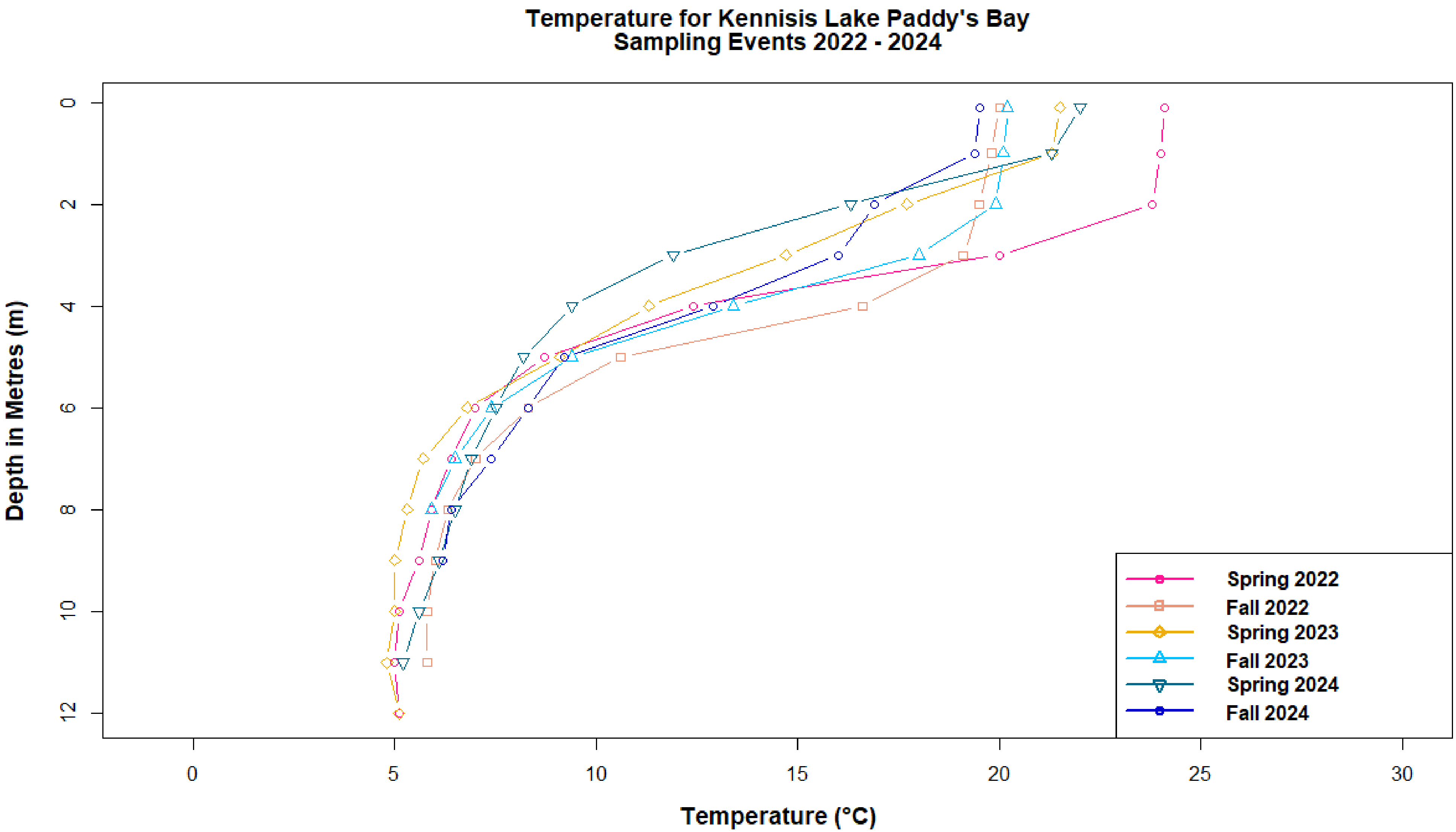


Figure 12j: Dissolved oxygen and temperature profiles on Kennisis Lakes sites throughout monitoring program (2022-2024).

Secchi Depth

Over the 2022 to 2024 monitoring period, Secchi depth data highlight changes in water clarity across Kennisis Lakes. Water clarity has generally been showing a declining trend across the program, with Secchi depths generally shrinking, particularly at sites with nutrient enrichment and algal activity BIG K-4 has consistently shown the greatest clarity, with Secchi depths often exceeding 6 metres, reflecting the lakes relatively low productivity and stable conditions. In contrast, LITTLE K-1 showed persistently lower clarity, especially during fall sampling periods (e.g. 2.9 m in fall 2023), which may be linked to localized nutrient loading, sediment inputs, or increased algal growth.

Seasonal patterns align with expected trends, showing improved water clarity in early spring when reduced temperatures and limited sunlight restrict algal growth. By summer and fall, clarity declines across most sites as biological productivity increases, driven by warmer conditions, longer daylight hours, and nutrient availability. A particularly sharp decline at Paddy's Bay in fall 2023 (2.75m) coincided with elevated TP levels and suspected algal blooms.

While the data from 2022 to 2024 reflects short-term fluctuations, long-term monitoring suggests an ongoing decline in Secchi depth over the past several decades. A linear regression analysis spanning 1992 to 2024 (Figures 13 & 14) is included in the Trends section and further illustrates this downward trajectory.

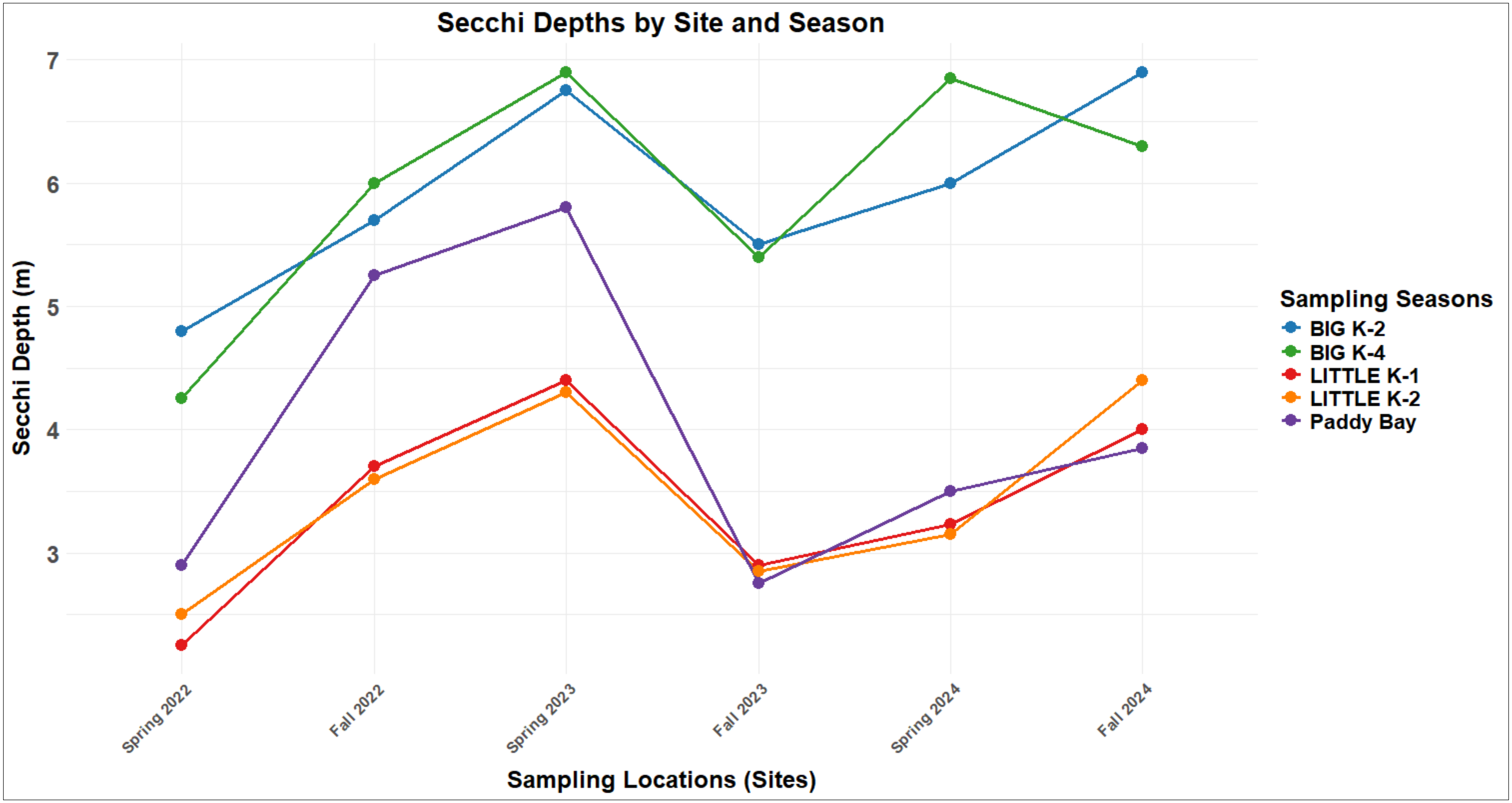


Figure 13 Secchi depth measurements in the Kennisis Lakes by year and season (2022-2024), showing a gradual decline in water clarity, with the highest depths recorded in 2022 and a levelling off in 2024.

Total Metals Analysis

The total metals analysis across sites on the Kennisis Lakes reveals several trends and points of interest regarding metal concentrations across the sampled sites. These measurements help identify areas where concentrations approach or exceed established guideline limits, providing valuable insight for ongoing water quality management, a brief summary of key highlights is below.

- Aluminium – The concentration at Paddy's Bay (0.0808) exceeds the guideline limit of 0.075 , making it the only site where aluminium levels surpass acceptable thresholds. This suggests a localized source of aluminium, potentially linked to soil erosion, runoff, or other anthropogenic influences. Given that elevated aluminium levels can be toxic to aquatic life, further investigation is recommended to identify the source and assess potential ecological impacts.
- Iron – Although iron concentrations remain below the guideline limit of 0.30 , Paddy's Bay exhibits the highest recorded value (0.197), significantly higher than at other sites. This trend suggests localized enrichment, which may be influenced by sediment inputs or natural geochemical variability. While not currently exceeding the limit, consistent monitoring at this site could help determine whether levels are trending upward over time.
- Cadmium – While cadmium concentrations are generally low across most sites, detectable levels at Little K-2 (0.00015 µg/L) and Paddy's Bay (0.00017 µg/L) exceed the guideline limit of 0.1 µg/L. These values, though slightly above the limit, highlight the importance of monitoring cadmium as it can accumulate in aquatic ecosystems, potentially posing long-term risks to aquatic organisms and overall water quality.
- Barium: A strikingly high value of 1.013 at Paddy's Bay contrasts with much lower concentrations at other sites. While still below the guideline limit of 2.0 , this result warrants further scrutiny, as elevated barium levels may indicate natural geological contributions or anthropogenic activities, such as runoff from nearby developments or infrastructure.
- Molybdenum: Detectable only at Paddy's Bay (0.00054), molybdenum is well below the guideline limit of 0.040 . However, its presence at this site alone raises questions about localized inputs, potentially from industrial, agricultural, or natural sources.

Table 4 in Appendix D of this report provides a detailed summary of the total metals analysis conducted for the Kennisis Lakes in 2024. This table includes measurements of 39 analytes across five sampling locations: BIG K-2, BIG K-4, LITTLE K-1, LITTLE K-2, and Paddy's Bay. Each analyte is presented alongside its guideline limit (where available), with corresponding concentrations measured at each site. The data highlights any exceedances of these limits, which may indicate localized environmental conditions or anthropogenic influences. This analysis serves as a valuable resource for understanding the baseline metal concentrations in the lakes and identifying potential areas of concern for water quality management.

Anomalies and Special Events

Haliburton County experienced unseasonably warm temperatures in 2024, with warmer conditions beginning earlier in the year than average and persisted longer into the fall. These unusual climatic patterns may be influenced by the El Niño phenomenon, which is known to drive warmer weather conditions and disrupt typical seasonal patterns.

Unseasonably warm weather can significantly impact water quality parameters, as evidenced by the data collected through this program. Elevated temperatures can lead to increased stratification in lakes, reducing oxygen levels in deeper waters and potentially causing **hypoxic** conditions. This stratification can also influence nutrient cycling, leading to higher concentrations of nutrients like phosphorus in surface waters – which may promote algal blooms [22]. Additionally, warmer temperatures can increase the metabolic rates of aquatic organisms, further altering the chemical composition of the water [23].

Trends

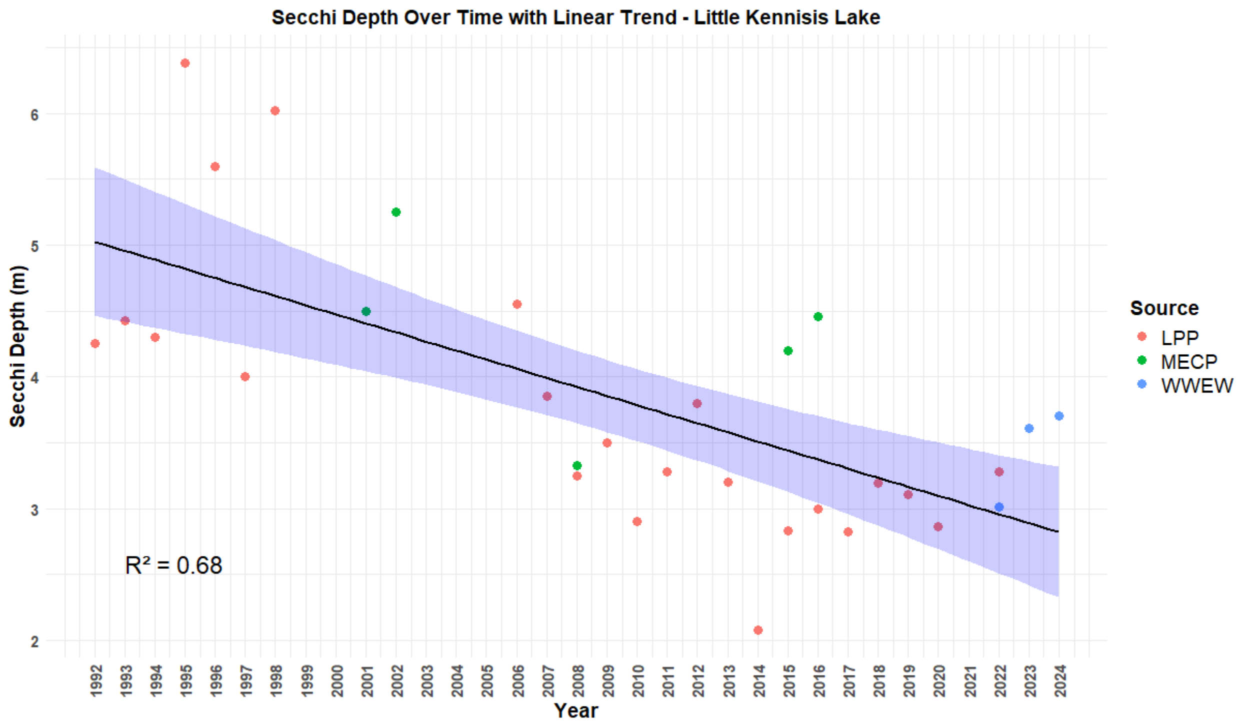
The following figures show a long-term linear trend for the Kennisis Lakes, using scatter points to represent measurements from various monitoring programs and a linear regression line superimposed to highlight changes over time. Historic data from multiple sources including:

- Ministry of Natural Resources and Forestry's Broad Scale Monitoring (BSM) program
- Ministry of Environment, Conservation and Parks (MECP) Lake Trout Lake Testing program
- Lake Partner Program (LPP)

- Woodlands and Waterways EcoWatch Testing the Waters program
- Kennisis Lake Cottage Owners' Association Independent Water Quality Sampling

Secchi Depth

Figure 14 Long term Secchi depth measurements in Little and Big Kennisis Lakes (1992-2024) showing a significant declining trend with R-Squared value of 0.68, based on data from multiple water quality programs.



Figures 15 Long term Secchi depth measurements in Little and Big Kennisis Lake (1992-2024) showing a significant declining trend with R-Squared value of 0.68, based on data from multiple water quality programs.

These figures show a clear declining trend in Secchi depth measurements for Little and Big Kennisis Lake over the past 32 years, with an R^2 value of 0.68 indicating a moderately strong correlation between time and decreasing water clarity. In the early 1990s, clarity exceeded 8m on average on Big Kennisis and 5m on average on Little Kennisis, however recent measurements are falling below 6m and 3m respectively. This consistent downward trend may reflect cumulative impacts of increased nutrient inputs (e.g. rising phosphorus) sedimentation or dissolved organic carbon, all of which reduce light penetration in the water column.

This trend is concerning, as reduced water clarity is often an early indicator of shifts to lake health and have cascading impacts on aquatic ecosystems, including reduced light availability for submerged vegetation and changes in both thermal and oxygen dynamics. This observed trend, and lack of data between 1992-2022 significantly highlights the need for continued, ongoing long-term monitoring.

pH

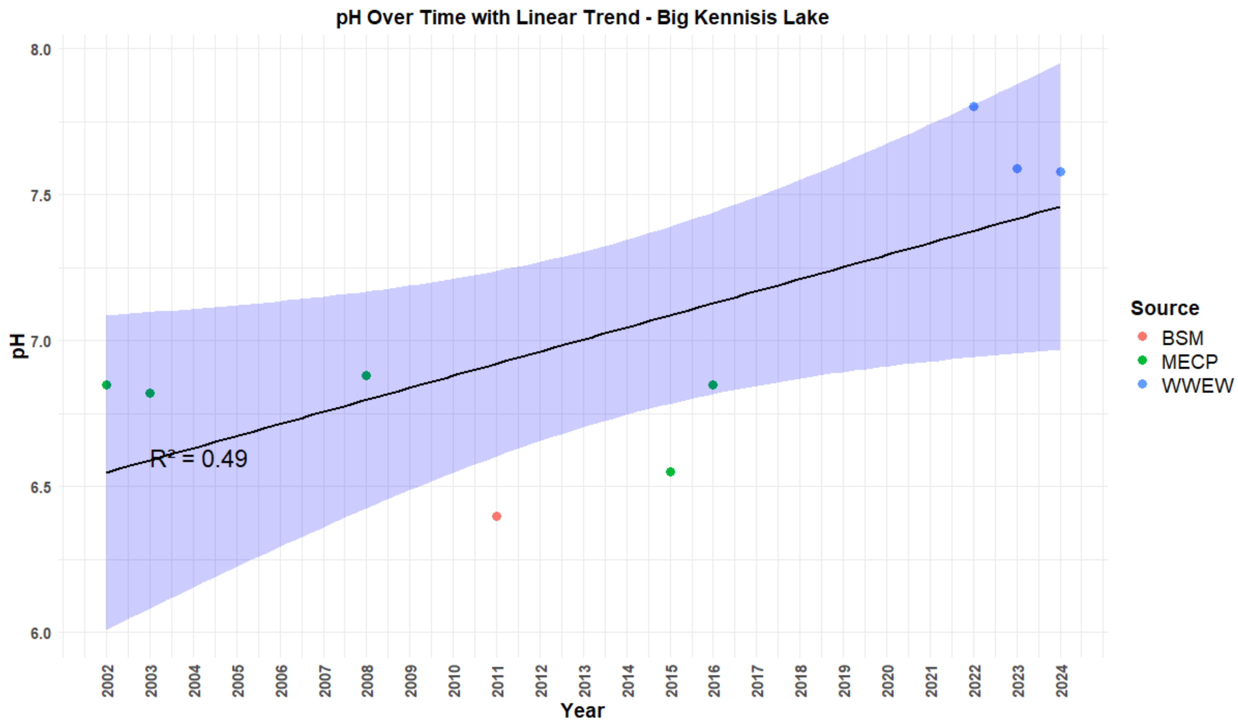


Figure 16 pH measurements in Big Kennisis Lake over time (2002-2024) with an insignificant upward trend (R-Squared=0.49), reflecting improving conditions and potential influences of reduced acid rain deposition.

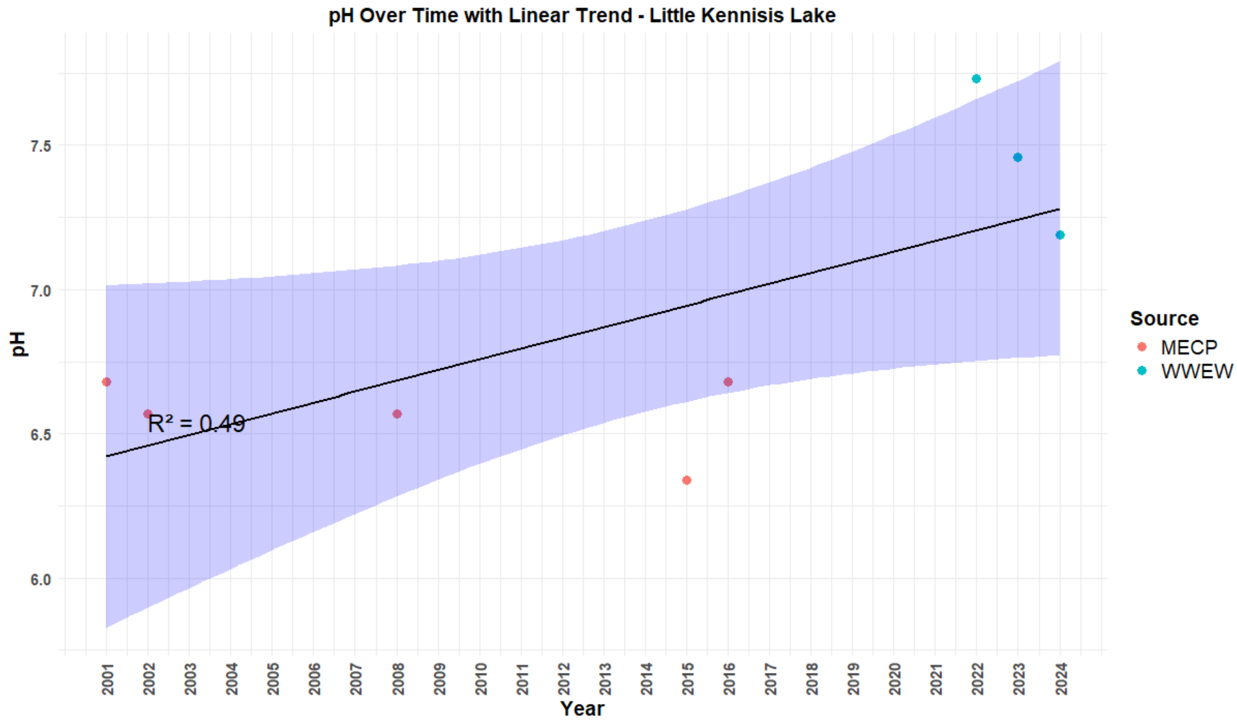


Figure 17 pH measurements in Little Kennisis Lake over time (2001-2024) with an insignificant upward trend (R-Squared=0.49), reflecting a improving conditions and potential influences of reduced acid rain deposition.

The above figures show an upward trend in pH measurements for Big and Little Kennisis Lake over the monitoring period of 2002-2024, and 2001-2024 respectively, with an R^2 value of 0.49 showing a weak positive correlation between time and increasing pH levels. Despite the weak correlation and low R squared value, the data still reflects an upward trend in pH values. Even the lowest values collected by WWEW in 2024 are significantly higher than some of the highest values collected outside WWEW in the past 2 decades. It is likely that more data collection in following years will further define this trend and increase the R squared value, further affirming the need for continued monitoring efforts. In the early 2000s, pH values were lower, averaging near 6.5 – indicative of more acidic conditions. Since then, pH values have steadily increased, reaching values above 7.5 in recent years. This trend may be influenced by several factors, including a decrease in acid rain deposition, which has been well-documented across North America due to improved air quality regulations. Climatic factors, such as increased temperatures and longer stratification periods, may also enhance biogeochemical processes that influence pH, including higher rates of primary production [24].

Total Phosphorus

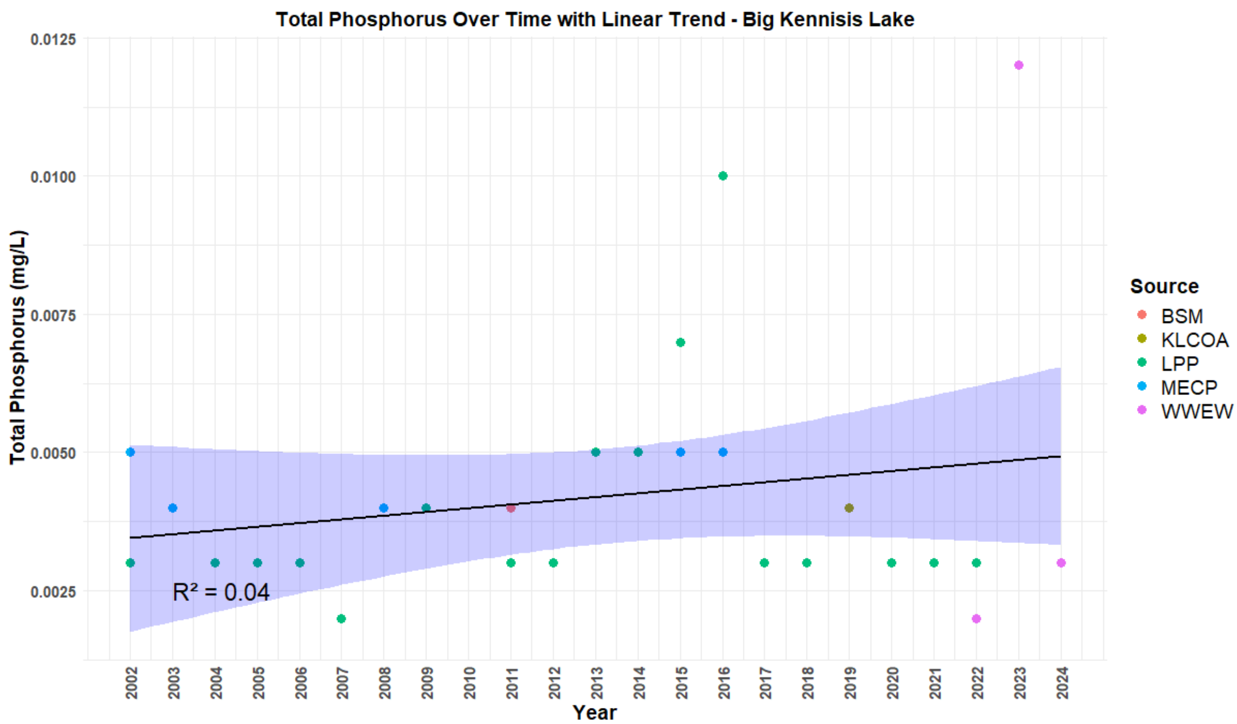


Figure 18 Total Phosphorus concentrations in Big Kennisis Lake over time (2002-2024), with data sourced from multiple water quality monitoring programs.

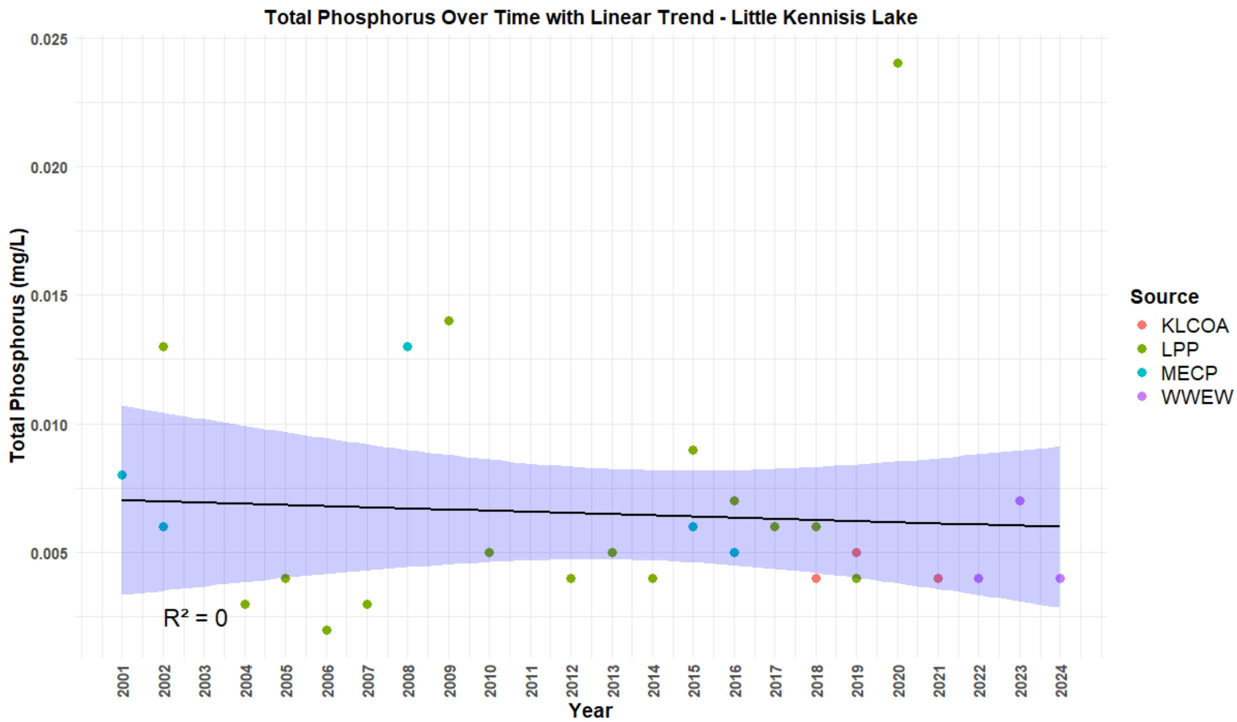


Figure 19 Total Phosphorus concentrations in Little Kennisis Lake over time (2002-2024), with data sourced from multiple water quality monitoring programs.

Figures 18 and 19. above shows TP concentrations over time for Big and Little Kennisis Lakes, spanning from 2002 to 2024, with data contributions from multiple sources including the WWEW program, MECP Lake Trout Lake Testing and Lake Partner Program. A linear regression analysis indicates a slight upward trend in TP concentrations across the monitoring period.

While TP values remain relatively low overall, staying primarily below the guideline limit of 0.01 mg/L, the slight upward trajectory reflects periodic spikes (e,g, 2015, 2016, 2023). These increases may be attributable to external factors such as watershed inputs (runoff, sediment disturbances) and internal loading during periods of turnover or algal growth. Notable outliers in 2016 and 2023 underscore the importance of episodic nutrient events that contribute to variability.

The inclusion of WWEW data from 2022 to 2024 provides a significant extension to the dataset, confirming sustained phosphorus levels but also highlighting the need for ongoing monitoring.

Program Future Goals

Tracking Ice-On / Ice-Off

Another valuable parameter to track is Ice-on and Ice-off events. An ‘ice-on’ event occurs when a lake is fully covered by a layer of ice that is thick enough to stand on, while an ‘ice-off’ event refers to when a lake becomes free of ice. Timing and duration of ice cover reflects the health of a watershed since freeze-thaw cycles are correlated to changes in air and water temperature [26]. This fluctuation is becoming more prevalent as a result of climate change. By reporting these events, patterns can be discerned and baselines for future assessments can be established. The most effective way to collect this information is through citizen science since reporting ice-on and ice-off events only requires a simple visual observation and no special equipment.

A case study for this kind of tracking is IceWatch [27], a division of NatureWatch. Anyone can visit this website to submit a reported event. Submission requirements consist of location (location name, coordinates, habitat type, and province), observation date, and nature of ice event (ice on, ice off, or no ice). Optional criteria to submit includes air temperature, photo upload, and notes.

While there is some data available for Haliburton County, it is very sporadic and incomplete. Many lakes feature only one reported incident or have only one type of ice event being reported (ie reporting ice-on but not ice-off, and vice versa) which doesn’t allow for historical trends to be mapped.

For WWEW’s application, it's possible to either report events to a county-specific project through an existing program or create an independent program, emulating the existing models. Ultimately, this endeavour will commence April 2025.

Future monitoring recommendations

- Expansion of reference lakes - should be a phrased to reflect our programs ‘questions’: impacts of:
    - Drawdown Lakes - prioritizing lakes that experience drawdown
    - Development status of lakes - prioritizing minimally developed

To broaden our understanding of water quality dynamics, we intend to expand our reference lake set beyond Stocking Lake. Specifically, the focus will extend to incorporating lakes that do not experience controlled water fluctuations, providing a unique opportunity to assess the impact of drawdowns via the Trent Severn Waterway system.

Conclusion

The 2024 water quality monitoring program for the Kennisis Lakes has provided critical insights into the current state of the lakes physical and chemical parameters, while also contributing to a growing long-term dataset that supports trend identification and future management decisions. Throughout the sampling program, parameters such as alkalinity, sulfate, and pH exhibited stability, largely remaining within guideline limits, reflecting a well-buffered system. However, notable fluctuations in nutrient concentrations, particularly phosphorus and nitrogen, highlight both external disturbances and seasonal dynamics influencing water quality.

Key events, such as the August 2023 beaver dam failure, and subsequent sediment inputs, were linked to elevated phosphorus levels and reduced water clarity, particularly at Paddy's Bay and Little Kennisis Lake. While phosphorus levels have since begun to stabilize in 2024, their year by year increase underscores the need for vigilance, as sustained nutrient enrichment can propel algal growth and long-term ecosystem degradation. Ammonia concentrations similarly revealed site-specific spikes, suggesting influences from sediment release, runoff and delayed turnover dynamics driven by unseasonably warm conditions.

Water clarity, measured via Secchi depth continues to show a downward trend, aligning with long-term regression analyses spanning 1992-2024. This decline likely reflects cumulative impacts of nutrient loading, sedimentation and increased algal biomass. Such trends, while gradual, serve as early indicators of emerging challenges that necessitate ongoing monitoring and adaptive management strategies.

The data collected over the 2022-2024 monitoring period not only establishes a robust baseline for understanding the Kennisis Lakes current state but also highlights the interconnectedness of climatic conditions, external disturbances, and internal lake processes. Moving forward, the continuation of this program remains essential for detecting and addressing changes in water quality, supporting informed decision-making, and fostering community stewardship through citizen science participation. By expanding monitoring protocols, enhancing data precision and integrating long term trends, the Woodlands and Waterways EcoWatch – Testing the Waters program reaffirms its commitment to protecting Haliburton County's water resources for generations to come.

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Appendices

Appendix A - Glossary

Anoxic: This describes water with no oxygen, often found in areas called “dead zones”, where most aquatic life cannot survive.

Cyanobacteria: Tiny, photosynthetic bacteria found in water. Under the right conditions, they will grow rapidly into large groups called blooms.

Effluent: Wastewater or liquid byproducts from sewage systems or industry that often end up in lakes, rivers or other waterbodies.

Epilimnion: The upper layer of a lake that gets the most sunlight. This layer is warmer, less dense, and usually has more oxygen than the deeper layers.

Eutrophic lakes (Eutrophication): Lakes with high nutrient levels that lead to an increase in organic matter. As this matter breaks down, it uses up oxygen, creating areas without enough oxygen for most aquatic life.

Humification: The process of turning plant material ,like leaves and stems, into decomposed organic matter.

Hypoxic: Describes water with very low oxygen levels, which makes it hard for aquatic life to survive.

Hypolimnion: The deepest, coldest, and densest layer of a lake that does not mix with the water above it.

Ice-off: The date when a lake is completely free of ice.

Ice-on: The date when a lake is fully covered with a layer of ice thick enough to be considered safe, usually above 6 inches.

Ionic Strength: This measures how many charged particles (ions) are in thee water. High ionic strength can make it harder for aquatic life to get the nutrients, minerals and oxygen they need.

Lake Turnover: A natural mixing process in lakes that happens when surface water cools, becomes heavier, and sinks, mixing with the water below. Wind can also help with this mixing.

Leaching: The process where water drains chemicals or minerals out of the soil and carries them away.

Photic zone: The top layer of water in a lake or ocean that gets enough sunlight for plants and algae to grow through photosynthesis.

Thermal Stratification: The formation of distinct temperature layers in a lake due to sunlight. Lakes usually have three layers: the warm surface layer (epilimnion), the colder bottom later (hypolimnion), and the middle layer where the temperature changes quickly (metalimnion).

Thermocline: The layer in a lake where the temperature drops rapidly, separating the warm upper layer from the cold bottom layer.

Appendix B - Example Watershed Report Card

The watershed report card example can be found at this link, or by scanning the QR Code below.

Appendix C – ALS Laboratories Limit 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
Nitrate	0.020
Nitrite	0.010
Sulfate	0.30
Total Kjeldahl Nitrogen	0.050
Total Phosphorus	0.0020

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 D – Total Metals Data Table for Kennisis Lakes

Table 4 in Appendix D of this report

*Table 4 – Result values per site sampled on Kennisis Lake from Total Metals Analysis (Laboratory method E-420), all guideline limits and resulting values are reported in mg/L. **[Include reference numbers to literature sourced guideline limits here]**.*

Analyte	Guideline Limit	BIG K-2	BIG K-4	LITTLE K-1	LITTLE K-2	PADDY'S BAY
Aluminium (mg/L)	0.075	0.0148	0.0132	0.0462	0.0470	0.0808
Antimony (mg/L)	0.020	<LOR	<LOR	<LOR	<LOR	<LOR
Arsenic (mg/L)	0.0005	0.00015	0.00015	0.00021	0.00022	0.00019
Barium (mg/L)	2.0	0.0119	0.0119	0.0136	0.0136	1.0130
Beryllium (mg/L)	0.011	<LOR	<LOR	<LOR	<LOR	<LOR
Bismuth (mg/L)	0.01	<LOR	<LOR	<LOR	<LOR	<LOR
Boron (mg/L)	0.20	<LOR	<LOR	<LOR	<LOR	<LOR
Cadmium (µg/L)	0.1 µg/L	<LOR	<LOR	0.09 µg/L	0.15 µg/L	0.17 µg/L
Calcium (mg/L)	1.5 - 20	2.01	2.02	1.88	1.84	1.96
Cesium (mg/L)	Not Available	<LOR	<LOR	<LOR	<LOR	<LOR
Chromium (mg/L)	0.001	<LOR	<LOR	<LOR	<LOR	<LOR
Cobalt (mg/L)	0.009	<LOR	<LOR	<LOR	<LOR	<LOR

Copper (mg/L)	0.001	0.00056	0.00051	0.00058	0.00064	0.00063
Iron (mg/L)	0.30	0.014	0.013	0.086	0.097	0.197
Lead (mg/L)	0.001	<LOR	<LOR	<LOR	<LOR	<LOR
Lithium (mg/L)	0.00015	<LOR	<LOR	<LOR	<LOR	<LOR
Magnesium (mg/L)	Not Available	0.486	0.475	0.454	0.446	0.432
Manganese (mg/L)	0.12	0.00301	0.00279	0.00626	0.00622	0.0104
Molybdenum (mg/L)	0.040	<LOR	<LOR	<LOR	<LOR	0.00054
Nickel (mg/L)	0.025	<LOR	<LOR	<LOR	<LOR	<LOR
Ortho-phosphorous (mg/L)	0.020	<LOR	<LOR	<LOR	<LOR	<LOR
Potassium (mg/L)	Not Available	0.478	0.414	0.378	0.381	0.353
Rubidium (mg/L)	Not Available	0.00123	0.00132	0.00123	0.00140	0.00152
Selenium (mg/L)	0.010	<LOR	0.000056	0.000058	0.000076	0.000068
Silicon (mg/L)	Not Available	0.79	0.80	1.28	1.25	1.36
Silver (mg/L)	0.010	<LOR	<LOR	<LOR	<LOR	<LOR
Sodium (mg/L)	Not Available	0.874	0.853	0.756	0.754	0.587
Strontium (mg/L)	7.0 mg/L	0.0212	0.0212	0.0185	0.0186	0.0216

Sulfur (mg/L)	250	0.95	1.01	0.92	1.22	0.64
Tellurium (mg/L)	0.1	<LOR	<LOR	<LOR	<LOR	<LOR
Thallium (mg/L)	0.003	<LOR	<LOR	<LOR	<LOR	<LOR
Thorium (mg/L)	Not Available	<LOR	<LOR	<LOR	<LOR	<LOR
Tin (mg/L)	Not Available	<LOR	<LOR	0.00019	0.000281	<LOR
Titanium (mg/L)	Not Available	<LOR	<LOR	<LOR	0.00064	<LOR
Tungsten (mg/L)	0.030	<LOR	<LOR	<LOR	<LOR	<LOR
Uranium (mg/L)	0.005	0.00001	<LOR	0.000018	0.000017	0.000081
Vanadium (mg/L)	0.006	<LOR	<LOR	<LOR	<LOR	<LOR
Zinc (mg/L)	0.030	<LOR	<LOR	<LOR	<LOR	0.0035
Zirconium (mg/L)	0.004	<LOR	<LOR	<LOR	<LOR	<LOR

Appendix E – ALS Chemical Analysis Methodology

Table 5: 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)	Waterloo – Environmental	Water	APHA 4500-P E (mod).	Total Phosphorus is determined colourimetrically using a discrete analyzer after heated persulfate digestion of the sample.
Total Metals (Matrix: Water)					
E420	Total Metals in Water by CRC ICPMS	Waterloo - Environmental	Water	EPA 200.2/6020B (mod)	Water samples are digested with nitric and hydrochloric acids,and analyzed by Collision/Reaction Cell ICPMS. Method Limitation (re: Sulfur): Sulfide and volatile sulfur species may not be recovered by this method.
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.					