Environmental Services

Swan Lake Water Quality Monitoring
2024 Annual Report

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MARKHAM

Swan Lake Monitoring Program
2024 Annual Report

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List of Acronyms

DO	Dissolved Oxygen
DOC	Dissolved Organic Carbon
GIS	Geographic Information System
LED	Light Emitting Diode
MASL	Meter Above Sea Level
MDL	Method Detection Limit
OGS	Oil and Grit Separator
OMNRF	Ontario Ministry of Natural Resources and Forestry
PAC	Poly Aluminum Chloride
SAV	Submerged Aquatic Vegetation
TKN	Total Kjeldahl Nitrogen
TP	Total Phosphorus
TRCA	Toronto and Region Conservation Authority
VAC	(Swan Lake) Village Amenities Committee
WHO	World Health Organization

Executive Summary

Background

Swan Lake is situated in the City of Markham at the intersection of Sixteenth Avenue and Williamson Road. Swan Lake has an approximate area of 5.5 ha and a maximum water depth of 4.5 m (from the edge of the Lake at 210 meter above sea level). A gravel pit in the 1960s and 1970s, Swan Lake is currently a community feature with multiple trails and urban development surrounding it.

Several issues were discovered with Swan Lake in 2010, including high phosphorus levels and significant algal blooms during the summer months, which led to low oxygen levels and degraded fish habitats. A Phoslock treatment was administered in 2013 to reduce the phosphorus levels and algal blooms in Swan Lake.

In 2019, the City of Markham conducted a study to define a Water Quality Management Strategy for Swan Lake. The Strategy, finalized in July 2020, recommended a chemical treatment in 2021. In August 2021, 13 tonnes of Poly Aluminum Chloride (PAC) were applied to the Lake in a controlled manner over several days.

The Swan Lake Long-Term Management Plan, which was developed based on the 2019 Strategy and extensive consultation with stakeholders, was received by the Markham Sub Committee in November 2021 and approved by the Council in December 2021. It describes a phased adaptive approach, including Core, Complementary and Alternative measures, and periodic reviews to adapt the Plan to the Lake conditions.

In 2024, all Core measures were implemented as planned, including a second application of PAC based on the treatment plan developed by our consultant, AECOM. About nine tonnes of PAC was applied over two application events in late June, with each application event separated by one or two days of downtime to allow for floc formation and environmental testing.

Additional submerged aquatic vegetation was planted in the Lake following PAC application. It is expected that the relative water clarity would help establish the plants, which in turn will improve water clarity further. A geese management program, and a fish inventory and the removal of bottom-dwelling fish were completed in 2024 similar to previous years.

A Flow Diversion feasibility study and a chloride treatment pilot project continued in 2024.

Water quality monitoring of Swan Lake has been conducted almost annually since the first treatment in 2013 to track water quality and the continued effectiveness of the treatment. The collected data presented in this report is part of the ongoing monitoring program that will allow for continuous assessment of the water quality in Swan Lake and will be used to implement and adapt the Long-Term Management Plan for Swan Lake.

This report discusses observations at the monitored stations in the Lake throughout 2024.

Results- Lake Water Quality

Water quality is regularly monitored at two shoreline sites: the Dock and the Bridge, on a bi-weekly basis (from April to November). Samples and measurements are taken at 0.5 m or 1 m increments for the depth of the lake. A level logger is used to record the water level in the Lake. A Dissolved Oxygen (DO) logger was also installed 1 m from the Lake bottom to record the diurnal changes in DO.

Trent University collected samples and launched loggers in Swan Lake in the summer of 2024 to support a study on the environmental fates of lanthanum from La-modified bentonite in the ecosystem of Swan Lake. Data provided by Trent researchers have been incorporated in this report.

The following paragraphs provide the monitoring results for the 2024 monitoring period, as well as annual summaries of available data from 2016 to 2024. The figures include plots of measured DO, water clarity, phosphorus concentration, chloride concentration, and geese count.

Targets

Phosphorus concentration and clarity were compared to the eutrophication thresholds and/or the interim targets developed for Swan Lake through the 2019 Water Quality Management Strategy. For DO and chloride, Federal and/or Provincial water quality Guidelines or Objectives are shown for perspective. It should be noted that Swan Lake is not a natural waterbody, and there is no requirement for it to comply with these guidelines and objectives. Where technically and economically feasible, the City will aim to meet these guidelines and objectives to protect and enhance the aquatic environment.

Dissolved Oxygen (DO), Temperature, and pH

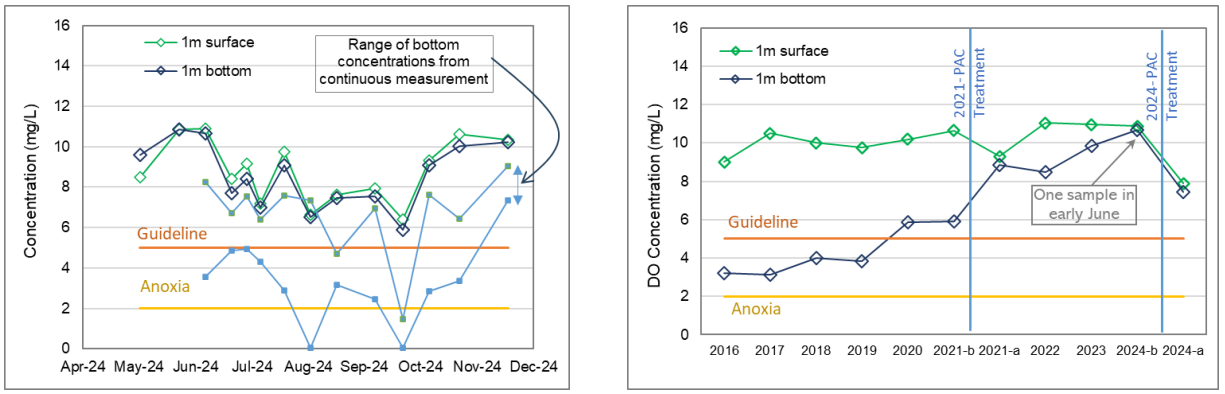
The minimum dissolved oxygen concentration required for the protection of warm water fish is 5 mg/L for water temperatures up to 20 °C, and 4 mg/L for temperatures above 20 °C. DO concentrations for the 1m from the surface and 1m from the bottom layers are shown below.

Day-time concentrations measured during biweekly visits were above the DO guideline (above 6.4 mg/L at the surface and above 5.9 mg/L at 1 m from the bottom).

While measured daytime DO levels did not indicate anoxia during the sampling events, continuous measurements at the Dock as well as at the deepest point in the lake (i.e., monitored at a logger commissioned by Trent University) showed a decline in bottom water DO about 50% of the time during August and September, when a dry and warm period followed a wet summer. These declines could have led to periodic anoxic episodes, increasing the potential for nutrient release from the sediments. However, the PAC treatments effectively bind phosphorus in the sediments, preventing its release even under anoxic conditions. Monitoring data support this effect, as surface and bottom phosphorus concentrations do not indicate anoxia-driven phosphorus enrichment, and overall bottom water DO has improved since the PAC treatments.

Lower DO concentrations could have lethal or sub-lethal (physiological and behavioral) effects on fish; however, some fish can acclimate to lower oxygen levels and survive concentrations between 1 and 3 mg/L. During anoxic episodes, which are temporary and restricted to the bottom of the water column, they can also avoid low oxygen conditions.

Figure ES-2: 2024 Monitoring Results and 2016-2024 Annual Results- Dissolved Oxygen



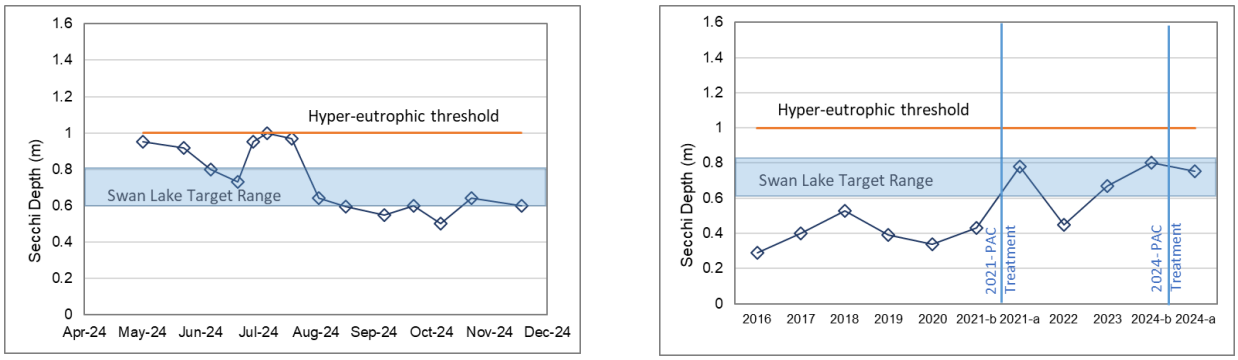
Note 1: DO concentrations are shown at 1 m from the surface (average of 0.5 and 1 m) and 1 m from the bottom (average of two bottom depths). The range shown (light blue lines) is minimum and maximum daily concentrations from the two loggers at the Dock and the deepest point for the sample collection days. DO trends logged in days between sampling days are not reflected in the plot.
Note 2: Historical data are shown for the average growing period (June-Sep) unless otherwise indicated. Data before 2016 are not shown for legibility.

The pH measured at the lab was about 8 throughout the year. High pH is consistent with high levels of algae. Algae take up carbon dioxide, a weak acid, from the water for photosynthesis, causing the water to become more basic (higher pH).

Water Transparency (Secchi Depth)

Secchi depth represents water transparency, which declines when the algae level increases. In the trophic state classification scheme, growing period average water clarity of under 1 m is the threshold for a hyper-eutrophic condition. The proposed interim target for Swan Lake is 0.6-0.8 m based on correlation with the phosphorus target. In 2024, the average water clarity during the growing season was within the target, with occasional declines to 0.5 m later in the fall.

Figure ES-3: 2024 Monitoring Results and 2016-2024 Annual Results- Secchi Depth

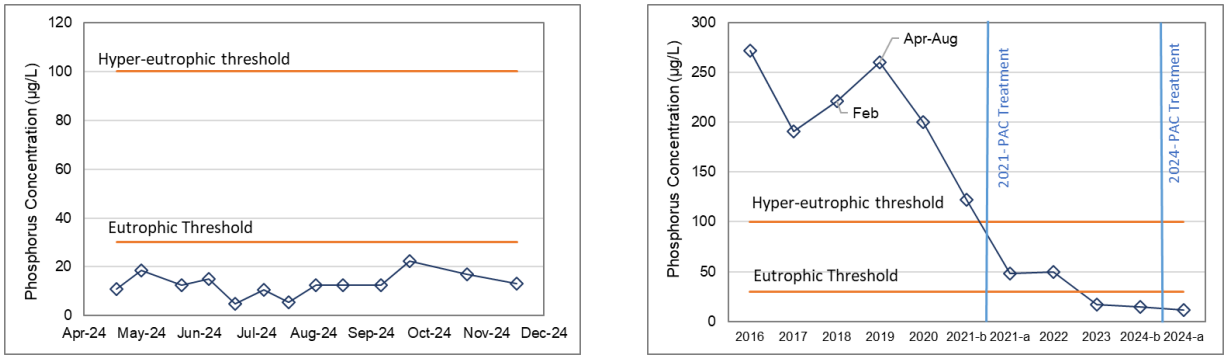


Phosphorus and Nitrogen Concentrations

Phosphorus concentration is the most important indicator of the trophic state in Swan Lake. It is an indication of how prone the Lake is to algae growth.

Phosphorus concentrations above 100 µg/L represent a hyper-eutrophic condition, which lead to high algae concentrations. In 2024, total phosphorus concentration in the top 0.5 and 1.5 m depths averaged under 12 µg/L during the growing season (under the 30 µg/L threshold for eutrophic condition, and well below the interim target of 50-100 µg/L). There was significant improvement in phosphorus concentrations after treatment by PAC.

Figure ES-1: 2024 Monitoring Results and 2016-2024 Annual Results- Total Phosphorus



Note 1: The 2024 values are averages of samples collected at 0.5 and 1.5 m from the surface.
Note 2: Annual concentrations are summaries of the growing period (June-Sep) unless otherwise indicated.

In 2024, total nitrogen concentrations over the growing season averaged about 0.52 mg/L (below the 0.65 mg/L threshold for a eutrophic condition). In 2024, ammonia and nitrate concentrations (the forms available for uptake by biota) were generally very low (except in September and November), and nitrogen was mainly present in its organic form.

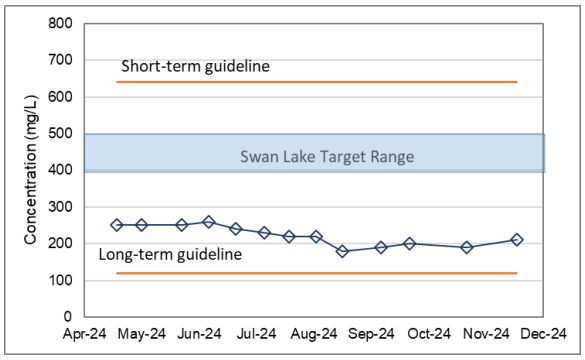
Chloride Concentration

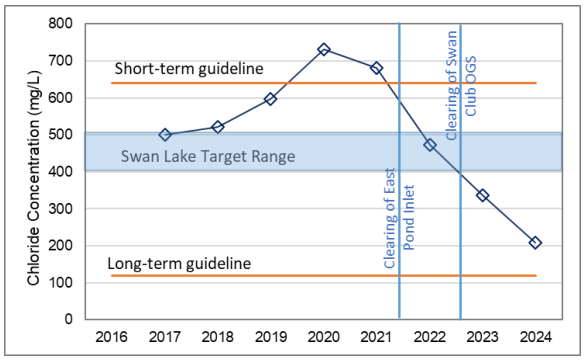
Chloride concentration has been increasing in urban lakes as a result of de-icer application for winter maintenance of roads and walkways. Chloride does not biodegrade, readily precipitate, volatilize, or bioaccumulate. It does not adsorb readily onto mineral surfaces and therefore when introduced, concentrations remain high in surface water.

Chloride guidelines developed for generic environmental data include a long-term guideline (120 mg/L) and a short-term guideline (640 mg/L). The long-term guideline has been developed to protect all organisms (present in Canadian aquatic systems) against negative effects during chronic indefinite exposure. The short-term guideline aims to protect most species against lethality during a sudden hike in chloride concentration for an acute short period (24-96 hrs). These guidelines may be over-protective for areas with an elevated concentration of chloride and associated adapted ecological community. For such circumstances, it has been suggested that site-specific (higher) targets be derived considering local conditions such as water chemistry, background concentrations, and aquatic community structure. The site-specific interim target for chloride for Swan Lake is 400-500 mg/L consistent with 2013-2014 values.

In 2024, chloride levels were below the target and declined considerably compared to previous years, continuing previous declines observed since 2020.

Figure ES-4: 2024 Monitoring Results and 2016-2024 Annual Results- Chloride



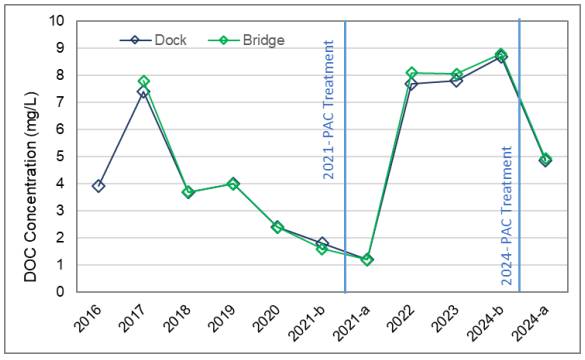


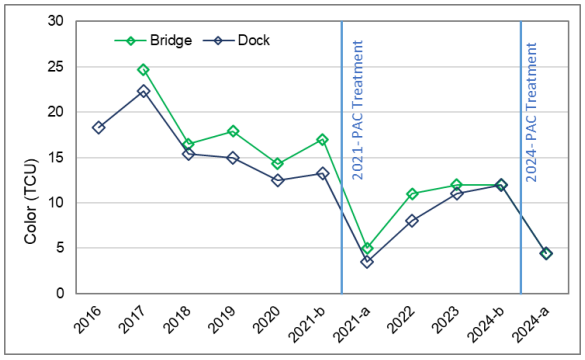
In 2024, water samples were collected from various inlets to the Lake and analyzed for chloride. These data will be used to update the chloride mass balance following the completion of the Flow Diversion Feasibility Study currently underway.

Dissolved Organic Carbon and Color

Dissolved organic carbon (DOC) and colour indicate the organic content of lake water. In 2024, DOC ranged between 4 and 9 mg/L, with color change from 3 to 12 TCU at both stations. DOC in 2022 and 2023 was considerably higher than in previous years, even before treatment. The increase may potentially be associated with the remnants of Phragmites in the Lake, as the roots were not removed. Both color and DOC declined sharply in 2024 following the PAC treatment, which precipitates organic matter.

Figure ES-5: 2016-2024 Annual Results- DOC and Color





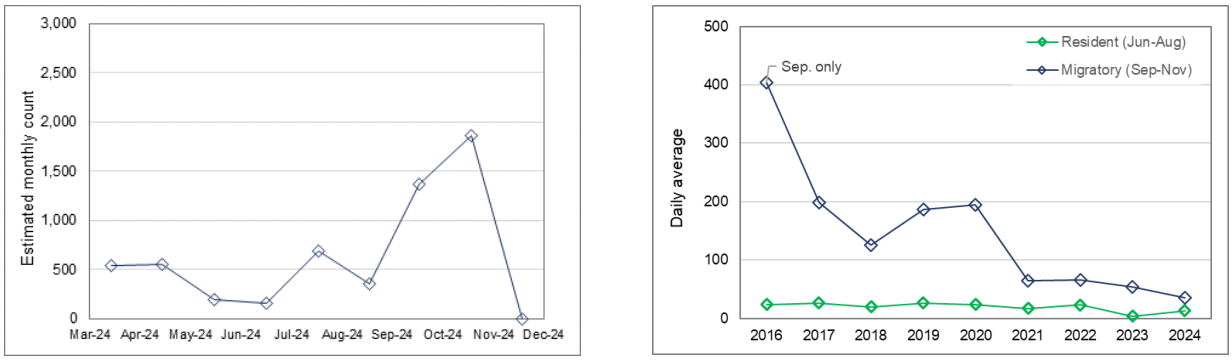
Geese Count

Geese are the primary external source of nutrients in the Lake. Therefore, active geese management is completed annually. The geese control program started in 2014, focusing on resident geese. The program extended to the management of migratory geese in 2016.

The 2024 program focus of control was laser light, avian distress call and limited strategic zinc crackler pyro, as well as geese relocation. A laser emitter was installed on the south island emitting at 1 ft above water surface to prevent overnight goose populations from accumulating in Swan Lake.

The 2024 efforts were very effective in reducing the number of migratory geese visiting the Lake, further lowering the counts. The geese count data helped provide more certainty in the results, and were used to more effectively schedule hazing efforts.

Figure ES-6: 2024 Monitoring Results and 2016-2024 Annual Results- Geese Count



Note 1: 2024 data are the sum of counts in each month, compensated for days with no count.
Note 2: Annual trends are shown as daily averages of counts over June-August and September to November, representing resident and migratory geese, respectively.

Fish Inventory

A fish inventory and removal campaign were completed to remove bottom-dwelling fish, which could interfere with the chemical treatment efficacy. A limited number of fish species were caught in the Lake through this intensive effort: Common Carp (non-native), Brown Bullhead, and Fathead Minnow, as well as Goldfish and a hybrid of Carp/Goldfish.

Algal Growth

In 2024, very limited surface scums were observed along the shoreline around the Dock, as well as in the northern bay at the Bridge site. While the Lake was dominated by phytoplankton from late June, surface scums were not widespread.

Samples were collected and sent to the laboratory for phytoplankton analysis. Test results showed higher diversity and 37 to 44 percent lower cyanobacteria count compared to 2023 at the Dock and the Bridge stations, respectively.

Five samples were analyzed for phytoplankton between May and November. The total cyanobacteria cell count was below or close to Health Canada's indicator value for the potential production of cyanotoxins of 50,000 cells/mL, except in August (three and two times higher at the Dock and the Bridge, respectively).

Several algal blooms with potentially toxic cyanobacteria were observed in years before 2011; however, testing completed before 2011 and following treatment (2013-2016) did not detect any Microcystin in the water. In 2016, a bloom was tested and resulted in a Microcystin concentration of 73 µg/L. Extended blooms were observed at several sites in 2018; however, cell density was at half of World Health Organization (WHO)'s threshold for significantly increased human health risk due to toxins. Since the 2021 PAC treatment, very limited surface scum has been observed at Swan Lake.

Summary and Recommendations

Overall, the management activities in recent years that focused on the significant nutrient loadings identified in the water quality improvement study (i.e., chemical treatment and fish management to reduce internal loads and geese management to reduce external loads), were effective at improving water quality in the Lake as shown in reduced phosphorus concentrations and improved dissolved oxygen levels. These improvements represent a positive step towards improving the aquatic habitat in the Lake and meeting the long-term water quality goals.

In 2024, chloride levels decreased considerably likely due to clearing the blockage at the East Pond inlet and the Swan Lake Club Oil and Grit Separator (OGS), which resulted in reduced untreated flows to the Lake. Dilution by cleaner water could have contributed to lower chloride concentrations in the Lake.

While internal and external source controls successfully reduced nutrient concentrations, the Lake was dominated by phytoplankton, and water clarity did not improve. In addition to a prolonged dry and warm period in late summer and throughout the fall of 2024, this could be partly due to the absence of Submerged Aquatic Vegetation (SAV), which has been replaced by phytoplankton (algae) due to low water clarity. To ameliorate this condition, an SAV planting initiative was implemented in 2023 and 2024 at fenced areas along the north shore of the Lake.

The 2025 monitoring program will follow the recommendation of the Long-Term Management Plan. As per the Long-Term Management Plan, in 2025 at the end of Phase 1, a 5-year review will be completed to evaluate the effectiveness of Core measures and identify the need for additional Complementary measures in Phase 2.

An evaluation of SAVs planting and fish stocking will be pursued, and studies and research on strategies to further reduce chloride concentration in the Lake by diverting runoff will continue. A new pilot project is being considered to apply ultrasound technology for algae control.

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1. Introduction

Swan Lake is situated in the City of Markham at the intersection of Sixteenth Avenue and Williamson Road, as shown below in Figure 1. Swan Lake has an approximate area of 5.5 ha and a maximum water depth of 4.5 m (from the deepest point to the Lake edges at 210 meter above sea level). Formerly a gravel pit in the 1960s and 1970s, Swan Lake is currently a community feature with multiple trails and urban development.

Several issues were discovered with Swan Lake in 2010, including high phosphorus levels and significant algal blooms during the summer months, which led to low oxygen levels and degraded fish habitats. A Phoslock treatment was administered in 2013 to reduce the phosphorus levels and algal blooms in Swan Lake.

In 2019, the City of Markham conducted a study to define a Water Quality Management Strategy for Swan Lake. The Strategy, which was finalized in July 2020, recommended chemical treatment starting in 2021. In August 2021, 13 tonnes of PAC were applied to the Lake in a controlled manner over several days.

The Swan Lake Long-Term Management Plan, which was developed based on the 2019 Strategy and extensive consultation with stakeholders, was received by Markham Sub Committee in November 2021 and approved by the Council in December 2021. It describes a phased adaptive approach, including Core, Complementary and Alternative measures, and periodic reviews to adapt the Plan to the Lake conditions.

Core and Complementary activities planned in the Long-Term Management Plan and completed fin 2024 included enhanced geese management, fish removal, and water quality monitoring, as well a second application of PAC and additional planting of submerged aquatic vegetation.

Water quality monitoring of Swan Lake has been conducted annually since treatment in 2013 in order to track water quality and the effectiveness of management activities. The 2024 monitoring results presented in this report are part of the ongoing monitoring program that will allow for continuous assessment of the water quality in Swan Lake and help establish a long-term plan for the treatment of Swan Lake.

In 2024, sampling for chloride measurement was also conducted at several locations to determine the relative contribution of each source to the Lake.

Trent University collected samples and launched loggers in Swan Lake in the summer of 2024 to support a study on the environmental fates of lanthanum from La-modified bentonite in the ecosystem of Swan Lake. Data provided by Trent researchers have been incorporated in this report.

2. Monitoring Program

2.1 Annual Water Quality Monitoring

2.1.1 Locations

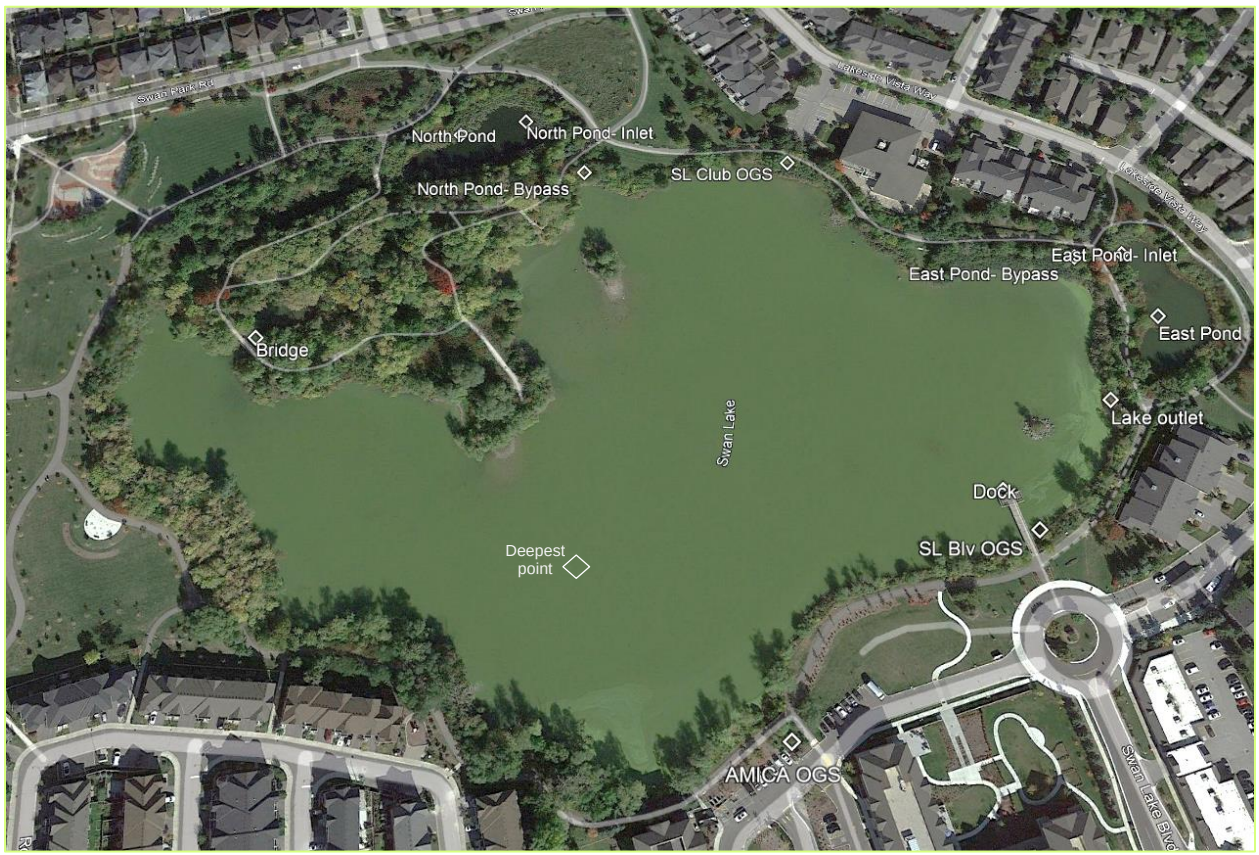
Water quality was monitored at two shoreline sites, the Dock, and the Bridge, as shown in Figure 1. On average, the water depth at the Dock is approximately 2.5 meters, which allows it to represent Swan Lake as a whole. The water depth at the bridge is about 0.5 meters, and it is used to represent the conditions of the shallow bays around Swan Lake. Field testing and sampling for laboratory analysis were completed at both sites to ensure the water conditions at Swan Lake were properly represented.

During the bi-weekly monitoring, samples and measurements were taken at 0.5 m or 1 m increments for the depth of the Lake. The dock site was the deeper of the two sites, allowing for sampling and monitoring from 0.5 – 2.5 m, whereas the bridge site was shallow, and sampling was typically only achievable under the surface, slightly above the bottom of the Lake to avoid sediment contamination.

When the water level dropped to around 2 m, samples were not collected from the 2.5 m depth at the Dock station.

Trent University placed their loggers at the deepest point (shown on the Figure), which was about 3.5 m deep.

Figure 1: Swan Lake and Runoff Monitoring Stations



2.1.2 Duration and Frequency

In 2024, water quality was monitored bi-weekly from April to November.

A total of 13 sampling events were completed.

2.1.3 Parameters and Methodology

Vertical water quality profiling, water transparency readings (Secchi depth), and photographic documentation were performed during each site visit.

Field testing was done utilizing an YSI ProODO meter to determine the temperature and DO at each sampling interval over the vertical profile of the lake. To ensure accurate readings, the meter and probe were stored in a proper carrying bag and regularly calibrated as instructed in the handheld quick-start guide.

A HOBOware U26 oxygen logger was mounted at the Dock on June 5, 2024, and recorded the DO and temperature of the water every 15 minutes throughout the day. Before the first use, the logger was calibrated for DO at 100% saturation and 0% saturation (using a sodium sulfite solution). An anti-fouling guard was also installed on the sensor cover to protect against fouling. The sensor was placed 1m above the lakebed at the same location as the level logger.

Water transparency was measured as part of the field testing at both the dock and bridge monitoring sites. Transparency was measured using a Secchi disk by lowering it into the water while rotating the handle until the black and white pattern of the Secchi disk was no longer visible. The water depth read from the Secchi disk was then recorded as the transparency (i.e., water clarity).

Water samples for laboratory testing were taken using a horizontal water sampler at different depths. Parameters analyzed at various stations and times included:

- Nutrients including Total Phosphorus (TP), ortho phosphorus, ammonia, nitrate, nitrite, Total Kjeldahl Nitrogen (TKN)
- Chloride, color, Dissolved Organic Carbon (DOC), pH
- Phytoplankton (taxonomic identification and total cell counts)

Observations of Swan Lake were noted, and photographs were taken during each monitoring/inspection site visit. Photographs provide a way to record the condition of vegetation and algae around Swan Lake. Completed inspection forms and photos can be found in Appendix A.

2.1.4 Targets and Thresholds

Generic thresholds for eutrophic and hyper-eutrophic conditions in the lakes are provided in Table 1.

Table 1: Eutrophic State Classification

Parameter	Eutrophic Condition	Hyper-eutrophic Condition
Secchi Depth (m)	1-2.1	<1
Total Phosphorus (µg/L)	31-100	100
Total Nitrogen (mg/L)	0.65-1.20	>1.20
Chlorophyll a (µg/L)	9.1 – 25	> 25

The 2019 Water Quality Management Strategy proposed a set of interim targets for Swan Lake to be used as triggers for management actions if the triggers are tripped in two consecutive years. Numerical values

were defined for total phosphorus (100 µg/L) and Secchi depth (0.6-0.8 m, as updated in 2021 based on correlation with the phosphorus target).

For DO and chloride, Federal and/or Provincial water quality Guidelines[1] or Objectives[2] were considered for perspective. It should be noted that Swan Lake is not a natural waterbody, and there is no requirement for it to comply with these limits. Where technically and economically feasible, the City will aim to meet these limits to protect and enhance the aquatic environment.

The minimum dissolved oxygen concentration required for the protection of warm water fish is 5 mg/L for water temperatures up to 20 °C, and 4 mg/L for temperatures above 20 °C. Lower concentrations could have lethal or sub-lethal (physiological and behavioral) effects on fish. However, some fish can acclimate to lower oxygen levels and survive concentrations between 1 and 3 mg/L. Furthermore, fish can avoid areas of low oxygen concentrations.

Chloride guidelines developed based on generic environmental data include a long-term guideline (120 mg/L) and a short-term guideline (640 mg/L). The long-term guideline has been developed to protect all organisms (present in Canadian aquatic systems) against negative effects during indefinite exposure. The short-term guideline will protect most species against lethality during a sudden hike in chloride concentration for a short period (24-96 hrs). These guidelines may be over-protective for areas with an elevated concentration of chloride and associated adapted ecological community. For such circumstances, it has been suggested that site-specific (higher) targets be derived considering local conditions such as water chemistry, background concentrations, and aquatic community structure. The site-specific interim target for chloride in Swan Lake is 400-500 mg/L consistent with 2013-2014 values.

For Cyanotoxins, the Health Canada guideline for recreational activities was updated from 20 µg/L to 10 µg/L in 2022[3]. The 2022 guidelines also provide indicator values for the potential production of cyanotoxins including:

- Total cyanobacteria cells: 50,000 cells/mL
- Total cyanobacterial biovolume: 4.5 mm^3/L
- Total chlorophyll a: 33 µg/L

2.2 Runoff Monitoring

In the Swan Lake catchment, salt application for winter maintenance is mainly completed by the City's Road department and the Swan Lake Village Corporation.

Winter maintenance of 1 km of the catchment roads and sidewalks is completed by the City of Markham. The City prescribes and tracks the quantity of salt distributed to the City roadways based on current and future forecast models and temperatures to determine the required action and material usage in compliance with the desired level of service and O.Reg. 239/02 requirements.

The remaining roads and parking areas, as well as private walkways and driveways, are serviced privately. As per the Village Amenities Committee (VAC), the Village Corporation employs "a qualified, reputable cleaning and maintenance service employing Smart About Salt principles to plow/shovel and their insurance recommends the de-icing methods of rock salt, applied as necessary to maintain their insurance and mitigate potential claim".

[1] Canadian Council of Ministers of the Environment (CCME) Water Quality Guidelines for the Protection of Aquatic Life (http://ceqg-rcqe.ccme.ca/en/index.html)
[2] Ontario Provincial Water Quality Objectives (PWQO) (https://www.ontario.ca/page/water-management-policies-guidelines-provincial-water-quality-objectives#section-13)
[3] Health Canada, 2022. Guidelines for Canadian Recreational Water Quality, Cyanobacteria and their Toxins, Ottawa, Ontario.

Chloride in salting materials is readily dissolved in water and transported overland by runoff or infiltrated into soils, contaminating groundwater and surface water. A fraction of chloride in applied road salt is retained by soil and is not observed in surface runoff. As a result, salt loading to surface water occurs primarily in winter and spring during melt conditions but continues through the summer and fall via the discharge of impacted groundwater, dry deposition of dust to the lake surface, and non-point source runoff washing dry salt from land surfaces. Salt accumulated in the ponds could also be discharged into the Lake through the flushing of stormwater ponds.

In 2024, water samples were collected from various inlets to the Lake to quantify and determine the relative contribution of each source to chloride concentration in Swan Lake. Samples were collected from both ponds' inlets, as well as outfalls from the ponds and OGS's to the Lake.

Conductivity was also measured in a number of samples, as this parameter can be used as a surrogate for chloride. Samples were collected during four snowmelt events from January to March 2024.

2.3 External Data

Trent University collected water, sediment and biological samples and launched loggers in Swan Lake in the summer of 2024 to support a study on the environmental fates of lanthanum from La-modified bentonite in the ecosystem of Swan Lake. Data provided by Trent researchers included DO and temperature profiles and Chl-a concentrations at the deepest point of the Lake.

2.4 Water Level Monitoring

Prior to 2024, water level was monitored using HOBOware U20 Water logger mounted at the Dock. In 2024, the logger was replaced with a Dipperlog vented data logger from Heron Instrument, which eliminated the need for barometric compensation. The data logger records the pressure and temperature of the water every 15 minutes.

3. Results

3.1 2024 Water Quality

The following sections discuss water quality results in 2024.

3.1.1 Dissolved Oxygen and Temperature

Table 2 provides the measured DO profile over the 2024 monitoring period. At the Dock station, all day-time surface and deep-water concentrations measured during sampling events were above 6 mg/L. All measurements at the Bridge indicated a DO concentration of above 4.6 mg/L with a summer average concentration of 5.6 mg/L

Table 2 also provides measured temperature profiles in 2024, indicating warm water throughout the depth in the summer months.

Profiles of temperature and dissolved oxygen (see Figure 3) indicate that Swan Lake was transiently stratified in May and June (when temperature decline is greater than 1 °C per m of depth). Transient stratification can cause reduced mixing/aeration and lead to anoxia with the release of nutrients from the sediments.

Data collected by Trent University on July 15 shows stratification at the deepest point, where DO drops from 7.5 mg/L at 2 m to below 1 mg/L at depths greater than 3 m (Figure 2). The decline in DO occurs below the top of the thermocline where temperature decreases with depth by 1°C per m or more, reducing mixing and reoxygenation of the bottom water below that depth.

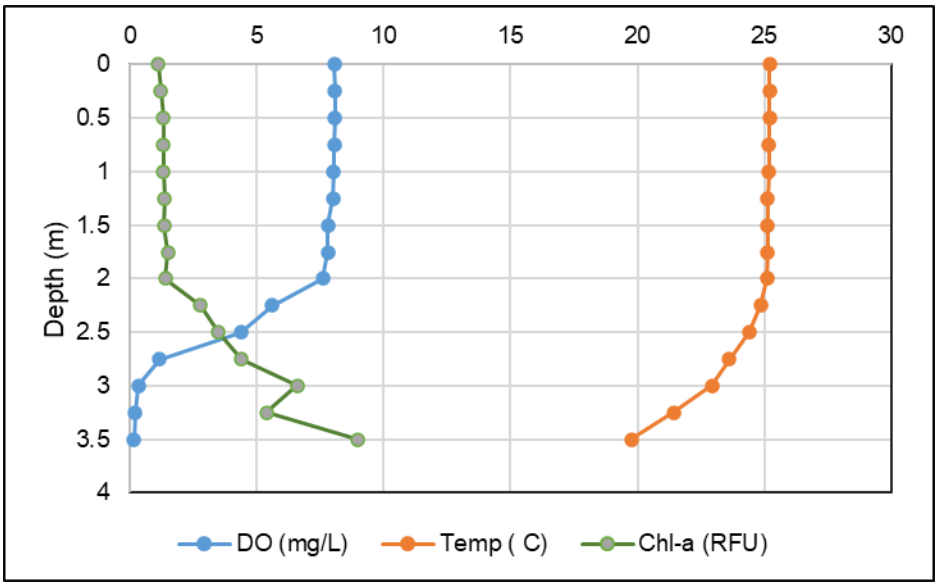
In 2024, in addition to using the YSI ProODO meter for bi-weekly measurements of temperature and DO over the vertical profile, a continuous logger was also placed 1 m above the lake surface to measure the diurnal changes in DO. DO increases during daylight hours when photosynthesis occurs and decreases at night when respiration continues but photosynthesis does not.

Continuous measurement of DO from July to November indicated that DO concentrations have a diurnal pattern, typical of freshwater lakes. These data are mostly consistent with the data logger used by Trent University researchers at the deepest point. While surface concentrations were always above 4 mg/L regardless of the time of day, deep water concentrations dropped to anoxic levels for several days in the second half of August and several days mid September, when there was minimal precipitation and warmer than usual weather.

Table 2: Measured Daytime DO and Temperature

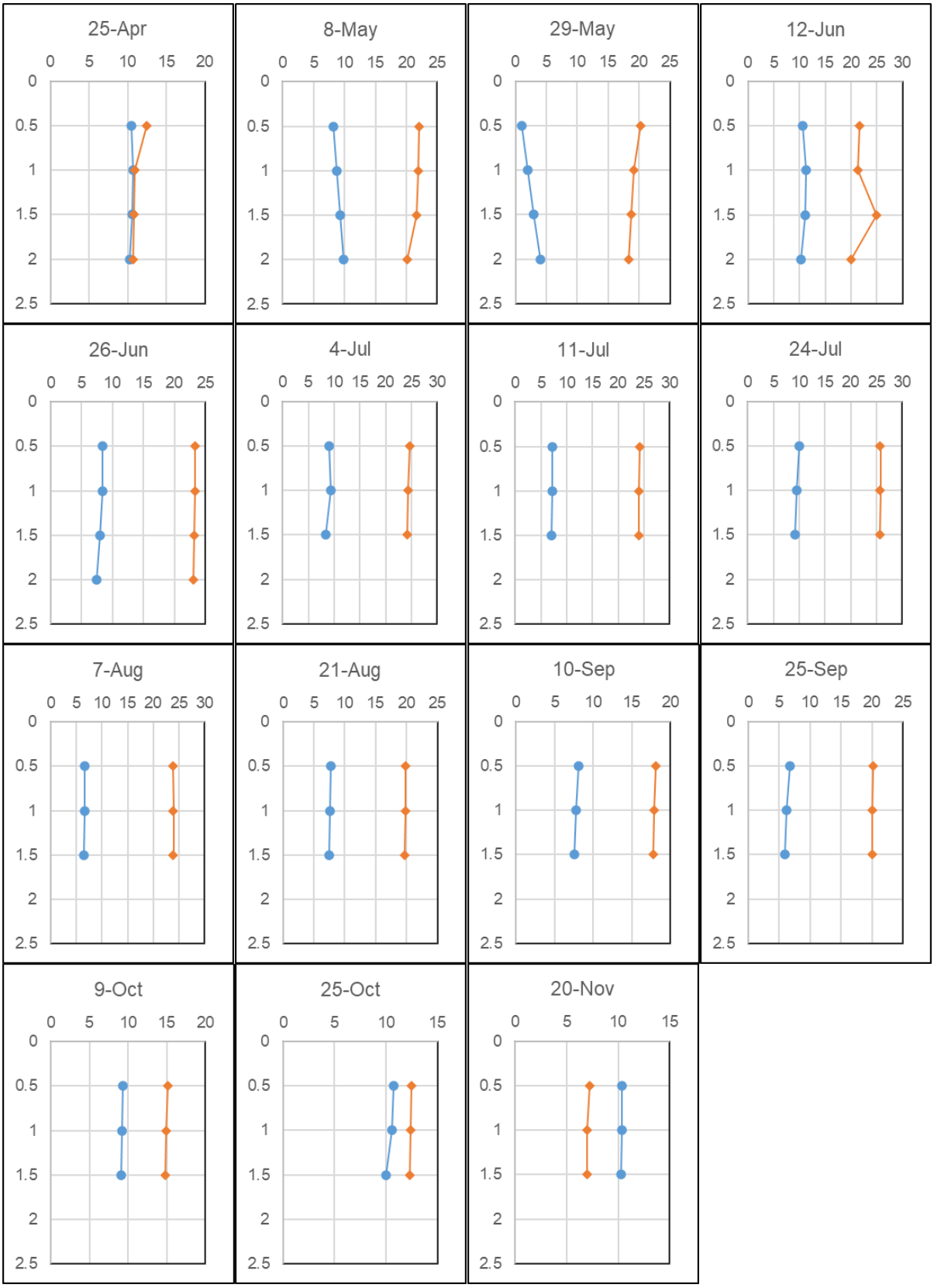
	DO Concentration (mg/L)					Temperature (°C)				
	Bridge	Dock				Bridge	Dock			
	Depth (m)	Depth (m)				Depth (m)	Depth (m)			
Date	0.5	0.5	1	1.5	2	0.5	0.5	1	1.5	2
4/25/2024	10.1	10.5	10.7	10.6	10.3	11.0	12.5	10.9	10.8	10.7
5/8/2024	-	8.3	8.7	9.3	9.9	-	21.6	21.3	25.0	20.0
5/29/2024	13.9	10.8	10.9	11.4	10.3	22.1	22.0	21.9	21.6	20.1
6/12/2024	11.1	10.6	11.2	11.1	10.3	18.0	20.2	19.2	18.7	18.3
6/26/2024	4.9	8.4	8.4	8.0	7.4	23.7	23.4	23.4	23.2	23.1
7/4/2024	6.8	9.1	9.3	8.4	-	23.5	24.6	24.4	24.1	-
7/11/2024	5.9	7.2	7.2	7.0	-	23.2	24.1	24.0	24.0	-
7/24/2024	5.2	9.9	9.6	9.1	-	25.2	25.7	25.7	25.6	-
8/7/2024	5.4	6.7	6.6	6.5	-	23.0	23.8	23.9	23.9	-
8/21/2024	4.6	7.7	7.5	7.5	-	18.2	19.8	19.8	19.7	-
9/10/2024	5.7	8.1	7.8	7.6	-	16.9	18.1	17.9	17.8	-
9/25/2024	6.0	6.7	6.1	5.9	-	19.8	20.2	20.0	20.0	-
10/9/2024	8.5	9.4	9.2	9.1	-	15.1	15.1	14.9	14.8	-
10/25/2024	9.7	10.7	10.6	10.0	-	10.2	12.5	12.4	12.3	-
11/20/2024	9.0	10.4	10.3	10.2	-	7.3	7.2	7.0	7.0	-

Figure 2: Vertical Profiles on July 15, 2024, at the Deepest Point



Data courtesy of Trent University

Figure 3: Temperature (orange) and DO (blue) Profile at the Dock Station in 2024



Note: The vertical axis shows depth (m), while the horizontal axis represents both Temperature (°C) in orange, and DO (mg/L) in blue.

3.1.2 Water Transparency

A robust measure of algal biomass is the measurement of the Secchi disk depth or transparency.

Table 3 summarizes the results of the water transparency readings. Transparency at the Dock station averaged 0.76 m over the growth season, and was within the interim target for Swan Lake of 0.6-0.8 m. Water transparency at the Bridge site was generally equal to the water depth.

Table 3: 2024 Secchi Depth Results (m)

Date	Dock	Bridge
25-Apr	0.95	0.63
8-May	0.92	0.565
29-May	0.8	0.5
12-Jun	0.73	0.34
26-Jun	0.95	0.46
11-Jul	1	0.5
24-Jul	0.97	0.5
7-Aug	0.64	0.5
21-Aug	0.59	0.46
10-Sep	0.55	0.43
25-Sep	0.6	0.53
9-Oct	0.5	0.41
25-Oct	0.64	0.4
20-Nov	0.6	0.4

3.1.3 Nutrients Concentrations

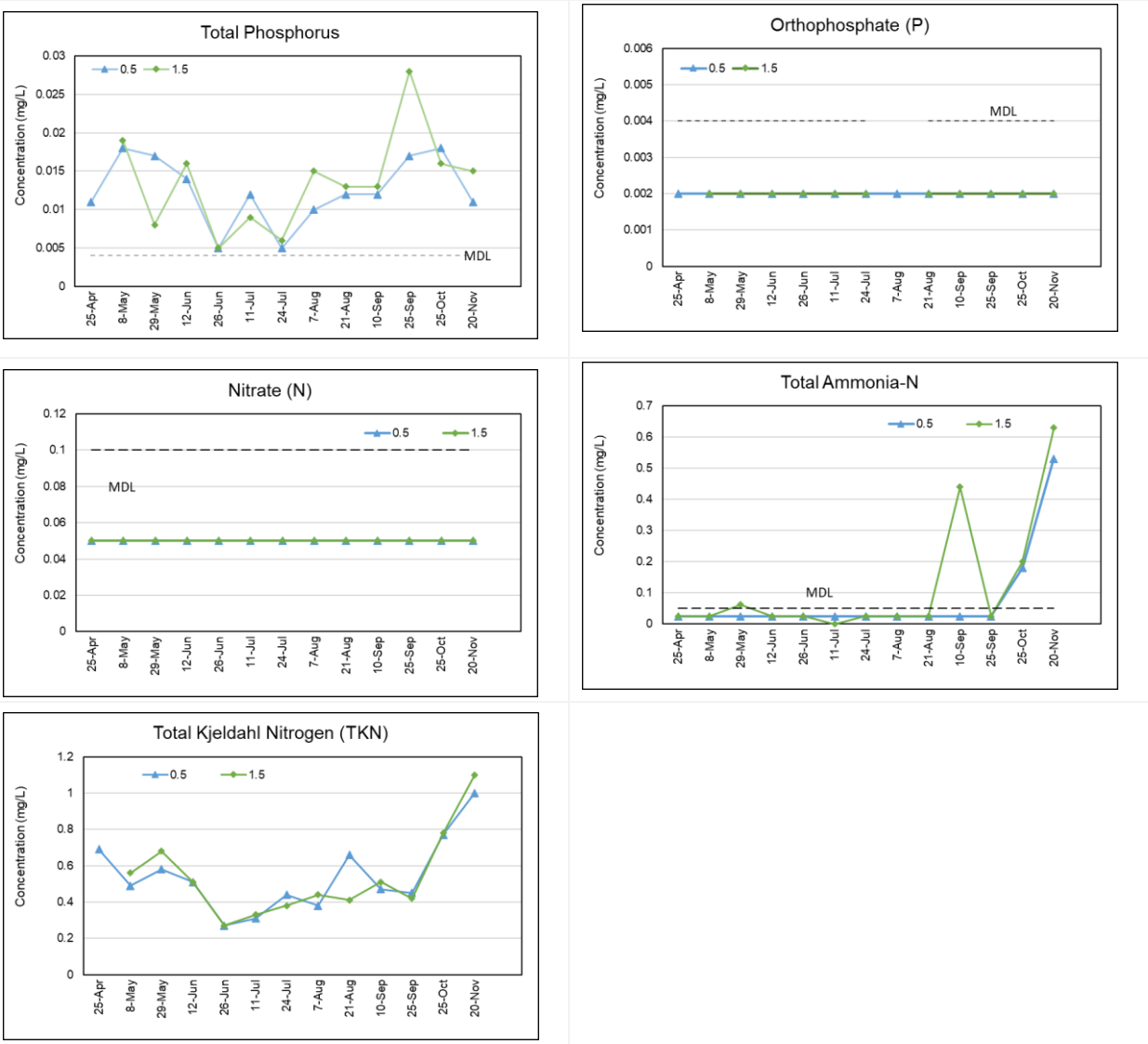
Samples collected during each visit were tested for TP, Orthophosphate, TKN, Nitrate, Nitrite, and Ammonia. The results can be found in Figure 4 for the Dock site and Figure 5 for the Bridge site. The Certificates of Analysis from Bureau Veritas Laboratories are in Appendix B. Nutrient concentrations are shown for the depths sampled.

Total phosphorus concentration at 0.5 and 1.5 m depths averaged under 12 µg/L during the growing season and was below 30 µg/L throughout the year (threshold for a eutrophic condition).

Following the PAC treatment, total phosphorus declined to very low levels near the laboratory detection limit, then increased over the summer reaching a peak in September, consistent with phosphorus loading to the lake from external sources. Orthophosphate and total ammonia concentrations were low throughout this period in the surface and bottom water with few exceptions indicating that internal loading due to anoxia was not significant. In the late fall, total ammonia concentrations increased, likely due to reduced uptake by algae.

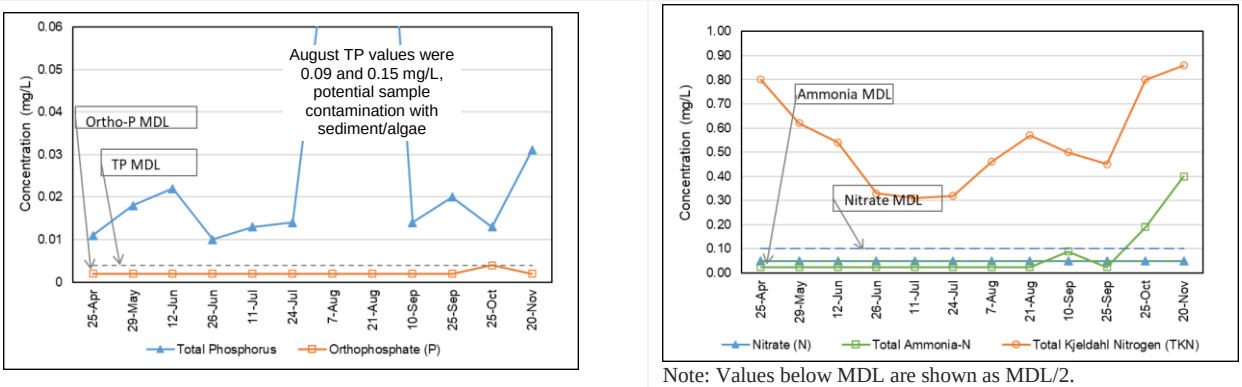
Total nitrogen concentrations over the growing season averaged about 0.52 mg/L (below the 0.65 mg/L threshold for a eutrophic condition). Total concentrations at the Bridge site averaged 0.5 mg/L. Ammonia and nitrate are the directly bioavailable forms of nitrogen, with Ammonia being the most usable form for algae. In 2024, Ammonia and Nitrate concentrations were generally close to or below Method Detection Limit (MDL), and nitrogen was mainly present as organic compounds (i.e., TKN less Ammonia) with the exception of fall samples. Bioavailable nutrient pulses (orthophosphate and ammonia) in late summer and fall are consistent with the release of these nutrients due to episodic anoxia and decomposition of organics, including algae.

Figure 4: 2024 Measured Nutrients Concentrations - Dock Site



Note: Values below MDL are shown as MDL/2

Figure 5: 2024 Measured Nutrients Concentrations - Bridge Site



Note: Values below MDL are shown as MDL/2.

MARKHAM Environmental Services

3.1.4 pH

pH measured at the lab ranged from 7.4 to 8.38 throughout the year, which is within the PWQO range (6.5-8.5).

3.1.5 Chloride in Lake and Runoff

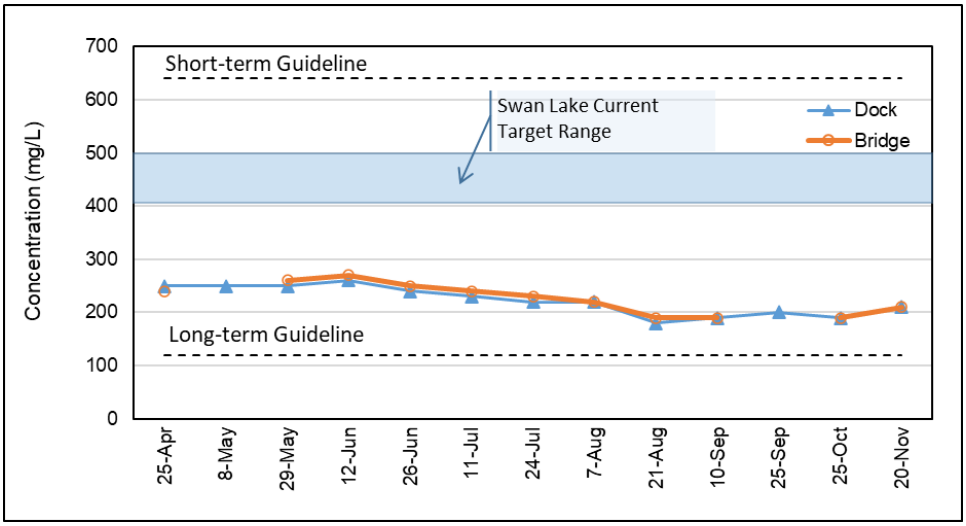
Surface samples collected during each visit were also analyzed for Chloride, as summarized in Figure 6.

Water quality testing results indicated that the samples contained between 180 and 270 mg/L of Chloride.

In 2024, chloride levels further decreased considerably compared to 2021 and 2022, likely due to clearing the blockage at the East Pond inlet and Swan Club OGS, which resulted in lower untreated flows to the Lake.

Chloride guidelines developed based on generic environmental data include a long-term guideline (120 mg/L) and a short-term guideline (640 mg/L). The interim target for chloride is 400-500 mg/L consistent with 2013-2014 values. In 2024, all samples met these targets.

Figure 6: Chloride Concentrations in Swan Lake in 2024



In 2024, water samples were collected from various inlets to the Lake and analyzed for chloride.

These data, along with scattered data from previous years, are shown in Table 4. Based on this limited dataset, chloride concentration in the spring runoff from the pond catchments is about 1700 mg/L for the East Pond and 880 for the North Pond (average of pond inlet measurements, except for January 13th, 2022, and Jan 24, 2024, where samples were collected from standing water). This concentration would not usually end up in the Lake, except through the East Pond bypass when the pond inlet was blocked. At other times, the bypass would carry 'cleaner' water (after the first flush), with concentrations around 200 mg/L. Flows from the ponds to the Lake have an average concentration of about 380 mg/L (average of pond and outlet concentrations).

The runoff collected from the Swan Lake Blvd. OGS contained an average of about 2000 mg/L of chloride, while from the AMICA OGS had a concentration of about 620 mg/L. Samples collected from the Swan Club OGS has an average concentration of about 2400 mg/L. Samples were also collected from the shoreline runoff, which resulted in very low chloride concentrations (about 25 mg/L).

These data will be used to update the chloride mass balance following the completion of the Flow Diversion Feasibility Study, which is currently underway.

Table 4: Chloride Concentrations in Runoff

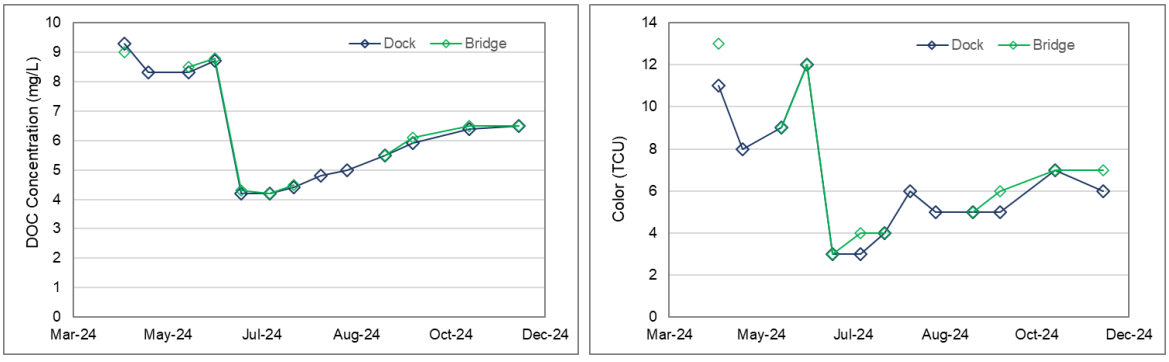
Date	Inflow to Ponds		Bypass from Pond to Lake		Inflow to Lake from Ponds				Inflows to Lake from OGS		
	East Pond	North Pond	East Pond	North Pond	East Pond-in pond	From south	North Pond-in pond	Road	Swan Lake Blvd.	AMICA	Swan Club
3/20/2012 *	577	673			572		56				
3/26/2021	957	98.5			343		199				
4/11/2021		79	131			673					
1/13/2022 **	13200								3160		
2/15/2022	2340	2120						326	836	360	
3/6/2022	380	410			410		180		1200	610	
3/16/2022	3700	3100							4800	470	
3/24/2022	1200	1100	150						1900	240	
4/6/2022	2800		350							1100	
1/18/2023	2000	1200	240							120	
2/8/2023	3900	650								450	
2/9/2023	360	340				960		120	420	300	
3/24/2023	1300	630	180								
1/15/2024	1900	210	270	120					3300	2100	4200
1/24/2024 **	8400										8200
1/26/2024	560		150						320		680
2/29/2024	2100		220	280							
Average	1720	881	210	200	384				1943	620	2440

* Data were used cautiously since the exact location of samples and sampling conditions are not known.
** Standing water, not used in calculations.

3.1.6 DOC Concentrations and Color

Surface samples collected during each visit were also analyzed for DOC and Color. The results are summarized in Figure 7. Both DOC and colour dropped after the treatment and remained lower than pre-treatment levels throughout the season.

Figure 7: Measured DOC and Color in 2024



3.1.7 Algae Growth

In 2021, samples were collected before and after chemical treatment and sent to the laboratory for phytoplankton and cyanobacteria identification. Test results are summarized in Figure 8 below and show a significant reduction in concentrations following the treatment, consistent with the particle scavenging characteristics of the treatment chemicals. Phytoplankton density increased almost five weeks post-treatment to values comparable to pre-treatment levels.

In 2022, limited algae scum was observed in early June, and while the Lake was dominated by phytoplankton for the remainder of the monitoring period, surface scums were not widespread. Four sets of samples were collected from the Lake between August and December for phytoplankton identification, as shown in Figure 9. These results should be considered with caution due to lab errors in the identification of Microcystis. In general, the 2022 results showed lower diversity and higher total counts compared to 2021.

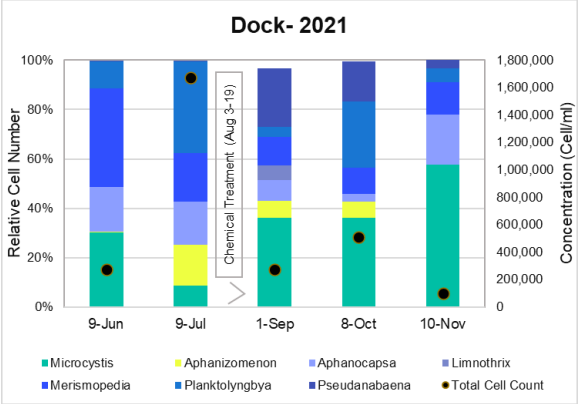
Abraxis tests were performed on June 29, July 14, and August 11, 2022, and resulted in Microcystin levels below the recreational limit (recently updated to 10 µg/L). Nonetheless, the presence of known toxin producers at high cell densities suggests that cyanotoxins can potentially occur at elevated concentrations that exceed recreational guidelines. Toxin concentrations can vary tremendously over small spatial and temporal scales, and it is, therefore, possible that higher concentrations occurred elsewhere in the Lake or at different times.

In 2023, seven samples were analyzed for cyanobacteria identification. The results are shown in Figure 10 and indicate significantly lower cell counts compared to 2022. Cell counts in August and September decreased from about 2,000,000 cells/mL in 2022 to 50,000 cells/mL in 2023. The dominant genera of *Microcystis* (Chroococcales order) and *Cylindrospermopsis* (Nostocales order) stayed as such in both 2022 and 2023, with several genera of the Synechococcales order also present in relatively high percentages in 2023.

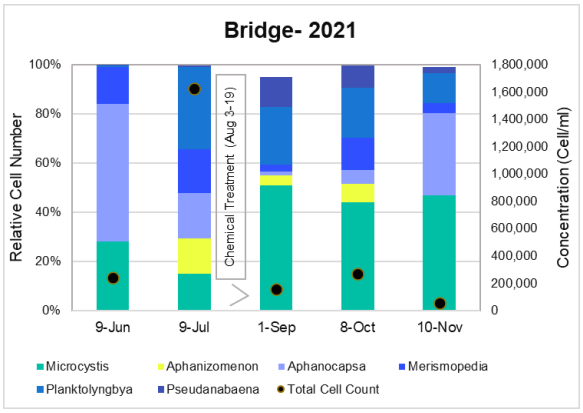
In 2024, five samples were collected for phytoplankton identification as shown in Figure 11. Total cyanobacteria cell counts were about 40% lower in 2024 compared to 2023, with average growing season concentrations at 63,000 and 44,000 cells/mL at the Dock and Bridge stations, respectively, compared to the guideline of 50,000 cells/mL. While total cell counts were the highest in June and July in 2023, in 2024, the highest counts were in August.

Besides the actual identification and counting of cells, analysis of chlorophyll-a (chl-a), which is the green algal pigment used in photosynthesis, provides a measure of algae biomass. Concentrations of chl-a were recorded by Trent University using an Enigma probe at a depth of 1 m, indicating an average of 16 µg/L over the growing season, which is within the eutrophic state.

Figure 8: Planktonic Cyanobacteria Population in Swan Lake in 2021

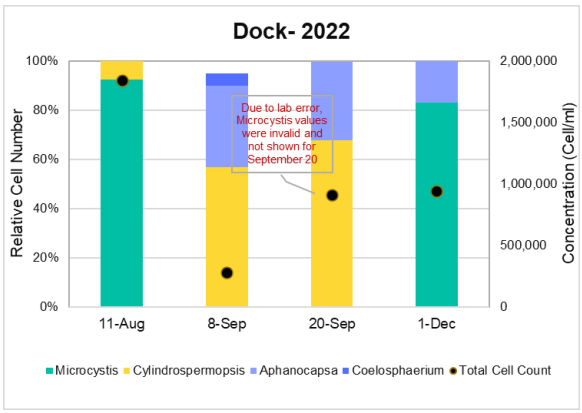


Other genera present at less than 3% include: Planktothrix and Coelosphaerium

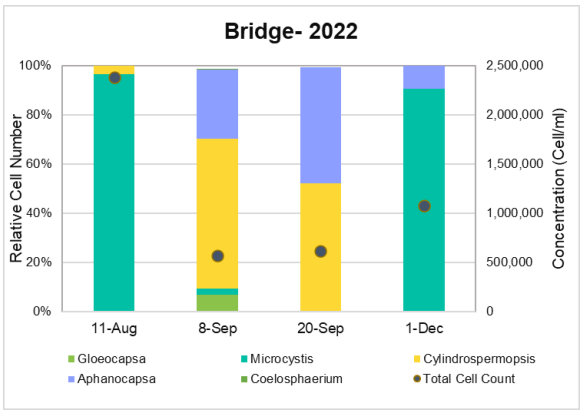


Other genera present at less than 3% include: Aphanothece, Gomphosphaeria, Phormidium, Planktothrix and Limnothrix

Figure 9: Planktonic Cyanobacteria Population in Swan Lake in 2022

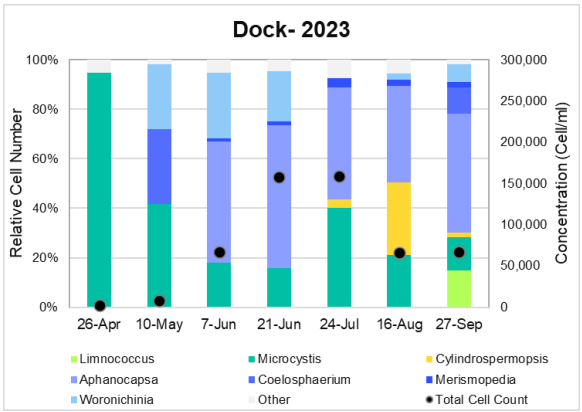


Other genera present at less than 3% include: Gloeocapsa, Anabaena , Oscillatoria and Merismopedia

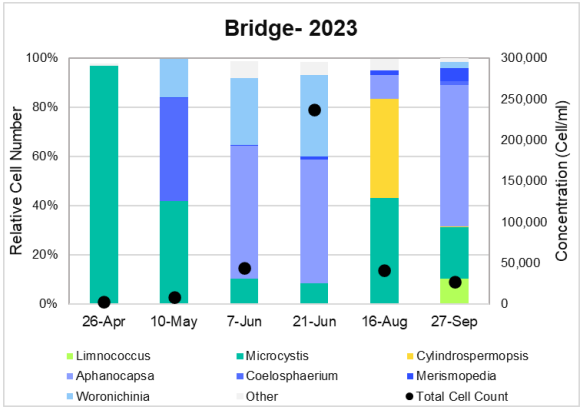


Other genera present at less than 3% include: Anabaena , Oscillatoria, Coelosphaerium and Merismopedia

Figure 10: Planktonic Cyanobacteria Population in Swan Lake in 2023

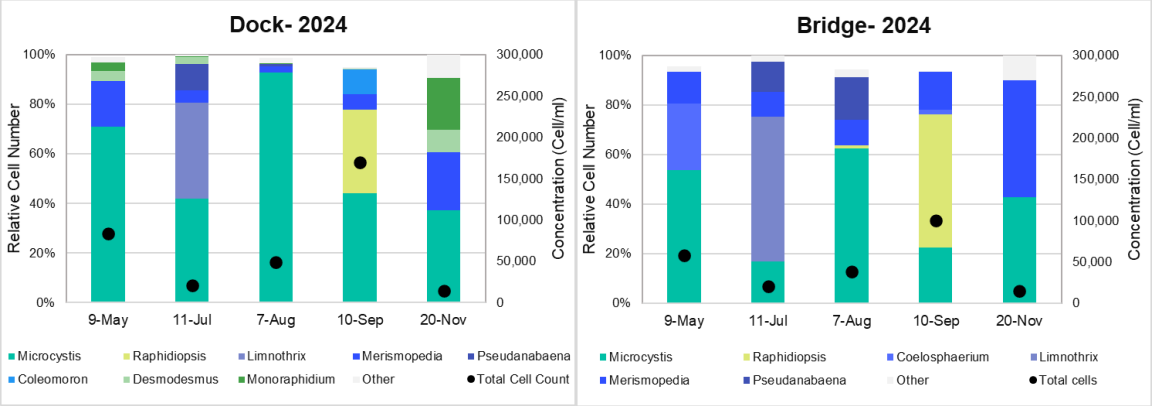


Other genera present at less than 3% include: Gloeocapsa, Gomphosphaeria, Anabaena, Aphanizomenon, Woronichinia, Chroococcus, Glaucospira, Leptolyngbya, Snowella



Other genera present at less than 3% include: Gloeocapsa, Gomphosphaeria, Pseudanabaena
Chroococcus, Glaucospira, Microchaete, Snowella

Figure 11: Planktonic Cyanobacteria Population in Swan Lake in 2024



Other genera present at less than 3% include: Coelosphaerium, Woronichinia
Total cell count referred to total cyabobacteria until 2023, and total phytoplankton in 2024.

Other genera present at less than 3% include: Coleomoron, Woronichinia

3.2 2024 Water Level

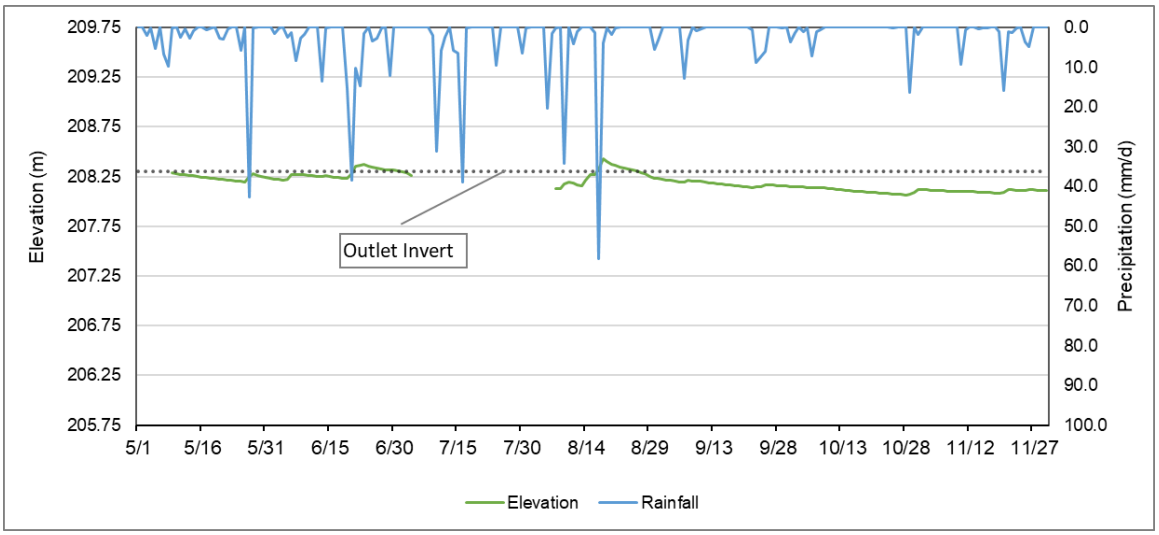
In 2024, the measured water level changed from a maximum of 208.45 m in August to a low of 207.26 m in November. Total precipitation in 2024 was 1055 mm, as recorded at the Markham Museum station.

The maximum water level recorded or estimated between 2017 and 2024 ranged from 208.25 m to 208.48, when total precipitation ranged from 670 to 934 mm.

While 2024 was a wet year during the summer, there was an extended dry and warm period from August to the end of the Fall, which resulted in low water level and lower oxygen levels at depth .

Measured water level and daily precipitation data from the nearby rain gauge are shown in Figure 12.

Figure 12: Lake Elevation Records and Precipitation in 2024



3.3 Water Quality Trends

Water quality monitoring of Swan Lake has been conducted annually since treatment in 2013 to track water quality and the effectiveness of implemented mitigation measures. The following paragraphs and Figure 13 provide a summary of water quality trends for the period of monitoring.

Dissolved Oxygen (DO)

Historical records of DO and temperature profile show that Swan Lake thermally stratifies during the summer despite its shallow depth. Anoxic conditions were observed at depths below 2 m, to as high as 1 to 1.5 m (in 2016). The majority of surface concentrations have been above 5 mg/L since 2014. In 2024, all day-time surface and bottom concentrations measured during sampling events at the Dock station were above 6 mg/L. DO concentrations, however, have a diurnal pattern, often decreasing at night. Data collected by two continuous loggers in 2024 indicated that deep water concentrations dropped to anoxic levels for several days in the second half of August and several days mid September, when there was minimal precipitation and warmer than usual weather potentially resulting in transient thermal stratification and reduced mixing of the bottom water.

Water Clarity (Secchi Depth)

In Swan Lake, Secchi depth has typically been quite low throughout the summer, but it increases in November, reflecting the end of the growing period for phytoplankton. The average annual values shown in Figure 13 are all below 1 m, except in 2014 and 2021, following chemical treatment. In 2024, water clarity, which increased to 1 m following the treatment, was above 0.5 m for the remainder of the monitoring period until late November.

Total Phosphorus (TP)

Average growing period (May - September) TP concentrations indicated hyper-eutrophic conditions in earlier monitored years except for the post-treatment years, 2013 and 2014. TP, has been consistently low since the 2021 treatment and dropped to below 30 µg/L in 2023 and 2024.

Nitrogen Compounds

Total nitrogen (TN) concentration over the growing period was above the 1.2 mg/L threshold for a hyper-eutrophic condition in earlier years, except in the post-treatment year, 2014. TN dropped to below the eutrophic threshold after the 2021 and 2024 treatment. Nitrogen is, however, not believed to be the limiting nutrient for eutrophication in Swan Lake (i.e., the nutrient that elicits the largest response in algae growth).

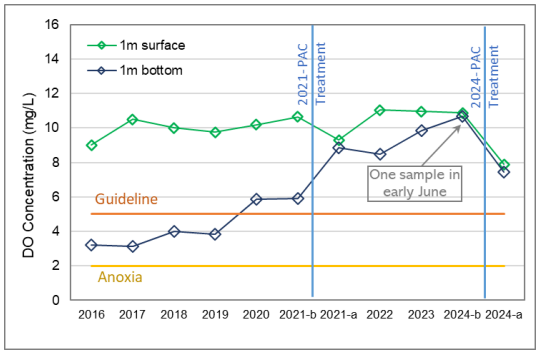
Inorganic nitrogen compounds (NO_2, NO_3, and NH_3) have often been below detection limits, indicating relatively low levels of bioavailable nitrogen concentrations. In 2024, ammonia and nitrate concentrations were generally very low (except higher ammonia in the fall), and nitrogen was mainly present as organic matter.

Chloride

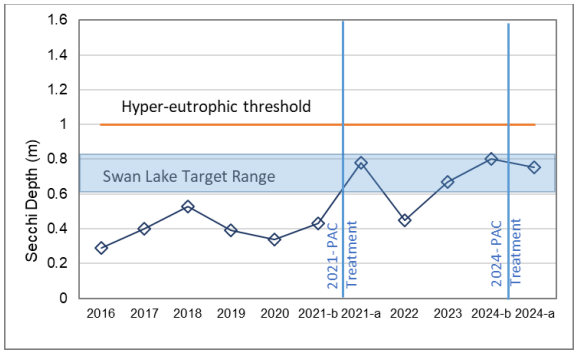
Chloride concentrations were increasing in Swan Lake over the past few years with a slight drop in 2021. Removing the blockage at the East Pond inlet and cleaning of the Swan Club OGS resulted in lower untreated flows to the Lake, lowering chloride concentration in Swan Lake post 2022. The Long-Term Management Plan for the Lake suggests that the main mechanism for lowering chloride levels would be source control. Emerging technologies (chloride removal using biochar) and the feasibility of flow redirection are currently being studied.

Figure 13: Historical Water Quality Results (Growing-Season Averages)

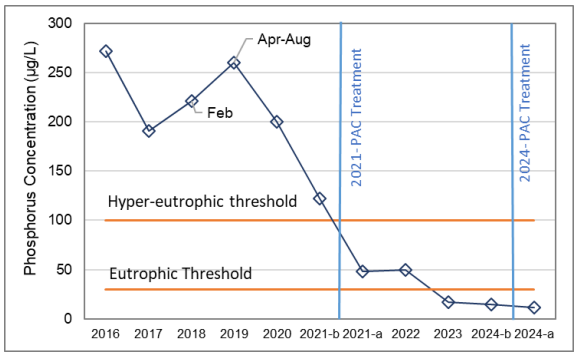
DO



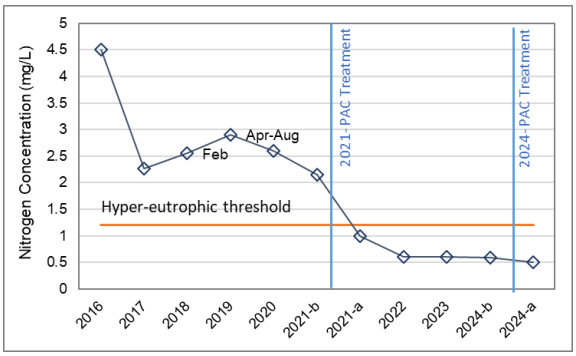
Secchi Depth



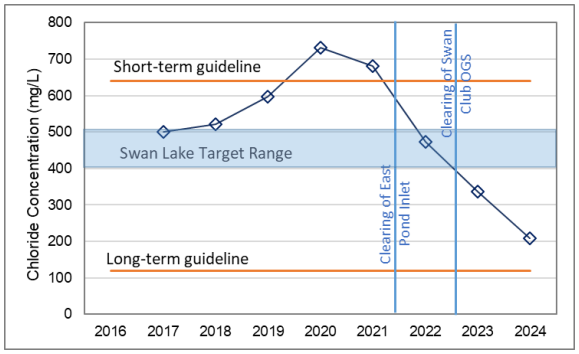
Total Phosphorus



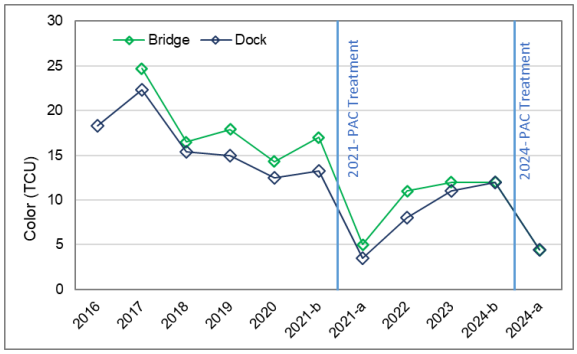
Total Nitrogen



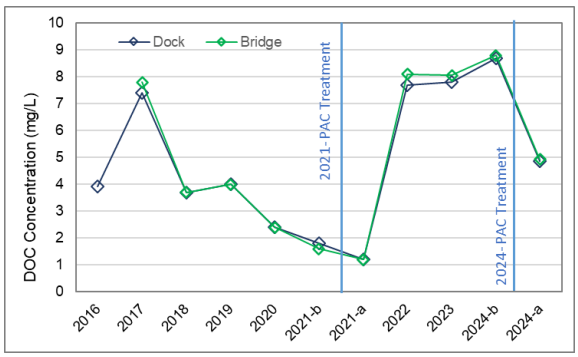
Chloride



Color



DOC



Algae Blooms and Cyanobacteria

Table 5 provides a summary of the observed algae blooms in the Lake over the years. It also shows any tests conducted to measure toxins (mainly in terms of Microcystin concentration) in the Lake water.

Table 5: Records of Algae Blooms and Toxicity

Year/Period	Algae Blooms Observation	Toxicity Test Result
Before 2011	Several blooms of cyanobacteria were observed	Microcystin concentration under detection limit
2013-2016	No apparent cyanobacteria proliferation and blooms; no resident concern related to the Lake's water quality	Microcystin concentration under detection limit
2016	A bloom was detected at one location	Microcystin concentration of 73 µg/L in one sample tested (recreational guideline is 20 µg/L)
2017	No bloom was observed	-
2018	Extended blooms were observed at several sites	Not tested for toxicity; cell density was at half of WHO's threshold for significantly increased risk for human health
2019	Extended blooms were observed at several sites	Microcystin toxicity was measured with test strips; all samples were below 10 µg/L
2020	Blooms were observed at several sites	Microcystin toxicity was measured with test strips; all samples were below 10 µg/L
2021	Blooms were observed at several sites before treatment; the high biomass was inhibited by the August PAC treatment; however, by October, cyanobacteria were as high as in previous summers and falls.	Not tested for toxicity
2022	Surface scums were not widespread; Lab results showed lower diversity and higher total counts compared to 2021.	Microcystin toxicity was measured with test strips; all samples were below 10 µg/L
2023	Surface scums were not widespread; Lab results showed higher diversity and significantly lower total counts compared to 2022.	Not tested for toxicity
2024	Surface scums were not widespread; Lab results showed higher diversity and about 40% decline in total counts compared to 2023.	Not tested for toxicity

While internal and external source controls in in recent years have successfully reduced nutrient concentrations to below the specified targets, the Lake has been dominated by phytoplankton, and water clarity improvements were modest. This could be due to warmer weather and partly due to the absence of SAV, which has been replaced by phytoplankton (algae) due to historically high concentrations of total phosphorus. SAV compete with algae for nutrients and light, and the establishment of SAV growth may help to reduce phytoplankton blooms over the growing season.

SAV would prevent sediment resuspension, take up nutrients, and act as habitat for zooplankton, which in sufficient densities would help control algal blooms. The return of SAV could be key to shifting the Lake to a clear state and, this shift seems unlikely without active bio-manipulation to break the cycle of high turbidity- phytoplankton dominance – high turbidity[4]. Therefore, in 2023 and 2024, the Toronto Region Conservation Authority (TRCA) was contracted to implement a SAV planting pilot project in fenced areas

[4] Scheffer, M. Alternative Attractors of Shallow Lakes. The Scientific World (2001) 1, 254-263.

along the north shore of the Lake. An evaluation of the SAV planting success and habitat conditions is being considered in 2025.

4. Geese Management

4.1 Geese Management Approach

Geese reduction at Swan Lake is necessary due to the nutrient load they contribute to the Lake.

In 2024, the geese management program was completed by two external contractors.

The Wildlife Management Group Inc., an external consultant, was hired to use science- based and Environment Canada-approved techniques for managing Canada goose. Activities included nest depredation (nest monitoring, and subsequent removal between April and May), and adult goose mitigation through laser light, avian distress call and limited strategic zinc crackler pyro.

The TRCA was hired to relocate resident geese from Swan Lake (and Toogood Pond) and to remove the nests and eggs from the area.

The strobe lights purchased in 2020 at the request of Friends of Swan Lake Park were also installed on the Lake and the two adjacent stormwater management ponds. Strobe lights work by using a solar-powered LED light that flashes every two seconds and is intended to disrupt the geese's sleep patterns and discourage them from staying on the Lake.

4.2 Geese Count

In 2024, the geese count was completed by the consultant, City staff, and volunteers from the community.

WMG recorded the number of geese observed during each visit. Staff counted the number of geese every two weeks, coinciding with the water quality sampling site visits. All counts and other wildlife observations were recorded in a geese count App developed using ArcGIS Survey123 software.

4.3 Results

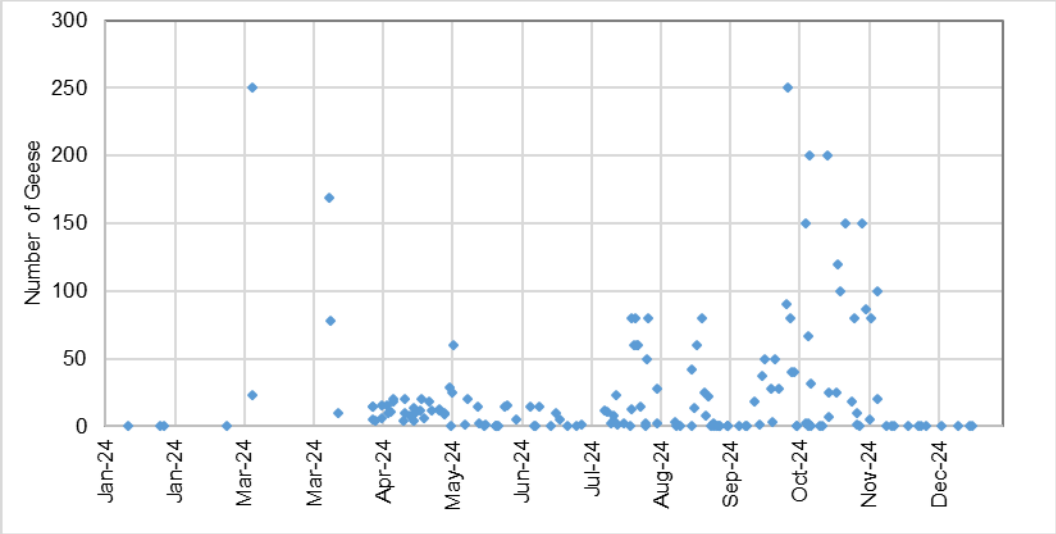
Figure 14 illustrates the number of geese counted at Swan Lake throughout the 2024 monitoring period.

In this figure, a significant increase in geese numbers is evident when they migrate south; however, the mitigation measures employed effectively reduced the number of geese present at different times of the day. Fewer geese were counted in August and September of 2024 compared to previous years, likely due to the prolonged warm weather conditions and delayed migration. Any impact that strobe lights might have had on the geese count is not readily evident from the data.

In total, 14 Canada Geese were rounded up from Swan Lake in 2024.Twenty-six adults and six goslings were rounded up and relocated from Toogood Pond.

In addition, eight nests and 68 eggs were managed at Swan Lake in April and May.

Figure 14: 2024 Geese Count Results at Swan Lake

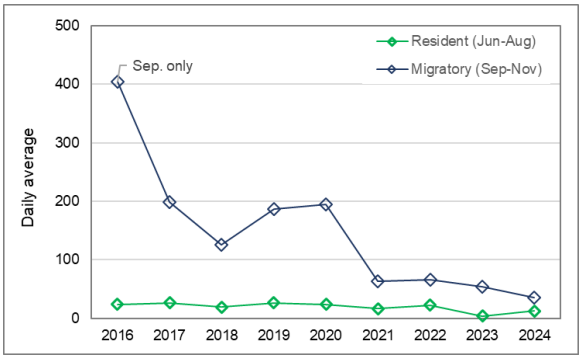


4.4 Historical Trends

Active geese management has been completed annually since 2014. The geese management program focused on resident geese at the beginning and extended to the management of migratory geese in 2016.

Daily Averages of counts are shown for each year in Figure 15. Data are summarized for June to August and September to November, representing resident and migratory geese, respectively. Despite a general increase in geese population in Southern Ontario, the numbers at Swan Lake have been controlled over the past years.

Figure 15: Historical Geese Counts



5. Management Activities

5.1 Chemical Treatment

Between June 17 to June 25, 2024, about nine tonnes of PAC was applied to reduce phosphorus concentrations and ultimately algal production in the Lake. Each application event was separated by one or two days of downtime to allow for floc formation and environmental testing.

5.2 Fish Inventory and Removal

The Long-Term Management Plan for Swan Lake (2021) has a provision for managing bottom-dwelling fish to reduce sediment disturbance.

Since 2021, the City has hired the TRCA annually to complete a fish inventory and removal operation.

In 2021, three fish species were captured across five different sampling events. The three species were Brown Bullhead (*Ameiurus nebulosus*), which were relocated to Milne Dam, Common Carp (*Cyprinus carpio*), which were euthanatized, and Fathead Minnow (*Pimephales promelas*), which were returned to the Lake.

The same three fish species as in 2021 were captured during one electrofishing sampling event and one netting sampling event on August 23 and 24, 2022. In 2022, the TRCA was informed by the Ontario Ministry of Natural Resources and Forestry (OMNRF) that a Fish Stocking license would not be granted due to the possibility of disease transfer. Instead, OMNRF requested that both Common Carp and Brown Bullhead be euthanized.

An electrofishing day on August 21, 2023, resulted in the capture of the same three fish species, with the addition of the non-native goldfish. Fish were captured using an electrofishing boat and a fyke on April 24, 2024, included the four species caught in 2023, as well as two new species: a hybrid species of Goldfish and Common Carp, and a single Emerald Shiner, which is presumed to be the result of a bait bucket release. A total of 266 Brown Bullhead, Common Carp, Goldfish and hybrids were euthanized in 2024.

A summary of the results so far is shown in Table 6. Differences in years could be explained by the timing of sampling (April vs. August) and the use of nets (e.g., fewer fathead minnows in 2023 when nets were not used).

Table 6: Fish Species Collected from Swan Lake

Date	Fish Species	Number of Fish
April 2021 (3 days electrofishing + 2 days nets)	Brown Bullhead	210
	Common Carp	7
	Fathead Minnow	>10,000
August 2022 (1 day electrofishing, 1 day nets)	Brown Bullhead	80
	Common Carp	20
	Fathead Minnow	875
August 2023 (1 day electrofishing)	Brown Bullhead	84
	Common Carp	103
	Fathead Minnow	14
	Goldfish	2
April 2024 (1 day electrofishing, 1 day net)	Brown Bullhead	193
	Common Carp	1
	Fathead Minnow	1521
	Goldfish	13
	Common Carp x Goldfish	59
	Emerald Shiner	1

The TRCA has recommended that in 2025, consideration should be given to returning some/all the Brown Bullhead to the lake (rather than removal) since they are a native fish, and it is important to have some benthic feeders in a lake ecosystem.

The Long-Term Management Plan has provisions for restocking of the Lake with a variety of fish species when the water quality is amenable. It was envisaged that this would be through the OMNRF stocking program; however, as per recent communications, their inventory was low, and therefore, the City is pursuing other avenues for sourcing largemouth bass and bluegill as the species to introduce first.

5.3 Submerged Aquatic Vegetation Planting

Phase 2 of the Long-Term Plan included provisions for introducing native submerged plants in Swan Lake to help solidify the sediment and provide fish habitat.

After a review of 2022 water quality results by the City's limnologist consultant, it was determined that the introduction of submerged aquatic plants (macrophytes) should be advanced to Phase 1 of the plan so that beneficial plant communities can compete with and help mitigate algae (phytoplankton) growth. Macrophytes will increase water clarity, which, in turn, enhances their own growing conditions. Aquatic plantings will complement existing management activities.

The planting of SAVs was implemented in June 2023 by planting 1500 wild celery (*Vallisneria americana*) stems in four fenced areas along the north shore of the Lake as a pilot project. In 2023 plantings were targeted around 30cm -1m deep as optimal growing depths for Wild Celery. Observations in 2024 indicated better establishment at the 20 cm depth areas, with an overall low rate of establishment at about 30%, potentially due to the turbidity and fluctuating water levels. In 2024, another 1500 stems were planted in a depth of about 20 40 cm. Naturally growing aquatic plants were also abundant in 2024.

In 2025, existing plants will be monitored for survival and natural propagation, and a decision about further SAV planting will be made through the five-year review process.

6. Summary and Conclusions

6.1 Summary of Monitoring Results

Through the Swan Lake monitoring program, data were collected in 2024. The collected data provide insight into long-term trends in water quality and will also help determine the need for and impact of management activities on Swan Lake.

Dissolved oxygen, temperature, and water transparency were measured at two stations through bi-weekly site visits. Profiles of temperature and dissolved oxygen indicated that Swan Lake was thermally stratified in May and June. The minimum dissolved oxygen concentration required for the protection of warm water fish is 5 mg/L, which was met in the surface water, however, continuous measurements at depth indicated that DO dropped to anoxic levels for most days in the second half of August and several days mid September at depths below about 2.5 m, when there was minimal precipitation and warmer than usual weather.

pH measured at the lab was about 8, indicative of alkaline conditions due in part to high levels of photosynthesis by algae.

Transparency at the Dock station averaged at 0.76 m over the growing season and was within the interim target for Swan Lake of 0.6-0.8 m based on correlation with the phosphorus target.

Water samples were analyzed for nutrients (phosphorus and nitrogen compounds). Total phosphorus concentration in the 0.5 and 1.5m depth averaged at 12 µg/L during the growing season (June-September) and throughout the year (below the 30 µg/L threshold for eutrophic conditions). Concentrations also met the interim PWQO for total phosphorus of 20 µg/L for lakes to avoid nuisance concentrations of algae.

Total nitrogen concentrations over the growing season averaged about 0.52 mg/L (below the 0.65 mg/L threshold for a eutrophic condition).

Chloride concentrations in the Lake were within the interim target range specified for the Lake (between 190 and 250 mg/L compared to 400-500 mg/L), and were considerably lower than 2021 values, continuing the prior declining trend.

Chloride concentrations were also measured in stormwater runoff to the ponds and the Lake (from ponds, OGS's, and overland flow) during snow melt and spring freshet. The data will be used to update the chloride balance and determine the relative contribution of each source to chloride concentration in Swan Lake.

In 2024, limited surface scum was found at both the Dock and Bridge sampling sites; however, the Lake was dominated by phytoplankton. Samples analyzed for cyanobacteria indicated lower total counts than 2023. Chlorophyll-a concentrations were below the hyper-eutrophic concentration.

The water level at the logger location changed from a maximum of 208.45 m in August to 207.26 in November.

6.2 Summary of Management Activities

In 2024, geese management was completed through nest depredation and adult goose mitigation using laser light, avian distress call and limited strategic zinc crackler pyro, as well as geese relocation in the spring. These mitigation measures effectively reduced the number of geese present at different times of

the day further down from 2023 counts. Any impact that strobe lights might have had on the geese count is not readily evident.

A second application of PAC was completed in June to reduce phosphorus concentrations and ultimately algal production in the Lake.

Fish management and the removal of bottom-dwelling fish was completed by the TRCA, and 193 Brown Bullhead and 73 Common Carp/Goldfish were captured and euthanized. Any Fathead Minnow captured were released back to the Lake.

Further planting of SAV in fenced areas along the north shore of the Lake was completed to improve water clarity.

6.3 Conclusions

Based on the measured nutrient concentrations in 2024, Swan Lake is classified as mesotrophic for total phosphorus (as well as nitrogen, but not for transparency; see Table 1 for definitions). Figure 16 provides a summary of phosphorus concentrations since 2010.

Overall, the management activities in 2021-2024 that focused on the significant nutrient loadings identified in the water quality management plan (i.e., chemical treatment and fish management to reduce internal loads and geese management to reduce external loads), were effective at improving water quality in the Lake as shown by reduced phosphorus concentrations, improved dissolved oxygen levels, and lower densities of cyanobacteria. These improvements represent a positive step towards improving the aquatic habitat in the lake and meeting the long-term water quality goals.

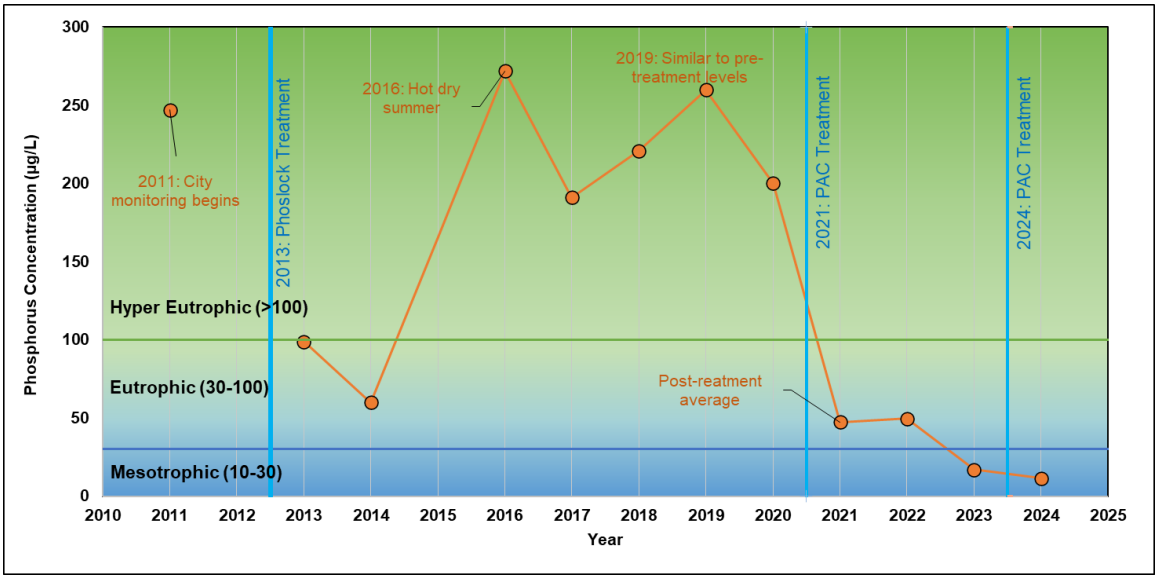
In recent years, chloride levels decreased considerably, likely due to clearing the blockage at the East Pond inlet and the Swan Club OGS, which resulted in lower untreated catchment flows to the Lake.

While internal and external source controls successfully reduced nutrient concentrations, the Lake was dominated by phytoplankton, and water clarity did not improve. This could be partly due to the absence of SAV, which has been replaced by phytoplankton (algae) due to low water clarity. The planting of SAVs stated in June 2023 and continued in 2024 to help improve water clarity.

The 2025 monitoring program will follow the recommendation of the Long-Term Management Report.

Additional measures that will be implemented in 2025 include a review of the Phase 1 of the Long-Term Management Plan, evaluation of SAV planting outcome, fish stocking, and evaluation of cost and feasibility of treatment options to reduce chloride concentration, and research into using biochar for chloride removal. A new pilot project is being considered to apply ultrasound technology for algae control.

Figure 16: Trophic State Classification for Swan Lake based on Phosphorus Concentration



Appendix A : Swan Lake Water Quality Inspection Forms

Appendix B : Certificates of Analysis

Appendix C : Canada Goose Management Program 2024- Summary Report