Swan Lake Water Quality Monitoring 2022 Annual Report

March 2023

Project Number: 22198

MARKHAM

Environmental Services

Prepared By:

Zahra Parhizgari, M.Sc., P.Eng.
Senior Environmental Engineer,
Stormwater

Reviewed By:

Robert J. Muir, M.A.Sc., P.Eng.
Manager, Stormwater

Tammy Karst-Riddoch, Ph.D.
Senior Aquatic Scientist, AECOM Canada

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 MASL). 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 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 provisions for chemical treatment every three years. Activities planned for 2022 included enhanced geese management, fish removal, water quality monitoring, and investigation of additional measures to improve water quality in the Lake.

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.

In 2022, sampling for chloride measurement was also conducted at several locations to determine the relative contribution of each source to the Lake.

This report discusses observations at the monitored stations in the Lake and several runoff stations throughout 2022.

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 1m increments for the depth of the lake. A level logger is used to record the water level in the Lake.

The following paragraphs provide the monitoring results for the 2022 monitoring period, as well as annual summaries of available data from 2011 to 2022. The figures include plots of measured dissolved oxygen (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 limits. Where technically and economically feasible, the City will aim to meet these limits to protect and enhance the aquatic environment.

Dissolved Oxygen (DO), Temperature, and pH

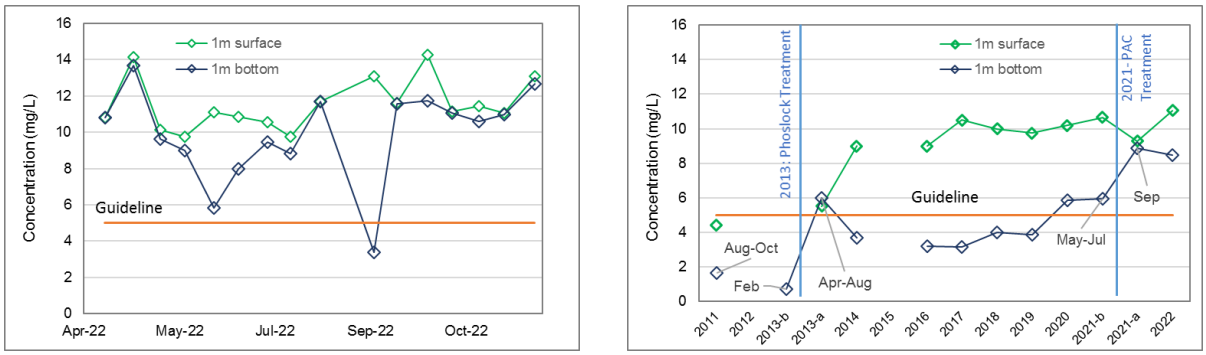
The minimum dissolved oxygen concentration required for the protection of warm water fish is 5 mg/L for water temperatures up to 20 °C, and 4 mg/L for temperatures above 20 °C. DO concentrations for the 1m from the surface and 1m from the bottom layers are shown below.

Measured day-time surface concentrations were above the DO guideline throughout 2022 (above 9.5 mg/L). DO concentration at the bottom layer was also above the guideline, except for two measurements at 2.2 and 3.4 mg/L, which occurred on dates when the water column was thermally stratified.

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.

Although measured DO levels did not indicate anoxia during the sampling events, its decline at the bottom of the water column could suggest that if the stratification persisted, it could have led to anoxic episodes (at night when respiration occurs), contributing to the release of nutrients from the sediments. Such potential occurrence would, however, be less severe than pre-treatment conditions as implied from the annual trend of day-time surface and bottom concentrations.

Figure ES-2: 2022 Monitoring Results and 2011-2022 Annual Results- Dissolved Oxygen



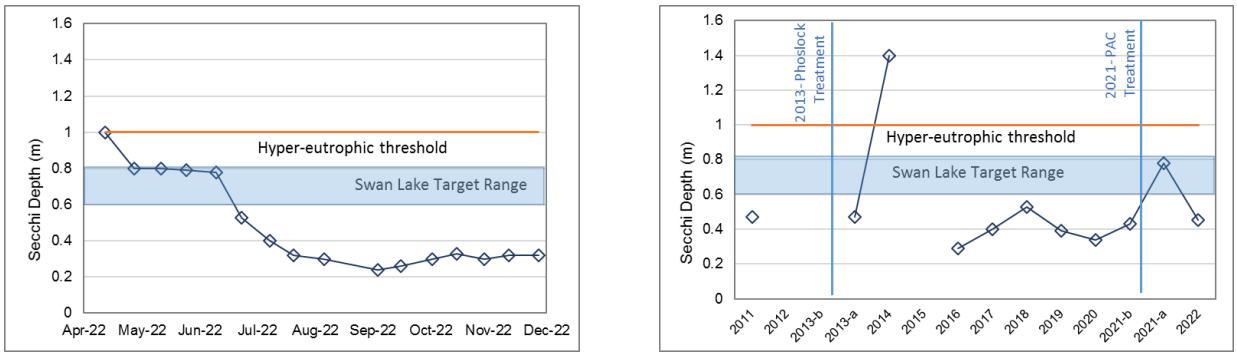
Note 1: DO concentrations are shown at 1 m from the surface (average of 0.5 and 1 m) and 1 m from the bottom (average of two bottom depths).
Note 2: Historical data are shown for the average growing period (June-Sep) unless otherwise indicated.

pH measured at the lab ranged from 7.5 to 9.4 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 2022, water clarity was above 0.5 m until the end of June but dropped to below 0.4 m for the remainder of the monitoring period.

Figure ES-3: 2022 Monitoring Results and 2011-2022 Annual Results- Secchi Depth

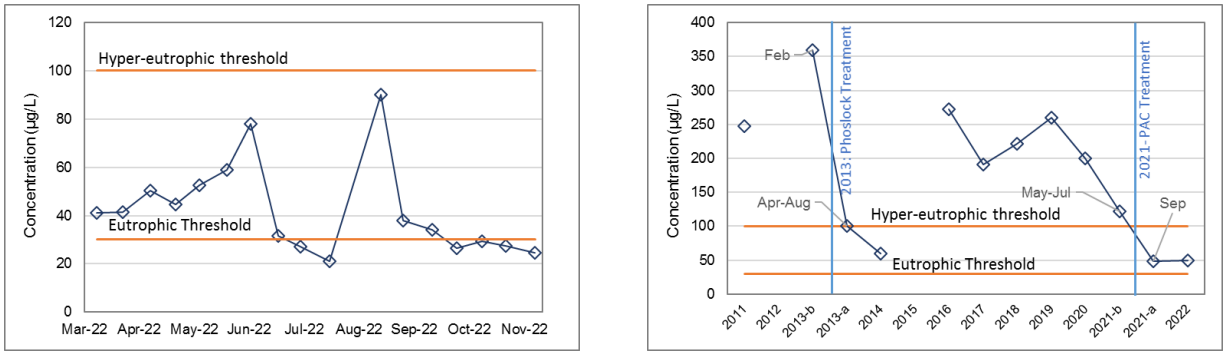


Phosphorus and Nitrogen Concentrations

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. Total phosphorus concentration in the top 0.5 and 1.5 m depths averaged under 50 µg/L during the growing season (under the 100 µg/L threshold for a hyper-eutrophic condition, and below the interim target of 50-100 µg/L). There was significant improvement in phosphorus concentrations after treatment by Phoslock and PAC.

Figure ES-1: 2022 Monitoring Results and 2011-2022 Annual Results- Total Phosphorus



Note 1: The 2022 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.

Total nitrogen concentrations over the growing season averaged about 0.60 mg/L (below the 1.2 mg/L threshold for a hyper-eutrophic condition). In 2022, ammonia and nitrate concentrations (the forms available for uptake by biota) were generally very low (except in April), and nitrogen was mainly present as organic matter.

Chloride Concentration

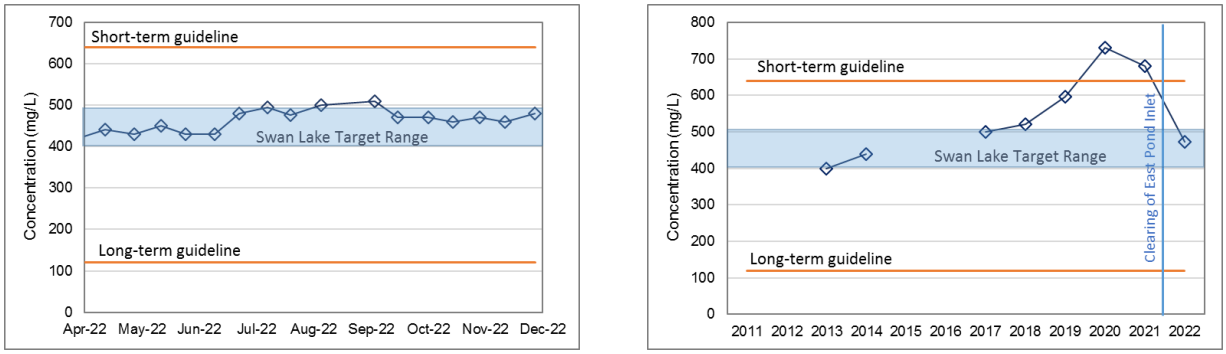
Chloride concentration has been increasing in urban lakes as a result of de-icer application for winter maintenance of roads and walkways. Chloride does not biodegrade, readily precipitate, volatilize, or bioaccumulate. It does not adsorb readily onto mineral surfaces and therefore when introduced, concentrations 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 interim target for chloride is 400-500 mg/L consistent with 2013-2014 values.

In 2022, chloride levels reduced considerably compared to 2021, likely due to clearing the blockage at the East Pond inlet, which resulted in lower catchment flows from the inlet bypass to the Lake. The lower water level in the summer may have resulted in more concentrated amount of chloride starting from end of June.

Figure ES-4: 2022 Monitoring Results and 2011-2022 Annual Results- Chloride



In 2022, water samples were collected from various inlets to the Lake and analyzed for chloride. The mass balance established using these data is documented in a separate report.

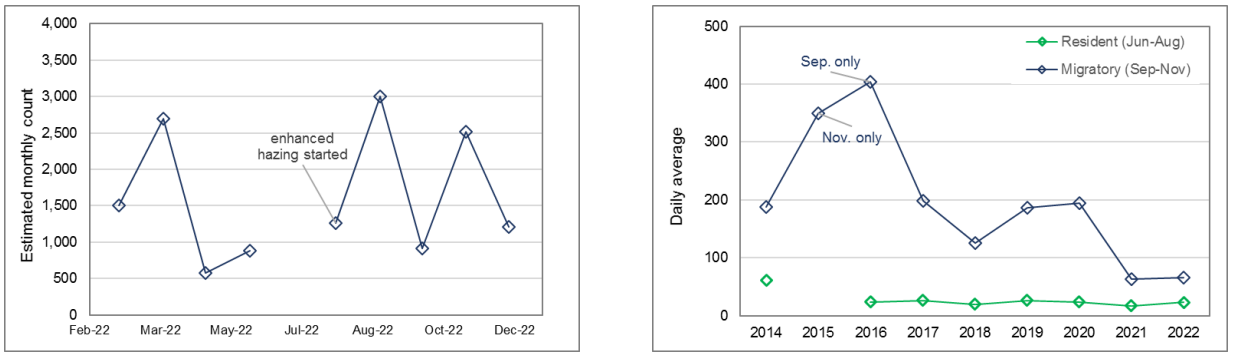
Geese Count

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 2022 program included a hazing program in the Spring, with an expanded version starting in mid-August to mid-December, nest management and geese relocation, the installation of nine strobe lights on the Lake and adjacent stormwater ponds, and geese count program.

In 2022, the increased hazing efforts were very effective in reducing the number of migratory geese visiting the Lake, similar to those achieved in 2021 when the extended program started. The strobe lights did not have any noticeable impact on the counts. The geese count data helped provide more certainty in the results, and were used to more effectively schedule hazing efforts.

Figure ES-5: 2022 Monitoring Results and 2011-2022 Annual Results- Geese Count



Note 1: 2022 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.

Other management activities completed in 2022 included a fish inventory, the removal of bottom-dwelling fish to reduce sediment disturbance, and Phragmites management through spraying and physical removal.

Algal Growth

In 2022, 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 and cyanobacteria. Test results showed lower diversity and higher total counts compared to 2021.

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 WHO's threshold for significantly increased human health risk. These results suggest that in most years, toxin-producing cyanobacteria are not the dominant form of phytoplankton in Swan Lake. In recent years, Abraxis tests have resulted in Microcystin levels below the recreational limit (20 µg/L, recently updated to 10 µg/L).

Summary and Recommendations

Overall, the management activities in 2021/2022 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 2022, chloride levels decreased considerably compared to 2021, likely due to clearing the blockage at the East Pond inlet, which resulted in lower catchment flows from the inlet bypass 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 submerged aquatic vegetation (SAV), which has been replaced by phytoplankton (algae) due to low water clarity.

The 2023 monitoring program will follow the recommendation of the Long-Term Management Plan. Additional measures will be investigated for the return of SAVs to the Lake, as well as strategies to reduce chloride concentration in the Lake.

Table of Contents

Appendices

Appendix A : Swan Lake Water Quality Inspection Forms

Appendix B : Certificates of Analysis

Tables

Figures

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 210m). 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.

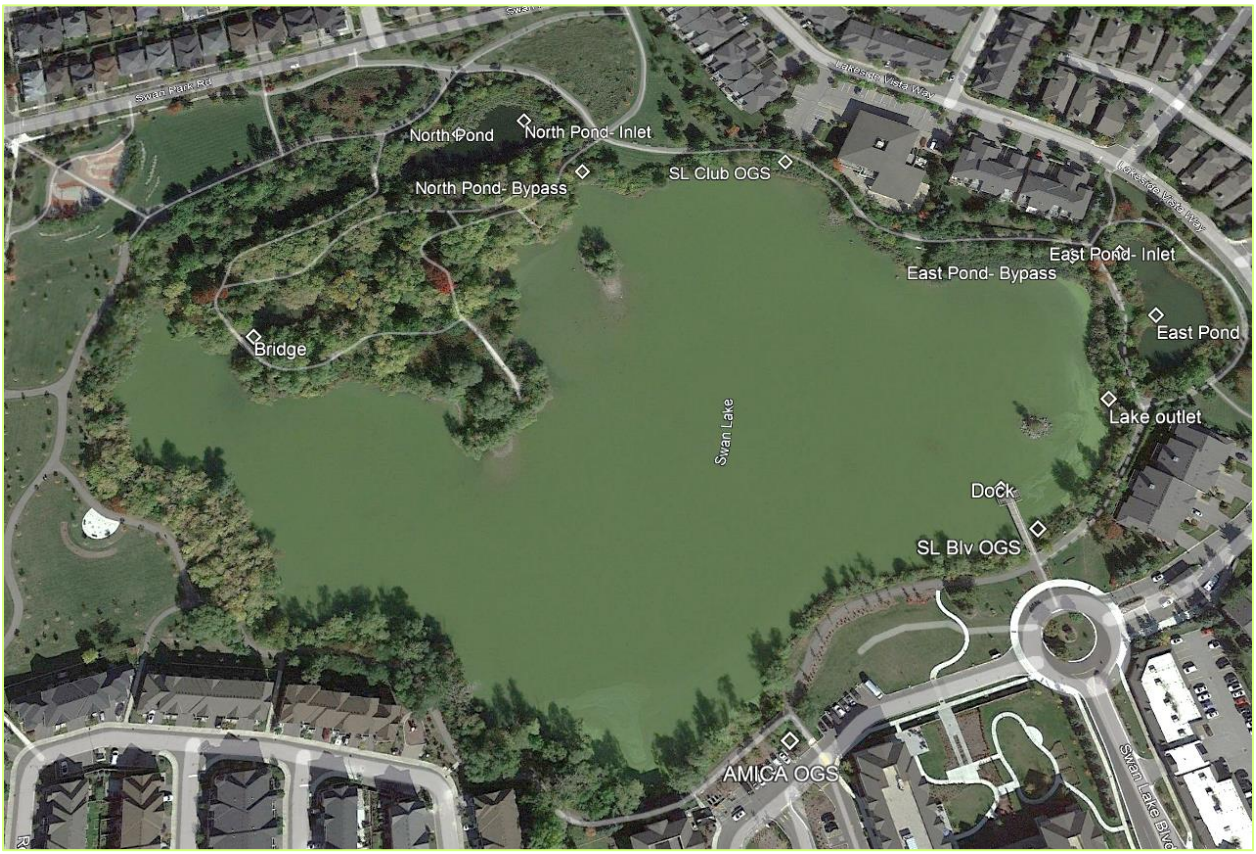
In August 2021, 13 tonnes of Poly Aluminum Chloride (PAC) were applied to the Lake in a controlled manner over several days.

The Swan Lake Long-Term Management Plan was received by Markham Sub Committee in November 2021 and approved by the Council in December 2021. It describes a phased adaptive approach, including provisions for chemical treatment every three years. Activities planned and completed for 2022 included enhanced geese management, fish removal, and water quality monitoring, as well as investigation of additional measures to improve water quality in the Lake.

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 2022 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 2022, sampling for chloride measurement was also conducted at several locations to determine the relative contribution of each source to the Lake.

Figure 1: Swan Lake and Runoff Monitoring Stations



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.

2.1.2 Duration and Frequency

In 2022, water quality was monitored bi-weekly from April to November.

A total of 17 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 dissolved oxygen (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.

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 and ortho phosphorus, ammonia, nitrate, Total Kjeldahl Nitrogen (TKN)
- Chloride, color, Dissolved Organic Carbon (DOC), pH
- Phytoplankton

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

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.

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 interim target for chloride 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

[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.

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".

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, 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 2022, 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. Samples were also collected from the shoreline runoff and Swan Lake Blvd.

The outfalls were not flowing during some sampling events, in which case, samples were collected from the pool of water present. There was no flow/ visible water at the outfall from the Swan Club's OGS, and therefore, no sample was collected at this location.

Conductivity was also measured in a number of samples, as this parameter can be used as a surrogate for chloride. Samples were collected during seven snowmelt events from November 2021 to April 2022.

2.3 Water Level Monitoring

The water level was monitored using HOBOware U20 Water logger mounted at the Dock. The data logger records the pressure and temperature of the water every 15 minutes. The measured pressure is compensated using a baro-logger to calculate water depth. Missing data were calculated using the methodology developed in 2021.

3. Results

3.1 2022 Water Quality

The following sections discuss water quality results in 2022.

3.1.1 Dissolved Oxygen and Temperature

Table 2 provides the measured DO profile over the 2022 monitoring period.

At the Dock station, all measured day-time surface concentrations were above 5 mg/L throughout 2022. At 1.5- 2 m depth, the DO was also above the guideline, except on two occasions, but never under 2 mg/L, which would be indicative of anoxic conditions. All but one measurement at the Bridge indicated a DO concentration of above 4 mg/L. Night-time oxygen was not recorded.

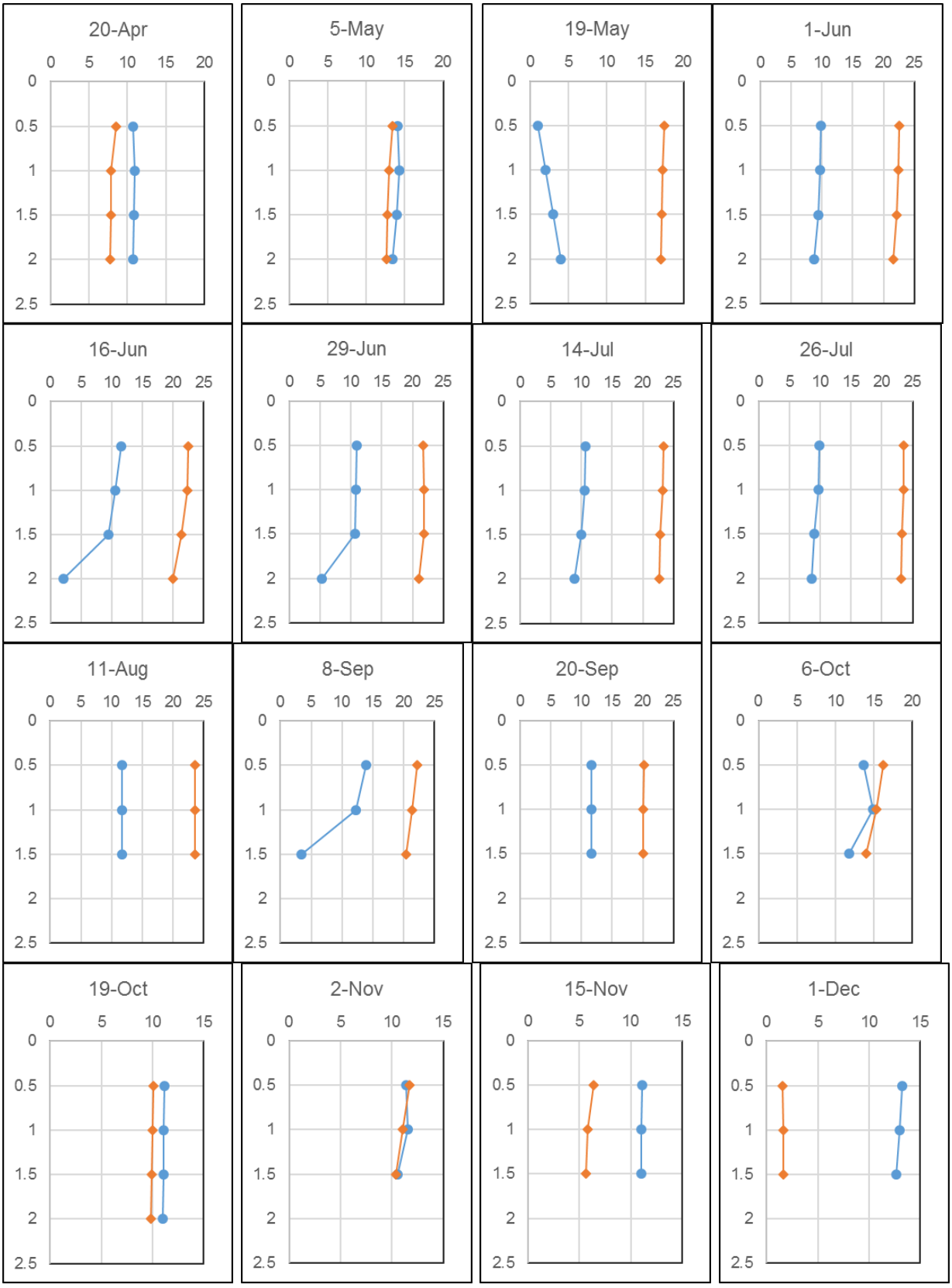
Table 2 also provides measured temperature profiles in 2022, indicating warm water throughout the depth in the summer months.

Profiles of temperature and dissolved oxygen (see Figure 2) indicate that Swan Lake was thermally stratified during June and transiently in the fall (when temperature decline is above 1 °C per m of depth or DO decline of above ~2 mg/ m of depth). Transient stratification can cause reduced mixing/aeration and lead to anoxia with the release of nutrients from the sediments.

Table 2: Measured 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
4/20/2022	10.3	10.7	10.9	10.8	10.8	8.7	8.5	7.8	7.8	7.7
5/5/2022	12.2	14.1	14.3	13.9	13.5	12.7	13.4	13.0	12.7	12.6
5/19/2022	7.4	10.2	10.1	10.0	9.3	14.9	17.5	17.3	17.2	17.0
6/1/2022	4.4	9.9	9.6	9.4	8.7	20.1	22.5	22.4	22.2	21.6
6/16/2022	4.2	11.6	10.6	9.5	2.2	21.6	22.5	22.3	21.4	20.0
6/29/2022	4.7	10.9	10.8	10.7	5.3	20.1	21.7	21.8	21.8	21.0
7/14/2022	3.4	10.6	10.5	10.0	8.9	21.0	23.4	23.2	22.8	22.7
7/26/2022	4.5	9.8	9.7	9.1	8.6	21.3	23.5	23.5	23.2	23.1
8/11/2022	4.8	11.7	11.7	11.7	-	22.0	23.6	23.6	23.6	-
9/8/2022	8.6	13.9	12.3	3.4	-	21.2	22.2	21.4	20.4	-
9/20/2022	7.7	11.6	11.6	11.6	-	19.4	20.2	20.1	20.0	-
10/6/2022	10.2	13.7	14.9	11.8	-	16.5	16.2	15.3	14.0	-
10/19/2022	9.8	11.2	11.1	11.1	11.0	9.0	10.1	10.0	9.9	9.8
11/2/2022	7.6	11.4	11.5	10.6	-	8.6	11.7	11.1	10.4	-
11/15/2022	9.1	11.1	11.1	11.0	-	1.1	6.4	5.8	5.6	-
12/1/2022	13.7	13.2	13.0	12.7	-	0.6	1.5	1.6	1.6	-

Figure 2: Temperature (orange) and DO (blue) Profile at the Dock Station



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

3.1.2 Water Transparency

Table 3 summarizes the results of the water transparency readings. Transparency at the Dock station was above 0.5 m until the end of June but dropped to below 0.4 m for the remainder of the monitoring period. The proposed interim target for Swan Lake is 0.6-0.8 m. Water transparency at the Bridge site was generally equal to the water depth.

Table 3: 2022 Secchi Depth Results (m)

Date	Dock	Bridge
20-Apr	1	0.43
5-May	0.8	0.43
19-May	0.8	0.43
1-Jun	0.79	0.465
16-Jun	0.78	0.5
29-Jun	0.53	0.44
14-Jul	0.4	0.38
26-Jul	0.32	0.2
11-Aug	0.3	0.3
8-Sep	0.24	0.2
20-Sep	0.26	0.15
6-Oct	0.3	0.2
19-Oct	0.33	0.2
2-Nov	0.3	0.2
15-Nov	0.32	0.2
1-Dec	0.32	0.2

3.1.3 Nutrients Concentrations

Samples collected during each visit were tested for Total Phosphorus (TP), Orthophosphate, Total Kjeldahl Nitrogen (TKN), Nitrate, and Ammonia. The results can be found in Figure 3 for the Dock site and Figure 4 for the Bridge site. The Certificate of Analysis from Bureau Veritas Laboratories is in Appendix B. Nutrient concentrations are shown for the depths sampled.

Total phosphorus concentration at 0.5 and 1.5 m depths averaged under 50 µg/L during the growing season and throughout the year (below the 100 µg/L threshold for a hyper-eutrophic condition).

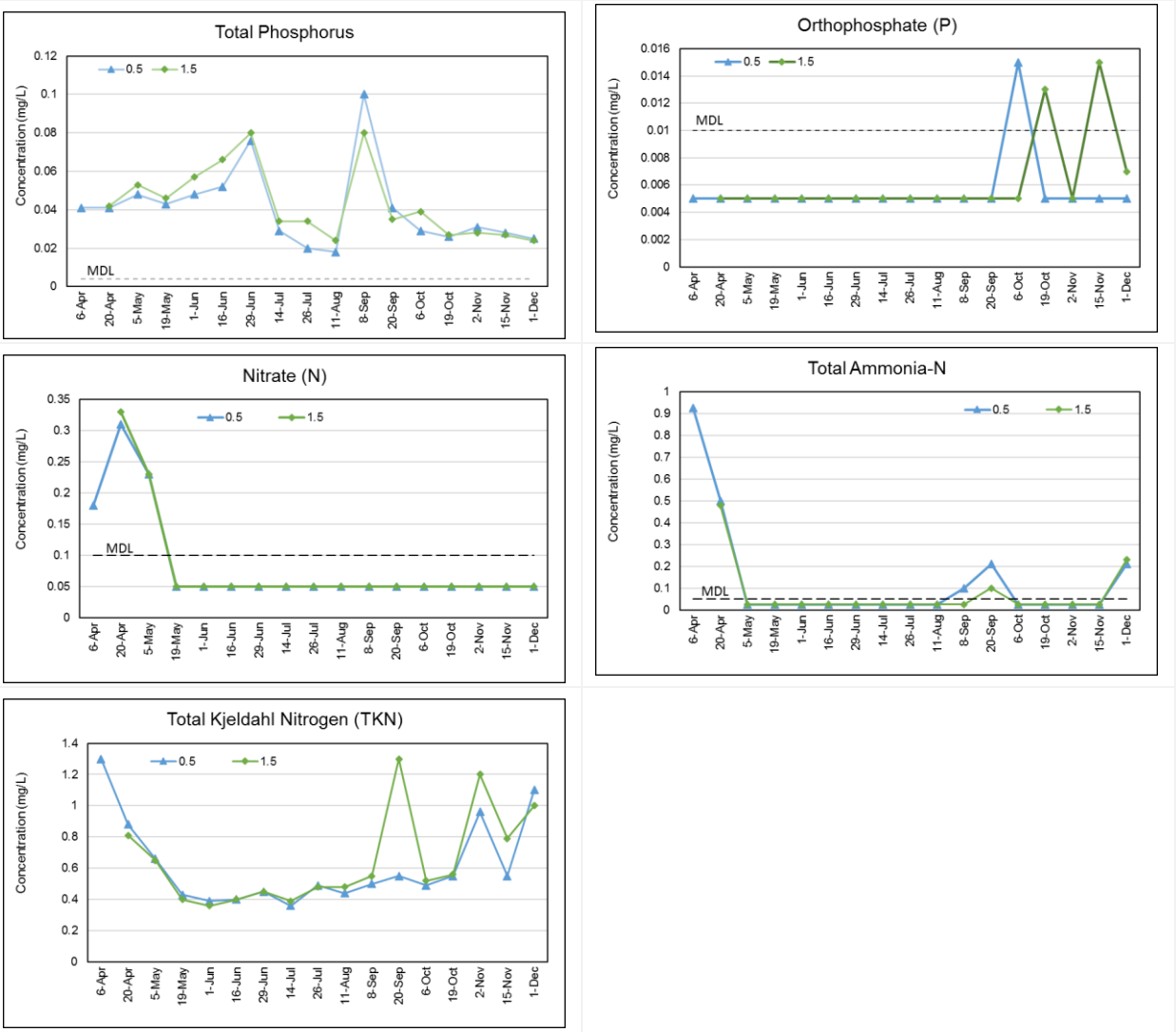
The summer peak in total phosphorus (September 8) occurred during a dry period when the Lake was stratified. Still there was no concurrent increase in orthophosphate or ammonia to suggest that there was a pulse of nutrient release from the sediments due to anoxia. Therefore, it is possible that anoxia or decomposition-related internal nutrient loading occurred in the days preceding the September 8 sampling event resulting in the increased algae abundance and elevated total phosphorus. Other potential mechanisms include wind-driven suspension of nutrient-rich sediments or germination of resting cells in the sediments.

Total nitrogen concentrations over the growing season averaged about 0.60 mg/L (below the 1.2 mg/L threshold for a hyper-eutrophic condition). Total concentrations at the Bridge site averaged 0.62 mg/L. Ammonia and nitrate are the directly-bioavailable forms, with Ammonia being the most usable form for algae. In 2022, 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 spring 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.

Elevated nitrate and ammonia in early spring are common in eutrophic waterbodies due to colder water temperatures and lack of uptake by plants and algae. Spring increase in TP as nitrate and ammonia/TKN (and transparency) decline suggests increasing spring algal activity, peaking in late June.

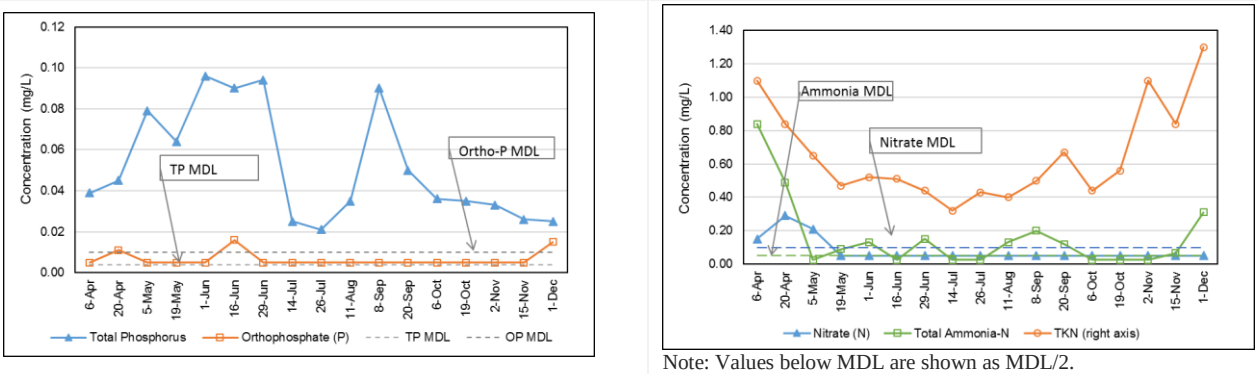
TP declined between June 29 and July 14, likely reflecting a collapse of the spring/early summer algal community. TP remained relatively low until September 8, when a bloom could have developed (although there is no supporting evidence from other indicators suggesting a bloom event). Pulses of elevated Ortho-P and ammonia in late summer and fall are consistent with transient stratification and anoxia followed by mixing that introduces nutrients into the water column and/or decomposition of algae.

Figure 3: Measured Nutrients Concentrations - Dock Site



Note: Values below MDL are shown as MDL/2

Figure 4: Measured Nutrients Concentrations - Bridge Site



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

3.1.4 pH

pH measured at the lab ranged from 7.5 to 9.4 throughout the year, with higher values measured between July and September, reflecting high algae production.

3.1.5 Chloride in Lake and Runoff

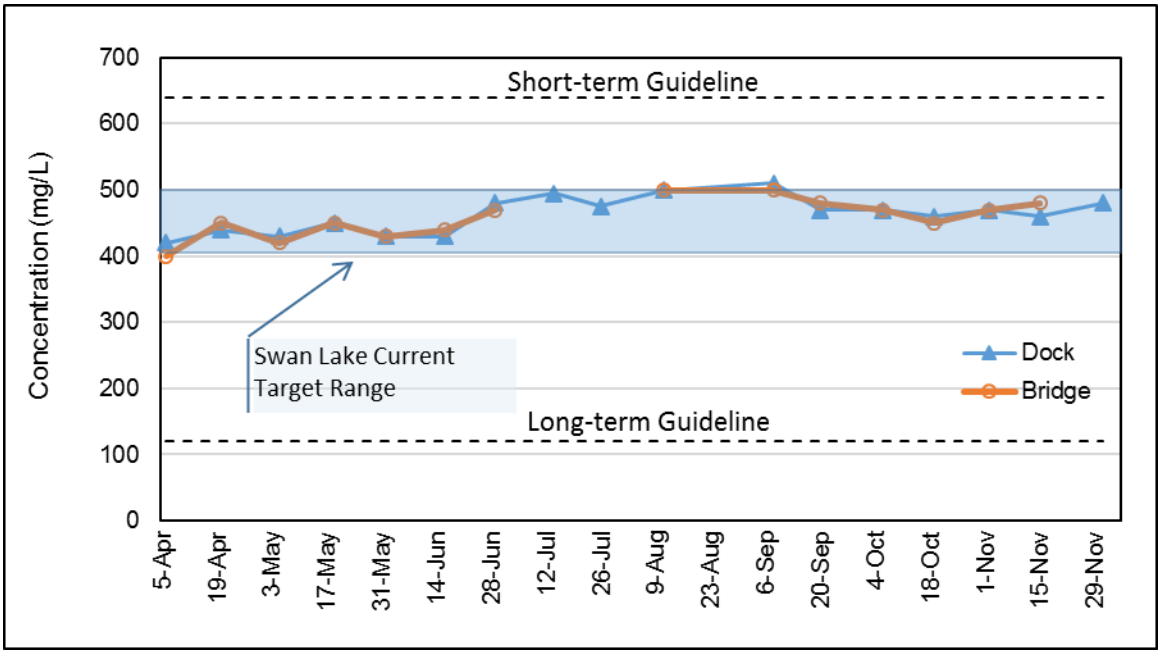
Surface samples collected during each visit were also analyzed for Chloride, as summarized in Figure 5.

Water quality testing results indicated that the samples contained between 400 and 510 mg/L of Chloride.

In 2022, chloride levels decreased considerably compared to 2021, likely due to clearing the blockage at the East Pond inlet, which resulted in lower catchment flows from the inlet bypass to the Lake. The lower water level in the summer may have resulted in a more concentrated amount of chloride starting from the end of June.

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.

Figure 5: Chloride Concentrations in Swan Lake in 2022



In 2022, 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 1000 mg/L (median of pond inlet measurements, except for January 13). 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 350 mg/L (average of pond and outlet concentrations).

The runoff collected from SLB OGS contained about 2000 mg/L of chloride, while AMICA OGS had a concentration of about 500 mg/L. Samples were also collected from the shoreline runoff, which resulted in very low chloride concentrations (about 25 mg/L). The OGS at Swan Club did not have any flow through the outfall due to blockage, and it is possible that this OGS requires maintenance and may convey the untreated runoff towards the Lake through an overland path.

The mass balance established using these data is documented in a separate report.

Table 4: Chloride Concentrations in Runoff

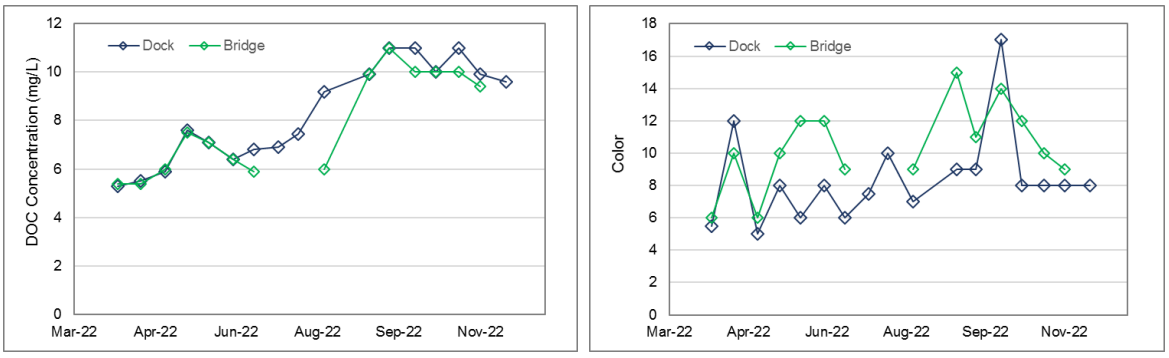
Date	Inflow to Ponds		Bypass from Pond to Lake	Inflow to Lake from Ponds				Inflows to Lake from OGS	
	East Pond	North Pond	East Pond	East Pond- in pond	From south	North Pond- in pond	Road	Swan Lake Blvd.	AMICA
3/20/2012 *	577	673		572		56			
3/26/2021	957	98.5		343		199			
4/11/2021		79	131		673				
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
Median/average	1029		210	345				1900	470

* 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 Dissolved Organic Carbon (DOC), and Color. The results are summarized in Figure 6. Increased DOC and colour may be associated with high decomposition rates releasing DOC.

Figure 6: Measured DOC and Color in 2022



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 7 below, and show a significant reduction in concentrations following the treatment, potentially due to 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.

Abraxis tests were performed on June 29, July 14, and August 11 and resulted in Microcystin levels below the recreational limit (recently updated to 10 µg/L).

Four sets of samples were collected from the Lake between August and December for phytoplankton identification, as shown in Figure 8. These results should be considered with caution due to lab errors in the identification of Microcystis. In general, the results showed lower diversity and higher total counts compared to 2021. While total microcystins concentrations were below 10 µg/L during the monitoring events in 2022, 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.

Figure 7: Planktonic Cyanobacteria Population in Swan Lake in 2021

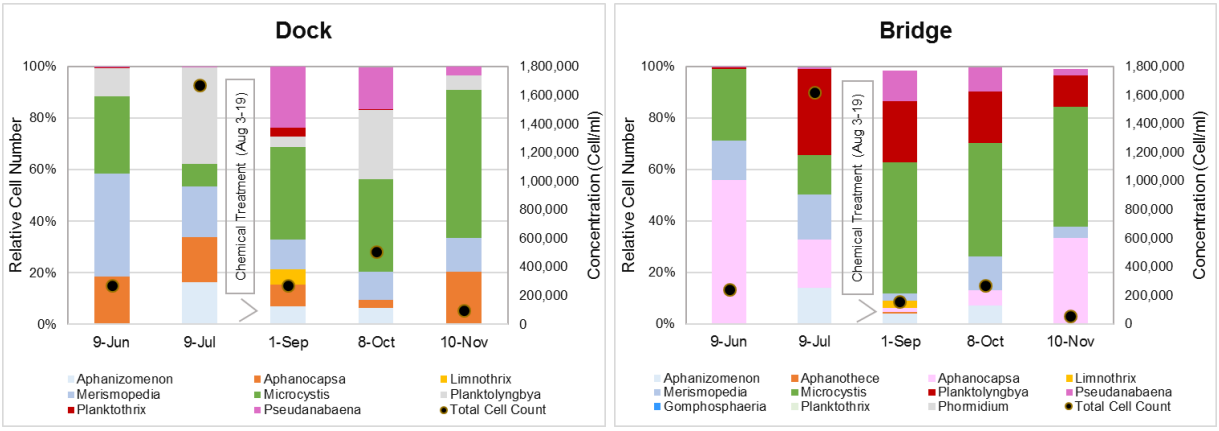
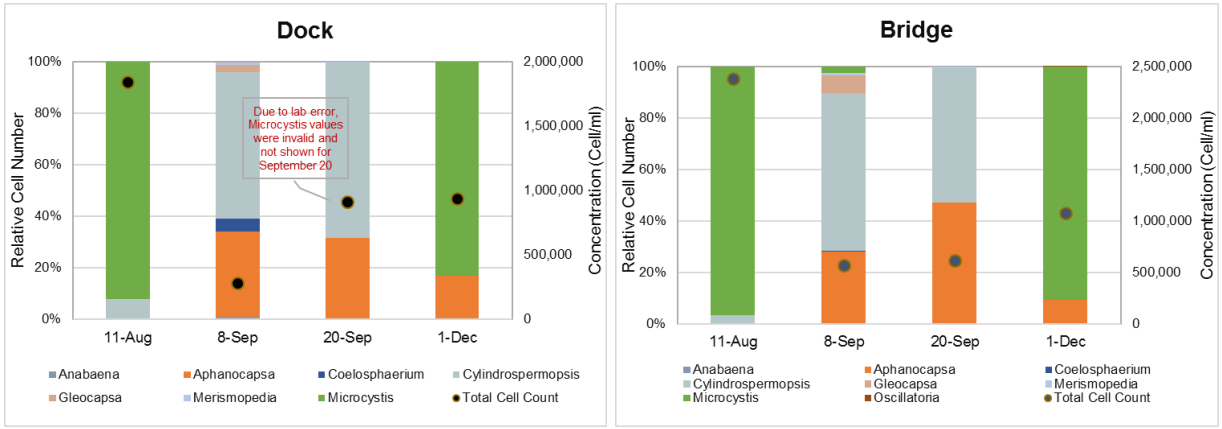


Figure 8: Planktonic Cyanobacteria Population in Swan Lake in 2022



3.2 2022 Water Level

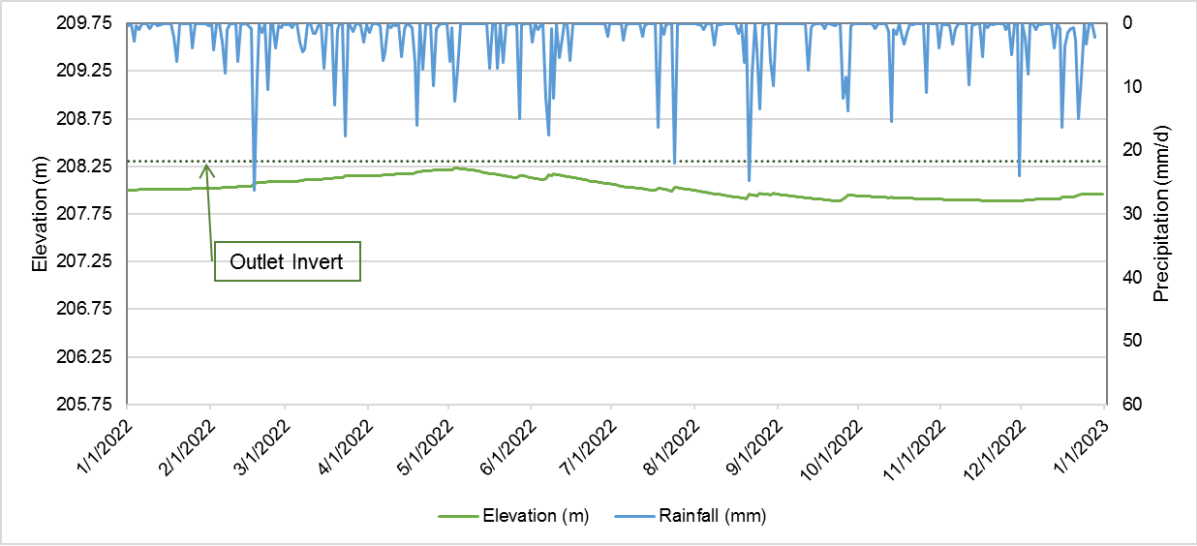
In 2022, the calculated water level changed from a max of 208.23 m in May to a low of 207.9 in November. Total precipitation in 2022 was 670 mm, as recorded at the Markham Museum station.

The maximum water level recorded or estimated between 2017 and 2021 ranged from 208.25 m to 208.48, when total precipitation ranged from 745 to 934 mm.

In addition to 2022 being a relatively dry year, the clearing of the blockage at the East Pond inlet resulted in lower flows from the inlet bypass to the Lake, further lowering the water level in Swan Lake. Extended dry periods in 2022 coincide with the approximate time of stratification.

Calculated water level and daily precipitation data from the nearby rain gauge are shown in Figure 9.

Figure 9: Lake Elevation Records and Precipitation in 2022



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 10 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 2022, day-time surface concentrations at the Dock station were above 9.5 mg/L. DO concentration at the bottom layer was also above the guideline, except for two measurements at 2.2 and 3.4 mg/L, which occurred on dates when the water column was thermally stratified.

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 10 are all below 1 m, except in 2014 and 2021, following chemical treatment. In 2022,

water clarity was above 0.5 m until the end of June but dropped to below 0.4 m for the remainder of the monitoring period.

Total Phosphorus (TP)

Average growing period (May - September) TP concentrations indicated hyper-eutrophic conditions in all monitored years except for the post-treatment years, 2013 and 2014, as well as 2021 and 2022. There was no monitoring in 2015.

Nitrogen Compounds

Total nitrogen concentration over the growing period has been above the 1.2 mg/L threshold for a hyper-eutrophic condition, except in the post-treatment year, 2014, and in 2021 and 2022. 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 2022, ammonia and nitrate concentrations were generally very low (except in April), and nitrogen was mainly present as organic matter.

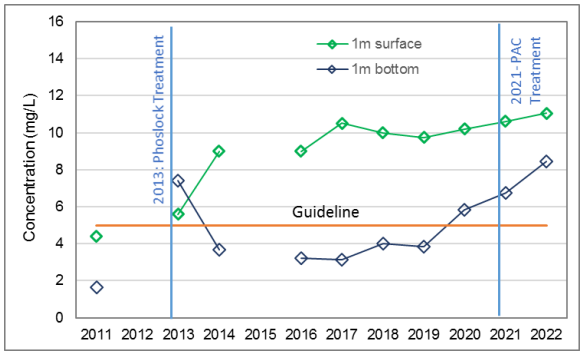
Chloride

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 resulted in lower flows from the inlet bypass to the Lake, lowering chloride concentration in Swan Lake in 2022.

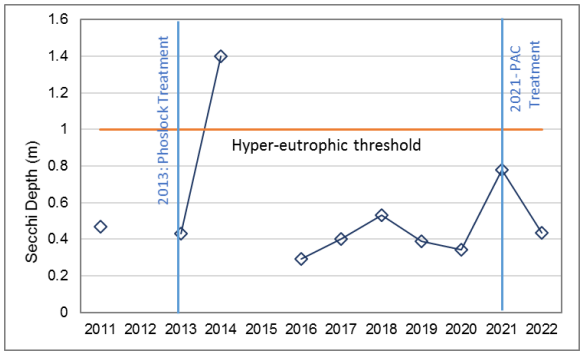
The Long-Term Management Plan for the Lake suggests that the main mechanism for lowering chloride levels would be source control. Emerging technologies and flow redirection may be considered in the future.

Figure 10: Historical Water Quality Results (Growing-Season Averages)

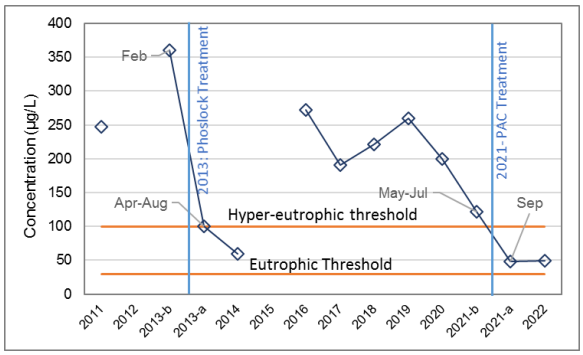
DO



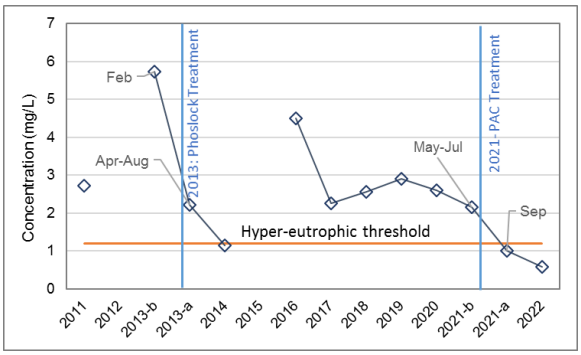
Secchi Depth



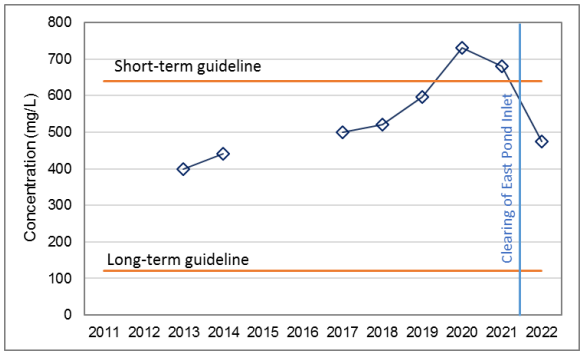
Total Phosphorus



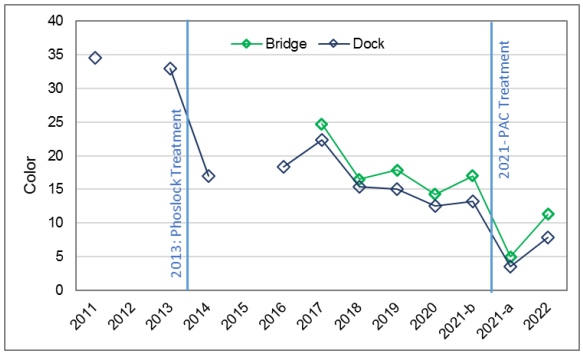
Total Nitrogen



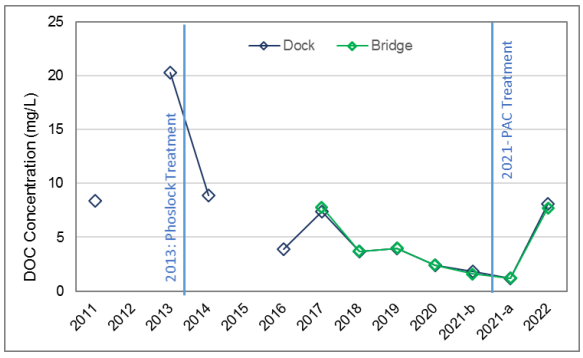
Chloride



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 scum 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

While internal and external source controls in 2021/2022 successfully reduced nutrient concentrations to below the specified targets, in 2022, the Lake was dominated by phytoplankton, and water clarity did not improve. 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. SAV compete with algae for nutrients and light, and the establishment of SAV growth may help to reduce phytoplankton blooms later in the season.

SAV would prevent sediment resuspension, take up nutrients from the water, 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; however, this shift seems unlikely without active bio-manipulation to break the cycle of high turbidity- phytoplankton dominance – high turbidity[4].

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

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 2022, the geese management program was completed by two external contractors.

Border Control Bird Dogs, an external consultant, was hired to chase (i.e., 'haze') terrestrial geese by border collies (including the Toogood Pond, where they also performed egg oiling). Program activity frequency was modified in 2021 to focus on the migration seasons. The frequent geese chasing would encourage the geese to relocate to a quieter place and reduce the number of resident geese at Swan Lake.

The Toronto Region Conservation Authority (TRCA) was hired to relocate resident geese from Swan Lake (and Mount Joy Park) 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 2022, the geese count was completed by the consultant, City staff, and volunteers from the community.

Border Control Bird Dogs 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.

Staff also developed a geese count App using ArcGIS Survey123, which a number of residents used to record geese count and note other wildlife observations.

4.3 Results

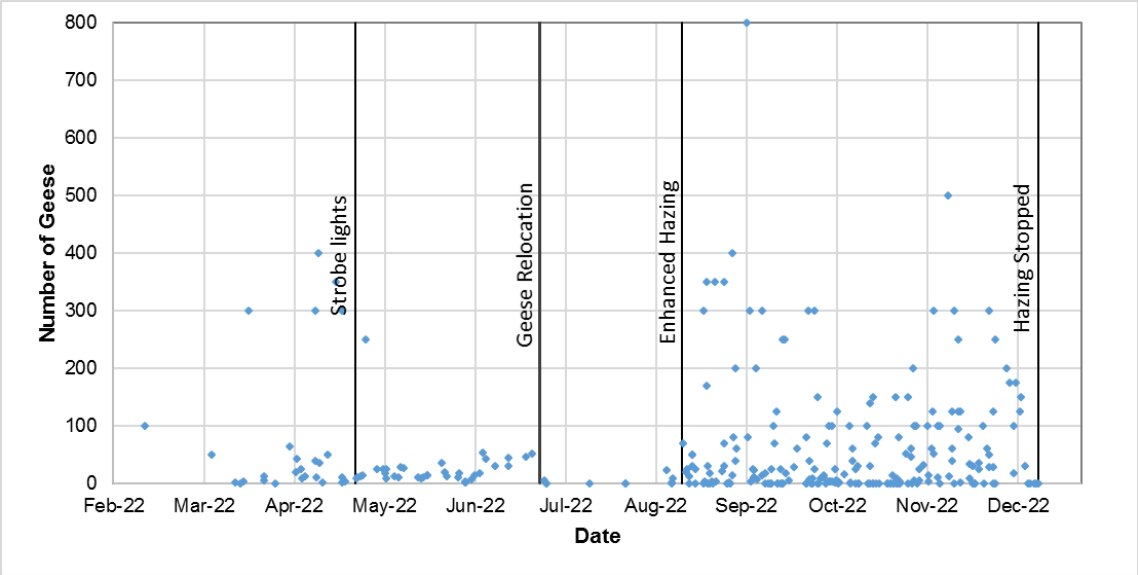
Figure 11 illustrates the number of geese counted at Swan Lake throughout the 2022 monitoring period.

In this figure, a significant increase in geese during the fall months is evident, which occurs when they migrate south; however, the increased hazing frequency (starting on August 15) effectively reduced the number of geese present at different times of the day. Following the enhanced hazing, daily numbers dropped to below 400 and remained much lower than in previous years and similar to 2021. Any impact that strobe lights might have had on the geese count is not readily evident from the data. Limited data are available for June and July when hazing was not occurring.

In addition, six nests and 28 eggs were managed at Swan Lake from late April to early May.

In total, 46 Canada Geese were rounded up from Swan Lake and 25 from Mount Joy Park on June 28, 2022. Fifteen of the birds were goslings. All birds were captured except for adults who could fly away.

Figure 11: 2022 Geese Count Results

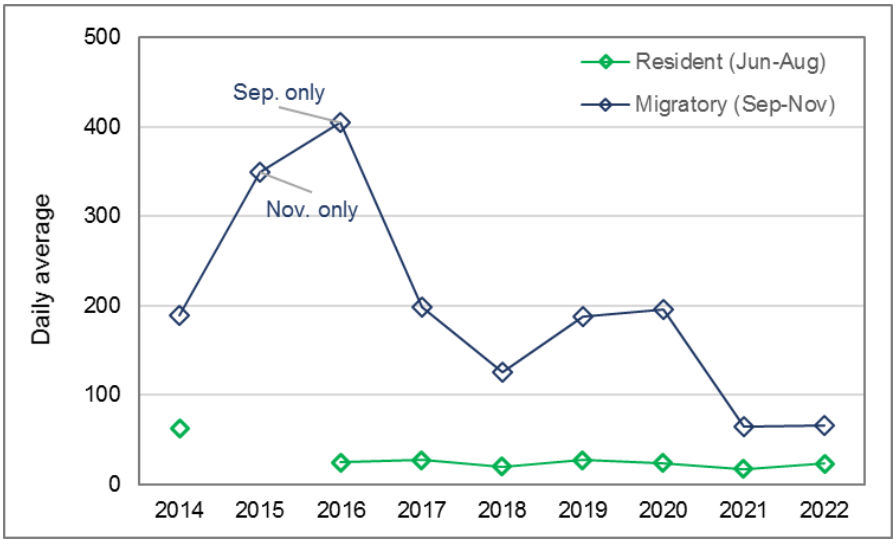


4.4 Historical Trends

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 12. 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 12: Historical Geese Counts



5. Other Management Activities

5.1 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.

Similar to 2021, the City hired the TRCA in 2022 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.

TRCA completed the 2022 work under License to Collect Fish for Scientific Purposes #1101177 (AU2022-00242). TRCA applied for a Fish Stocking License similar to 2021, but was informed by the Ontario Ministry of Natural Resources and Forestry (OMNRF) that the license would not be granted in 2022 due to the possibility of disease transfer. Instead, OMNRF requested that both Common Carp and Brown Bullhead be euthanized.

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. A summary of the results for both years is shown in Table 6. The timing of the sampling (April vs. August) likely influenced the catch because water temperatures are warmer in August, and fish are less active in cold water.

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

5.2 Shoreline Restoration

As part of the Parks Refresh program for Swan Lake, herbicides were used on the Phragmites/common reeds in Swan Lake and the two stormwater management ponds, followed by physical removal by an amphibious vehicle. The herbicide application was carried out by licensed contractors working on behalf of the TRCA, following and taking all necessary safety precautions to protect the public. A second application is planned for the spring of 2023.

6. Summary and Conclusions

6.1 Summary of Monitoring Results

Through the Swan Lake monitoring program, data were collected in 2022. 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 June and in the fall. The minimum dissolved oxygen concentration required for the protection of warm water fish is 5 mg/L, which was met in the surface water and the bottom layer, except on two occasions.

pH measured at the lab ranged from 7.4 to 9.7, with higher values measured between July and September, indicative of high algae concentration.

Transparency at the Dock station was above 0.5 m until the end of June but dropped to below 0.4 m for the remainder of the monitoring period. The proposed interim target for Swan Lake is 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 under 50 µg/L during the growing season (June-July) and throughout the year (below the 100 µg/L threshold for a hyper-eutrophic condition).

Total nitrogen concentrations over the growing season averaged about 0.6 mg/ (below the 1.2 mg/L threshold for a hyper-eutrophic condition).

Chloride concentrations in the Lake were within the target range specified for the Lake (between 400 and 500 mg/L), and considerably lower than 2021 values.

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 were used to establish a chloride balance and determine the relative contribution of each source to chloride concentration in Swan Lake.

In 2022, 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 diversity and higher total counts than 2021.

The water level at the logger location changed from a maximum of 208.25 m in May to 207.9 in November.

6.2 Management Activities

In 2022, geese management was completed by chasing terrestrial geese by border collies and egg oiling, as well as nest management and geese relocation in the spring. Program frequency was modified in 2021 to focus on the migration seasons. Nine strobe lights were also maintained on the Lake and the two stormwater management ponds. The increased hazing frequency (starting on August 15) effectively reduced the number of geese present at different times of the day to about 50% of numbers in 2020, and comparable to those in 2021. Any impact that strobe lights might have had on the geese count is not readily evident.

Fish management and the removal of bottom-dwelling fish was completed by the TRCA, and 80 Brown Bullhead and 20 Common Carp were captured and euthanized. About 900 Fathead Minnow captured were released to the Lake.

As part of the shoreline restoration program, herbicides were used on the Phragmites/common reeds in Swan Lake and the two stormwater management ponds, followed by physical removal by an amphibious vehicle.

6.3 Conclusions

Based on the measured nutrient concentrations in 2022, Swan Lake is classified as a low-eutrophic condition. Figure 13 provides a summary of phosphorus concentrations for all the years with available data.

Overall, the management activities in 2021/2022 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 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 2022, chloride levels decreased considerably compared to 2021, likely due to clearing the blockage at the East Pond inlet, which resulted in lower catchment flows from the inlet bypass to the Lake.

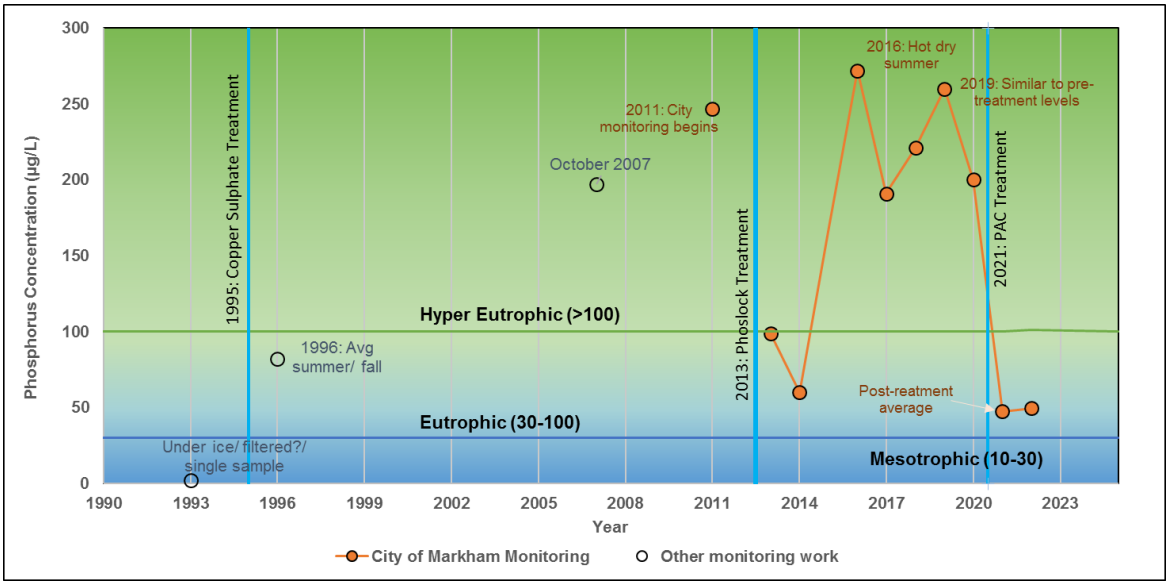
While internal and external source controls successfully reduced nutrient concentrations, the Lake was dominated by phytoplankton, and water clarity did not improve.

This could be partly due to the absence of submerged aquatic vegetation (SAV), which has been replaced by phytoplankton (algae) due to low water clarity.

The 2023 monitoring program will follow the recommendation of the Long-Term Management Report. In addition, continuous dissolved oxygen loggers will be considered at the monitoring sites to evaluate potential anoxic episodes at night and better determine periods of transient stratification and bottom anoxia as they relate to internal nutrient loads. This information can inform the nutrient budget for the lake and future chemical dosing requirements. Phytoplankton taxonomy will also be expanded to include all taxa to provide additional information on phytoplankton dynamics and support future management decisions.

Additional measures will be investigated for the return of SAV to the Lake, as well as the evaluation of cost and feasibility of treatment options to reduce chloride concentration and improve oxygen levels in the Lake.

Figure 13: Trophic State Classification for Swan Lake based on Phosphorus Concentration



Appendix A : Swan Lake Water Quality Inspection Forms

Appendix B : Certificates of Analysis