Friends of Swan Lake Park

Summary of Lake Management Discussions for Swan Lake

Swan Lake Park is a municipal park located at 25 Swan Park Road in the City of Markham, Ontario. Swan Lake, within Swan Lake Park, has poor water quality and deteriorating aquatic habitat. A bird's eye view of Swan Lake Park is available courtesy of Thomas Yee Swan Lake Park by Drone - DJI Mavic Mini - YouTube.

Founded in 2019, the Friends of Swan Lake Park ("FOSLP") are residents of Markham committed to saving Swan Lake and Swan Lake Park through environmentally best practices that will restore aquatic and terrestrial habitat and provide safe lake water for sustainable human and wildlife activity.

The following report outlines the history of lake management at Swan Lake and Markham's current plan for addressing water quality issues in Swan Lake and summarizes the additional options recommended by FOSLP.

Contents

November 30, 2023

1) History of Lake Management

a) Creation of Swan Lake Park (1993 – 2000)

Swan Lake was an active gravel quarry in the 1960s and 1970s until it filled with water. During the 1970s the pit was used as a local landfill site and there was some illegal dumping of household waste which has resulted in some environmentally sensitive areas within the park and lake. The lake was stocked with largemouth bass around 1992 and an application of Copper Sulfate was applied in 1995 presumably to address algae issues.

During the 1990s, the area was slated for conversion from active farmland to urban development. The December 1993 *Swan Lake Community Environmental Management Study*[1] set out the developer's objectives and plan for the conversion of the gravel pit into a community feature with multiple trails including "a diverse natural habitat for aquatic and terrestrial wildlife … that incorporates passive use opportunities surrounding the lake". The plan was accepted by Markham and substantially completed by 2000 and serves as an important benchmark for ongoing restoration discussions.

There are no natural surface level streams flowing into or out of Swan Lake. However, the original development included the integration of Swan Lake with the area stormwater systems. Six stormwater sources direct stormwater flows into the lake. The lake depth is regulated by an outflow pipe to the area's stormwater system which effectively maintains the average depth at 1.65 m. (see Appendix C).

b) Treatment with Phoslock (2013)

By 2012, Swan Lake was described by the city's consultant, Freshwater Research[2] , as a "highly eutrophic lake with a history of cyanobacterial blooms". Freshwater Research noted that of 17 man-made urban lakes in Ontario, Swan Lake exhibited the third-highest total phosphorus concentration and the highest chlorophyll concentration in a subset of six lakes. Freshwater recommended abatement efforts be taken to address external phosphorus load but noted that most of the water quality problems originated from internal phosphorus sources including the bottom sediments, and recommended a Phoslock treatment.

In 2013, a 25.2 tonne Phoslock treatment was administered. The treatment improved water quality from hyper-eutrophic to eutrophic conditions for two years but by 2016 the water quality was as low or lower than in the pre-treatment year.

c) Swan Lake Water Quality Improvement Program (June 2020)

In June 2020, FOSLP submitted a report to Markham Council outlining a variety of lake management options for consideration[10]. Markham staff submitted for Council's approval a *"Swan Lake Quality Improvement Program"*[3] that outlined reasons for rejecting a number of the lake management proposals submitted by FOSLP. To address the increasing recurrence of algal blooms and the concerns about cyanobacteria, Markham staff recommended another treatment of Phoslock in 2021. To contain algal blooms, future treatments would be triggered following two consecutive summers of a hypereutrophic state (phosphorus levels exceeding 150 ug/L) implying treatments every 5 – 7 years. Phoslock was not available for use in Canada in August 2021 so 13 tonnes of Poly Aluminum Chloride (PAC) were applied to the lake under the guidance of Markham's consultant AECOM.

In December 2020, FOSLP submitted a report *"A Pathway to Sustainable Water Quality for Swan Lake"*[11] to Markham Council focusing in greater detail on additional lake management options that should be considered in addressing the issues in Swan Lake. In addition, in February 2021, FOSLP submitted a report titled *Literature Review of Potential Engineering Solutions for the Restoration of Swan Lake*[16] by the Centre for Advancement of Water and Wastewater Technologies at Fleming College which provided commentary on some of the concepts raised by FOSLP. Markham Council directed staff to consider the submission from FOSLP and Fleming College and to prepare a long-term plan for Swan Lake. Most of the recommendations were rejected [16(a), 16(b)] in the long-term plan.

d) Swan Lake Long-Term Plan (2021)

In December 2021, Markham Council approved the *Swan Lake Long-term Water Quality Plan*[5] which describes a phased adaptive approach, including provisions for periodic chemical treatments initially every three years. Highlights of the plan are provided in the following section followed by concerns expressed by FOSLP.

e) Independent Workshop (2026)

In May 2023, FOSLP submitted a report[15] outlining additional lake management options for Markham's consideration. At the request of FOSLP, Markham Council asked staff to consider incorporating a "workshop" of independent consultants into the planned 2026 review of the Long-term Plan for Swan Lake to consider FOSLP's recommendations.

2) Markham's Long-term Plan for Swan Lake (December 2021)

a) Goal and Interim Targets

The long-term plan[5] includes the following goal statement.

GOAL: To improve the overall health of Swan Lake, which will provide opportunities for no-contact activities for the enjoyment of the community.

The table below sets out the "Interim" water quality targets for the initial five year period (2021 – 2025).

Parameter	Current Values	Interim Target	Objective and Rationale
Total Phosphorus (µg/L)	>200	50 - 100	Current value: the average of growing season TP values in the period since 2016 has been 200. Interim target: will provide a low eutrophic condition in the first year after treatment increasing to eutrophic in year 3.
Secchi Transparency (m)	< 0.5	0.6 – 0.8	Based on correlation with the phosphorus target. Secchi is also a substitute for Chlorophyll a.
Frequency of algae blooms	Annual	Every 3 years	Trigger for treatment every three years
Internal phosphorus load (kg/yr.)	53	0 - 25	Both internal and external loads should be controlled to achieve the lake concentration target (see above)
External phosphorus load (kg/yr.)	30	15	

b) Scheduled Activities

Based on subsequent discussions and undertakings, Markham's current activities closely mirror the "Option 2" activities outlined in the orignal plan.

Option 2 - Expanded Core, Accelerated Complementary and Alternative Measures

	Activity	Phase 1 Core+ Complementary Measures (Years 1-5)	Phase 2 Core+ Alternative Measures (Years 6-10)	Phase 3 Core+ Alternative Measures (Years 11-25)
Core	Water quality monitoring and annual reporting to Subcommittee	☑	☑	☑
Core	Geese management and explore enhanced methods	☑	☑	☑
Core	Remove benthic-dwelling fish	☑	☑	☑
Core	Maintenance of stormwater management facilities (by developers then City)	☑	☑	☑
Core	Community Engagement	☑	☑	☑
Core	Chemical treatment (adjusted frequency at the end of each Phase)	☑	☑	☑
Complementary	Shoreline planting / Improvements	☑		
Complementary	Chemical oxygenation pilot project (by research institute)	☑		
Complementary	Fish management plan and fish stocking (by MNDMNRF)	☑		
Complementary	Planting of submerged plants	☑		
Complementary	New technologies for chloride treatment	☑		
Alternative	Investigate contribution from groundwater and dumping areas if required		☑	
Alternative	Evaluate/design structural modifications such as lake water recirculation and stormwater redirection, if required		☑	
Alternative	**Evaluate implemented measures and report back**	☑	☑	☑

Cost Included

c) Actions Undertaken by Markham Staff Since December 2021

A listing of Key Measures considered under the plan and their perceived technical feasibility and effectiveness is provided in Appendix B. Actions undertaken by Markham staff include:

i) **Measure IL1**: A Poly Aluminum Chloride (PAC) treatment was applied in July 2021 and a second treatment is planned for the summer of 2024.

ii) **Measure OL1:** In 2023, Markham installed an oxygen monitor at the dock to track oxygen levels over a 24-hour cycle.

iii) **Measure NF2**: In 2023, the Toronto Region Conservation Authority ("TRCA") initiated a pilot aquatic plant project with the planting of wild celery in five areas.

iv) **Measure EL3**: Markham staff are working with the TRCA on redesigning the shoreline[7] around the lake to restrict Canada geese and to improve recreational access to the lake. First phase involving removal of phragmites was undertaken in 2022 and 2023. Shoreline construction is expected to start in 2024.

v) **Measure IL2**: The TRCA was engaged to undertake a fish inventory and removal of bottom feeding fish such as carp and goldfish from Swan Lake. The following table summarizes the fish species identified through 2022.

Fish Species in Swan Lake

Historical Sightings	TRCA Samples	
	April 2021 (a)	**August 2022** (b)
Black Crappie Carp Catfish Fathead Minnow Goldfish Largemouth Bass Pumpkinseed Sunfish	Brown Bullhead (210) Common Carp (7) Fathead Minnow (> 10,000) (a) 3 days electrofishing + 2 day nets	Brown Bullhead (80) Common Carp (20) Fathead Minnow (875) (b) 2 days electrofishing + 1 day nets

d) Additional Actions Proposed by FOSLP

Friends of Swan Lake Park proposed four actions following the adoption of the long-term plan.

i) **Measure CL2:** In 2022, FOSLP recommended research by a York University research team[18] into the use of BioChar (a type of charcoal filter) into the removal of nutrients and chloride from the lake system. This application may be feasible in stormwater inflow areas or in concert with flows directed through the North Channel[15]. Markham staff, based on the recommendations of their consultant AECOM,[9] requested budget funding to support continuing research into this possible application.

ii) **Measure CL3:** FOSLP submitted two reports[13,14] detailing the source of the stormwater flows into the lake with recommendations on rerouting the flows. Subsequently, Markham staff undertook an analysis of the inflows confirming that the stormwater sources were contributing on average 4 metric tonnes of chloride each year[6]. These reports triggered two actions: a) removal of the blockage in one of the stormwater pipes that was triggering excess flows into the lake, and 2) Council approval of $150,000 for a "Flow Diversion Study" into the feasibility of rerouting stormwater flows as proposed by FOSLP. The report is expected in 2024.

iii) **Measure OL1**: In May 2022, FOLSP recommended research by Fleming College[17] into the use of calcium peroxide as a source for improving oxygen levels. Based on AECOM's analysis[9], Markham has declined to proceed with this "early stage" research.

iv) **Measure OL1:** In May 2023, FOSLP requested approval for a University of Toronto research team[19] to install an oxygenation device for three months on Swan Lake during the summer of 2023 at no cost to the city. It was expected that the research would help gauge the sensitivity of the sediments to mechanical aeration. Staff denied the request on the basis that previous recommendations by Freshwater Research had indicated that mechanical oxygenation would be detrimental to the restoration efforts.

3) FOSLP Goal of Sustainable Restoration

The Friends of Swan Lake Park's stated goal is the sustainable restoration of Swan Lake – in terms of water quality and in terms of the aquatic environment, both of which have deteriorated significantly.

Sustainable restoration involves restoring the water quality to a stable improved level in ways that can be sustained by natural elements with minimal human intervention in the future.

FOSLP has chosen two benchmarks for measuring restoration success.

The first benchmark is the comprehensive 1993 Environmental Management Study[1] that the developers outlined for Swan Lake. and which was accepted by Markham. This document sets out details that serve as an environmental benchmark for the aquatic and terrestrial environment.

Secondly, FOSLP adopted the challenging objective of "mesotrophic" level for water quality believing that it represents a stable and sustainable level for water quality that supports basic human interaction with the water. Lower levels such as "low-level eutrophic", as proposed in the current plan, while an improvement, are still not considered to be environmentally stable or healthy.

FOSLP proposes that the long-term water quality plan should:

1) Contain a specific target for algae content. The stated objective is for the reduction of algae; however, under the current plan, there is no direct monitoring of algae content in the lake, rather Secchi Disc measures are used as a proxy.
2) Provide for phosphorus and nitrogen targets and Secchi measures for mesotrophic level.
3) Establish a chloride target of meeting or exceeding long-term Federal guidelines.
4) Establish a target for oxygen levels that provides both a sustainable environment for aquatic life and is at a level sufficient to reduce the release of nutrients from the sediments.

a) Additional Action Required

FOSLP's view is that sustainable restoration can be accomplished only by addressing all three of the primary issues within Swan Lake: (1) excessive nutrients (2) high chloride levels, and (3) low oxygen levels.

The primary shortcoming of Markham's current long-term plan is that it focuses only on addressing nutrient**s** by reducing external load through an aggressive geese management program and by reducing internal phosphorus load through a periodic chemical program. These efforts are an important building block towards restoration but are expected to produce only marginal improvements in water quality and are not environmentally nor financially sustainable over time. FOSLP's May 2023 report[15] raises the question of whether the removal of the some of the sediments is not a more timely, effective, and sustainable solution for addressing internal nutrient load rather than the current plan of periodic chemical treatments.

Markham's current plan incorporates virtually no direct actions to address the two chronic structural issues facing the lake:

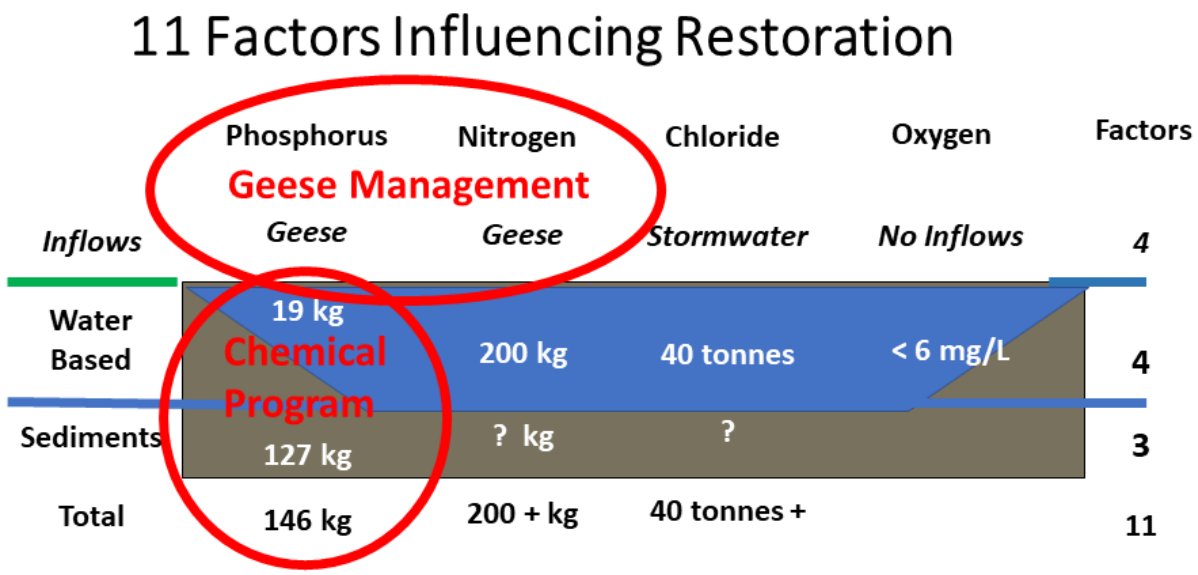
First structural challenge is Swan Lake's role within the area's stormwater system. Markham's subsequent agreement to undertake the Flow Diversion Study may identify ways of redirecting some of the stormwater away from the lake. It is unlikely stormwater inflows can be eliminated totally since the lake serves as an important component of local area flood control. Reduction of future inflows of road salt is an important part of the solution; however, there are no plans to address the build-up of 30-40 tonnes of chloride already within the lake. A drawdown of the lake as proposed by FOSLP could reduce over 50% of the existing chloride content.

The second structural issue is that the lake is a stagnant body of water. The current plan suggests oxygen levels will improve with the reduction in algae levels. While helpful, as a stagnant body of water, the lake will face perpetual low oxygen challenges even with lower levels of algae. Swan Lake is a man-made structure – it will require a man-made solution to provide a sustainable source of oxygen.

b) Other Possible Actions

In its May 2023 report, "*Towards a Comprehensive Restoration Plan for Swan Lake*"[15], FOSLP reviewed a range of lake management options to address inflows of external nutrients and contaminants and options for removing water-based and sediment-based nutrients and contaminants.

Research on water quality in Swan Lake suggests there are eleven (11) factors to be considered in a comprehensive program for restoring water quality.



The current long-term plan addresses only four of the factors directly. By reducing the algae levels, there is expected to be an indirect improvement in oxygen levels since less oxygen will be consumed as the algae dies in the fall.

Current Long-term Plan	Nutrients P	Nutrients N	Cl	O	Factors Addressed	Restoration Timeframe	Costs	Concerns
Geese, Fish Management & Monitoring	1	1			2/11	25 year	$3.3 m	Perpetual program
Chemical (Phoslock/PAC)	2			0.5	2.5/11	25 year	$1.4 m	Addresses only Phosphorus
2021 Long-term Plan	3	1	0	0.5	4.5/11	25 year	$4.7 m +	Uncertainty of success, timeline
* Costs exclude Shoreline Restoration								

A plan including a drawdown to reduce chloride already in the lake, the removal of some of the sediments, and a sustainable oxygenation program such as recycling via the North Channel can potentially address all 11 elements and provide an opportunity to discontinue the chemical treatment program.

The core question to be answered is whether the potential additional costs of addressing the sediments materially increases the environmental outcomes and reduces other costs.

Path #2: Water & Sediment	Factors Addressed	Restoration Timeframe	Costs	Benefits/Concerns
Geese, Fish Management & Monitoring	2/11	10 + years	$3.2 m	Potential to reduce water monitoring costs
Rerouting stormwater	1/11	3 - 5 years	$0.7 m +	Essential. Excludes rerouting costs
Drawdown	4/11	1 - 3 years	$	Addresses chloride, Downstream, Refill
Recycling Via North Channel	1 /11	10 + years	$	Reduces need for additonal filtration
Sediment Removal & Storage (SW)	7/11	1 year	$1.5 - $3.7 m	**Shoreline Restoration Impact, Capacity**
Comprehensive Water & Sediment Plan	11/11	10 + years	$5.4 - 7.6 m +	**Faster aquatic recovery, greater assurance of success, potentially better results, potential to reduce monitoring costs**
* Costs exclude Shoreline Restoration & Rerouting Stormwater				

c) Independent Workshop in 2026

FOSLP recommended that Markham convene a Solution Workshop of independent experts to advise Council on the framework for a comprehensive plan for sustainable restoration of Swan Lake. Council has asked staff to consider incorporating the Solution Workshop into the planned 2026 plan review.

REFERENCES:

City of Markham Reports

1) The Swan Lake Community Environmental Management Study, Cosburn Patterson Wardman Limited, December 1993
2) Water Quality and Remediation Options for Swan Lake, Freshwater Research, August 27, 2012*
3) Swan Lake Water Quality Improvement Program, City of Markham, June 15, 2020
4) Swan Lake Water Quality Management, Freshwater Research, July 17, 2020
5) Swan Lake Long-term Water Quality Plan, City of Markham, November 16, 2021
6) Water Flow and Chloride Analysis, City of Markham, April 2022*
7) Shoreline Restoration Proposal, Toronto and Region Conservation Authority, May 2022
8) 2022 Swan Lake Monitoring Report, City of Markham, March 2023
9) Calcium Peroxide and Biochar Proposals – Review, Tammy Karst-Riddock, AECOM, April 18, 2023*

Friends of Swan Lake Park Reports

10) Pathway to Sustainability, June 1, 2020
11) A Pathway to Sustainable Water Quality for Swan Lake, December 15, 2020
12) Park Improvement Survey, March 2021
13) Pathway to Sustainable Water Quality: Ending Swan Lake's Stormwater Management Role, June 4, 2021
14) Action Plan to End Swan Lake's Stormwater Management Role, May 2022
15) Towards a Comprehensive Restoration Plan for Swan Lake, May 2023

Research Submitted by FOSLP*

16) Literature Review of Potential Engineering Solutions for the Restoration of Swan Lake, Barbara Siembida-Lösch, Fleming College, February 2021.
    a. Evaluation of Recommendations by FOSLP, Freshwater Research April 8, 2021
    b. Review of Measures Proposed by FOSLP, Markham staff, April 12, 2021
17) Research Proposal on Use of Oxygen Releasing Compounds, Dr. Barbara Siembida-Lösch, Centre for Water and Wastewater Technologies, Fleming College, April 2022
18) Research into Removal of Nutrients and Chloride from Swan Lake, Dr. Rama Pulicharla, Dr. Satindar K. Brar, York University, May 2, 2022
19) Research Proposal into Nutrient Release from Sediments, Dr. Amy Bilton, University of Toronto

*** Reports available on request. All other reports are available at *https://friendsofswanlakepark.ca/resources/archives/***

APPENDIX A: Water Quality Monitoring (2022)

Water quality monitoring of Swan Lake has been conducted almost annually since the first Phoslock treatment in 2013 to track water quality and the continued effectiveness of the treatment.

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

The following summary for water conditions is extracted from the 2022 Water Quality Monitoring Report[8]. The projection for the impact of the 2021 chemical treatment was that it would generate the best outcomes during the second year following the treatment with conditions deteriorating thereafter. The data for 2022 reflects the second-year impact. The 2023 results are expected to be available in March 2024.

a) 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 taken for testing for phytoplankton and cyanobacteria showed lower diversity and higher total counts compared to 2021.

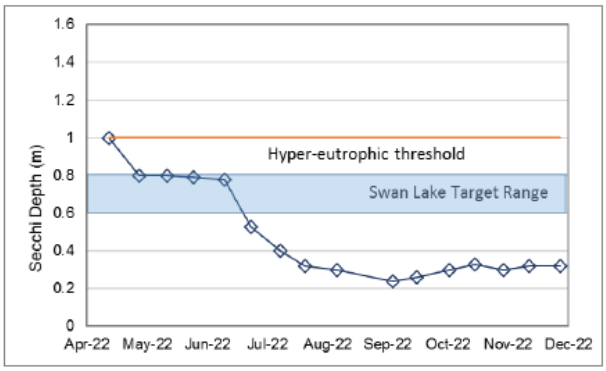
Several algal blooms with potentially toxic cyanobacteria were observed in years before 2011; however, testing completed before 2011 and following treatment (2013-2016) did not detect any Microcystin in the water. In 2016, a bloom was tested and resulted in a Microcystin concentration of 73 µg/L. Extended 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).

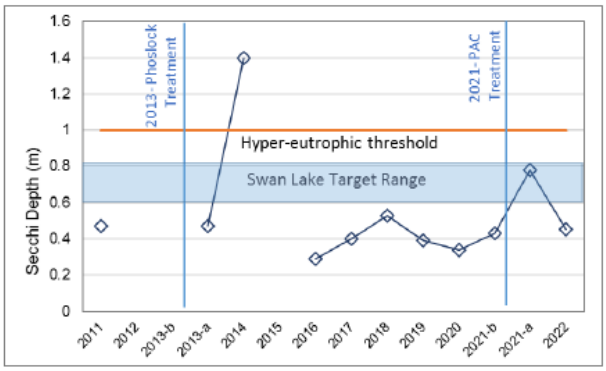
b) Water Transparency (Secchi Depth)

The water testing process does not directly track Chlorophyll a, so Secchi depth measures have been adopted as a "substitute" for measuring algae levels.

Secchi depth represents water transparency, which declines when the algae level increases. In the trophic state classification scheme, during the 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



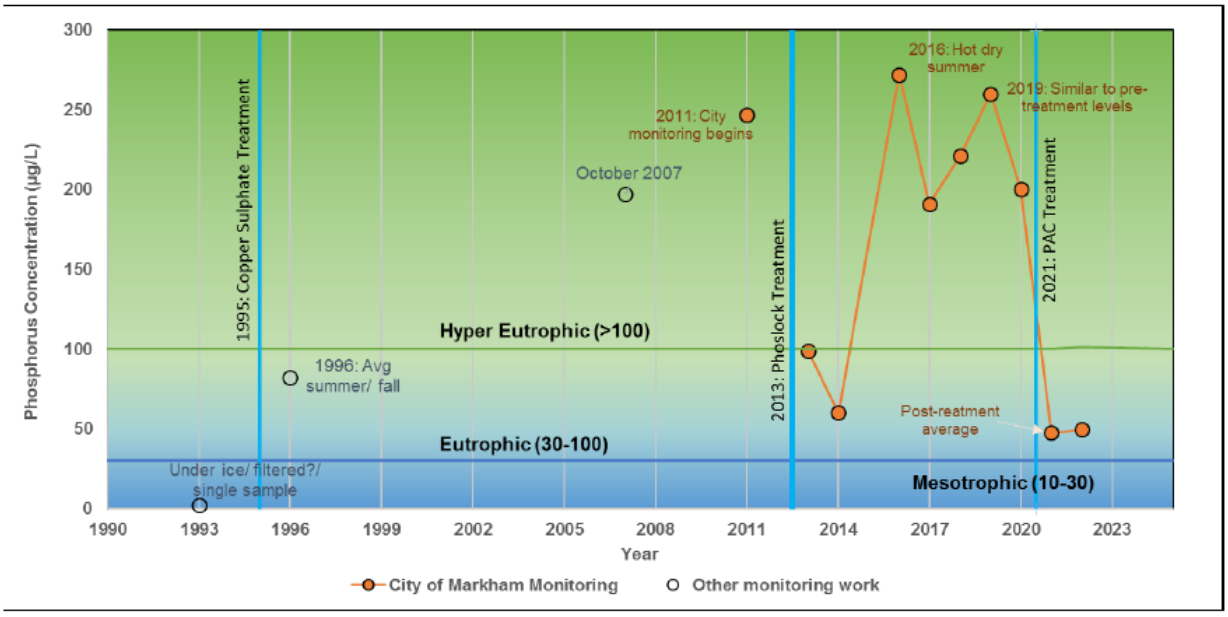


c) Phosphorus and Nitrogen Concentrations

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



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.

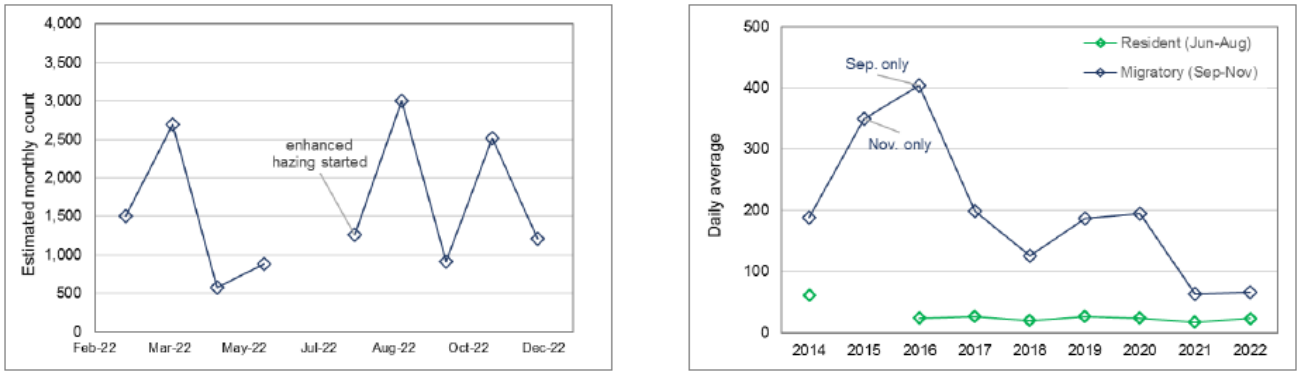
d) Geese Count

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 a 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.

e) 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.

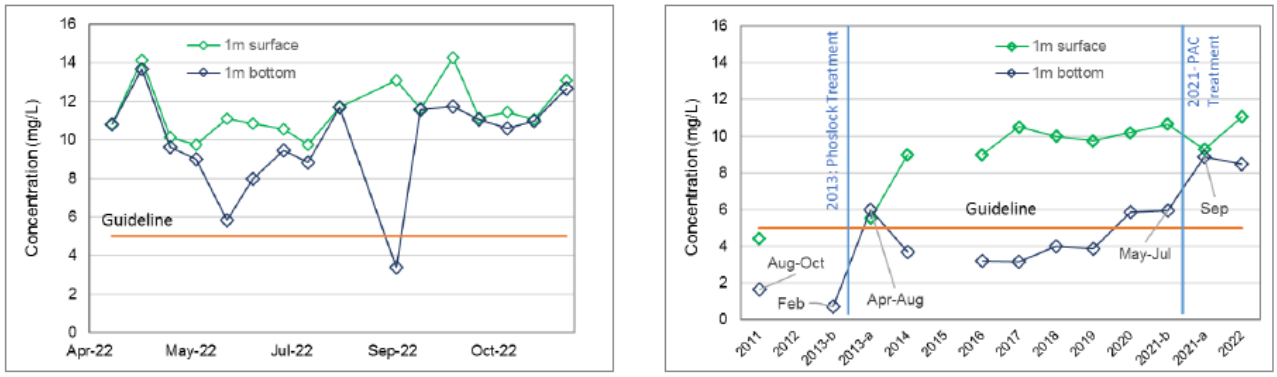
Measured day-time surface concentrations were above the DO guideline throughout 2022 (above 9.5 mg/L). DO concentration at the bottom layer was also above the guideline, except for two measurements at 2.2 and 3.4 mg/L, which occurred on dates when the water column was thermally stratified.

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).

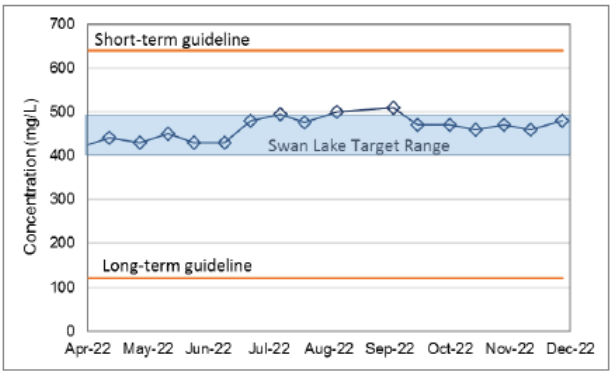
f) Chloride Concentration

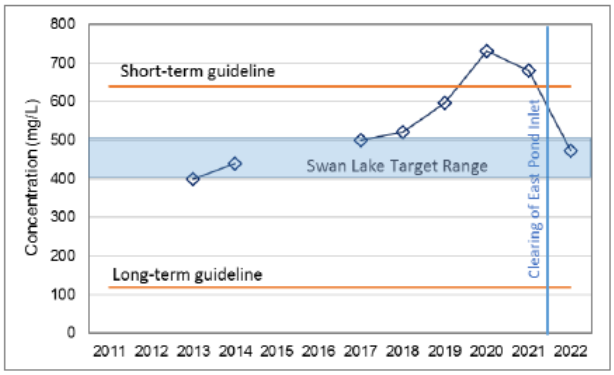
Chloride concentration has been increasing in urban lakes as a result of de-icer application for winter maintenance of roads and walkways. Chloride does not biodegrade, readily precipitate, volatilize, or bioaccumulate. It does not adsorb readily onto mineral surfaces and therefore when introduced, concentrations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





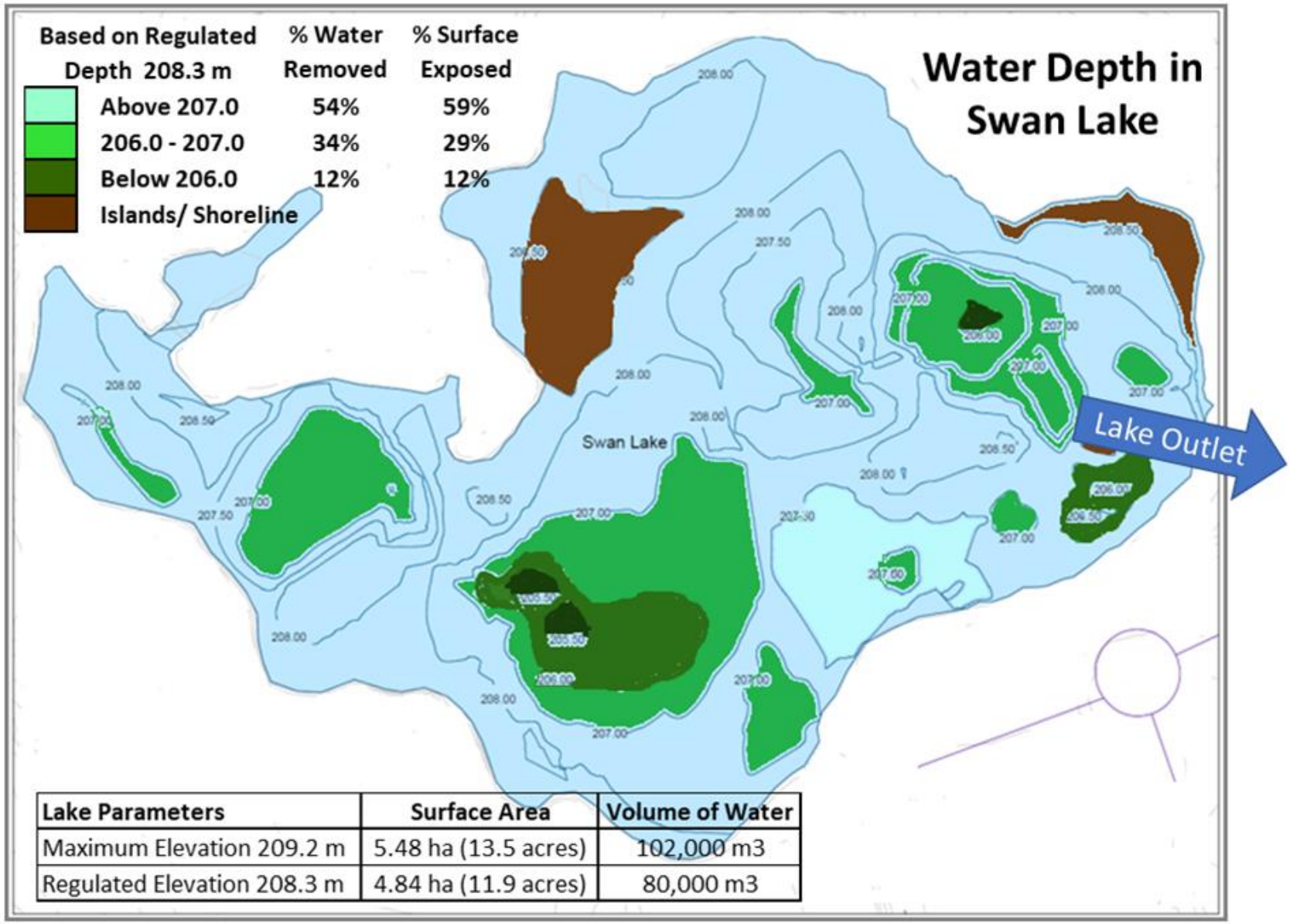
In 2022, water samples were collected from various inlets to the Lake and analyzed for chloride. The mass balance established using these data is documented in a separate report.

APPENDIX B: Markham's 2021 Long-term Plan

Table 9: Evaluation of Optional Measures

Issue	Measure No.	Description	Technical Feasibility and Effectiveness	Unit Cost
Internal Load	IL1	Chemical Treatment for Phosphorus Control	Feasible; lowers nutrient input from the most significant and bioavailable source and hence the most immediate and effective solution.	$150,000 per full application (three-year intervals)
	IL2	Bottom-Dwelling Fish Management	Feasible; lowers internal load release.	$18,000 initial $5000 annually
	IL3	Nitrogen Control (by pumping & treatment or artificial wetlands)	Water pumping and treatment will result in increased water temperature, and significant disturbance of the area. Artificial wetlands provide geese habitat and promote settling of solids beneath the mats. Nitrogen will be controlled by lowering productivity through other management measures, and does not need targeted treatment.	Significant
External Load	EL1	Geese Management (including Toogood Pond)	Feasible; lowers nutrient input from the most significant external source.	Existing measures: $27,000 annually New measures: $40,000 annually
	EL2	Stormwater Management Ponds Maintenance (2 wet ponds)	Feasible; lowers nutrient input; currently maintained by the developers and, once ponds are assumed, by the City.	$1500 annually $500,000 cleanout ($33,000 annualized)
	EL3	Shoreline Planting/ Improvements	Feasible; lowers nutrient input by blocking geese access to the Lake, intercepts nutrient runoff	$35,000 design $125,000 implementation
	EL4	Groundwater and historic dumping areas	Groundwater requires extensive investigation. A study of the dumping areas will involve the developers and private owners; low priority	Significant
Oxygen Level	OL1	Mechanical or chemical oxygenation	Mechanical circulation will have negative impacts because of sediment disturbance and nutrient release. Calcium peroxide may be used in a pilot project.	Pilot project TBD through a research institute
Chloride Level	CL1	Winter Maintenance on Private Land	Stakeholder engagement for snow and salt management will help reduce chloride concentration.	Privately funded
	CL2	Physical or Biological Treatment	Existing methods are not very effective; New technologies may be considered when proven effective.	TBD
	CL3	Redirecting Stormwater	Involves private landowners and York Region and detailed study to assess impacts/feasibility, and chloride levels may not impact desired aquatic biota; low priority.	Significant
Natural Features	NF1	Shoreline Planting/ Improvements	Feasible; will provide fish habitat	See EL3
	NF2	Planting of Submerged Water Plants	Feasible; will help solidify sediment and provide fish habitat	TBD
	NF3	Fish Management Plan and Fish Stocking	Feasible; once water quality improves.	TBD for the Plan MNDMNRF for Fish Culture program

APPENDIX C: Water Depth in Swan Lake



Lake Parameters	Surface Area	Volume of Water
Maximum Elevation 209.2 m	5.48 ha (13.5 acres)	102,000 m3
Regulated Elevation 208.3 m	4.84 ha (11.9 acres)	80,000 m3