Environmental Services

Swan Lake Long-Term Management Plan Phase 2

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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 5.3 ha and a maximum water depth of 4.0 m from the edge of the Lake at 209 meters above sea level (masl). At an average elevation of about 208.2 masl (estimated or measured over the last decade), the lake maximum depth is 3.2 m and surface area is about 3.9 ha.

A gravel pit in the 1960s and 1970s, Swan Lake is currently a community feature with multiple trails and urban development surrounding it.

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

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

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

During 2021-2025, Core measures from Phase 1 and some Complementary and Alternative measures from Phase 2 and Phase 3 of the plan were implemented in an adaptive manner to improve the Lake water quality.

This report provides an update to the Swan Lake Long-Term Management Plan based on an assessment of the effectiveness of measures already implemented, and evaluating other lake management measures to further enhance water quality. This plan is an important step in ensuring the long-term sustainability of Swan Lake as a valued recreational and ecological asset for the community.

Summary of Management Outcomes (2021-2025)

Management actions implemented since 2021 have been highly effective, with all primary interim targets achieved or exceeded. Observed responses align closely with predictions, particularly with respect to the dominant role of internal phosphorus loading and the effectiveness of chemical treatment. Improvements in dissolved oxygen conditions and the establishment of submerged aquatic vegetation (SAV) further confirm that internal loading has been effectively controlled and that key ecological feedbacks are now supporting improved lake function.

Swan Lake has transitioned from a highly eutrophic, internally driven system to a more stable condition in which water quality is governed primarily by external inputs.

Monitoring data and updated modelling indicate that water quality improvements have met or exceeded the interim targets established in the 2021 Plan.

Issues and Opportunities

Through the review of Swan Lake conditions over time and the characteristics of the contributing catchment, a number of issues and opportunities were identified that will drive any rehabilitation options for Phase 2 (2026-2030), as follows:

- Swan Lake is not a natural feature, and water does not enter and exit the system like in most natural systems. Contaminants that enter the system build up over time, leading to poor water quality.
- The land use surrounding Swan Lake has changed significantly over the past 30 years. Starting as farmlands, it has changed to a residential community, including a gated community and senior housing development. Major land use types include community/ infrastructure (75 %) open water, including the Lake (15%) and tree canopy or parks (10 %).
- Average contributions from different sources of water to the Lake include direct precipitation (47%), direct runoff (4%), and controlled runoff (49%). Due to scarcity of data, groundwater has not been quantified independently and rather calculated as the balance of other measured or estimated inflows and outflows.
- Two stormwater ponds and three oil and grit separators (OGS) collect and treat runoff from 80% of the catchment.
- The City owns most of the Lake except for a small portion in the south.
- The two stormwater ponds and two OGS units are owned and maintained by the developers. Storm sewer lines within the catchment are owned by the City and the private condominium corporation. The Region of York owns the 16th Avenue sewer line.
- Winter maintenance of 1 km (15%) of the catchment roads and sidewalks is completed by the City of Markham, and the remaining roads, as well as about 3600 m2 of parking areas, are serviced privately.
- Internal phosphorus loading, historically the dominant source of nutrients to the lake, has been effectively controlled following in-lake treatment and is now negligible.
- External phosphorus inputs, including contributions from stormwater runoff and waterfowl, now represent the primary sources influencing lake water quality.
- Dissolved oxygen conditions have improved substantially, meeting guidelines for aquatic life and limiting internal phosphorus release potential from sediments.
- Submerged aquatic vegetation (SAV) has become established under recent conditions, representing a significant ecological shift toward a more stable, clear-water state.
- While water quality has improved significantly, the lake remains sensitive to external inputs and ongoing watershed influences.
- Chloride concentrations have declined substantially from historical levels but remain governed by external loading associated with road salt use and watershed processes.
- Groundwater contributions to water and chloride balance remain uncertain and may influence long-term system response.
- Stormwater infrastructure performance and maintenance continue to play an important role in controlling water and contaminant inputs to the lake.
- Climate variability, including warmer temperatures and altered runoff patterns, may influence future nutrient and chloride dynamics and water quality.

- The fish community remains simplified, and ongoing management is required to support ecological balance.
- Swan Lake continues to provide important recreational, aesthetic, and ecological value, with strong community interest in maintaining and improving lake conditions.

Multiple management measures were developed in consultation with stakeholders and evaluated to address each of the identified issues. Each optional measure was evaluated for technical feasibility and effectiveness (water quality), maintenance and operation needs terrestrial and aquatic environment, construction impacts, public safety, the cost to the City, and community benefits/impacts.

The residents of Swan Lake Village have been very involved in making observations about the Lake conditions, and have pursued a number of initiatives and provided the City with several reports and presentations. All information and input provided have been thoroughly considered in the updates of this plan.

Goal Statement

The City of Markham's Strategic Plan and the Greenprint Plan aim at building a safe, sustainable, and complete community through protecting and enhancing the natural environment and built form. A goal statement has been defined accordingly for Swan Lake, as follows:

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

This goal statement is supported by a series of numerical guidelines as interim targets, updated for Phase 2 (2026-2030). The guidelines are as follows:

Parameter	Current Values	Interim Target	Objective and Rationale
Total phosphorus (µg/L)	<20	≤20 (<30 for single events)	Aligns with the Provincial Water Quality Objective (20 µg/L) as a benchmark and reflects current observed conditions. The target is intended to maintain current conditions, recognizing that only modest further reductions may be achievable or warranted.
Secchi Transparency (m)	~0.6–0.8	≥0.6	Represents sufficient light availability to support establishment and persistence of submerged aquatic vegetation (SAV). At current nutrient levels, Secchi is influenced by multiple factors and is no longer a reliable surrogate for phosphorus.
Chloride Concentration (mg/L)	~200 (2024–2025 average)	200–400	Reflects substantial improvement from historical conditions (>700 mg/L). Target maintains concentrations below levels associated with increased ecological risk while recognizing constraints from ongoing road salt use, background concentrations, and potential groundwater inputs.
Frequency of algae blooms	Periodic blooms; densities near guideline thresholds	Reduced frequency, duration, and severity; generally, ≤50,000 cells/mL	Based on Health Canada recreational guidance for primary contact use. Target supports reduced health risk and improved conditions while recognizing that blooms may still occur under certain conditions. Focus is on long-term system response rather than elimination.
Internal phosphorus load (kg/yr)	~0	≈0 (negligible)	Internal loading has been effectively controlled following treatment and is no longer a dominant source. Maintaining negligible internal loading is critical to sustaining current lake conditions.
External phosphorus load (kg/yr)	9–17	≤12–15	External inputs now control lake phosphorus concentrations. Target reflects recent post-treatment conditions with an allowance for variability in flow. Continued BMP implementation is required to maintain gains and limit increases during higher-flow years.

Recommended Strategy

Based on the evaluation of management outcomes (2021–2025) and additional measures, a phased approach is recommended for Swan Lake. This strategy follows an adaptive management approach, through which management activities will be adjusted to maximize benefits and minimize impacts. The phased approach includes the following components:

Phase 1 (2021-2025): Core Measures - Completed:

a) Continue water quality monitoring and report on quality annually through Markham Subcommittee
b) Continue geese management and explore enhanced methods
c) Remove benthic-dwelling fish
d) Maintenance of stormwater management facilities (by developers then City)
e) Community engagement in reducing nutrient and chloride, data sharing, as well as progress reviews and plan updates
f) Chemical treatment in 2021 and 2024
g) Shoreline planting/improvements
h) Chemical oxygenation pilot project (by research institute) – not pursued

i) Evaluate Phase 1 measures

In Phase 1, several Complementary and Alternative measures that were identified for Phase 2 and Phase 3 were advanced, including:

- Fish stocking
- Planting of submerged plants
- New technologies for chloride (biochar research by York U)
- Flow diversion assessment

In Phase 1, several additional Complementary Measures were identified and implemented including:

- Ultrasound for algae control
- Water and chloride budget
- Submerged aquatic plant survey

Phase 2 (2026-2030): Adapted Core Measures and Complementary Measures:

j) Items a) to e) in Phase 1
k) Chemical treatment with adjusted frequency and dosage
l) Fish management plan and fish stocking
m) New technologies for chloride treatment (complete research by York U and evaluate chloride uptake by halophytes)
n) Lake sediment survey
o) Targeted groundwater flow and chloride monitoring
p) Shoreline plantings/improvements
q) Submerged aquatic plant survey
r) Ultrasound for algae control
s) Evaluate Phase 2 measures

Phase 3 (post 2030): Adapted Core Measures with or without Alternative Measures

t) Items j) to k) in Phase 2 with modifications if required
u) Investigate contribution from groundwater, if required
v) Evaluate/design structural modifications such as lake water recirculation and stormwater redirection, if required

At the end of Phase 2, a 5-year summary report will be completed, summarizing the effectiveness of the Adapted Core measures and evaluating additional Complementary measures to consider in Phase 3. Additional Complementary measures will be advanced based on needs to further improve water quality and considering the technical feasibility and cost-effectiveness of additional measures.

The total cost for implementing Core and Complementary measures for the next 25 years as per the recommended plan, is about $5,584,000 (including pond cleanout), funded from the Environmental Services lifecycle. Implementing all measures, including the Alternative Measures, would cost about 8.7 to 23.6 million dollars (depending on the flow diversion scenario, and the extent of groundwater remediation work).

Glossary of Terms

BMP	Best Management Practices
CCME	Canadian Council of Ministers of the Environment
DFO	Department of Fisheries / Fisheries and Ocean Canada
DO	Dissolved Oxygen
DOC	Dissolved Organic Carbon
DW	Dry Weight
ECA	Environmental Compliance Application
FDC	Foundation Drain Collection
FOSLP	Friends of Swan Lake Park
GIS	Geographic Information System
GLISA	Great Lakes Integrated Sciences + Assessments
LED	Light Emitting Diode
LMP	Long-Term Management Plan
LOI	Loss of Ignition
MASL	Meter Above Sea Level
MDL	Method Detection Limit
MECP	Ministry of Environment, Conservation, and Parks
MNDMNRF	Ministry of Northern Development, Mines, Natural Resources and Forestry
MNR(F)	Ministry of Natural Resources (and Forestry)
MOE(E)	Ministry of Environment (and Energy)
OGS	Oil and Grit Separators
OMNRF	Ontario Ministry of Natural Resources and Forestry
PAC	Poly Aluminum Chloride
REE	Rare Earth Elements
SAV	Submerged Aquatic Vegetation
TBD	To be Determined
TKN	Total Kjeldahl Nitrogen
TP	Total Phosphorus
TRCA	Toronto and Region Conservation Authority
US EPA	United States Environmental Protection Agency
VAC	(Swan Lake) Village Amenities Committee
WHO	World Health Organization

Table of Contents

1. Introduction 1

1.1 Background 1

1.2 Purpose 1

2. Overview of Swan Lake 2

2.1 Swan Lake Catchment 2

2.1.1 Climate 2

2.1.2 Land Cover and Land Use 2

2.2 Lake Morphometry and Hydrology 4

2.2.1 Morphometry 4

2.2.2 Inflows 6

2.2.3 Outflows 6

2.3 Natural Features 6

2.4 Swan Lake Significance 7

2.5 Ownership and Maintenance 7

2.5.1 Swan Lake 7

2.5.2 Catchment Servicing 7

3. History of Lake Management 9

3.1 Before 2010 9

3.2 2010 to 2020 10

4. Swan Lake Conditions (2010-2025) 12

4.1 Water Quality 12

4.2 Water Balance 21

4.3 Nutrient Budget 22

4.4 Chloride Budget 24

4.5 Sediment Quality 25

5. Phase 1 Projects and Initiatives (2021-2025) 26

5.1 Fish Management 26

5.2 Geese Management 27

5.3 Chemical Treatment 28

5.4 Aquatic Vegetation Management 29

5.5 Algae Management 30

5.6 Removal of Invasive Plants 30

5.7 Chloride Management 30

5.8 Evaluation of Management Outcomes (2021-2025) 32
5.9 Summary and Costs 33
5.10 Stakeholder Engagement and Education 34
5.10.1 Resident Initiatives and Public Consultation 34
5.10.2 Engagement and Education 34
6. Policy Direction and Goal Statement 35
6.1 Federal and Provincial Regulations 35
6.2 Markham Strategies and Bylaws 35
6.3 Goal Statement and Level of Service 36
7. Analysis and Discussion of Lake Management Measures 38
7.1 Measures to Control Internal Nutrient Load 39
7.1.1 Chemical Treatment for Phosphorus Control 39
7.1.2 Bottom-Dwelling Fish Management 39
7.1.3 Nitrogen Control 39
7.2 Measures to Control External Nutrient Load 40
7.2.1 Geese Management 40
7.2.2 Stormwater Management Facilities Maintenance 40
7.2.3 Shoreline Planting and Access 40
7.2.4 Groundwater and Historic Dumping 40
7.3 Measures to Improve Oxygen Level 41
7.4 Measures to Control Chloride Concentration 41
7.4.1 Winter Maintenance on Private Land 41
7.4.2 Physical or Biological Treatment 41
7.4.3 Redirecting Stormwater 42
7.5 Measures to Improve Natural Heritage Features 42
7.5.1 Shoreline Planting 42
7.5.2 Planting and Evaluation of Submerged Water Plants 42
7.5.3 Fish Stocking 43
8. Proposed Strategy 44
8.1 Summary of Evaluation of Lake Management Measures 44
8.2 Recommended Strategy 45
9. References 1

Appendices

Appendix A : Public Consultation

Tables

Table 1: Hypsometry of Swan Lake (2016 Survey Date, calculation revised in 2026).....5
Table 2: Swan Lake Average Morphometry 5
Table 3: Trophic State Classification 15
Table 4: Records of Algae Blooms and Toxicity 20
Table 5: Swan Lake Annual Water Balance (m^3).....22
Table 6: Representative Phosphorus Input Parameters for Atmospheric Deposition and Runoff Concentrations from Stormwater Sources 23
Table 7: Calculated Annual Phosphorus Loads (Apr-Nov) for External and Internal Sources (kg/yr) 23
Table 8: Fish Species Collected from Swan Lake Since 2021.....26
Table 9: Evaluation of Management Outcomes Relative to 2021 LMP Targets.....32
Table 10: Proposed Interim Targets for Swan Lake for the next five years (2026-2030).....37
Table 11: Evaluation of Lake Management Measures.....44
Table 12: Life-Cycle Cost Estimate.....47

Figures

Figure 1: Swan Lake Location Map.....3
Figure 2: Swan Lake Catchment.....4
Figure 3: Swan Lake Bathymetry (2016 Survey), Contours in m above Sea Level (masl).....5
Figure 4: Growing-season Dissolved Oxygen Concentrations at Surface and Bottom Stations in Swan Lake (2016–2025).....13
Figure 5: Growing-season Average Chloride Concentrations in Swan Lake (2016–2025).....14
Figure 6: Historical (1990-2020) Trophic State Classification for Swan Lake based on Mixed Layer Growing Period Average Phosphorus Concentration 16
Figure 7: Growing-season (June–September) Average Total Phosphorus (TP) Concentrations in Swan Lake (2016–2025) with Trophic State Thresholds.....17
Figure 8: Growing-season (June–September) Average Total Nitrogen (TN) Concentrations in Swan Lake (2016–2025) with Trophic State Thresholds.....17
Figure 9: Average Cyanobacteria Cell Densities at Dock and Bridge Stations in Swan Lake (2021–2025).....18
Figure 10: Growing-season Average Secchi Depth in Swan Lake (2016–2025).....19
Figure 11: Measured or Estimated Monthly Water Level.....21
Figure 12: Historical Geese Counts at Swan Lake (2016–2025).....28

1. Introduction

1.1 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 5.3 ha and a maximum water depth of 4.0 m (from the deepest point at 205.0 to the Lake edges at 209 meters above sea level). At an average elevation of about 208.2 masl (estimated or measured over the last decade), the lake maximum depth is 3.2 m and surface area is about 3.9 ha.

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 (Freshwater Research 2020). The Strategy, which was finalized in July 2020, recommended chemical treatment starting in 2021. In August 2021, 13 tonnes of PAC were applied to the Lake in a controlled manner over several days.

The Swan Lake Long-Term Management Plan, LMP or the Plan (City of Markham, 2021), which was developed based on the 2019 Strategy (Freshwater Research, July 2020) and extensive consultation with stakeholders, was received by Markham Sub Committee in November 2021 and approved by the Council in December 2021. The Plan described a phased adaptive approach, including Core, Complementary and Alternative measures, and periodic reviews to adapt the Plan to the Lake conditions.

During 2021-2025, Core measures from Phase 1 and some Complementary and Alternative measures from Phase 2 and Phase 3 of the Plan were implemented in an adaptive manner to improve the Lake water quality.

1.2 Purpose

This report provides an update to the Swan Lake Long-Term Management Plan. based on an assessment of the effectiveness of measures already implemented, and evaluating other lake management measures to further enhance water quality. This plan is an important step in ensuring the long-term sustainability of Swan Lake as a valued recreational and ecological asset for the community.

2. Overview of Swan Lake

2.1 Swan Lake Catchment

Swan Lake (the 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 is located within the Rouge Watershed, which is described as an extraordinary resource in Southern Ontario (Toronto and Region Conservation Authority, 2007). A map of the Lake catchment area is provided in Figure 2.

2.1.1 Climate

The Rouge watershed experiences a continental climate moderated by the Great Lakes. The area is influenced by warm, moist air masses from the south and cold, dry masses from the north (Toronto and Region Conservation Authority, 2007). In an average year, precipitation in the watershed ranges from 700 to 1000 mm. York Region has historically experienced an average total annual precipitation of about 850 mm. Mean annual evapotranspiration is about 500 mm per year, with the highest values occurring during the summer months (June, July, and August).

Global climate change will affect the watershed, along with all the watersheds in York Region. Climate change models differ as to how these changes will manifest during any given year; however, it is expected that the climate of southern Ontario will become warmer, wetter, and more unpredictable with greater variations and increases in extreme weather. These changes may result in changes throughout an ecosystem, such as impacts on water balance, water availability, groundwater levels, streamflow, channel and stream bank stability, surface water quality, and terrestrial and aquatic habitats (Toronto and Region Conservation Authority, 2007).

According to climate models for York Region (Ontario Climate Consortium, GLISA and Clean Air Partnership, 2016), temperatures are very likely to increase in all seasons and on average for the year. While the range in average monthly temperatures is not expected to change significantly, it is very likely average temperatures will increase in all months and seasons (by 3.3 °C on average across seasons). Winter and summer months will likely experience more warming than those in fall and spring by the 2050s. Warmer winter temperatures lead to more precipitation falling as rain instead of snow in York Region and increase the number of winter runoff events from melting snow and ice.

2.1.2 Land Cover and Land Use

Swan Lake's catchment covers an area of about 42.9 ha, with major land use types being community/ infrastructure (75 %), open water including the Lake (15%), and tree canopy or parks (10 %).

Land use surrounding Swan Lake has changed significantly over the past 30 years. Starting as farmlands, it has changed to a residential community, including a gated community and senior housing development.

Figure 1: Swan Lake Location Map

Figure 2: Swan Lake Catchment

Note: Sewer lines are shown in green, while catchment areas are shown in purple
OGS: Oil and Grit Separator, shown as green circles.

2.2 Lake Morphometry and Hydrology

2.2.1 Morphometry

Swan Lake has an approximate area of 5.3 ha and a maximum water depth of 4.0 m (from the deepest point at 205 m to the Lake edges at 209 m asl).

The hypsometric characteristics and morphometry of Swan Lake updated in 2026 using survey data collected in 2016 are shown in Table 1, Table 2, and Figure 3.

Table 1: Hypsometry of Swan Lake (2016 Survey Date, calculation revised in 2026)

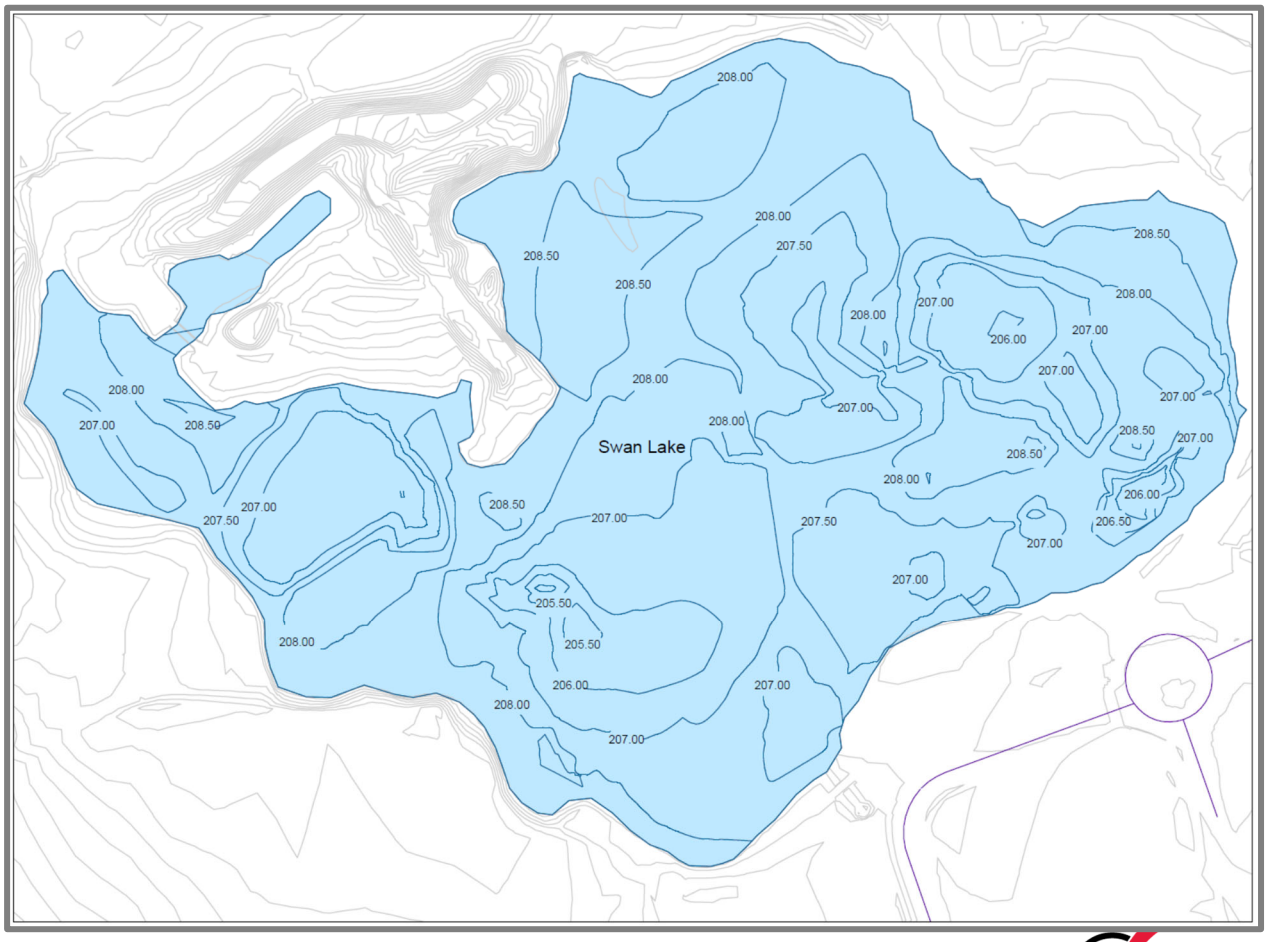
Elevation (masl)	Depth (m)	Volume of Layer (m^3)	Volume below (m^3)	Area of Layer (m^2)
209	0	26,447	76,000	57,000
208.5	0.5	9,153	49,553	47,442
208.3*	0.7	12,388	40,400	44,000
208	1	14,529	28,012	33,385
207.5	1.5	8,825	13,483	23,175
207	2	2,830	4,658	7,408
206.5	2.5	1,499	1,828	4,144
206	3	306	329	1,110
205.5	3.5	23	23	93
205	4	0	0	0

*invert of the outlet weir

Table 2: Swan Lake Average Morphometry

Parameter	Value
Catchment area (ha) including the Lake and the two ponds	45
Surface area (ha) at 209 m	5.7
Volume (1000 m^3) at 209 m	76
Mean depth at 209 masl (m)	1.3
Maximum depth at 209 masl (m)	4

Figure 3: Swan Lake Bathymetry (2016 Survey), Contours in m above Sea Level (masl)



2.2.2 Inflows

Water enters Swan Lake through direct precipitation on the Lake, as well as controlled and uncontrolled stormwater runoff from the surrounding subdivisions. The uncontrolled area relates to the shoreline area (~4 ha). Two wet extended detention ponds (#104- North Pond and #105-East Pond) attenuate the stormwater runoff generated from the controlled catchment (31. 9 ha). Three Oil and Grit Separators (OGS) treat runoff from a combined area of 1.69 ha before discharging to the Lake (AECOM, May 2025).

Runoff is collected by local storm sewers and conveyed to North and East Ponds. Low intensity rainfall events drain directly into these ponds, while high intensity events are diverted to Swan Lake when flows are high enough to spill over weirs located at the inlet of each pond. The North pond discharges treated and attenuated runoff to the municipal storm sewer system on Williamson Road. The East Pond discharges runoff to the private residential development's Foundation Drain Collection System which ultimately drains to the storm sewer south of 16th Ave.

The normal water level elevation within the ponds and the Lake is expected to be similar to the adjacent groundwater elevation.

2.2.3 Outflows

The water captured by Swan Lake is either infiltrated, evaporated, or discharged through a restricted outfall discharging to the 16th Ave. storm sewer. This outfall (invert elevation at 208.3 masl) was built to maintain a constant water level and positive drainage of the Lake. As per the initial plan (Cosburn Patterson Wardman Limited; Cosburn Giberson Landscape Architects; Michael Michalski Associates., 1995), the Lake release rate is limited to 100 L/s to accommodate the downstream drainage constraint at the 16th Ave. storm sewer (2-year peak flow of 1.166 m^3/s).

2.3 Natural Features

Swan Lake is home to a diverse community of terrestrial species; however, the fish community has been very limited.

Members of the resident group Friends of Swan Lake Park (FOSLP) compiled a list of birds observed at the Lake throughout the year (Friends of Swan Lake Park, March 2020). The list includes both resident and migratory species, such as resident and migratory Canada Geese and other waterfowl and Trumpeter swans. For several years, the Village of Swan Lake also brought in a pair of Mute swans to the Lake each year, and a team of residents would care for them during their stay throughout the warm season.

Small mammals usually found in the urban areas of Southern Ontario are frequently spotted in the Park.

Snapping turtles reside in Swan Lake and although anecdotally poaching is commonplace, they are still regularly sighted in the Park.

Based on available records, the Lake was stocked with largemouth bass in 1992; however, none of the fish was left in the Lake by 2005 (Gartner Lee Limited, 2006). In recent years, the Toronto and Region Conservation Authority (TRCA) have completed fish inventories for the City, and encountered a limited number of fish species, including Common Carp and goldfish (non-native), Brown Bullhead, and Fathead Minnow. All these fish species are considered tolerant to poor habitat (e.g., non-ideal water quality) conditions. The small number of only three fish species in a lake does not constitute a well-balanced community (TRCA, August 2021).

Invasive plant species observed included Black Locust, Common Reed Grass (*Phragmites australis*), Dog Strangling Vine, Chinese Elm, Manitoba Maple, Oriental Bittersweet, Tartarian Honeysuckle, and Garlic Mustard (Friends of Swan Lake Park, March 2020).

2.4 Swan Lake Significance

The original objective for the Lake set out by the developers in 1993, was to transform the inactive gravel pit into a diverse natural habitat for aquatic and terrestrial wildlife… that incorporates passive use opportunities surrounding the Lake' (Cosburn Patterson, Cosburn Ginnerson and Michal Michalski, 1993).

While the objective of diverse natural habitat for aquatic life has not been realized despite many studies completed over the years by the developers and the City, Swan Lake has been a community feature within the Swan Lake Park (the Park), with multiple trails and urban development surrounding it. The Park is widely used by residents and visitors. Many avid bird-watchers and photographers enjoy and record the diversity of natural features within the Park.

A survey conducted by the Friends of Swan Lake Park in 2020 (Friends of Swan Lake Park, 2021) indicated that residents "support a long-term plan that involves investment in sustainable solutions and restoration of the aquatic and land-based habitat".

Through ongoing consultation described in Section 5.9, Friends of Swan Lake Park have advocated for Official Plan designation of Swan Lake Park as a Natural Heritage Feature and Swan Lake as a 'Key Hydraulic Feature' given groundwater interactions identified through water budget analyses. Official Plan designations updates are being assessed city-wide as part of the current Official Plan update (see Section 6.3).

2.5 Ownership and Maintenance

2.5.1 Swan Lake

In early 2001, the City took ownership of most of the Lake as part of the subdivision assumption process, except for a small portion of the southeast corner (within Block 9). This was due to the risk of liability associated with the elevated metal concentration within the sediment of that portion of the lake. This portion of the lake is currently under private ownership. The owner of Block 9 undertook a Risk Assessment of the contamination in 2006 and recommended leaving the contaminated sediment at the bottom of the lake portion of Block 9 without disturbance (Water and Earth Science Ltd., March 2006).

2.5.2 Catchment Servicing

The Swan Lake catchment includes residential development, including a gated condominium community and the Swan Lake Park.

The two stormwater ponds and three OGS constructed to collect and treat runoff from 80% of the catchment are owned and maintained by the developers. Currently, the developers are responsible for the stormwater ponds and their maintenance. The ponds will be assumed by the City at a future date The ponds will require sediment removal by the developer prior to assumption which can improve treatment efficiency. City staff have been advised that this cleaning activity is currently being planned to complete in the short term (A. Hossein personal communication, April 23, 2026). Ultimately, the Swan Lake Boulevard and the Park blocks will also be conveyed to the City. All other works, including the upstream storm sewer will remain private.

Storm sewer lines within parts of the Pond 104 catchment are owned by the City, and the remaining sewers are privately owned. The Region of York owns the 16th Ave. sewer, which receives flows from the stormwater ponds and the Lake. This system discharges south of 16th Ave. into the City of Markham's storm sewer system, currently undergoing flood capacity upgrade design as part of the Markham Village Phase 2 Flood Control implementation.

Winter maintenance of 1 km (15%) of the catchment roads and sidewalks is completed by the City of Markham and the remaining roads, and about 3600 m^2 of parking areas are serviced privately (E. O'Hara, personal communication, July 21, 2021).

3. History of Lake Management

3.1 Before 2010

In 1993, the Swan Lake (Markham) Limited completed an Environmental Management Study (Cosburn Patterson, Cosburn Ginnerson and Michal Michalski, 1993) to provide input to the proposed development of the Swan Lake Community for the rehabilitation and use of the former gravel pit, and to address stormwater drainage design. Through this study, an environmental master plan was developed to transform the inactive gravel pit into a 'diverse natural habitat for aquatic and terrestrial wildlife… that incorporates passive use opportunities surrounding the Lake'. This would be accomplished through the implementation of a variety of approaches to create fish and waterfowl habitat, preservation and enhancement of lakeshore vegetation, stabilization of fill slopes, and management of access. Best management practices included the use of extended detention facilities to control runoff from a 25 mm rainfall event with subsequent release over a 24-hour period. A rehabilitation plan was prepared in 1994 to support the application and propose a fisheries compensation plan for the habitat loss caused by the construction of the two ponds (Cosburn Patterson Wardman, 1994).

On October 11, 1995, the (then) Town of Markham established a Senior Management group to address the environmental issues at Swan Lake. The Town engaged the Department of Fisheries (DFO), Ministry of Natural Resources (MNR), Ministry of Environment (MOE), and the TRCA in the review and approval process for the rehabilitation of Swan Lake. In 1996, copper sulphate (an algaecide) was applied to the Lake.

A number of environmental studies were completed in the 1990s to mid 2000s primarily in support of the development of Swan Lake Village and other areas, several of which dealt with the proposed land severance for Block 9 in Swan Lake (see Figure 1).

In 2003, Gartner Lee Limited was retained to provide technical opinion on aquatic sediment quality in Block 9 (Gartner Lee Limited, 2003). This study found slightly elevated concentration of metals and nutrients in the Lake water and slightly elevated concentrations of metals in the Lake sediments mostly concentrated within the water portion of Block 9, but recommended that the contaminated sediment be left undisturbed to avoid releasing the metals and nutrients back into the Lake. The study also concluded that, although low levels of some contaminants were present, sediment quality did not threaten either the use of Swan Lake by aquatic life or the health of aquatic life in Swan Lake.

Additional sampling was completed in December of 2005 to further assess the environmental condition of sediment, water quality, and aquatic habitat in Swan Lake, both within and adjacent to Block 9 (Gartner Lee Limited, 2006). Gartner Lee recommended that management actions be undertaken both on the site and in the watershed drained by the stormwater discharges to Swan Lake, to reduce urban runoff (especially phosphorus) into the Lake in order to prevent any future deterioration of water or sediment quality in Swan Lake. They also recommended that a management plan be developed to protect and enhance Swan Lake as an urban amenity, which could include habitat for aquatic life.

In 2007, Daniels Corporation (Swan Lake landowner) hired the service of Michalski Nielsen Associates Ltd. to prepare a report regarding the rehabilitation of Swan Lake. The report indicated that total phosphorus and turbidity were above acceptable levels. No actions were recommended in the report (Michalski Nielsen Associates Limited, 2008). The report was circulated to the Ministry of Northern Development, Mines, Natural Resources and Forestry (MNDMNRF) and DFO. MNDMNRF indicated that they closed their file and are no longer considering any further rehabilitation of Swan Lake. DFO, in their letter dated October 22, 2008, were "pleased that Swan Lake has been rehabilitated".

3.2 2010 to 2020

In 2010, Professor Van Loon, a resident of the Swan Lake community, raised concerns about the water quality in Swan Lake (Van Loon, Jon, 2010). In response, the City initiated a study including the monitoring of the Lake and adjacent stormwater management ponds. In 2012, the City hired a consultant (Freshwater Research), who studied the Lake and found out that high levels of phosphorus in the Lake were contributing to the growth of blue-green algae, low oxygen levels in the water, and hence degraded fish habitat (Freshwater Research, 2012).

In 2013, Council authorized a project to help improve the Lake water quality (City of Markham, February 4, 2013). In the summer of 2013, 25 tonnes of Phoslock, a bentonite clay with lanthanum ions, was applied across the Lake to remove phosphate from the water column and intercept phosphorus released from the bottom sediments at the cost of about $100,000.

Water quality has been monitored in Swan Lake since 2013 to track the effectiveness of the Phoslock treatment. In 2014, water quality monitoring indicated a 60% reduction in total phosphorus in surface and mid-layers of lake water. This reduction improved Lake's trophic state from hypereutrophic to eutrophic (Freshwater Research, February 2015).

Active geese management started in 2014, focusing on resident geese at the beginning and extended to the management of migratory geese in 2016.

In 2016, however, the Lake returned to hypereutrophic conditions (Freshwater Research, January 2017).

In 2019, the City initiated a study to define a short-term and a long-term strategy for water quality management in Swan Lake (Freshwater Research, July 2020). This strategy described the development of Swan Lake's water quality based on the review of historical monitoring data. It determined the contribution of various sources to the phosphorus mass balance and separated external loads from internal ones. Management goals and targets were proposed as a sequence of triggers for the initiation of appropriate management actions as follows:

1. The surface bloom of a potential or proven toxic strain of cyanobacteria to trigger direct attention.
2. The occurrence of two blooms within a period of four years that cover at least 25% of the Swan Lake area.
3. Water quality not compliant with the interim goal of growing period average 0.15 mg/L total phosphorus concentration in the surface mixed layer.
4. Water quality not compliant with the interim goal of growing period average 0.45 m Secchi disk transparency.

A number of management approaches were developed and evaluated, and the following recommendations were made:

- A treatment to address internal loading as phosphorus release from sediment
- Sediment analysis to assist with proper chemical treatment dosing.
- Continued waterfowl management.
- Continued water quality monitoring at two shore sites.
- Determination and potential management of the abundance of bottom-dwelling fish.
- Application of best management practices to decrease the nutrient contribution from the shoreline.
- Investigation of phosphorus load from historic dumping areas.

These recommendations were presented to the City Council on June 15, 2020, and the following resolutions were passed (City of Markham, 2020):

- Continue annual water quality monitoring; and,
- Continue with the annual geese control and review additional options relating to vegetation, tree planting, and strobe lights with regard to geese control and report back in the fall of 2020 with recommendations; and,
- Undertake the sediment analysis in fall of 2020, which will provide data related to the frequency and dosage of the chemical treatment and will provide direction on the service level and timing of future treatments; and,
- Undertake a chemical treatment commencing in 2021 based on the results of the sediment analysis, and further,
- Introduce a new fish management program in 2021.

4. Swan Lake Conditions (2010-2025)

4.1 Water Quality

Water quality monitoring of Swan Lake has been conducted annually since treatment in 2013 to track water quality and the continued effectiveness of the Phoslock application. Water quality was monitored at the deepest point (main or central station) and since 2017 at two shoreline sites, the Dock and the Bridge. The water depth at the dock is approximately 2-2.5 m, which allows it to represent Swan Lake as a whole. This was confirmed through a comparison of existing data (Freshwater Research, March 2018). The water depth at the bridge is about 0.5 meters deep, and it is used to represent the conditions of the shallow bays around Swan Lake. Annual reports are prepared each year to provide a picture of current water quality and identify trends. The following summary presents key water quality conditions for the historical period 2010–2020 (as presented in the 2021 Plan), followed by an update for the Phase 1 implementation period (2021–2025).

In order to provide a perspective on the water quality conditions, Federal and Provincial guidelines and standards are listed here. It should be noted, though, 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) and Temperature

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 (MOEE, 1994).

Historical records of DO and temperature profile show that Swan Lake thermally stratifies during the summer despite its shallow depth. Low oxygen (<2 mg/L) conditions have been observed at depths below 2 m, to a depth as shallow as 1 to 1.5 m (in 2016). The majority of surface concentrations have been above 5 mg/L since 2014.

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.

Anoxic water at the sediment/water interface triggers phosphate release, and it was found to be the main reason for low water quality in Swan Lake in earlier years.

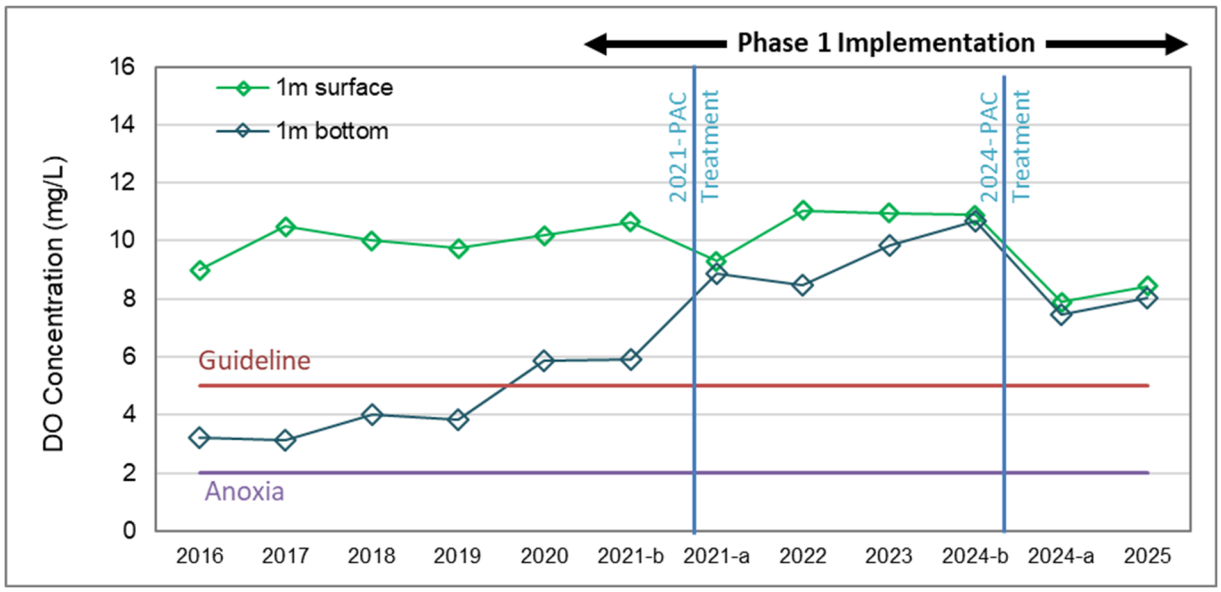
Following the 2021 PAC treatment, bottom DO concentrations improved substantially, with measurements generally exceeding 7–8 mg/L during daytime sampling events (Figure 4). This improvement indicates a reduction in sediment oxygen demand and a corresponding decrease in potential for internal phosphorus loading due to anoxia.

To better characterize diel variability in DO, continuous monitoring was implemented beginning in 2024, recognizing that lower concentrations may occur at night and between routine sampling events, and are not always captured through daytime monitoring. Data collected in 2024 and 2025 indicate that hypoxic conditions (DO <2 mg/L) were limited to depths of approximately 2.5 m below the water surface and occurred for short durations during periods of low precipitation and warmer-than-average temperatures. These results are consistent with DO monitoring by Trent University researchers at a deep location in the lake, providing confidence in the data collected at the City's Dock site. Under typical summer water levels, transient hypoxia would affect only about 1% of lake area and less than 0.5% of lake volume. Even if low oxygen extended upward to 2.0 m below the surface, the affected zone would remain limited to about 5.5% of lake area. For comparison, historic low-oxygen conditions extending to approximately

1.5 m below the surface would affect about 13% of lake area and nearly 8% of lake volume. These changes represent a substantial reduction in both the extent and persistence of low-oxygen conditions compared to pre-Phase 1 conditions.

Following the 2024 PAC treatment, mean surface DO concentrations decreased relative to earlier years. This change is interpreted as a positive response, reflecting reduced phytoplankton biomass and lower rates of photosynthetic oxygen production, rather than a decline in water quality. The reduced difference between surface and bottom DO concentrations indicates a more balanced oxygen regime and improved overall lake condition.

Figure 4: Growing-season Dissolved Oxygen Concentrations at Surface and Bottom Stations in Swan Lake (2016–2025).



Improvements in bottom DO following the 2021 PAC treatment and reduced surface supersaturation after 2024 reflect reduced phytoplankton productivity and improved oxygen balance.

Chloride

Chloride guidelines developed based on generic environmental data (CCME, 2011) include a long-term guideline (120 mg/L) and a short-term guideline (640 mg/L).

Chloride concentration had been increasing in Swan Lake from about 400 mg/L in 2013 to above 700 mg/L in 2020. Spot measurements of chloride in stormwater runoff (courtesy of FOSLP) in 2021 indicated concentrations ranging from 80 mg/L in the inlet from North Pond to 670 mg/L in the inlet from East Pond.

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.

The long-term exposure guideline has been developed to protect all organisms (present in Canadian aquatic systems) against negative effects during indefinite exposure. The short-term exposure 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 example, watercourse concentrations in Rouge River watershed urban areas and shallow groundwater concentrations in the GTA help characterize background

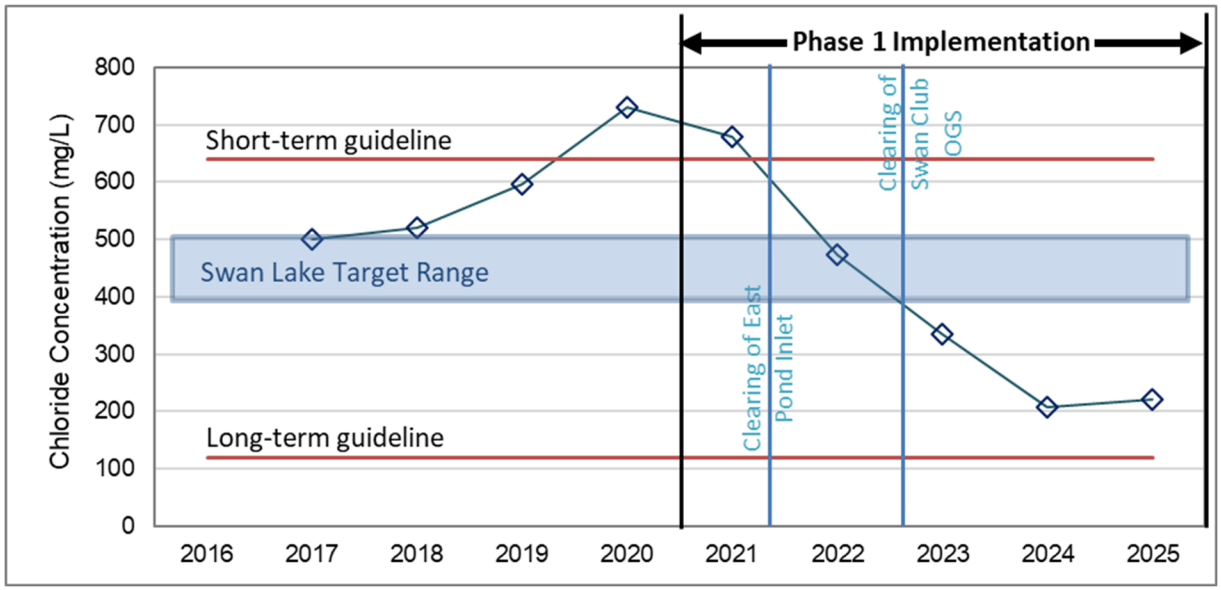
concentrations and are consistently higher than the short-term guideline. For such circumstances, it has been suggested that site-specific (higher) targets be derived considering local conditions such as water chemistry, background concentrations, and aquatic community structure. In 2021, a site-specific interim chloride management target of 400–500 mg/L was established, consistent with concentrations observed in 2013–2014. This target was intended to be revisited as additional monitoring and modelling data become available to improve understanding of chloride sources and loading dynamics, and implications for aquatic biota. Future refinement of the chloride management target, however, should consider both ecological thresholds and the practical limits of reduction achievable through active stormwater management, recognizing that additional reductions may be constrained by site conditions and background sources (e.g., chloride in groundwater).

Chloride concentrations in Swan Lake increased through 2020 and 2021, reaching peak levels exceeding 700 mg/L. As part of Phase 1 implementation, corrective actions were undertaken, including removal of a blockage at the East Pond inlet and maintenance of the Swan Club oil-grit separator (OGS). These measures reduced the contribution of untreated stormwater flows with elevated chloride concentrations to the lake (see Figure 5).

Following these actions, chloride concentrations declined substantially. Since 2022, concentrations have remained within or below the interim management target range of 400–500 mg/L, with further reductions observed in recent years. Average chloride concentrations were approximately 200 mg/L in 2024 and 2025, representing a significant improvement relative to pre-Phase 1 conditions.

Recent concentrations are also below endpoint concentrations reported for sensitive aquatic organisms (e.g., zooplankton species, 259–454 mg/L) used in the derivation of the long-term Canadian Water Quality Guideline. These results indicate a reduced potential for adverse ecological effects associated with chloride under current conditions.

Figure 5: Growing-season Average Chloride Concentrations in Swan Lake (2016–2025).



Chloride concentrations increased through 2020–2021, followed by a substantial decline after implementation of Phase 1 management measures, including stormwater infrastructure maintenance.

Nutrients and Trophic State

The supply of nutrients, primarily phosphorus and nitrogen, is one of the main factors that control the growth of plants and algae in lakes. In Swan Lake, phosphorus is the limiting nutrient for algae production and algal biomass is generally strongly related to phosphorus. Nitrogen is usually in large supply relative to phosphorus and increases in nitrogen alone do not typically increase algal biomass (but can enhance algal production when phosphorus levels are high). In productive, stratified lakes like Swan Lake, the concentrations and chemical species of phosphorus and nitrogen are variable within and between years due to the complex cycling of these elements by physical, chemical, and biological processes.

Total phosphorus (TP) is the total of all phosphorus in water and includes particulate and dissolved forms. Algae, however, can only take up dissolved (soluble) reactive inorganic phosphorus, called orthophosphate. Nitrogen in lakes occurs in several forms, including organically bound and inorganic (nitrate, nitrite, and ammonia) nitrogen. As with phosphorus, the relative amounts of different forms of nitrogen are strongly controlled by physical, chemical, and biological processes, and vary within the water column and between seasons.

The amount of primary production (plants including algae and cyanobacteria) during the growing period defines a lake's trophic state. Lakes with low, moderate, high, and excessively high productivity are termed oligotrophic, mesotrophic, eutrophic, and hyper-eutrophic. There are several indicators of lake productivity; however, the trophic state is best described using a combination of indicators given the complexities of factors controlling primary production and variability in those indicators. Thresholds generally applied for different trophic conditions in lakes are provided in Table 3.

Table 3: Trophic State Classification

Parameter	Oligotrophic	Mesotrophic	Eutrophic	Hyper-eutrophic
Secchi Transparency (m)	> 4	2-4	1-2.1	<1
Total Phosphorus (µg/L)	< 10	10 - 30	31 -100	> 100
Total Nitrogen (µg/L)	< 350	350 - 650	650 -1200	> 1200
Chlorophyll a (µg/L)	< 3.5	3.5 - 9	9.1 - 25	> 25
Anoxic Factor (d/yr)	< 20	20 - 40	41 - 60	> 60

Note: The Anoxic Factor is a measure of anoxia and is defined as the number of days per year that a sediment area equal to the lake surface area is covered by anoxic water.

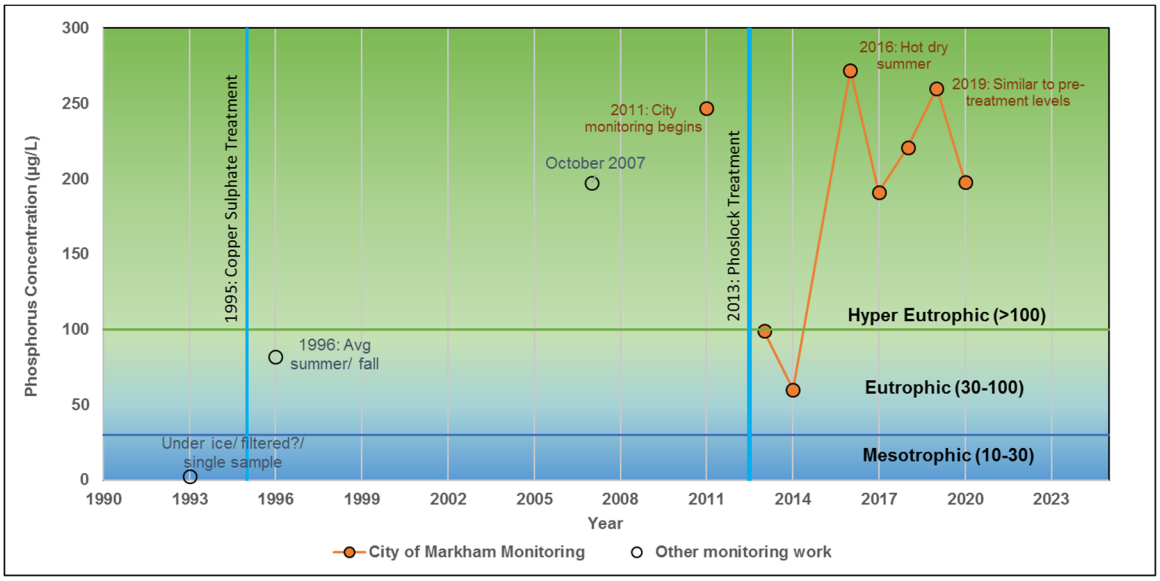
Historical average growing period (May - October) TP concentrations indicated hyper-eutrophic conditions in all monitored years except for the two years following Phoslock treatment, 2013 and 2014 (2015 was not monitored, see Figure 4). The lake returned to hyper-eutrophic conditions by 2016, reflecting a gradual loss of treatment effectiveness following the 2013 Phoslock application. TP concentration typically decreases after spring and increases in late summer and fall, partially caused by phosphorus release from sediment during summer anoxia and the arrival of migratory geese (Freshwater Research, July 2020). In Swan Lake, whole lake TP is usually higher than the upper mixed layer concentration. This higher water column average is due to elevated TP concentrations at deeper depths, closer to the sediments (Freshwater Research, August 2021).

Historical total nitrogen (TN) concentration over the growing period was above 1.2 mg/L, representing a hyper-eutrophic condition, except in the post-Phoslock treatment year, 2014. Nitrogen is, however, not believed to be the limiting nutrient for eutrophication in Swan Lake. Nonetheless, inorganic nitrogen compounds (nitrite, nitrate, ammonia) have often been below detection limits,

indicating relatively low levels of bioavailable nitrogen concentrations (Freshwater Research, July 2020).

Figure 6 provides a schematic of trophic state classification for Swan Lake based on solely phosphorus concentrations.

Figure 6: Historical (1990-2020) Trophic State Classification for Swan Lake based on Mixed Layer Growing Period Average Phosphorus Concentration



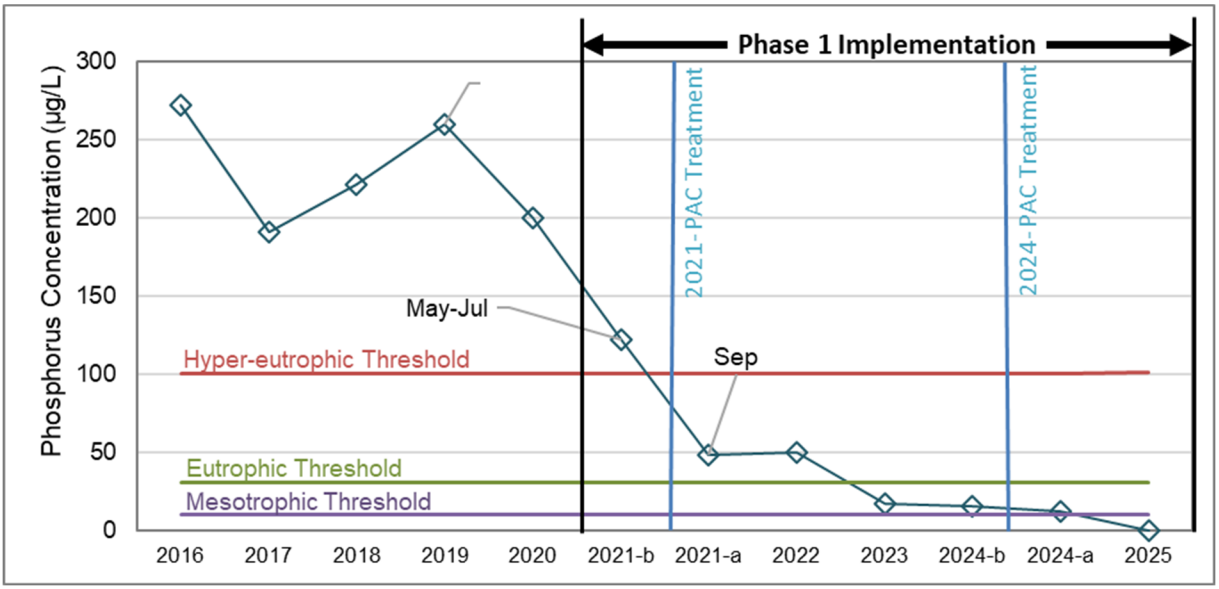
Following implementation of Phase 1 management measures, including the 2021 and 2024 PAC treatments, total phosphorus (TP) concentrations declined substantially (Figure 7). Growing-season average TP decreased from hyper-eutrophic levels (>100 µg/L) observed prior to 2021 to approximately 40–50 µg/L immediately following the 2021 treatment, and further declined to below 30 µg/L by 2023. TP concentrations have remained within the mesotrophic to low eutrophic range since that time, with 2024 and 2025 values approaching or within the mesotrophic threshold. This represents a marked and sustained shift in trophic state from hyper-eutrophic conditions to mesotrophic–eutrophic conditions.

Total nitrogen (TN) concentrations also declined significantly following Phase 1 implementation (Figure 8) Prior to 2021, TN concentrations were consistently within the hyper-eutrophic range (>1.2 mg/L). Following treatment, TN concentrations decreased to approximately 1.0 mg/L in 2021 and further declined to approximately 0.5–0.7 mg/L in subsequent years. These values are consistent with mesotrophic conditions, indicating a transition from hyper-eutrophic to mesotrophic trophic status based on nitrogen concentrations.

The observed reductions in both phosphorus and nitrogen are consistent with improvements in overall lake condition, including reduced algal biomass and improved dissolved oxygen conditions. Despite the reduction in nitrogen concentrations, phosphorus remains the limiting nutrient in Swan Lake, as TN:TP ratios remain elevated (generally >15 by mass based on growing season averages), indicating sufficient nitrogen availability relative to phosphorus. For this reason, changes in trophic state continue to be primarily driven by reductions in phosphorus loading and availability.

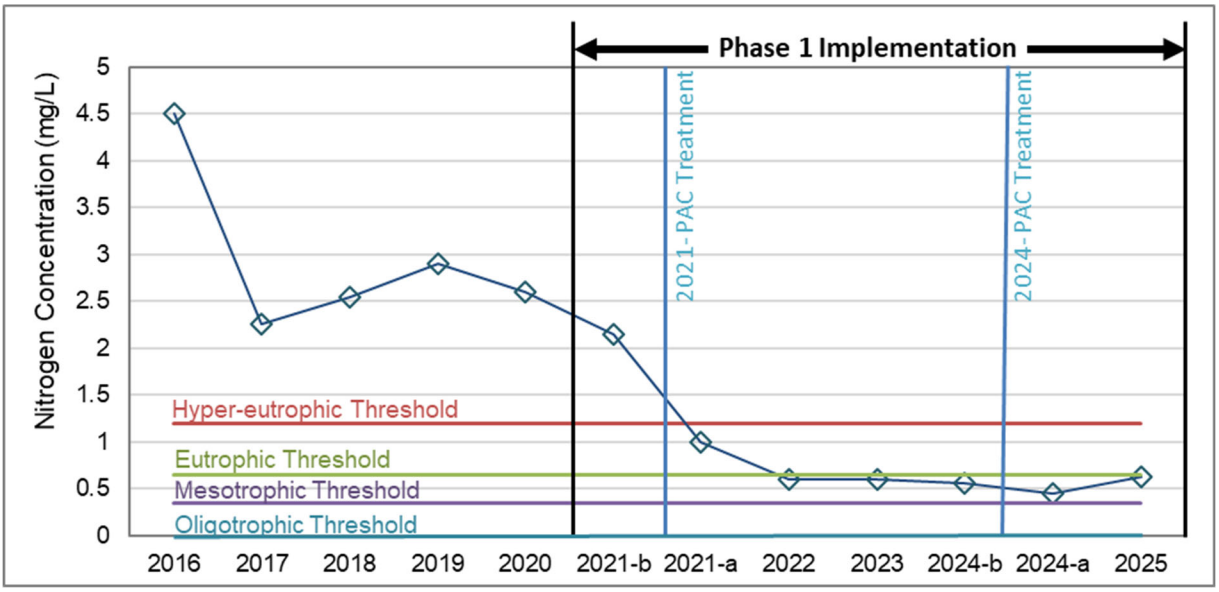
Overall, the sustained reduction in nutrient concentrations achieved in Phase 1 supports a fundamental shift in trophic state to a meso-eutrophic state.

Figure 7: Growing-season (June–September) Average Total Phosphorus (TP) Concentrations in Swan Lake (2016–2025) with Trophic State Thresholds



TP concentrations were consistently within the hyper-eutrophic range prior to 2021 and declined substantially following Phase 1 implementation, with concentrations remaining within the mesotrophic to low eutrophic range since 2023.

Figure 8: Growing-season (June–September) Average Total Nitrogen (TN) Concentrations in Swan Lake (2016–2025) with Trophic State Thresholds



TN concentrations declined from hyper-eutrophic levels prior to 2021 to values consistent with mesotrophic conditions following Phase 1 implementation.

Phytoplankton and Water Clarity (Secchi Transparency)

Chlorophyll a is the primary photosynthetic pigment produced by plants, and is commonly used as an indicator of algal production in lakes. Chlorophyll a was measured for several years, and it was shown to be highly and significantly correlated with the Secchi disk readings (Freshwater Research, July 2020).

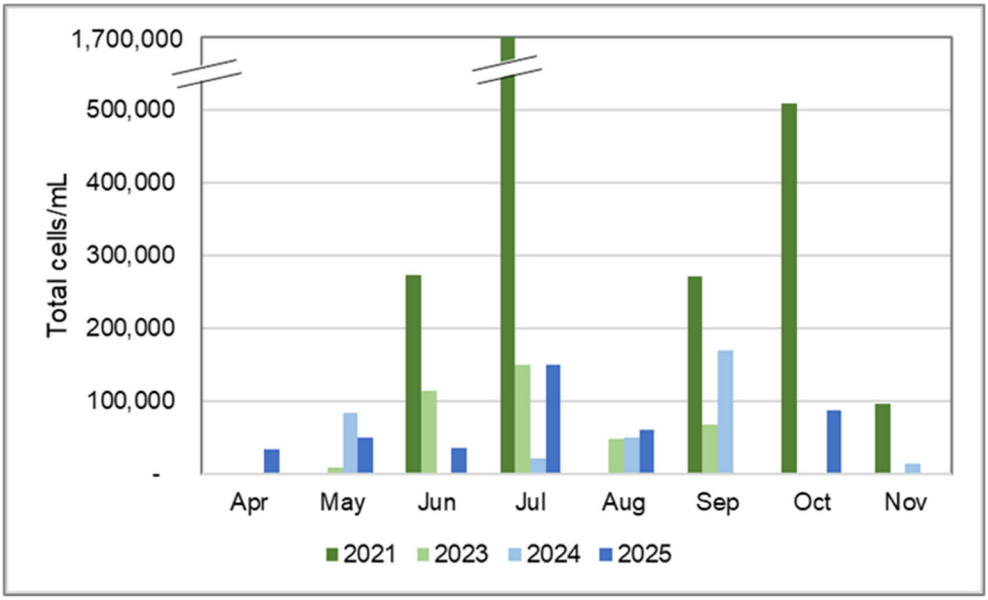
In Swan Lake, Secchi Transparency has typically been quite low throughout the summer, but it increases in November, reflecting the end of the growing period for phytoplankton. The average growing period values are historically all below 1 m, except in 2014, the year following the Phoslock treatment.

Following implementation of Phase 1 management measures, indicators of phytoplankton biomass and water clarity show measurable improvement, although responses are more variable than nutrient concentrations.

Chlorophyll a is not routinely monitored due to analytical constraints, including sample preservation requirements and longer laboratory processing times. In 2023, chlorophyll a was measured and was consistent with reduced phytoplankton biomass relative to pre-Phase 1 conditions, but was still characteristic of hyper-eutrophic conditions in August and mesotrophic conditions in June.

In recent years, phytoplankton densities have been used as primary indicators of algal abundance, as they provide a more direct and reliable measure of phytoplankton levels. Phytoplankton densities have generally declined following Phase 1 implementation and have remained lower in recent years (Figure 9). Average growing-season cyanobacteria densities in 2025 were similar to those observed in 2024 and approximately 40% lower than in 2023, with mean values of approximately 65,000 and 44,000 cells/mL at the Dock and Bridge stations, respectively. These values are near or below the Health Canada indicator guideline of 50,000 cells/mL for the potential presence of cyanotoxins above primary contact recreational thresholds (i.e., for swimming), and indicate a reduced risk relative to historical conditions.

Figure 9: Average Cyanobacteria Cell Densities at Dock and Bridge Stations in Swan Lake (2021–2025).

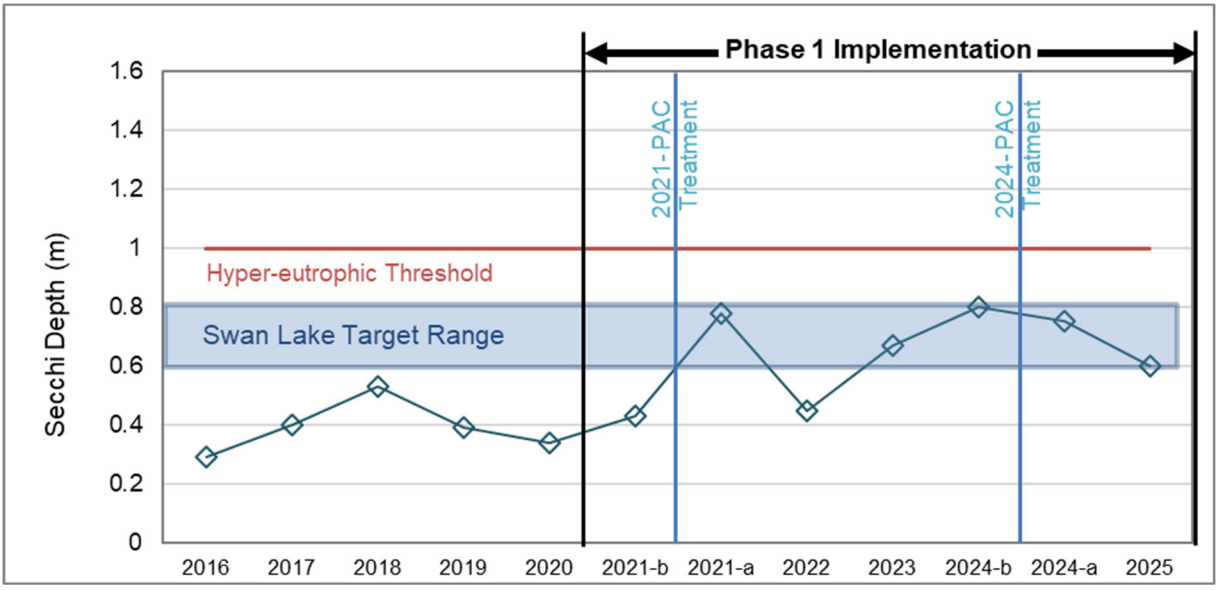


Cell densities decreased following the 2021 PAC treatment and remained lower through 2025, with values generally near or below the Health Canada indicator guideline of 50,000 cells/mL.

Secchi depth has shown modest improvement, increasing from approximately 0.3–0.5 m during the 2016–2020 period to approximately 0.6–0.8 m in 2023 and 2024, with a value of 0.6 m observed in 2025 (Figure 10). While these values remain within the hyper-eutrophic eutrophic range, the observed increase in transparency is consistent with reduced algal biomass and improved water quality.

Although the increase in Secchi depth following Phase 1 implementation was modest in absolute terms, it substantially improved light penetration to the lakebed. Based on the lake hypsometry and an estimated euphotic depth of approximately two times Secchi depth, the proportion of bottom sediments receiving light under typical summer water levels increased from about 50% during the 2016–2020 period to about 84% under recent conditions (2023–2025). This increase in illuminated bottom area is sufficient to support establishment and expansion of submerged aquatic vegetation, as discussed later in the report.

Figure 10: Growing-season Average Secchi Depth in Swan Lake (2016–2025)



Showing modest improvements in water clarity following Phase 1 implementation.

Algae Bloom and Cyanotoxins

Prior to implementation of Phase 1 management measures, algal blooms were observed intermittently, with more extensive and persistent events occurring in some years (e.g., 2018–2020). Cyanotoxin testing conducted between 2011 and 2016 generally reported concentrations below detection limits, with the exception of a single elevated measurement of 73 µg/L in 2016. Subsequent screening in 2019 and 2020 indicated microcystin concentrations below 10 µg/L. These results suggest that while blooms were present, toxin-producing cyanobacteria were not consistently dominant.

In 2021, elevated cyanobacteria biomass was observed prior to PAC treatment in August, and while the application reduced concentrations initially, biomass levels increased again later in the season. Since 2022, however, a sustained change in conditions has been observed.

Surface scums have not been widespread since 2022 and have generally been limited in extent and duration. These observations are consistent with phytoplankton monitoring results, which indicate reduced cyanobacteria biomass and increased community diversity relative to pre-Phase 1 conditions. As described in the previous section, phytoplankton monitoring indicates a continued shift toward

lower cyanobacteria densities, with total cell counts declining substantially in 2023 and a further reduction of approximately 40% observed in 2024. These lower densities have been maintained through 2025.

Cyanotoxin monitoring results since 2021 have remained below recreational guideline values where measured, indicating a low risk of adverse health effects under current conditions. While individual sampling events have exceeded Health Canada's indicator value of 50,000 cells/mL for potential cyanotoxin production, these occurrences have been episodic and not associated with widespread surface accumulations.

Overall, these results indicate a shift away from bloom-prone conditions toward a more stable system with reduced cyanobacteria dominance and lower potential for toxin occurrence.

Table 4: 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 (Chorus I, 2021)
2019	Extended blooms were observed at several sites	Microcystin toxicity was measured with test strips; all samples were below 10 µg/L
2020	Blooms were observed at several sites	Microcystin toxicity was measured with test strips; all samples were below 10 µg/L
2021	Blooms were observed at several sites before treatment; the high biomass was inhibited by the August PAC treatment; however, by October, cyanobacteria were as high as in previous summers and falls.	Not tested for toxicity
2022	Surface scums were not widespread; Lab results showed lower diversity and higher total counts compared to 2021.	Microcystin toxicity was measured with test strips; all samples were below 10 µg/L
2023	Surface scums were not widespread; Lab results showed higher diversity and significantly lower total counts compared to 2022.	Not tested for toxicity
2024	Surface scums were not widespread; Lab results showed higher diversity and about 40% decline in total counts compared to 2023.	Not tested for toxicity
2025	Surface scums were not widespread; Lab results showed similar diversity and total counts compared to 2024.	Not tested for toxicity

Bacterial Contamination

Animal droppings in and around the Lake may result in elevated levels of *Escherichia -Coli* in the water; however, since direct contact is not defined as a beneficial use of the Lake, *E-Coli* is not measured.

4.2 Water Balance

A water balance model was developed to support the 2019 water quality management report. The model was updated in 2020 using runoff estimates from the PCSWMM model to support the Swan Lake chemical treatment planning and scenario analysis. In 2024, surface runoff calculation was further refined using a more detailed InfoWorks model as part of a feasibility analysis for diverting stormwater runoff away from Swan Lake.

Meteorological data were taken from the Markham Museum meteorological station, complemented with data from the Mount Joy Community Center and the Buttonville Airport station. Evapotranspiration was estimated using the Priestley-Taylor model. Surface runoff from all outfalls was used from the 2024 model.

Various reports, including those prepared in support of development applications in the area, were reviewed to develop an estimate of groundwater exchange between the Lake and the surrounding area. Based on these reports, groundwater flow in and out of the Lake was estimated to range between 10 and 300 m^3/day; however, there is not enough spatial and temporal resolution to use these values in the water balance analysis, and therefore, a reliable estimation of groundwater contribution is not feasible.

Collected water level data were used to estimate outflow by assuming that discharge starts when the water level reaches an elevation of 208.3 m, i.e., the invert of the overflow weir. The existing water level data (2017-2024) were extrapolated to the previous years by correlating water level with rainfall and evapotranspiration, and outflows were estimated accordingly. Outflow data measured in 2023, and a more refined lake volume calculation were used to further refine this estimation (Figure 11). Table 5 provides a summary of the annual water balance established for Swan Lake and used in the nutrient budget (City of Markham, April 2026).

Figure 11: Measured or Estimated Monthly Water Level

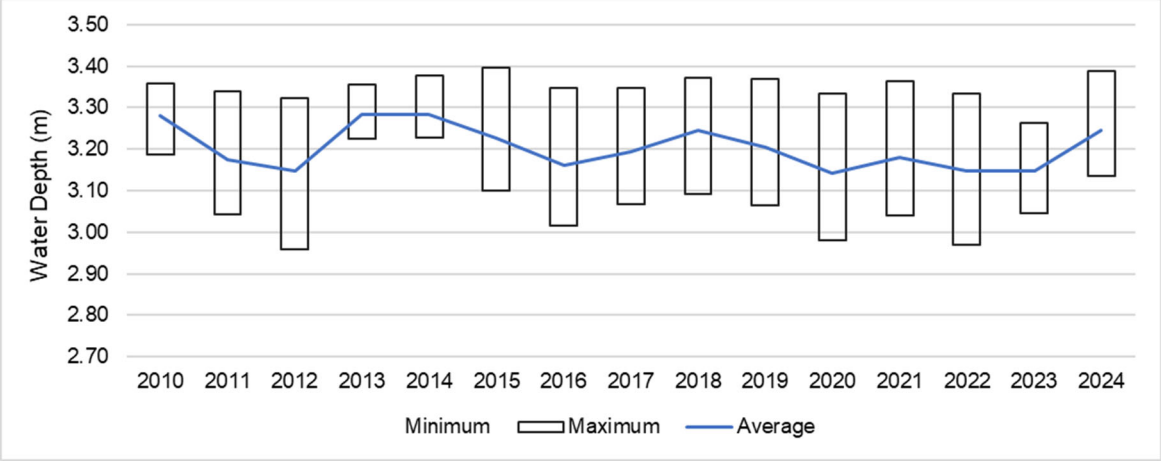


Table 5: Swan Lake Annual Water Balance (m^3)

Year	Precipitation on Lake	Evaporation from Lake	Inflow from Pond 104	Inflow from Pond105	Shoreline Runoff	Inflow from OGSs	Outflow	Balance
2010	36,529	40,307	3,870	8,227	3,270	9,937	51,128	7,064
2011	30,140	42,770	5,596	10,306	2,841	8,467	51,527	7,015
2012	23,329	41,834	327	905	2,126	6,335	24,556	16,104
2013	34,252	44,593	6,717	12,122	3,126	9,764	47,648	14,224
2014	33,246	41,523	2,586	5,706	3,270	9,937	19,079	26,447
2015	33,167	39,966	4,005	7,972	3,142	9,377	36,698	14,501
2016	29,887	42,900	6,044	11,665	2,915	8,781	39,598	4,099
2017	25,546	44,556	458	1,710	2,620	7,566	17,533	2,091
2018	32,798	45,700	2,099	5,131	3,227	9,693	24,477	15,886
2019	41,175	43,560	6,993	61,830	4,040	11,971	36,173	93,720
2020	40,779	42,093	4,751	56,818	3,973	11,723	33,258	79,138
2021	34,551	46,140	4,788	48,893	3,226	9,765	20,110	66,453
2022	37,831	43,711	7,330	57,197	3,623	11,015	47,649	70,841
2023	29,524	39,324	1,263	2,913	3,131	9,171	13,878	14,697
2024	34,971	41,605	5,205	9,689	3,046	9,484	33,872	26,253

4.3 Nutrient Budget

Phosphorus has been established as the most important variable to control water quality in Swan Lake, and the relative contribution from various sources influences the most efficient management options. Phosphorus sources include external (stormwater runoff, precipitation, and geese) and internal sources (release from bottom sediments and sediment resuspension).

The mass balance analysis conducted previously (Freshwater Research, July 2020) and (Freshwater Research, August 2021) was based on monitoring data and water balance estimates available at the time and provided estimates of external and internal phosphorus loading.

Quantification of the internal load is challenging as phosphorus originating from anoxic bottom sediments, macrophytes, or sediment disturbances immediately mixes with the phosphorus already present in lake water so that any fluxes or inputs cannot be directly estimated in shallow lakes. Annual internal loads were estimated from monitoring data in a mass balance analysis and confirmed by other methods (Freshwater Research, July 2020).

The contribution of geese to external load was estimated using the enumeration by the City staff, the geese management contractor, as well as data provided by residents volunteering to assist with geese count. According to this information, the waterfowl population (mainly Canada Geese, *Branta canadensis*) has been stabilized at lowest levels since 2016with approximately 20-30 resident geese throughout the year and higher numbers during migration (sometimes in the order of 1000). The nutrient budget assumes 0.6 g/d of phosphorus for each goose.

Other external sources of phosphorus were estimated based on the annual volumes and selected phosphorus concentrations in the rain and runoff from various land cover types (Table 6).

Table 6: Representative Phosphorus Input Parameters for Atmospheric Deposition and Runoff Concentrations from Stormwater Sources

Phosphorus Source	Phosphorus Concentration	Comment
Atmospheric deposition	16.7 mg/m^2	(Ministry of Environment, 2010)
Stormwater ponds	0.116 mg/L	2011/2012 monitoring data
Untreated from pervious areas	0.121 mg/L	(US EPA, 1983)
Untreated from rooftop	0.192 mg/L	
Untreated from other impervious areas	0.383 mg/L	

Source: (Freshwater Research, July 2020)

The phosphorus mass balance model was updated using an expanded monitoring dataset, revised lake morphometry and water balance information, and refined assumptions regarding external loading and in-lake processes (BlueCycle Canada, Inc., 2026). Updated estimates of annual loading over the open water season (April-November) from external and internal sources are presented in Table 7.

Table 7: Calculated Annual Phosphorus Loads (Apr-Nov) for External and Internal Sources (kg/yr)

Year	Atmospheric Deposition	Shoreline Runoff	Stormwater (Ponds/OGS)	Geese	External (Total)	Internal Load	Total Load
2014	0.47	0.40	2.2	16	19	22	41
2015	0.45	0.37	2.6	17	20	-	20
2016	0.43	0.27	0.7	17	18	85	103
2017	0.45	0.34	1.4	14	16	50	66
2018	0.47	0.47	11.8*	10	23	60	83
2019	0.44	0.44	9.8*	14	25	63	88
2020	0.42	0.27	6.0*	27	33	29	62
2021	0.45	0.40	9.8*	11	22	17	39
2022	0.42	0.34	1.0	12	14	3	17
2023	0.44	0.33	2.1	6	9	0	9
2024	0.46	0.48	5.2	5	11	0	11
2014–2020 Average	0.45	0.37	4.9	16	22	51	66
2021 (Transition Year – PAC Treatment)	0.45	0.40	9.8	11	22	17	39
2022–2024 Average (Phase 1 Implementation)	0.44	0.38	2.8	8	11	1	12

* Elevated phosphorus loads due to blockage of the Pond 105 inlet
Source: (BlueCycle Canada, Inc., 2026)

Model results indicate a fundamental shift in phosphorus dynamics in Swan Lake following Phase 1 implementation. In 2021, internal phosphorus loading was reduced following the August PAC treatment. Since 2022, internal loading has declined substantially and is negligible under current conditions, with predicted phosphorus concentrations closely matching observed values based on external inputs alone.

External phosphorus loading has also decreased in recent years following resolution of the Pond 105 inlet blockage and continued waterfowl management. Under current conditions, external loading is dominated by geese and runoff-derived sources, with atmospheric deposition and local uncontrolled shoreline runoff representing a minor contribution. Interannual variability in total loading is now primarily driven by hydrologic conditions and fluctuations in waterfowl presence.

Overall, Swan Lake has transitioned from a system historically influenced by both internal and external phosphorus sources to one in which water quality is controlled predominantly by external inputs. This shift reflects the effectiveness of in-lake chemical treatments and supporting watershed management measures and is consistent with recent observed improvements in water quality.

4.4 Chloride Budget

De-icing materials used for winter maintenance of roads, parking lots and walkways are the primary sources of chloride in urban lakes. Other common sources of chloride in urban centres include dust suppressants and water treatment salt (for water softening). Salt from water softening would not be expected to enter surface water systems, but rather discharge to wastewater collection systems.

Chloride in salting materials is readily dissolved in water, and transported overland by runoff or infiltrated into soils, contaminating groundwater and surface water. Dry salt can also be transported as wind-blown dust and re-deposited on land or water. As a result, salt loading to lakes occurs primarily in winter and spring during melt conditions, but continues through the summer and fall via discharge of impacted groundwater, dry deposition of dust to the lake surface, non-point source runoff washing dry salt from land surfaces, and flushing of stormwater ponds.

Winter maintenance of 1 km (15%) 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 upon current and future forecast models and temperatures to determine the required action and material usages in compliance with the desired service level of service and O.Reg 239/02 requirements (O. Reg. 239/02, 2013, amended 2018). Using the average salt usage rate, the City has used an average of 3,100 kg of salt per year over the past two years (R. O'Hara, personal communication, June 18, 2021). The remaining 5.5 km of roads, as well as about 3600 m^2 of parking areas, are serviced privately, and information on the level of service and quantities are not available at this time.

The amount of salt and hence chloride draining to the Lake depends on environmental variables and de-icing/snow removal operations.

A preliminary mass balance indicated that the average chloride load to Swan Lake increase by more than 50% between the periods of 2013-2014 and 2018-2020. Subsequent investigation in 2021 identified a blockage at the East Pond (Pond 105) inlet, which resulted in increased stormwater flows with elevated chloride concentrations entering the lake. This condition largely explains the observed increase in chloride loading and in-lake concentrations during this period. Removal of the blockage restored more typical flow conditions and contributed to the subsequent decline in chloride loads and concentrations after 2021.

The chloride budget for the Lake was updated in 2025 using an updated water balance model, together with recent information on salt usage and chloride concentrations in stormwater runoff (City of Markham, April 2026).

Average total chloride loading to Swan Lake (2022-2024) is estimated to be on the order of approximately 3 tonnes per year, half of which is from the three OGSs (no chloride treatment or water retention), about one ton from the East pond and about a half ton from the North pond. This represents a substantial reduction from the elevated loading observed between 2018 and 2021, when a blockage at the East Pond inlet resulted in increased conveyance of high-chloride runoff to the lake. Shoreline runoff contributes minimally to overall chloride loading (<0.1 t/year).

Flow diversion scenarios evaluated (AECOM, May 2025) indicate that targeted redirection of OGS flows and/or stormwater inputs could reduce chloride loading to the lake by approximately 20% to 60%.

depending on the extent of diversion and system modifications. However, these reductions must be considered in the context of system constraints, potential downstream impacts, and implementation feasibility and uncertainty regarding the role of groundwater contributions to the overall water balance and chloride loading to the lake.

4.5 Sediment Quality

In preparation for a chemical treatment, Swan Lake sediment was retrieved from five sites in October 2020. Three to four cores were taken per site, separated into two depth layers (0-5 cm and 5-10 cm), and pooled for each site. Samples were sent to Institut Dr. Nowak in Germany for analysis, including speciation, to determine the releasable phosphorus in the sediment.

Phosphorus concentrations averaged 700 mg/kg dry weight (DW), ranging from 420 mg/kg DW up to 1050 mg/kg DW. Phosphorus concentrations seem to be correlated to loss of ignition (LOI), which stands for the proportion of organic matter. The largest proportion of phosphorus was present in non-bioavailable, mineral fractions (Al/Fe-oxide bound, base releasable and residual phosphorus). The concentration of potentially bio-available phosphorus was about 40 mg/kg DW (Institut Dr. Nowak, December 2020). In general, the surface (0-5) cm layer indicated more polluted and slightly more organically-enriched sediments that are more prone to phosphorus release than the lower sampled layer (Freshwater Research, January 2021).

5. Phase 1 Projects and Initiatives (2021-2025)

During 2021-2025, Core measures from Phase 1 and some Complementary and Alternative measures from Phase 2 and Phase 3 of the Plan were implemented in an adaptive manner to improve the Lake water quality.

Core and Complementary activities completed 2025 included water quality (and biologic) monitoring, enhanced geese management, fish management, chemical treatment, management of aquatic vegetation and algae, and chloride management.

Details of water quality monitoring are provided in annual water quality reports. Other management measures are described in this section.

5.1 Fish Management

One of the findings of the 2020 water quality management study (Freshwater Research, July 2020) was that the control of bottom-dwelling fish (carp and goldfish) is necessary to ensure high efficiency of the chemical treatment.

Through a meeting with the MNRF staff, they were supportive of the non-native/invasive fish removal as well as the relocation of the bottom-dwelling Brown Bullhead. MNRF staff advised against the relocation of Brown Bullhead in later years due to the risk of contamination.

Since 2021, the City has hired TRCA to complete fish inventory, relocation, and removal efforts. Fish are captured using electrofishing and fyke netting, and removal efforts focus on invasive and benthic species that may contribute to sediment disturbance and internal nutrient cycling. Initial work in spring 2021 confirmed a simplified and disturbance-tolerant fish community dominated by Common Carp (non-native), Brown Bullhead (native, benthic), and Fathead Minnow. Efforts in subsequent years (2022–2025) continued to identify a limited number of species, including Brown Bullhead, Fathead Minnow, Goldfish, and hybrid Carp/Goldfish, with Common Carp notably absent in 2025. Over this period, Common Carp were largely eliminated, Goldfish and Common Carp/Goldfish hybrids emerged as the primary invasive species of concern, and Brown Bullhead remained the dominant native benthic species.

A summary of fish species captured since 2021 is provided in Table 8.

Table 8: Fish Species Collected from Swan Lake Since 2021

Date	Method	Brown Bullhead	Common Carp	Fathead Minnow	Goldfish	Common Carp x Goldfish	Emerald Shiner
April-21	3 days electrofishing + 2 days nets	210	7	>10,000	-	-	-
August-22	1 day electrofishing, 1 day nets	80	20	875	-	-	-
August-23	1 day electrofishing	84	103	14	2	-	-
April-24	1 day electrofishing, 1 day net	193	1	1521	13	59	1
April-25	1 day electrofishing, 1 day net	391	-	3586	354	1	-

In May 2025, 500 juvenile largemouth bass were introduced to the lake by a private contractor (Hidden Lane Fisheries, Smithville, ON), following consultation with TRCA and the MNRF. Fish stocking was identified as a complementary measure in the 2021 Plan to help improve trophic structure and support development of a more balanced fish community. Alternative stocking options, including Bluegill, were

considered but not pursued due to their potential to reduce zooplankton populations and indirectly promote algal growth.

The 2021 Plan recommended monitoring and removal of benthic fish for five years. Following the 2025 work, TRCA advised that fish monitoring should continue annually and that invasive species should continue to be removed. They have recommended that in 2026 consideration should be given to returning some/all the Brown Bullhead to the lake (rather than removal) since they are a native fish, and it is important to have some benthic feeders in a lake ecosystem. In addition, monitoring of the stocked largemouth bass population and evidence of spawning activity is recommended, along with public education measures (e.g., signage) to discourage the release of pet fish into the lake.

5.2 Geese Management

Active geese management started in 2014, focusing on resident geese and extended to the management of migratory geese in 2016. The frequent geese chasing would encourage the geese to relocate to a quieter place and reduce the number of resident geese at Swan Lake.

Additional measures were implemented in 2021 when the City hired the TRCA to remove existing nests and eggs and to relocate resident geese from Swan Lake.

From 2021 through 2023, the geese management program included a combination of hazing (using trained border collies), nest and egg management, relocation of resident geese, and deterrent measures (strobe lights). In 2024 and 2025, additional deterrent techniques were introduced, including laser emitters, avian distress calls, and limited use of pyrotechnics. Monitoring was conducted by contractors, City staff, and community volunteers, supported by a geese tracking application (ArcGIS Survey123), allowing for improved scheduling and targeting of management activities.

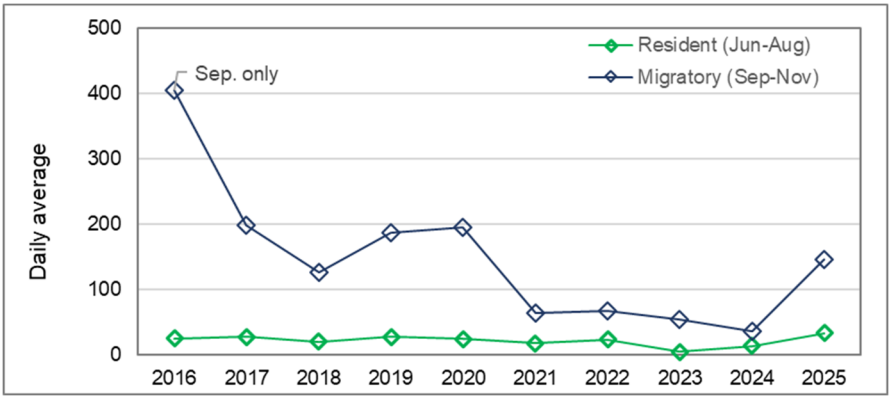
Overall, these measures have been effective in reducing both resident and migratory geese presence at the lake, particularly during peak migration periods in the fall (Figure 13).

At the request of FOSLP, and upon Council approval (City of Markham, September 2020), nine strobe lights were also purchased and installed on the Lake and the two adjacent stormwater management ponds between 2020 and 2025. 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. While the strobe lights were implemented, no consistent measurable effect on geese counts was observed. In contrast, active management measures (hazing, nest control, and relocation) have been the primary drivers of reduced geese presence at the lake.

Enhanced hazing programs, especially when implemented during late summer and fall migration periods, consistently resulted in reductions in daily geese counts. Nest and egg management also contributed to limiting local population growth, with annual nest counts generally ranging from approximately six to nine nests and 28 to 68 eggs managed per year. Relocation efforts further reduced the number of resident geese, with annual removals ranging from approximately 14 to over 40 birds in recent years.

Despite ongoing regional increases in Canada Goose populations, the sustained management program at Swan Lake has effectively controlled local geese numbers over time, particularly when compared to pre-management conditions. However, geese counts increased somewhat in 2025, likely reflecting natural population variability and the temporary removal of laser deterrent systems for product improvement.

Figure 12: Historical Geese Counts at Swan Lake (2016–2025)



5.3 Chemical Treatment

The quantification of different phosphorus sources in 2020 indicated that the effects of internal sources outpaced those from external sources. The phosphorus released from internal sources was believed to be highly bioavailable and quickly become incorporated into phytoplankton and bacteria. An in-lake treatment was therefore recommended as the most immediate and effective solution.

Freshwater Research reviewed various physical and chemical methods of internal load abatement and identified the methods that are limnologically feasible for Swan Lake as a chemical treatment with Phoslock or Poly Aluminum Chloride (PAC). A treatment with Phoslock was completed in 2013. This treatment had provided at least two growing periods of improved water quality and successfully controlled sediment phosphorus release according to the mass balance analysis. There was no obvious negative effect from the previous treatment (Freshwater Research, July 2020).

In order to secure an alternative treatment, the City also initiated a conversation with the Ministry of Environment, Conservation, and Parks (MECP) to explore the feasibility of a PAC treatment. Information on the Lake conditions and the effectiveness and application history of PAC was provided to the Ministry ((City of Markham, November 2019) and (City of Markham, December 2019)). The MECP reviewed this information and agreed that if "after implementing source controls, the City determines that an aluminum-based treatment is necessary, the City should ensure that all measures are taken to monitor water quality and prevent any adverse effect from the application" (MECP, January 2020).

Specialized sediment collection and analysis were completed in the fall of 2020 in support of chemical treatment. Sediment analytical results were used to determine the appropriate Phoslock dosage for each area of the Lake (Freshwater Research, January 2021). A contractor procurement process was initiated in late 2020. However, the Phoslock supplier informed the City that Phoslock needed to undergo a new approval process for use in Canadian lakes, and it would not be available for a 2021 application (N. Trail, personal communication, February 7, 2021).

Following this revelation, at the request of the City, Freshwater Research conducted a feasibility assessment of an aluminum-based treatment (Freshwater Research, March 2021). While PAC was acknowledged as an effective solution, this review noted that the resulting flocculent gelatinous precipitate (aluminum hydroxide) would be chemically stable up to a pH of ~8.8 (pH in Swan Lake water is around 8-9; higher measurements in 2020 were a result of device malfunction). Aluminum would also be toxic to aquatic biota in acidic, poorly buffered waters (pH<7). It was therefore recommended to stagger the application over several days to prevent shocks of toxicity.

In order to determine the optimum dosage and duration for a safe application, the City hired AECOM Canada to develop a PAC treatment plan. This plan provided information on different PAC materials, PAC dosing (including jar test with Lake water) and application methods, and other special provisions for tendering purposes (AECOM, July 2021). A contractor was hired to implement this plan, which was fulfilled in August 2021.

In 2024, a second application of PAC was completed using a reduced dosage based on the updated treatment plan (AECOM, March 2024). Approximately nine tonnes of PAC were applied over two application events in late June, with each event separated by one to two days to allow for floc formation and environmental monitoring.

The reduced dosage reflects improved lake conditions following the 2021 treatment, including lower in-lake phosphorus concentrations and reduced sediment phosphorus accumulation over the intervening period. As a result, the estimated available sediment phosphorus for 2024 was approximately 38% lower than in 2021, and the total available phosphorus was approximately 20% lower, representing an overall reduction of about 30% in the mass of phosphorus requiring inactivation.

5.4 Aquatic Vegetation Management

Despite successful reductions in both internal and external nutrient loading in recent years, resulting in total phosphorus concentrations below target levels, Swan Lake has remained dominated by phytoplankton, and improvements in water clarity have been modest. This condition is likely influenced by warmer climatic conditions and the absence of submerged aquatic vegetation (SAV), which has historically been limited by elevated phosphorus concentrations. In the absence of SAV, phytoplankton remain the primary competitor for available nutrients and light, reinforcing a turbid, algae-dominated state.

Submerged aquatic vegetation plays a key role in maintaining clear-water conditions by stabilizing sediments, reducing resuspension, competing with phytoplankton for nutrients, and providing habitat for zooplankton and fish communities. The establishment of SAV is therefore considered an important mechanism for shifting the lake toward a more stable, clear-water condition.

The 2021 Plan identified the introduction of native SAV as a Phase 2 action. However, following review of 2022 water quality data, this measure was advanced to Phase 1 to support ongoing water quality improvements and complement existing management activities.

In 2023 and 2024, the City hired TRCA to implement a pilot SAV planting program along the north shore of the lake. In June 2023, approximately 1,500 stems of wild celery (*Vallisneria americana*) were planted within four fenced enclosures at depths of approximately 0.3 to 1.0 m. Monitoring in 2024 indicated variable establishment, with an overall survival rate of approximately 30% and improved growth observed in shallower areas (~0.2 m depth). In response, an additional 1,500 stems were planted in 2024 at shallower depths (approximately 0.2 to 0.4 m) to improve establishment success Naturally occurring aquatic vegetation was also observed to be abundant in 2024. However, the rate of establishment for planted wild celery was overall very low in 2025.

During the second PAC application in 2024, significant amounts of SAV, comprised primarily of small pondweed (*Potamogeton pusillus*), were observed and at times hindered the movement of the application boat. This represented the first observation of substantial SAV in the lake.

In July 2025, a comprehensive survey was conducted in accordance with a survey plan developed by AECOM to characterize the existing aquatic plant community. The survey found that SAV was abundant throughout the lake, with generally moderate to high cover at depths less than 2 m, and variable cover

ranging from high to absent at depths greater than 2 m. The community was dominated by native species, including muskgrass (*Chara* spp.) and Canada waterweed (*Elodea canadensis*), with lower abundances of small pondweed and curly-leaved pondweed (*Potamogeton crispus*). The establishment of this SAV community is consistent with improved water clarity and reduced algal biomass observed in recent years (BlueCycle Canada, April 2026).

Given the poor establishment of planted wild celery and the successful natural colonization of submerged aquatic vegetation, further planting is not warranted at this time.

5.5 Algae Management

Following the successful use of ultrasound technology to control algae blooms in a stormwater management pond in Markham, two similar units were installed at Swan Lake in 2025 to reduce phytoplankton and further improve water clarity.

Ultrasound is a low-cost and durable method commonly used to control algae growth in water-holding facilities, including drinking water reservoirs. When deployed, the ultrasound device generates vibrations that rupture gas vacuoles within algae cells (structures that control buoyancy) causing the algae to sink to deeper, lower-light areas of the pond where they become inactive. The low-power ultrasound waves used have no impact on aquatic animals, birds, or humans.

The system selected for Swan Lake consisted of two Water IQ Pulsar 3000 units powered by a land-based solar panel. This is the same equipment used in the Markham stormwater pond, allowing staff to benefit from familiarity with installation, operation, and demonstrated performance. The transducers were anchored to cinder blocks and strategically positioned in the lake to maintain direct line-of-sight coverage of all areas where algae had been observed. One limitation encountered was the 100-metre cable length between the solar panel and each unit, which constrained placement options. Evaluation of this technology for its effectiveness in Swan Lake is ongoing.

5.6 Removal of Invasive Plants

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 in 2022. The herbicide application, which was carried out by licensed contractors working on behalf of the TRCA, was repeated in the spring of 2023.

5.7 Chloride Management

Chloride was identified as a key issue in the 2021 Plan due to increasing concentrations in Swan Lake that exceeded applicable water quality guidelines. In urban watersheds such as Swan Lake, chloride loading is primarily associated with winter maintenance activities (e.g., road salt application), as well as contributions from stormwater infrastructure and potential groundwater pathways.

Chloride is a conservative contaminant that accumulates in aquatic systems and is not readily removed through natural processes or conventional in-lake treatments. As a result, chloride management is fundamentally constrained to source control and reduction of inputs, rather than in-lake remediation.

Given these constraints, the City's approach to chloride management has focused on improving understanding of sources and pathways, monitoring trends, and evaluating practical measures to reduce chloride loading to the lake. Management activities since 2021 have included:

- Monitoring and Data Collection

The City has continued to implement a monitoring program to characterize chloride concentrations in Swan Lake and key inflows, including stormwater management ponds and oil-grit separators (OGSs). This monitoring provides the basis for evaluating temporal trends, identifying potential sources, and supporting model development and management decision-making.

- Operations, Maintenance, and Inspection

Routine inspection and maintenance of stormwater infrastructure (e.g., ponds and OGS units) has been undertaken to ensure proper system function and to support water quality objectives. While these activities are not designed specifically for chloride removal, they are important for maintaining hydraulic performance and supporting overall watershed management.

- Water and Chloride Budget Development and Mass Balance Modeling

A comprehensive water and chloride budget was developed to quantify inflows, outflows, and chloride loading to the lake (City of Markham, April 2026). This work provides a foundational understanding of the relative importance of different sources and pathways and supports evaluation of potential management strategies.

A monthly chloride mass balance model was also developed to simulate lake chloride concentrations based on inflows, outflows, and estimated chloride loads (BlueCycle Canada, April 2026). The model was used to evaluate the relationship between external loading and observed lake concentrations and to assess the relative importance of different loading estimates. Overall, the model is considered a planning-level diagnostic tool, useful for understanding system behaviour, identifying key uncertainties, and supporting future refinement as additional monitoring data become available.

- Flow Diversion Study

Evaluation of source control through structural modification was included in Phase 3 of the Plan, to be pursued if other management measures were not sufficient. In 2022, and at the request of FOSLP, Council directed staff to bring forward this evaluation to Phase 1. In 2023, the City retained AECOM Canada to develop a dual drainage hydraulic model using InfoWorks ICM to assess the feasibility of diverting stormwater runoff from Swan Lake (AECOM, May 2025). The analysis focused on evaluating whether stormwater flows could be redirected without increasing flood risk within the study area or at downstream locations. A range of diversion scenarios was evaluated, including redirection of stormwater flows from key inflow points, capture and diversion of higher-strength “first flush” runoff, modification of existing flow control structures, expansion of upstream storage capacity, and implementation of combined or integrated approaches. The analysis estimated reductions in stormwater flows ranging from 6% to 46% for the scenarios evaluated.

- Research and Emerging Treatment Technologies

Evaluation of new technologies for chloride treatment was included in Phase 2 of the Plan. At the request and based on a proposal solicited by FOSLP, Council directed staff to support a research initiative by York University to evaluate potential treatment approaches for chloride removal from water using biochar filtration systems. Initial results indicate that the biochar materials tested to date are not effective for chloride removal under typical lake conditions, with increases in chloride observed in low-concentration samples and only limited reductions at higher concentrations. York University is currently testing alternative materials (e.g., eggshell-based media and polymers). This research scope agreed-upon by the City is expected to be completed by the end of 2026.

5.8 Evaluation of Management Outcomes (2021-2025)

Management activities implemented since 2021 have focused on reducing internal and external phosphorus loading, controlling waterfowl inputs, managing fish populations, and improving overall ecological function in Swan Lake. Monitoring data and updated modelling indicate that water quality improvements have met or exceeded the interim targets established in the 2021 Plan and are consistent with predicted responses described in FWR (2020) (Table 9).

Table 9: Evaluation of Management Outcomes Relative to 2021 LMP Targets

Parameter	2021 LMP Baseline	Interim Target (2021 LMP)	2022–2024 Observed	Status
Total Phosphorus (µg/L)	>200	50–100	~20–30	Exceeded
Secchi Transparency (m)	<0.5	0.6–0.8	~0.6–0.8	Achieved
Chloride (mg/L)	~700	400–500	~200	Exceeded
Frequency of Algal Blooms	Annual	Every 3 years	No significant surface blooms; minor localized accumulations	Achieved
Internal P Load (kg/yr)	~53	0–25	~0	Exceeded
External P Load (kg/yr)	~30	~15	~9–11 (typical)	Achieved

Total phosphorus concentrations declined from historically eutrophic conditions (>200 µg/L) to approximately 20–30 µg/L, substantially exceeding the interim target of 50–100 µg/L. This response is consistent with FWR (2020) predictions that control of internal phosphorus loading would be the primary driver of improved water quality. Mass balance modelling confirms that internal phosphorus loading, previously a dominant source (~50 kg/year), has been effectively eliminated and remains negligible through 2024 (BlueCycle Canada, April 2026). As a result, Swan Lake has transitioned from an internally driven system to one in which external inputs govern water quality.

External phosphorus loading has declined to approximately 9–11 kg/year under recent conditions, achieving the interim target and reflecting the combined effects of watershed management measures and improved stormwater system performance (BlueCycle Canada, April 2026). Continued control of external inputs is now the primary factor influencing future water quality.

Water clarity improved from less than 0.5 m to approximately 0.6–0.8 m, meeting the target range. While gains in Secchi depth are more moderate relative to phosphorus reductions, this response is consistent with shallow lake conditions where sediment resuspension and non-algal turbidity continue to influence clarity.

Reductions in algal bloom occurrence have been significant, with no widespread or persistent surface accumulations observed in recent years. Minor, localized accumulations have occasionally been observed along shoreline areas but do not represent whole-lake bloom conditions. Based on the FWR (2020) definition of bloom conditions in terms of aerial extent and persistence, the interim target has been

achieved. The additional PAC treatment applied in 2024 is expected to further support control of internal phosphorus release and help maintain these conditions.

Dissolved oxygen conditions have improved substantially as predicted by FWR (2020) with reduced phytoplankton biomass following internal and external phosphorus management. Historically, anoxic conditions near the sediment–water interface were significant, promoting internal phosphorus release and contributing to poor water quality. Recent monitoring indicates that low oxygen conditions are now limited in both extent and duration, generally confined to deeper portions of the lake, as would be expected for a shallow, warm-water, urban lake. Dissolved oxygen levels meet Provincial Water Quality Objectives for the protection of aquatic life, and anoxia during the open water season is no longer a significant concern that would require active management.

A key ecological response has been the establishment of submerged aquatic vegetation (SAV) in 2024–2025, representing a major shift from historically phytoplankton-dominated conditions. This development reflects improved light availability and reduced nutrient concentrations and is expected to contribute to long-term stabilization through sediment stabilization, nutrient uptake, and increased resistance to algal dominance.

Chloride concentrations have declined substantially from approximately 700 mg/L under pre-2021 conditions to approximately 200 mg/L in recent years, exceeding the interim target range of 400–500 mg/L. This improvement is attributed primarily to stormwater system maintenance, including removal of flow constraints (Pond 105 inlet blockage). Despite these gains, chloride remains a conservative parameter controlled by external loading associated with road salt application and watershed processes. As a result, further reductions may be limited under current conditions, and continued emphasis on source control and monitoring if it is shown that current concentrations are a detriment to aquatic habitat improvement.

5.9 Summary and Costs

Management actions implemented since 2021 have been highly effective, with all primary interim targets achieved or exceeded. Observed responses align closely with FWR (2020) predictions, particularly with respect to the dominant role of internal phosphorus loading and the effectiveness of chemical treatment. Improvements in dissolved oxygen conditions and the establishment of SAV further confirm that internal loading has been effectively controlled and that key ecological feedbacks are now supporting improved lake function.

Swan Lake has transitioned from a highly eutrophic, internally driven system to a more stable condition in which water quality is governed primarily by external inputs. Continued monitoring and adaptive management will be required to sustain these improvements, with a focus on controlling external nutrient inputs, maintaining internal nutrient control through periodic chemical treatments, maintaining stormwater system performance, and supporting long-term ecological stability.

Total cost for the implementation of Phase 1 measures was about $1,000,000 for water quality improvement (through the Environmental Services department), with additional expenses for shoreline management through the Operations department. Details are shown in Section 8 (Table 12).

5.10 Stakeholder Engagement and Education

5.10.1 Resident Initiatives and Public Consultation

The residents of Swan Lake Village have been very involved in making observations about the Lake conditions and the natural and built environment around it.

In 2010, Professor Jon Van Loon sent an email to Councillor John Webster asking for data regarding water quality in Swan Lake. He subsequently reviewed the reports provided and sent an email to all members of Markham Council asking for action to clean up the Lake. After the Phoslock treatment and for several years, he was actively following the initiatives and studies completed at Swan Lake.

In 2019, the newly formed resident group, Friends of Swan Lake Park (FOSLP), contacted the City to report their observations of the Lake, and to request available technical reports and drawings. Over the past seven years, FOSLP has been actively pursuing a number of initiatives and provided the City with several reports and presentations, which have been considered in the development of this Plan.

In March 2024, the City held a community meeting at Markham Museum for the members of the public interested in the Swan Lake water quality improvement program. The meeting was attended by more than 100 residents, and a presentation was delivered on the program details.

Extensive consultations with FOSLP and their external advisors were conducted in 2026, through which staff reviewed and held meetings with report authors to discuss these submissions. Appendix A provides the submissions, staff feedback, and meeting presentations and minutes.

5.10.2 Engagement and Education

The City maintains a website to share information and document activities and outcomes, including City Council directions related to Swan Lake (www.markham.ca/swanlake).

In 2020, algae signs were installed at multiple locations around Swan Lake to warn the public about the potential presence of toxic algae and against water contact for humans and pets.

Staff developed educational signs in 2021 to remind residents of the environmental impact of geese and to encourage them to submit geese observations through an online App, which has been used by a number of residents. Since 2023, staff have also been collaborating with researchers from Trent University, who are studying the bioaccumulation of Rare Earth Elements (REE) in aquatic biota. Swan Lake was chosen as a study site due to the presence of lanthanum, an REE used in the manufacturing of Phoslock.

6. Policy Direction and Goal Statement

6.1 Federal and Provincial Regulations

Based on a communication from the DFO, no review pursuant to the Fisheries Act or the Species at Risk Act is required for "artificial water bodies that aren't connected to a water body that contains fish at any time during any given year, such as quarries and aggregate pits" (Fisheries and Ocean Canada, 2021).

The MNDMNRF would be involved in the approval process of any undertaking on Crown Land. The bed of Swan Lake "is not designated as Crown Land, and as such activities affecting the bed of Swan Lake would not be subject to approvals under the Public Lands Act" (Ministry of Natural Resources, 2013).

The MECP has been involved in the approval of a chemical treatment for Swan Lake both in 2013 (Phoslock) and 2021 (PAC), and will need to be consulted for any future undertakings.

All new or retrofit stormwater management systems are regulated by the MECP through an Environmental Compliance Application (ECA) Section 53 of the Ontario Water Resources Act.

Through the Rouge River Watershed Plan, the TRCA supports "a healthy aquatic system that supports a diversity of native habitats and communities and provides sustainable public use opportunities" for the Rouge watershed (Toronto and Region Conservation Authority, 2007)

The TRCA regulates any proposed development, interference, or alteration within a Regulated Area ((O. Reg. 166/06, 1990), which does not apply to Swan Lake.

6.2 Markham Strategies and Bylaws

The City of Markham launched a strategic plan in 2008 called Building Markham's Future Together, which has been updated periodically. One of the goals of this plan is to build a safe, sustainable, and complete community through protecting and enhancing the natural environment and built form, among other approaches (City of Markham, 2019).

The City also launched a Greenprint plan in 2011 (City of Markham, 2011) to improve the natural environment and enhance the quality of life in Markham. The Greenprint is a 50 plus year plan with a bold vision and a strong leadership commitment to make Markham one of the most livable and sustainable communities in North America.

The City of Markham Official Plan (2014) provides land use policy direction to guide future growth and development in the City. The Markham OP includes policies for environmental protection, natural heritage conservation, water resource planning and the management of natural hazards. In accordance with the Planning Act, the City of Markham is undertaking a review of the City of Markham Official Plan (2014) to determine updates necessary to bring the plan into conformity with provincial policies and plans, integrate relevant direction from the York Region Official Plan (2022) and address local priorities and planning needs.

6.3 Goal Statement and Level of Service

Based on the review of applicable policies and strategies, as well as input received from stakeholders, a narrative was developed as a goal statement for water quality management in Swan Lake, as follows:

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

Numerical water quality targets for Phase 1 of the Plan were initially developed in 2019 (Freshwater Research, July 2020) and subsequently refined through evaluation of treatment scenarios (Freshwater Research, August 2021). For Phase 2 (2026-2030), these targets have been further reviewed and updated based on:

- Recent monitoring data and model results
- Lake and watershed characteristics
- Observed response to Phase 1 management measures
- Practical achievability under current conditions.

The proposed updated targets represent interim (adaptive) levels of service that reflect current achievable water quality conditions following implementation of Phase 1 management measures. While substantial improvements have been realized, Swan Lake remains in a transitional state, with ongoing ecological adjustment and variability in external inputs. These targets are considered appropriate for Phase 2 implementation and are intended to guide management over the next five years, after which they will be reviewed and updated based on monitoring results and continued improved understanding of system processes.

Table 10 presents the proposed interim (adaptive) targets for Swan Lake. Detailed descriptions of the targets and their rationale are described in Swan Lake Management Targets Update (BlueCycle Canada, Inc., 2026)

Table 10: Proposed Interim Targets for Swan Lake for the next five years (2026-2030)

Parameter	Current Values*	Interim Target*	Objective and Rationale
Total phosphorus (µg/L)	<20	≤20 (<30 for single events)	Aligns with the Provincial Water Quality Objective (20 µg/L) as a benchmark and reflects current observed conditions. The target is intended to maintain current conditions, recognizing that only modest further reductions may be achievable or warranted.
Secchi Transparency (m)	~0.6–0.8	≥0.6	Represents sufficient light availability to support establishment and persistence of submerged aquatic vegetation (SAV). At current nutrient levels, Secchi is influenced by multiple factors and is no longer a reliable surrogate for phosphorus.
Chloride Concentration (mg/L)	~200 (2024–2025 average)	200–400	Reflects substantial improvement from historical conditions (>700 mg/L). Target maintains concentrations below levels associated with increased ecological risk while recognizing constraints from ongoing road salt use, background concentrations, and potential groundwater inputs.
Frequency of Cyanobacteria blooms	Periodic blooms; densities near guideline thresholds	Reduced frequency, duration, and severity; generally, ≤50,000 cells/mL	Based on Health Canada recreational guidance for primary contact use. Target supports reduced health risk and improved conditions while recognizing that blooms may still occur under certain conditions. Focus is on long-term system response rather than elimination.
Internal phosphorus load (kg/yr)	~0	≈0 (negligible)	Internal loading has been effectively controlled following treatment and is no longer a dominant source. Maintaining negligible internal loading is critical to sustaining current lake conditions.
External phosphorus load (kg/yr)	9–17	≤12–15	External inputs now control lake phosphorus concentrations. Target reflects recent post-treatment conditions with an allowance for variability in flow. Continued BMP implementation is required to maintain gains and limit increases during higher-flow years.

*Unless otherwise indicated, targets represent open water season (April–November) average conditions.

7. Analysis and Discussion of Lake Management Measures

Through a review of the history and the current state of the Lake (Sections 2 to 5), and based on the proposed lake management objectives (Section 6), a number of issues and opportunities were identified for lake management for Phase 2 (2026-2030), including:

- Swan Lake is not a natural feature, and water does not enter and exit the system like in most natural systems. Contaminants that enter the system build up over time, leading to poor water quality.
- The land use surrounding Swan Lake has changed significantly over the past 30 years. Starting as farmlands, it has changed to a residential community, including a gated community and senior housing development. Major land use types include community/ infrastructure (75 %) open water, including the Lake (15%) and tree canopy or parks (10 %).
- Average contributions from different sources of water to the Lake include direct precipitation (47%), direct runoff (4%), and controlled runoff (49%). Due to scarcity of data, and intrinsic challenges with measurement in a shallow urban environment groundwater has not been quantified independently and rather calculated as the balance of other measured or estimated inflows and outflows.
- Two stormwater ponds and three oil and grit separators (OGS) collect and treat runoff from 80% of the catchment.
- The City owns most of the Lake except for a small portion in the south.
- The two stormwater ponds and two OGS units are owned and maintained by the developers. Storm sewer lines within the catchment are owned by the City and the private condominium corporation. The Region of York owns the 16th Avenue sewer line.
- Winter maintenance of 1 km (15%) of the catchment roads and sidewalks is completed by the City of Markham, and the remaining roads, as well as about 3600 m^2 of parking areas, are serviced privately.
- Internal phosphorus loading, historically the dominant source of nutrients to the lake, has been effectively controlled following in-lake treatment and is now negligible.
- External phosphorus inputs, including contributions from stormwater runoff and waterfowl, now represent the primary sources influencing lake water quality.
- Dissolved oxygen conditions have improved substantially, meeting guidelines for aquatic life and limiting internal phosphorus release potential from sediments.
- Submerged aquatic vegetation (SAV) has become established under recent conditions, representing a significant ecological shift toward a more stable, clear-water state.
- While water quality has improved significantly, the lake remains sensitive to external inputs and ongoing watershed influences.
- Chloride concentrations have declined substantially from historical levels but remain governed by external loading associated with road salt use and watershed processes.
- Groundwater contributions to water and chloride balance remain uncertain and may influence long-term system response.
- Stormwater infrastructure performance and maintenance continue to play an important role in controlling water and contaminant inputs to the lake.
- Climate variability, including warmer temperatures and altered runoff patterns, may influence future nutrient and chloride dynamics and water quality.

- The fish community remains simplified, and ongoing management is required to support ecological balance.
- Swan Lake continues to provide important recreational, aesthetic, and ecological value, with strong community interest in maintaining and improving lake conditions.

Multiple management measures were developed in consultation with stakeholders and evaluated to address these issues and opportunities, as described here. Each measure was evaluated for technical feasibility and effectiveness (water quality), maintenance and operation needs, terrestrial and aquatic environment, construction impacts, public safety, the cost to the City, and community benefits/impacts.

7.1 Measures to Control Internal Nutrient Load

7.1.1 Chemical Treatment for Phosphorus Control

Chemical treatment with Phoslock or Poly Aluminum Chloride (PAC) has been identified as the most effective and immediate method of controlling internal phosphorus load in Swan Lake (Freshwater Research, July 2020). Recent chemical treatments using PAC have effectively controlled internal phosphorus loads and should be continued in Phase 2 at a modified dosage and frequency. Prior to the next application, a targeted sediment survey following the approach used by Freshwater Research (January 2021) is recommended to confirm dosage requirements. Pending the results of the survey and observed lake phosphorus concentrations, the treatment may be postponed by more than three years following the last application.

A modified application of chemical treatment (PAC) to Swan Lake costs about $132,000 or $44,000 per year for a three-year cycle. A sediment survey costs about $15,000 (only one is required).

7.1.2 Bottom-Dwelling Fish Management

Bottom-dwelling fish (carp and goldfish), while not a significant source of phosphorus, contribute to the disturbance of lake sediment and thus the release of internal load. One study concluded that the presence of large carp contributed 23% to summer internal loading (Kelton & Chow-Fraser, 2005). Therefore, fish management is recommended as a method for internal load control.

Removal of bottom-dwelling fish cost about $10,000 annually.

7.1.3 Nitrogen Control

Targeted nitrogen control is not warranted for Swan Lake. Monitoring and prior studies confirm that phosphorus is the limiting nutrient in the system, and that reductions in phosphorus loading are the primary driver of water quality improvement. Nitrogen concentrations have declined in response to reduced productivity following phosphorus control, and additional reductions are expected through ongoing management measures, including geese management. In addition, cyanobacteria are less responsive to N-limitation, and low inorganic concentrations of nitrogen may give cyanobacteria a competitive advantage over other algae (Freshwater Research, August 2021).

Staff and City consultant previously reviewed a number of proposals brought forward by FOSLP to further decrease nitrogen load, including water circulation with pre-treatment, bioswales, and manufactured floating treatment wetlands, and recommended against them.

7.2 Measures to Control External Nutrient Load

7.2.1 Geese Management

Geese defecation contributed to more than 68% of the external phosphorus load in Swan Lake (2022-2024 average), and is thus an important load to manage. Geese management is therefore recommended to continue, including existing programs (hazing, nest and egg management, and relocation), as well as exploring new methods to deter migratory geese. As the strobe light have not been effective, these should be removed from the program.

The annual cost for the enhanced geese management programs at Swan Lake (and Toogood Pond) is about $50,000. Additional measures completed in 2021 cost about $8,500 (including extended hazing, nest management and geese relocation). Funds will be required for new methods such as nighttime hazing (at an estimated cost of $31,500 annually).

7.2.2 Stormwater Management Facilities Maintenance

Stormwater ponds and OGS's contribute to about 18% and 7% of the external load, respectively (assuming that the facilities are working as per design). Proper maintenance, including sediment removal and inlet and outlet cleaning, are essential in controlling the flow of nutrients to the Lake.

Currently, all these facilities are owned and operated by the developers. Once all existing underground and aboveground deficiencies are rectified, the City will proceed with the process of Acceptance for Maintenance of the two stormwater management ponds, followed by Assumption (transfer of ownership). Once Swan Lake Boulevard is assumed, the City will own and maintain sewer infrastructure and OGS assets on Swan Lake Boulevard.

The annual cost for the maintenance of the two stormwater ponds, including any future cleanout, will be through the City's pond maintenance program. Maintenance costs are in the order of a few thousand dollars for occasional repairs and about $500,000 per pond for cleanout and retrofit, occurring at an approximate frequency of every 15 years.

7.2.3 Shoreline Planting and Access

It is estimated that the shoreline runoff contributes to about 18% of the external load. This might be a conservatively high estimate given that phosphorus-based fertilizers are not used in the Park, and geese contribution has been included in the mass balance separately. Nonetheless, it will still be helpful to use Best Management Practices (BMP's) in the Park, including controlled lakeshore access via boardwalks and plantings around the lakeshore, to adsorb pollutants and prevent geese from accessing the Lake.

The Parks Department worked with the TRCA to develop a plan for shoreline planting/improvements. Design consultation for shoreline improvements was identified as one initiative through the Swan Lake Park, Parks Operations and Parks Refresh Draft Plan presented to Council on November 2, 2020. This work is ongoing and included the installation of geese exclusion posts and fencing with wire mesh, and shoreline planting. The list of plants selected was modeled from the TRCA - recommended riparian shoreline restoration initiatives, and include Serviceberry, Common Buttonbush, Red Osier Dogwood, Smooth Sumac and Common Elderberry.

7.2.4 Groundwater and Historic Dumping

Due to the lack of data, the nutrient budget for Swan Lake does not include any potential contribution of groundwater and the historic dumping in the surrounding area to the south and west of the Lake. This

dumping site was operational from 1983 to 1999 and received household waste, and so leaching of nutrients from the site is likely (Freshwater Research, January 2017).

Information on groundwater is scarce, and extensive site investigations and a detailed groundwater model will be required to quantify groundwater contribution.

Site investigation of the historic dumping areas will require participation of the developers and private owners, and given the minimal contribution of internal sources, this measure is therefore given lower priority.

7.3 Measures to Improve Oxygen Level

Historical monitoring indicated that Swan Lake experienced periods of oxygen depletion during summer stratification, which contributed to internal phosphorus release from sediments and degraded aquatic habitat conditions. As a result, various artificial oxygenation approaches, including mechanical aeration and chemical oxygen release methods, were previously considered.

Monitoring results since 2021 indicate that dissolved oxygen conditions have improved substantially. The extent and duration of low-oxygen conditions have been significantly reduced, and anoxia is no longer a dominant driver of internal phosphorus loading or water quality impairment in the lake.

Based on current conditions, active oxygenation measures are not recommended. Such measures would provide limited additional benefit and, in the case of mechanical aeration, could result in unintended adverse effects, including sediment disturbance and increased nutrient release. Chemical oxygenation approaches remain experimental and are not warranted given the observed improvements in dissolved oxygen conditions.

Ongoing monitoring will be used to confirm that current conditions are maintained; however, additional oxygen management measures are not warranted at this time.

7.4 Measures to Control Chloride Concentration

7.4.1 Winter Maintenance on Private Land

About 85% of the roads (5.5 km), as well as 3600 m^2 of parking areas in the catchment, are serviced privately. Salt reduction on private lands is, therefore, an important component of a chloride reduction strategy. This could be achieved through engaging the developers and private owners within the community on the rate and frequency of salt applications and chloride alternatives to prevent excessive salt application while keeping the appropriate level of service. Reduction of chloride load to the Lake could also be achieved through more frequent snow removal and disposal (rather than letting snowmelt find its way to the Lake).

It would be beneficial that winter operators are trained through the ‘Smart About Salt’ program to understand the impact of chloride on the environment and the importance of complying with recommended salting rates, the operation of the salting equipment at a higher threshold, and the merits of using low chloride products. The logistics of this measure will need to be discussed as the majority of winter maintenance is undertaken by private contractors for private landowners.

7.4.2 Physical or Biological Treatment

A number of methods were reviewed for removing dissolved chloride from the Lake water, including adsorption on media (e.g., , biochar), solar still, and biological treatment by chloride-tolerant plants (Fleming College, February 2021).

A research initiative is ongoing by York University to evaluate potential treatment approaches for chloride removal from water using biochar filtration systems. Initial results indicate that the biochar materials tested to date are not effective for chloride removal under typical lake conditions, with increases in chloride observed in low-concentration samples and only limited reductions at higher concentrations.

The use of salt-tolerant vegetation (halophytes) is an emerging, nature-based approach for managing chloride in urban environments. These plant species are adapted to saline conditions and may help to intercept, uptake, or retain chloride in soils before it is transported to receiving waters. However, successful chloride depletion in receiving waters by biological treatment or alien chloride-tolerant plants is questionable, and case studies with quantitative results are not reported in the scientific literature (Freshwater Research, April 2021).

A pilot-scale phytoremediation project is currently underway at Lake Wilcox (Richmond Hill), led by the Toronto and Region Conservation Authority (TRCA), York Region, Toronto Metropolitan University, and the Royal Military College. The project is evaluating the effectiveness of halophytes in reducing chloride concentrations through several applications, including roadside seed mixes, targeted plug plantings in salt-impacted soils, and integration with urban tree plantings to improve soil conditions and vegetation health. Monitoring of vegetation performance, soil chemistry, and associated environmental conditions is expected to provide insight into the feasibility and effectiveness of this approach.

At this time, application of halophytes in the Swan Lake watershed is considered a measure for future consideration, pending results from ongoing studies and evaluation of site-specific feasibility. The City will continue to monitor developments in this area, including outcomes from the Lake Wilcox project, to determine whether similar approaches could be incorporated into future chloride management strategies.

7.4.3 Redirecting Stormwater

In 2023, a feasibility study was completed for diverting stormwater runoff from Swan Lake (AECOM, May 2025) to identify scenarios where stormwater flows could be redirected without increasing flood risk within the study area or at downstream locations, and reduce chloride load to the Lake. The analysis estimated reductions in stormwater flows ranging from 6% to 46% for the scenarios evaluated, ranging in cost from $125,000 to $7,000,000. While these strategies may have nominal benefits in terms of chloride input, given that chloride concentration have decrease significantly since the initiation of this study, even the highest-ranking scenario are not recommended at this point. Structural measures for reducing chloride concentration may be considered in Phase 3 if other efforts for improving aquatic habitat are not successful due to chloride concentration.

7.5 Measures to Improve Natural Heritage Features

7.5.1 Shoreline Planting

See section 7.2.3.

7.5.2 Planting and Evaluation of Submerged Water Plants

Planting of submerged aquatic plants (SAV) was recommended in the 2021 plan once phosphorus was controlled to consistent concentrations below 0.100 mg/L and transparency improved. SAV has since colonized naturally in response to improved light conditions in the lake. SAV plantings, therefore, are no longer recommended as a management action.

Future efforts should focus on monitoring the developing plant community, with consideration of targeted plantings to introduce additional species (e.g., floating-leaved vegetation) to increase habitat diversity and ecological function.

A repeat comprehensive aquatic vegetation survey is recommended in approximately five years, unless earlier changes in lake conditions warrant reassessment. This timing would allow evaluation of the persistence, expansion, and composition of the naturally established plant community and help inform whether any additional vegetation management is needed. Estimated cost for this activity is $10,000.

7.5.3 Fish Stocking

Now that phosphorus concentrations in water are reduced, dissolved oxygen levels and water clarity have improved, and SAV has established, the water quality and habitat of Swan Lake could be suitable for additional fish species, and at which point a Fish Management Plan will be completed. The plan will include discussions with the TRCA and MNRF regarding suitable species and the potential of stocking, and will consider the success of the 2025 stocking program (overwintering survival). While habitat conditions in the open water season may support stocking, winter conditions under ice may not be favourable for overwintering of stocked fish due to the shallow conditions of the lake with little deep-water refugia and potential under-ice anoxia. The plan will also consider the installation of submerged woody habitat (e.g., logs) to increase structural complexity and enhance fish habitat.

The MNRF has indicated that they would support elevating Swan Lake as a potential candidate for a pilot project with Fish Culture, given the City allows public angler access to the Lake. Through this program, the Ministry will raise largemouth bass and bluegill sunfish in their hatcheries for stocking in stressed urban waterbodies not suitable for the typical stocking of trout or walleye. Public angler access, however, is key for any government-supported stocking (W. Wegman, personal communication, August 5, 2021).

8. Proposed Strategy

8.1 Summary of Evaluation of Lake Management Measures

Table 11 provides a summary of measures evaluated in Section 7 for feasibility, effectiveness, and costs over 25 years.

Table 11: Evaluation of Lake Management 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.	$132,000 per modified application (three-year intervals) $15,000 sediment survey
	IL2	Bottom-Dwelling Fish Management	Feasible; lowers internal load release.	$10,000 annually
	IL3	Nitrogen Control (by pumping & treatment or artificial wetlands)	Not recommended- Nitrogen does not control algae growth in Swan Lake	N/A
External Load	EL1	Geese Management (including Toogood Pond)	Feasible; lowers nutrient input from the most significant external source.	Enhanced measures: $50,000 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	Funded
	EL4	Groundwater and historic dumping areas	Not recommended except for flow and chloride measurements	$10,000
Algae Blooms	AB1	Ultrasound Treatment	Feasible; potentially reduces phytoplankton biomass preventing surface blooms. Effectiveness for Swan Lake is still being evaluated.	Funded
Oxygen Level	OL1	Mechanical or chemical oxygenation	Not recommended- Oxygen levels are within water quality objectives and no management (mechanical or chemical) is needed.	N/A
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	Review of chloride uptake by plants	Internal
	CL3	Redirecting Stormwater	Not recommended in Phase 2	$125K to $7M
Natural Features	NF1	Shoreline Planting/ Improvements	Feasible; will provide fish habitat	See EL3
	NF2	Planting and Evaluation of Submerged Water Plants	Not recommended. Natural colonization has occurred.	$10,000 (Survey every five years)
	NF3	Fish Management Plan and Fish Stocking	Feasible; pending outcomes of the 2025 stocking. Includes addition of submerged logs or other habitat structure	$10,000

8.2 Recommended Strategy

Based on monitoring, modelling, and evaluation of management outcomes for the 2021–2025 period, the core measures implemented in Phase 1 have been highly effective in achieving intended water quality improvements. Key targets for chloride, phosphorus, water clarity, algal bloom frequency, and internal loading have been met or exceeded, and the lake has transitioned from an internally driven system to one primarily influenced by external inputs.

Accordingly, the recommended strategy has been updated for Phase 2 and Phase 3 to focus on maintaining current conditions, optimizing management measures, and supporting long-term ecological stability through adaptive management, rather than expanding to more intensive or higher-cost interventions.

The plan relies on a set of "Core" measures established in Phase 1 that are deemed technically reliable and cost-effective. Additional "Complementary" measures are introduced in Phase 2 based on the review of Phase 1. Annual reporting and reporting at the end of each phase would be used to identify the need for additional measures to be considered in subsequent phases, and to refine the frequency and dosage of chemical treatment, based on monitoring and water quality results achieved. Further "Alternative" measures may also be considered in later phases (see items u) and v) but are expected to have a high cost, have challenges for implementation (e.g., activities on private lands) and may not be technically required to meet the proposed water quality goals.

The phased approach includes the following recommended measures:

Phase 1 (2021-2025): Core Measures - Completed:

a) Continue water quality monitoring and report on quality annually through Markham Subcommittee
b) Continue geese management and explore enhanced methods
c) Remove benthic-dwelling fish
d) Maintenance of stormwater management facilities (by developers then City)
e) Community engagement in reducing nutrient and chloride, data sharing, as well as progress reviews and plan updates
f) Chemical treatment in 2021 and 2024
g) Shoreline planting/improvements
h) Chemical oxygenation pilot project (by research institute) – not pursued
i) Evaluate Phase 1 measures

In Phase 1, several Complementary and Alternative measures that were identified for Phase 2 and Phase 3 were advanced, including:

- Fish stocking
- Planting of submerged plants
- New technologies for chloride (biochar research by York U)
- Flow diversion assessment

In Phase 1, several additional Complementary Measures were identified and implemented including:

- Ultrasound for algae control
- Water and chloride budget
- Submerged aquatic plant survey

Phase 2 (2026-2030): Adapted Core Measures and Complementary Measures:

j) Items a) to e) in Phase 1
k) Chemical treatment with adjusted frequency and dosage
l) Fish management plan and fish stocking
m) New technologies for chloride treatment (complete research by York U and evaluate chloride uptake by halophytes)
n) Lake sediment survey
o) Targeted groundwater flow and chloride monitoring
p) Shoreline plantings/improvements
q) Submerged aquatic plant survey
r) Ultrasound for algae control
s) Evaluate Phase 2 measures

Phase 3 (post 2030): Adapted Core Measures with or without Alternative Measures

t) Items j) to k) in Phase 2 with modifications if required
u) Investigate contribution from groundwater, if required
v) Evaluate/design structural modifications such as lake water recirculation and stormwater redirection, if required

At the end of Phase 2, a 5-year summary report will be completed, summarizing the effectiveness of the Adapted Core measures and evaluating additional Complementary measures to consider in Phase 3. Additional Complementary measures will be advanced based on needs to further improve water quality and considering the technical feasibility and cost-effectiveness of additional measures.

Table 12 provides a cost estimate for the 25-year life cycle based on the proposed phased approach. Cost estimate for some future measures is provided as an order of magnitude and for perspective.

The total cost for implementing Core and Complementary measures for the next 25 years as per the recommended plan, is about $5,584,000 (including pond cleanout), funded from the Environmental Services lifecycle. Implementing all measures, including the Alternative Measures, would cost about 8.7 to 23.6 million dollars (depending on the flow diversion scenario, and the extent of groundwater remediation work).

Table 12: Life-Cycle Cost Estimate

Measure	Phase 1 Plan	Phase 1 Actual	Phase 2 (2026-2030)	Phase 3 (2031-2050)	Total (Phases 2 and 3)	Current Life-Cycle (2021)	Increase Over Current Life-Cycle
Continue water quality monitoring	$149,000	$140,000	$168,000	$866,000	$1,034,000	$919,000	$115,000
Continue geese management and enhanced methods (including Toogood)	$275,000	$210,000	$419,000	$2,160,000	$2,579,000	$2,280,000	$299,000
Remove benthic-dwelling fish	$39,000	$50,000					
Fish management plan and fish stocking	$20,000	$10,000					
Planting of submerged plants	$20,000	$49,000					
Maintenance of stormwater management facilities	$2,000	$-	$6,000	$538,000	$544,000	$537,000	$7,000
Chemical treatment with adjusted frequency and dosage	$309,000	$331,000	$287,000	$1,040,000	$1,327,000	$1,380,000	$(53,000)
New technologies for chloride treatment	$50,000	$50,000	$-	$-	$-	$50,000	$(50,000)
Investigate dumping areas	$-	$-	$-	$20,000	$20,000	$-	$20,000
Investigate groundwater	$-	$-	$10,000	$-	$10,000	$-	$10,000
Evaluate structural modifications	$-	$120,000	$-	$-	$-	$120,000	$(120,000)
Other measures	$-	$15,000	$-	$-	$-	$-	$-
Evaluate measures	$25,000	$25,000	$28,000	$72,000	$100,000	$-	$100,000
Total	$889,000	$1,000,000	$908,000	$4,676,000	$5,584,000	$5,286,000	$298,000

Notes:
Phase 3 extended five years (20 years duration) to match 25-year life-cycle. Future life-cycle includes Phase 2 and Phase 3
Assumed pond cleanout/retrofit during the period.

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Appendix A : Public Consultation

Final – Rev 2

Swan Lake Management Options

Swan Lake Long-Term Management Plan:
Water Quality Monitoring Program
Preliminary Review

Prepared for:

Fred Peters
Friends of Swan Lake Park

Project No. 3645 | March 2026

NATURAL RESOURCE SOLUTIONS INC.
Aquatic, Terrestrial and Wetland Biologists

Swan Lake Management Options

Swan Lake Long-Term Management Plan: Water Quality Monitoring Program Preliminary Review

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Table of Contents

1.0 Purpose and Objectives 2
1.1 Background and Scope 2
2.0 Summary of Water Quality Monitoring Program Components 4
2.1 Water Quality Monitoring Program Components and Recommendations 6
2.1.1 Water Quality Parameters 6
2.1.2 Water Quality Sample Collection 7
2.1.3 Water Quality Sampling Locations 7
2.1.4 Water Quality Guidelines and Targets 8
3.0 Water Quality Monitoring Results 13
3.1 Adequacy of Water Quality Monitoring Program 15
3.2 Water Quality Monitoring Program Limitations 16
4.0 Water Quality Monitoring Program Enhancements 17
4.1 Swan Lake Management Strategy Program Considerations 18
5.0 Conclusions 22
6.0 References 24

1.0 Purpose and Objectives

Natural Resource Solutions Inc. (NRSI) was retained by the Friends of Swan Lake Park to complete a peer review of the monitoring and reporting completed to date as part of the City of Markham's 25-year water quality monitoring program preliminary (Phase 1). As part of this review, NRSI will assess:

- The adequacy of the monitoring program completed to date;
- The appropriateness and attainability of the water quality targets;
- Comparisons of the reported water quality conditions to recommended guidelines for the protection of aquatic life;
- General comparisons with similar surface water systems; and
- Potential enhancements or adjustments to the monitoring program.

In addition, this report will provide general guidance and recommendations to support the long-term Swan Lake water quality objectives, including:

- Lake management strategies to achieve and maintain surface water quality objectives;
- What level of water quality should be attainable or appropriate given the existing site conditions;
- Recommendations for specific areas that warrant further research or consideration; and
- Additional actions required to support future sustainable water quality targets for Swan Lake.

This review is intended to provide the Friends of Swan Lake Park with a concise summary of the water quality monitoring completed to date and support the development of further rehabilitation and remediation strategies for Swan Lake.

1.1 Background and Scope

Swan Lake is an artificial, manmade water body within the City of Markham that was historically used as a gravel quarry until the late 1970s when it was decommissioned and allowed to fill with water. Following this, it was used as a local landfill until its naturalization in the 1990s. Swan Lake has no natural surface water connections, however between the 1990s and early 2000s it was integrated into the local stormwater management system acting as an ad hock stormwater management pond serving to accumulate and sequester surface water runoff from the surrounding residential developments. Currently, Swan Lake exists as a shallow, eutrophic lake

with a history of cyanobacterial blooms and consistently poor surface water quality conditions. The surface area of the lake is approximately 5.5 ha with an average depth of 1.65 m and a maximum depth up to approximately 4.5 m. It is understood that anoxia is experienced at the deepest point in the lake but given the bathymetry and relatively low volume of water occupying this anoxic layer these anoxic conditions don't negatively affect the aquatic life within Swan Lake as a whole.

Following the identification of poor water quality conditions and degraded fish habitat in 2010 the City of Markham considered treatment options with the goal of improving these conditions. A series of phosphorus-controlling chemical treatments were undertaken between 2013 and 2024; Phoslock in 2013 and PAC in 2021 and 2024, with the intent of reducing phosphorus levels and algal blooms in the lake. Following these initial treatments the City of Markham prepared a Water Quality Management Strategy for Swan Lake in 2019 to set both short and long-term management objectives. Following the approval of this management strategy the City of Markham implemented the Swan Lake Long-Term Management Plan in 2021, which details an adaptive, phased management approach that incorporates core, complimentary, and alternative measures. These measures include a range of chemical treatments, shoreline rehabilitation, and annual water quality monitoring.

As part of this long-term management plan, Phase 1 core measures were to be implemented for a period of 5 years followed by a re-evaluation of the management strategy and implementation of preliminary rehabilitation measures. In advance of this Phase 1 re-evaluation the Friends of Swan Lake Park have requested a preliminary peer review of the works completed to-date.

The scope of this review includes:

- Water Quality Monitoring Program as outlined in the Swan Lake Long-Term Management Plan (Markham 2021);
- Swan Lake Water Quality Monitoring 2021 Annual Report (Markham 2022);
- Swan Lake Water Quality Monitoring 2022 Annual Report (Markham 2023);
- Swan Lake Water Quality Monitoring 2023 Annual Report (Markham 2024); and
- Swan Lake Water Quality Monitoring 2024 Annual Report (Markham 2025);

2.0 Summary of Water Quality Monitoring Program Components

The surface water quality monitoring program outlined as part of the City of Markham's Swan Lake Long-Term Management Plan included a combination of bi-weekly (April-November) field and laboratory water quality analyses at two pre-established monitoring stations to characterize the conditions within Swan Lake (Markham 2021). In addition, water temperatures (2021-2024) and dissolved oxygen concentrations were measured by continuous data loggers (2023-2024) to supplement bi-weekly sample collection at the two monitoring stations.

Surface water quality samples were analyzed, either in the field or through laboratory analysis, for the following parameters:

- Water Clarity (Secchi Depth)
- Nutrients
    - Total Phosphorus
    - Ortho-Phosphorus
    - Ammonia
    - Nitrate
    - Nitrite
    - Total Kjeldahl Nitrogen
- Chloride
- Colour
- Dissolved Organic Carbon
- Phytoplankton/Chlorophyll-a
- Temperature
- Dissolved Oxygen
- pH

These parameters were compared against a series of interim targets developed by the City of Markham to act as general numerical guidelines intended to be used as thresholds for hyper-eutrophic conditions. These interim targets were updated to generic thresholds for eutrophic/hyper-eutrophic conditions (Markham 2022), which are shown in Table 1.

References are made to additional total and dissolved Aluminum concentration monitoring as part of the ongoing phosphorus control chemical applications. However, this monitoring is omitted from annual monitoring results.

Table 1. Swan Lake Water Quality Guidelines and Targets

General Eutrophic State Water Quality Targets			
Parameter	**Eutrophic Condition**	**Hyper-Eutrophic Condition**	**Rationale**
Water Clarity (Secchi Depth) (m)	1-2.1m	<1	Based on objective of low-eutrophic conditions as a surrogate for Phytoplankton/Chlorophyll-a.
Total Phosphorus (µg/L)	31-100	>100	Based on low-eutrophic condition objective of the overall management plan.
Total Nitrogen (mg/L)	0.65-1.20	>1.20	Based on low-eutrophic condition objective of the overall management plan.
Provincial/Federal Water Quality Guidelines			
Parameter	**Guideline**	**Rationale**	
Chloride Concentration (mg/L)	640	Based on the assumption that meeting the guideline for long-term exposure for the protection of aquatic life (120 mg/L) is not achievable at this time.	
Total Cyanobacteria Cells (cells/mL)	50,000	Based on low-eutrophic condition objective and potential production of cyanotoxins as part of the overall management plan.	
Total Cyanobacterial biovolume (mm^3/L)	4.5	Based on low-eutrophic condition objective and potential production of cyanotoxins as part of the overall management plan.	
Total Chlorophyll-a (µg/L)	33	Based on low-eutrophic condition objective and potential production of cyanotoxins as part of the overall management plan.	
Cyanotoxins (µg/L)	10	Based on Health Canada Guideline for Recreational activities	

Following the completion of each monitoring year the results were compared to both the established guidelines and previous monitoring years' results in order to identify trends in surface water quality and note positive or negative changes in surface water quality conditions that could be attributed to ongoing Swan Lake rehabilitation operations.

2.1 Water Quality Monitoring Program Components and Recommendations

2.1.1 Water Quality Parameters

Based on NRSI's review of the components of the overall monitoring program, the surface water quality parameters identified as part of the core water quality monitoring program are consistent with eutrophication monitoring as part of an overall beneficial use impairment assessment (CWA 2025). These monitoring programs are intended to assess the potential risk of disruption to aquatic ecosystems, human health, and/or impairment to recreational use and serve as appropriate parameters to support the long-term condition monitoring within Swan Lake.

Despite Swan Lake's status as an artificial water body and not being intentionally constructed as a stormwater management facility (SWMF), the presence of multiple stormwater outlets to the lake make it a stormwater receiver and suggest that the lake serves as an ad hoc SWMF. Stormwater management facilities convey surplus surface water runoff from impervious surfaces for treatment and management and often convey additional contaminants from road runoff (such as heavy metals, hydrocarbons, and in-organic debris) which can have considerable degenerative effects on receiving aquatic ecosystems. The omission of common stormwater management pond contaminants (e.g., total metals, physical parameters, and organic contamination) from the monitoring program limits the comprehensiveness of the overall monitoring program in addressing potential effects of SWMF-related contaminants on aquatic conditions within Swan Lake.

In addition, the inclusion of additional supporting physical and organic parameters would be beneficial to provide context relating to the overall water quality conditions and effectiveness of the ongoing rehabilitative and management operations. These supporting parameters would help to characterize additional elements of the aquatic ecology within Swan Lake and provide context for changes to the suitability of the lake to support aquatic life over the longer term. Additional parameters would also provide context to the overall water quality monitoring program. It is recommended that additional water quality parameters be included as part of the ongoing monitoring program to provide further context for the existing water quality conditions.

The Following list identifies a range of parameters to be considered for inclusion in the monitoring program going forward, including:

Physical Parameters

- Total Suspended Solids (TSS)
- Conductivity

Total Metals

- Aluminum, Antimony, Arsenic, Barium, Beryllium, Bismuth, Boron, Cadmium, Calcium, Cesium, Chromium, Cobalt, Copper, Iron, Lead, Lithium, Magnesium, Manganese, Molybdenum, Nickel, Phosphorus, Potassium, Rubidium, Selenium, Silicon, Silver, Sodium, Strontium, Sulfur, Tellurium, Thorium, Tin, Titanium, Tungsten, Uranium, Vanadium, Zinc, and Zirconium.

Organics

- Biochemical Oxygen Demand (BOD)
- E. Coli (*Escherichia Coli*)
- Oil and Grease
- Polycyclic Aromatic Hydrocarbons

2.1.2 Water Quality Sample Collection

The sampling program intervals outlined bi-weekly sample collection between April and November to provide high resolution water quality data on an annual basis. This sampling program would be appropriate to characterize the background conditions in support of the long-term condition monitoring within Swan Lake. However, the presence of multiple stormwater outlet structures associated with Swan Lake and the assumed stormwater inputs have the potential to introduce high concentrations of surface water contaminants over a short timeline in response to spring freshet or significant precipitation events. The inclusion of focused spring freshet/precipitation (i.e., wet event) sampling events would be beneficial to provide additional context for understanding the overall water quality conditions, effectiveness of the ongoing rehabilitative and management operations, and the potential stormwater influences on the existing surface water conditions within Swan Lake.

It is recommended that additional spring freshet/precipitation event (i.e., wet event) monitoring be included as part of the monitoring program going forward.

2.1.3 Water Quality Sampling Locations

Swan Lake is a relatively stagnant lake with no significant currents and very minimal mixing throughout the lake. This limits the degree of water quality parameter concentrations evenness throughout the lake. Sampling within Swan Lake has occurred at two sampling locations; "Bridge" and "Dock," limiting the resolution of the water quality sampling results and the comprehensiveness of the overall monitoring program. The limited number of sampling stations has the potential to lead to gaps in the water quality characterization coverage. Anecdotal analysis of additional 2025 monitoring completed by Trent University suggests that the overall conditions throughout Swan Lake are somewhat consistent. However, the presence of multiple stormwater outlet structures to Swan Lake without monitoring in their immediate vicinity limits the ability to characterize the potential stormwater influences on the surface water quality conditions. The inclusion of additional monitoring stations within the vicinity of the existing stormwater outlet structures would improve the comprehensiveness of the overall monitoring program.

It is recommended that the inclusion of additional monitoring stations associated with the existing stormwater outlets be considered as part of the monitoring program going forward to provide additional context to the potential stormwater effects on Swan Lake and to improve the comprehensiveness of the overall monitoring program Swan Lake.

2.1.4 Water Quality Guidelines and Targets

The general eutrophic state water clarity targets established as part of the Swan Lake water quality monitoring program incorporate the expected ranges of water quality parameters for eutrophic and hyper-eutrophic conditions. For parameters not generally covered by the Canadian Council of Ministers of the Environment (CCME) Recommended Guidelines for the Protection of Aquatic Life the ranges are generally consistent with the expected range of conditions within shallow urban water bodies as opposed to the guidelines established under the Provincial Water Quality Objectives (CCME 2001 and MOEE 1994).

The City of Markham maintains that, given the manmade nature of Swan Lake, there is no requirement to comply with Ministry of Environment and Energy's (MOEE) guidelines or recommendations. However, it should be noted that the MOEE has indicated that all Provincial Water Quality Objectives (PWQO) are applicable to "*all waters of the province (e.g. lakes, rivers and streams) except in those areas specifically designated, such as areas influenced by MOEE approved point source discharges*." (MOEE 1994). No specific exemptions are identified for private or manmade water bodies.

Exemptions to PWQO guidelines may be applicable for areas where water quality does not meet the identified PWQO, provided that conditions not be allowed to degrade further and all practical measures are taken to upgrade the water quality to the objectives (MOEE PWQO Policy 3.2.2). These exemptions and accommodations are available where it is clearly demonstrated that all reasonable and practical measures to attain the Provincial Water Quality Objectives have been undertaken but where:

- Provincial Water Quality Objectives are not attainable because of natural background water quality;
- Provincial Water Quality Objectives are not attainable because of irreversible human-induced conditions;
- Attaining or maintaining Provincial Water Quality Objectives would result in substantial and widespread adverse economic and social impact; or
- Suitable pollution prevention techniques are not available.

In this scenario deviations from the PWQO may be allowed, subject to the approval of the MOEE, under the "Guideline for Handling Requests for Deviations" (MOEE 1994). In general, these guidelines are numerical concentrations recommended as levels that should result in negligible risk of adverse effects to be used as benchmarks or targets in the assessment and remediation of impacted sites.

It is recommended that the inclusion of PWQO guidelines be considered for inclusion as part of the Swan Lake monitoring program going forward.

Water Clarity

Water clarity, measured by secchi depth, was utilized within the monitoring program and is intended to be used as a surrogate to monitor for Phytoplankton (algae) blooms as a component of eutrophic and hyper eutrophic conditions. While water clarity itself is not directly associated with water quality conditions for the protection of aquatic life, the Health Canada has established water clarity guidelines for the protection of recreational water uses based on public health and aesthetic considerations (Health Canada 2024). Despite Swan Lake never being intended to support recreational uses, incorporating these recreational guidelines as part of the Swan Lake monitoring program would coincide with the water quality range for Eutrophic conditions while serving to support a degree of water safety applicable for recreational uses within and around Swan Lake.

It is recommended that the water clarity recreational water quality guideline (>1.2m) be incorporated as part of the monitoring program going forward (Health Canada 2024).

Total Phosphorus

Total phosphorus targets established under the Swan Lake monitoring program are generally consistent with the CCME guidelines for the protection of aquatic life trigger ranges for Canadian lakes and rivers. Phosphorus concentrations are not directly associated with water quality conditions to protect aquatic life, but they are directly associated with the risk of eutrophic conditions.

It is recommended that the total phosphorus water quality targets include the additional trigger ranges outlined as part of the Canadian Water Quality Guidelines for the Protection of Aquatic Life as part of the monitoring program going forward (CCME 2001).

Total Nitrogen

Total nitrogen targets are based on the general assessment ranges for eutrophic conditions. However, total nitrogen concentrations typically incorporate both organic nitrogen and ammonia concentrations within an environment and while there are recommended CCME guidelines for the protection of aquatic life for both nitrate and ammonia there are no specific guidelines for total nitrogen concentrations (CCME 2001). As such the application of general eutrophic condition assessment ranges for total nitrogen concentrations serve as appropriate water quality targets for the Swan Lake water quality monitoring program. However, the incorporation of additional guideline ranges for nitrogen-associated parameters, such as nitrate and ammonia, which are already included in the surface water monitoring program, would serve to increase the overall comprehensiveness of the Swan Lake monitoring program.

It is recommended that the nitrate and ammonia guidelines established through the Canadian Water Quality Guidelines for the Protection of Aquatic Life be incorporated into the monitoring program going forward (CCME 2001).

Chloride

Chloride targets as part of the Swan Lake monitoring program were established to coincide with the short-term exposure guideline, following the assumption that achieving the long-term exposure guideline was not possible at this time. The Canadian Water Quality Guidelines for the

Protection of Aquatic Life are intended to protect against the direct toxic effects of chloride (CCME 2001). Where exceedance of the long-term guideline is observed due to anthropogenically enriched water, such as within Swan Lake, toxic effects may not be observed due to the potential for adapted ecological communities within chronically exposed environments and highly tolerant species (CCME 2011). While these guidelines are not enforced limits they are intended as benchmarks or targets in the assessment and remediation of contaminated sites and aid in evaluating the effectiveness of site controls on water quality. The lack of reference to the potential impacts associated with exceeding the long-term exposure limit does somewhat limit the comprehensiveness of the annual analysis.

It is understood that the overall chloride targets are to be re-examined and potentially revised as part of the City of Markham's 2025 Water and Chloride Budget program, and it is recommended that these targets and the inclusion of the long-term guidelines be included as part of the monitoring program going (CCME 2001).

Dissolved Oxygen

The dissolved oxygen target as part of the Swan Lake monitoring program was established as the minimum dissolved oxygen concentration for the protection of warmwater fish species, as established by the PWQO (MOEE 1994). However, this guideline is intended as a general guide and the MOEE further indicates that where additional physical or chemical stressors are operating more stringent criteria may be required. Low oxygen levels are common in eutrophic lakes, such as Swan Lake, where oxygen depletion is facilitated by anaerobic activity. Chronic exposure to low dissolved oxygen levels lead to reduced growth in fish, and other aquatic species, and increased stress on aquatic ecosystems, which can include an increase in juvenile fish mortality (CCME 1998). More recent water quality guidelines have been established by CCME with the understanding that oxygen concentrations near the bottom of water bodies are further actively reduced as a result of sediment oxygen demand, which magnifies the effects of low dissolved oxygen levels on developing fish embryos and benthic aquatic organisms (CCME 2001). As such, the Canadian Water Quality Guidelines for the Protection of Aquatic Life for Dissolved Oxygen establish slightly higher concentration guidelines for the protection of warmwater ecosystems during both early and other life stages (CCME 2001).

It is NRSI's understanding that as part of the 2025 monitoring program, the results of which were not included as part of the initial review, new and substantial aquatic vegetation growth

has been observed throughout Swan Lake. It is expected that these newly established aquatic vegetation communities will have a beneficial effect on the dissolved oxygen conditions throughout Swan Lake.

However, given the early historic lack of aquatic vegetation and the recent establishment of the vegetation communities it is recommended that additional aquatic vegetation monitoring be considered for inclusion as part of the monitoring program going forward, with the potential to include additional dissolved oxygen concentration monitoring should the establishment of aquatic vegetation communities not take within Swan Lake.

Cyanobacteria and Cyanotoxins

Cyanobacteria related guidelines set out as part of the Swan Lake monitoring program are consistent with the Health Canada Guidelines for Canadian Recreational Water Quality (Health Canda 2024). Though these guidelines are intended to address the human health and safety of recreational surface water bodies, they do provide appropriate guidelines to comprehensively address microbiological hazards within Swan Lake.

Chlorophyll-a

Guidelines for Chlorophyll-a have been established as an index for eutrophication and cyanobacteria biomass to further address the human health and safety of recreational surface water bodies. These guidelines are consistent with Health Canada Guidelines for Canadian Recreational Water Quality and provide appropriate guidelines to comprehensively address microbiological hazards within Swan Lake (Health Canada 2024).

3.0 Water Quality Monitoring Results

The results of the City of Markham's 2021-2024 water quality monitoring program show relatively consistent water quality conditions within Swan Lake on an annual basis, with notable changes during each monitoring year that can be attributed to specific remediation activities. A review of the graphical depiction of annual monitoring results appears to indicate instances of monitoring gaps or omitted monitoring data;

- 2021 – July-September
- 2022 – Late August-September
- 2023 – Late April, June, and October
- 2024 – Late May, July, and September

Though these data gaps may be an artifact of the graphical depiction, the duration of these gaps appears to suggest that some biweekly monitoring may not have been completed or included, which could limit the interpretation of some water quality parameters. In order to ensure that the monitoring results are fully interpreted it is recommended that the full bi-weekly water quality results be reported, with explanations provided for gaps in water quality sampling coverage.

The results of specific water quality monitoring parameters are further discussed below.

Water Clarity

Water clarity monitoring results between 2021 and 2024 were reported on an annual basis as being generally below the guidelines for the duration of the growing season. This is an appropriate characterization of the conditions based on the reported water quality results. However, as part of each year's annual monitoring report the overall Secchi depths were averaged for comparison with identified water quality guidelines as part of the representation of the annual Secchi depth conditions. The conditions reported within Swan Lake appear to be approximately consistent with those seen in shallow eutrophic surface water bodies.

It is recommended that both the minimum and maximum Secchi depths be included as part of the annual water quality guideline analysis to note potential seasonal changes in water clarity.

Total Phosphorus

Total phosphorus concentrations between 2021 (following phosphorus control treatment) and 2024 were reported as consistently below the Eutrophic threshold and were well below the

elevated levels reported for 2021 prior to phosphors control treatment applications. This is reported as an improvement from prior conditions, which is an appropriate characterization of the conditions with Swan Lake. However, the inclusion of additional trophic status trigger ranges to further analysis can increase the comprehensiveness of the representation of the conditions within Swan Lake. The conditions reported within Swan Lake appear to be generally consistent with those seen in shallow eutrophic surface water bodies.

It is recommended that further trophic status ranges established under the Canadian Water Quality Guidelines for the Protection of Aquatic Life, including eutrophic, meso-eutrophic, mesotrophic, oligotrophic, etc., be considered for inclusion as part of the annual water quality analysis to provide context as to the overall water quality conditions (CCME 2004).

Total Nitrogen

Total nitrogen concentrations were reported as consistently below the eutrophic thresholds between 2021 and 2024. This appears to be an appropriate characterization of the conditions within Swan Lake. However, reported findings during 2021 and 2023 are not presented with direct comparison to the identified guidelines and bi-weekly sampling results were not reported for 2024 monitoring, so this statement cannot be verified. An analysis of water quality and nutrient trends in major drainage areas by Environment Canada identified the median national concentration range as between 0.002 - 6.9 mg/L, and between 0.005 - 0.382 mg/L for unimpacted sites with the highest concentrations identified within the Great lakes area (Environment Canada 2011). The conditions within Swan Lake, generally below 0.65 mg/L, suggest the conditions reported within Swan Lake appear to be generally consistent with those seen in shallow eutrophic surface water bodies.

It is recommended that bi-weekly water quality results be reported alongside the identified guidelines as part of the annual water quality analysis to provide context for the overall water quality conditions.

Chloride

Chloride concentrations have been reported as relatively consistent within each monitoring year, with a significant improvement in chloride concentrations attributed to rehabilitation works completed at the East Pond Inlet and Swan Lake Club Oil and Grit Separator (OGS) during 2024. Overall results were reported as consistently within and below the target concentration

ranges and short-term Guideline for the Protection of Aquatic Life, but consistently in excess of the long-term guidelines. This is an appropriate characterization of the existing conditions within Swan Lake. However, multiple gaps in full sampling coverage are noted within the reported data. The elevated chloride conditions reported within Swan Lake are consistent with those seen in online shallow water bodies that are subjected to road salt runoff contamination, such as with stormwater management ponds and their receiving water bodies.

It is recommended that the full bi-weekly water quality results be reported, with explanations provided for gaps in water quality sampling coverage.

Dissolved Oxygen

Dissolved oxygen concentration monitoring reported oxygen levels consistently above the established guidelines, suggesting stable, albeit still impaired conditions between 2021 and 2024, as shown by the repeated low dissolved oxygen events below the identified guideline. This is an appropriate characterization of the existing conditions within Swan Lake.

It is recommended that dissolved oxygen conditions alongside identified guidelines be included as part of the annual water quality analysis to provide context for the overall water quality conditions.

Cyanobacteria and Cyanotoxins

Cyanobacteria monitoring reported cell counts generally in excess of the recommended guidelines, with a general decreasing trend between 2022 and 2024. It is recommended that cyanobacteria conditions alongside identified guidelines be included as part of the annual water quality analysis to provide context as to the overall water quality conditions.

3.1 Adequacy of Water Quality Monitoring Program

Based on our review of the overall Swan Lake Monitoring Program it is NRSI's opinion that the existing water quality monitoring program is sufficient for a high-level characterization of the water quality from the perspective of monitoring the risk of eutrophic conditions within Swan Lake. However, the potential inclusion of the recommendations outlined above would support a more comprehensive characterization of surface water conditions and the evaluation of ecological conditions and functions within Swan Lake.

A review of the annual water quality monitoring reports between 2022 and 2024 further supports this with the results presented as part of each year's annual monitoring program sufficient for the high-level characterization of the existing conditions within Swan Lake. However, the inherent scope of the monitoring program has the potential to limit the overall comprehensiveness of the monitoring program as it relates to the protection of the aquatic ecosystem within Swan Lake. The consideration of the inclusion of some of the recommendations outlined above would support a more comprehensive monitoring program and better identify changes in surface water conditions.

3.2 Water Quality Monitoring Program Limitations

Despite the limited scope of the Swan Lake Monitoring Program and the high-level characterization of potential eutrophic conditions, the program itself does have some notable limitations to the extent of the conclusions that can be drawn. These include;

- Gaps in reported water quality monitoring data has the potential to lead to the misinterpretation of the conditions within Swan Lake.
- Limited sampling locations and depths as part of the monitoring program limit the comprehensiveness of sampling results, as it relates to the potential stormwater inputs into Swan Lake.

By their nature the water quality parameters included as part of the overall Swan Lake Monitoring Program are associated with eutrophication and algae blooms, with few implications that can be drawn with respect to the health of the aquatic habitat conditions within Swan Lake. Despite aquatic health not being the overall objective of the monitoring program the inclusion of additional aquatic health specific monitoring components would serve to improve the comprehensiveness of the program as a whole.

4.0 Water Quality Monitoring Program Enhancements

While the overall Swan Lake Water Quality Monitoring Program, if applied correctly, is appropriate to meet the intent of a high-level eutrophic condition characterization, the opportunity exists to expand it to provide a more comprehensive and high-resolution water quality characterization to support the overall Swan Lake Water Quality Management Plan. The following water quality monitoring program components are recommended for consideration to further refine the water quality monitoring program. These adjustments would help provide additional context to characterize the existing aquatic ecological conditions and ecosystem health. These recommendations include:

- Additional spring freshet and significant precipitation event (i.e., wet event) sampling to account for potential stormwater input effects on surface water conditions;
- Inclusion of PWQO Guidelines alongside Swan Lake Monitoring Program guidelines;
- Inclusion of Recreational Water Quality Guidelines for water clarity;
    - Inclusion of minimum and maximum water clarity readings, alongside the applicable targets/guidelines, as part of the annual water quality analysis to detail the range in conditions;
- Inclusion of CCME Canadian Water Quality Guidelines for the Protection of Aquatic Life guidelines for parameter analyses;
- Completion of all water quality monitoring components identified as part of the Swan Lake Monitoring Program on an annual basis;
    - A summary of omissions or alterations in monitoring from workplan components outlined as part of each annual report;
- Include complete bi-weekly water quality results as part of each annual report, along with explanations for any gaps in water quality sampling coverage;
- The inclusion of aquatic health-specific monitoring components to increase the comprehensiveness of the monitoring program.
    - Annual aquatic health monitoring can include the inclusion of benthic macroinvertebrate, zooplankton, and fish community composition, aquatic vegetation biomass, or composition assessment, herpetofauna nesting and overwintering assessment.

4.1 Swan Lake Management Strategy Program Considerations

Specific management and habitat restoration activities offer the potential to further support the improvement of water quality and aquatic habitat conditions within Swan Lake. These strategy considerations are intended to address some of the causes of degraded water quality conditions as opposed to addressing their symptoms, which support the foundation of an improved long-term strategy for Swan Lake to enhance aquatic ecosystem health, reduce eutrophication, and restore more natural lake function. Based on our understanding of the history of Swan Lake and its role in the wider stormwater system, both historic and ongoing high concentration nutrient loading is understood to be one of most significant factors contributing to the existing water quality conditions within Swan Lake. To support the enhancement of the surface water quality conditions within Swan Lake the following activities are proposed for consideration:

- **Comprehensive Oxygenation and Aquatic Vegetation Monitoring:** It is understood that newly established aquatic vegetation communities within Swan Lake have the potential to naturally address previously identified low dissolved oxygen levels within Swan Lake. As such, supplemental oxygenation may no longer be an appropriate response to induce meaningful long-term improvements in surface water conditions. However, given the historic aquatic vegetation conditions it is important to monitor and track the establishment and overall condition of these aquatic vegetation communities and their implications to the overall dissolved oxygen conditions and generally support widespread aquatic ecosystem health.

    - The implementation of a standardized aquatic vegetation monitoring program would help to monitor for changes in the overall aquatic health, with dissolved oxygen condition monitoring included should aquatic vegetation communities not consistently establish. It is expected that the healthy establishment of new aquatic vegetation communities could significantly improve surface dissolved oxygen conditions and contribute to the improvement of overall surface water quality conditions.

- **Sediment & Nutrient Management:** Identifying and addressing the internal and external nutrient sources will directly influence long-term aquatic ecosystem condition stability. Mitigating and controlling the additional nutrient inputs that originate from

stormwater and natural sources (e.g., goose droppings) is critical to addressing the underlying cause of the degraded aquatic ecosystem conditions in Swan Lake. While PAC and other phosphorus controlling chemical treatments temporarily help to mitigate surface water concentrations, it does not address the elevated concentrations within the sediment, nor does it influence long-term habitat stability. Following the implementation of targeted sediment and nutrient monitoring, the appropriateness of the additional chemical treatments can be further assessed.

An overall sediment and nutrient management strategy would support the characterization of overall sediment quality conditions throughout Swan Lake and support future management opportunities, including potential targeted sediment removal operations to address areas of significantly elevated sediment nutrient conditions.

While natural phosphorus loading from Canada Goose populations is understood to be short-lived, with most nutrients settling into the sediment, the Canada Goose monitoring and management operations completed to-date appear to have been effective at reducing resident goose populations, thereby helping to reduce additional external nutrient loading (Unckless and Makarewicz 2007). The continuation of these monitoring and management operations would support wider management and restoration operations and contribute to the improvement of surface water quality conditions.

A detailed sediment and nutrient management program, including the characterization of sediment conditions and the potential sediment and nutrient contributions into Swan Lake from upstream stormwater management facilities, as well as a detailed characterization of the sediment conditions throughout Swan Lake would help to direct restoration and management strategies. These would aid in addressing the underlying sources of degraded aquatic habitat conditions within Swan Lake and support the long-term improvement on surface water and aquatic ecosystem quality conditions.

- **Chloride Management:** Chloride concentrations have declined somewhat but remain above the long-term exposure guidelines. Addressing the inputs from upstream stormwater management, either by addressing outflow to Swan Lake or through application of targeted chloride-reducing measures (such as biochar), is critical to achieving any long-term improvements in surface water and aquatic ecosystems quality. It is understood that the overall chloride targets are to be re-

examined and potentially revised as part of the City of Markham's 2025 Water and Chloride Budget program. Additional supplementary filtration and chloride reduction programs similar to those recommended by the FOSLP as part of their December 2025 submission has the potential to significantly reduce Swan Lake's annual chloride loading, contributing to the overall improvement of the surface water quality conditions.

- **Enhanced Monitoring Program:** It is suggested that the water quality monitoring program be expanded and/or enhanced to include sediment quality monitoring (aligned with the Sediment Quality Guidelines for the Protection of Aquatic Life) and should consider the addition of sampling locations to help support the characterization of the existing conditions within Swan Lake, and to provide additional context for supplementary treatments and rehabilitative measures (such as limited targeted removal of contaminated or high concentration sediment deposits). Previous sediment monitoring, completed in 2020, was in line with the assessment of the risk of eutrophication but did little to assess the overall health and suitability of the aquatic ecosystem. Ideally, this monitoring would continue an annual basis during and following any restoration and management activities to monitor changes in sediment conditions.

- **Shoreline Habitat Enhancement:** Shoreline restoration and plantings would help to support the development of aquatic ecosystem structure, stabilize the nearshore aquatic ecosystem conditions, and contribute to the ongoing aquatic vegetation establishment program. Enhanced riparian habitats would also help to mitigate some of the natural nutrient and sediment loading. Engaging the Toronto and Region Conservation Authority to advise and support shoreline enhancements, included as part of the FOSLP's December 2025 Markham's Swan lake Water Quality Review, would strengthen the aquatic and shoreline enhancement program. But, as with other management strategies, shoreline enhancements would be most effective when implanted alongside measures that anticipated root causes of degraded water quality conditions, high nutrient concentration sediments.

  It is understood that one management strategy being considered involves the removal of excessive nearshore invasive aquatic plants (e.g., phragmites), previously completed in 2022. Future aquatic vegetation removals have been proposed by the FOSLP to remove additional aquatic vegetation has the potential to contribute to further reducing internal

organic nutrient loading going forward. However, given the high legacy concentrations of organic nutrients within the sediment, this proposed strategy would not provide a notable improvement to the overall conditions but would need to be applied along with other management strategies.

- **Algae Management:** The continuation of ultrasonic control measures, to inhibit algae bloom formation, has the potential to support natural ecosystem stabilization, improving surface water clarity and supporting aquatic vegetation growth. Similarly, direct algae treatment chemical applications have the potential to address the risk of algae blooms but would do little to address the perceived root causes of the degraded aquatic ecosystem within Swan Lake, the historic and ongoing high concentration nutrient sediments.

No single Swan Lake Management Strategy component will completely address the potentially degraded water quality or remove impediments to improving the conditions within the local aquatic ecosystem. However, the integration of a combination of these strategies has the potential to improve and enhance the overall sediment and water quality conditions and foster a more balanced and resilient aquatic ecosystem within Swan Lake. It is recommended that future Swan Lake Management Strategies consider the following components to enhance the effectiveness of individual management strategies and contribute to the improvement and enhancement of both sediment and water quality conditions within Swan Lake:

- Inclusion of a sediment quality monitoring program within Swan Lake and the adjacent Stormwater Ponds to characterize the existing conditions and support wider sediment and nutrient management programs. It is recommended this program continues through Phase 2 and 3 to monitor for changes in sediment loading and quality conditions.
- Implementation of an improved chloride management program, as identified as part of the City of Markham's 2025 Water and Chloride Budget program, and potential supplementary methods such as stormwater pond bypassing or filtration would help to address the elevated chloride concentrations recommendations. It is recommended this measure be implemented during Phase 2.
- Shoreline habitat enhancement and rehabilitation to contribute to the enhancement of aquatic habitat and nearshore aquatic ecosystem conditions, supporting the ongoing aquatic vegetation establishment program while mitigating some of the natural nutrient and sediment loading.

5.0 Conclusions

Within Swan Lake the overall water quality monitoring program completed between 2021 and 2024 provides an appropriate, if scoped, high-level assessment of the water quality conditions as they relate to the risk of eutrophication. The parameters included as part of the overall Swan Lake Monitoring Program offer a high-level assessment of the potentially degraded surface water quality conditions and the effectiveness of the treatment and remediation activities as part of the overall Swan Lake Management Strategy. Based solely on the results of the water quality monitoring program, the existing management activities appear to have had some success at improving the water quality conditions within the lake. However, even though many of the water quality parameters met the identified guidelines/targets, several were still noted to be in exceedance. With that said, the high-level nature of the water quality parameters included as part of the monitoring program, and the guidelines applied as part of the annual analysis, limit the overall comprehensiveness of the monitoring program and the conclusions that can be drawn from observable water quality trends as they relate to the health of the aquatic ecosystem.

Given artificial nature of Swan Lake, its urbanized nature, and proximity to the local Stormwater Management Ponds, the monitoring guidelines established as thresholds for hyper-eutrophic conditions are attainable and reasonable minimum thresholds. Achieving these minimum thresholds would present an appropriate starting point to support future strategies as the management of Swan Lake moves from a restoration/mitigation to improvement/enhancement approach.

In addition, the eutrophication focus of the monitoring program limits the ability to address the effects of historic and ongoing nutrient and contaminant loading on aquatic ecosystem health or to assess the effectiveness of the treatment and remediation activities completed to-date. It is, therefore, difficult to properly identify and address the underlying sources of many of the surface water quality concerns.

The expansion and enhancement of the water quality monitoring program, including the additional sampling recommendations, would improve the comprehensiveness of the monitoring program and support greater refinement of the overall management and restoration strategies for Swan Lake. This expansion and enhancement is recommended to include a combination of additional analysis guidelines (such as the PWQO, Recreational Water Quality Guidelines, and CCME Guidelines for the Protection of Aquatic Life), additional spring freshet and significant

precipitation sampling events, and the inclusion of aquatic health-specific monitoring components (such as benthic macroinvertebrate, zooplankton, fish community composition, aquatic vegetation, or native herpetofauna).

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Final

Swan Lake Management Options

Literature Review of Management Options and Effects of Increased Oxygenation in Swan Lake

Prepared for:

Fred Peters
Friends of Swan Lake Park

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NATURAL RESOURCE SOLUTIONS INC.
Aquatic, Terrestrial and Wetland Biologists

Swan Lake Management Options

Literature Review of Management Options and Effects of Increased Oxygenation in Swan Lake

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Table of Contents

1.0 Purpose and Objectives 2
1.1 Background and Scope 2
2.0 Literature Review Methods 4
3.0 Effects of Increased Oxygenation on Shallow Surface Water Bodies 5
3.1 Effects on Surface Water Quality 5
3.1.1 Reduction in Eutrophication 6
3.2 Effects on Nutrient Cycling and Sediment Chemistry 7
3.3 Biological Effects of Increased Oxygenation 8
3.4 Physical and System-Level Effects of Oxygenation 9
4.0 Relevance of Increased Oxygen to Swan Lake 11
5.0 Summary of Oxygenation Management Approaches 13
5.1 Artificial or Engineered Aeration 13
5.1.1 Diffused Aeration Systems 13
5.1.2 Gravity (Cascade) Aeration, ... 14
5.1.3 Fountain Aeration, ... 15
5.2 Chemical Oxygenation 16
5.3 Destratification and Mixing 18
6.0 Summary of Oxygenation Methods and Comparative Feasibility 20
7.0 Conclusions and Recommendations 24
7.1 Oxygenation Program Considerations 25
8.0 References 27

List of Appendices

Appendix I Key Findings and References

1.0 Purpose and Objectives

Natural Resource Solutions Inc. (NRSI) was retained by the Friends of Swan Lake Park to complete a literature review examining the potential benefits of increased oxygenation on surface water quality and overall ecological conditions within Swan Lake The review also evaluates available methods to enhance oxygenation, along with their associated impacts, feasibility, and applicability to the lakes specific conditions. Dissolved oxygen concentrations have been identified as a key limiting factor in preliminary water quality analysis. Accordingly, the objective of this review is to provide the Friends of Swan Lake Park with a concise, evidence-based summary of the potential ecological and water quality improvements associated with increased oxygenation, to support the development of further rehabilitation and remediation strategies for Swan Lake.

1.1 Background and Scope

Swan Lake is a manmade waterbody located within the City of Markham. The lake was historically operated as a gravel quarry until the late 1970s, after which it served as a local landfill until its naturalization in the 1990s. Although Swan Lake has no natural surface water inflows or outflows, it was integrated into the municipal stormwater management system between the 1990s and early 2000s. Since that time, it has functioned as an ad hock stormwater management facility, receiving surface water runoff from the surrounding residential developments.

Currently Swan Lake exists as a shallow, highly eutrophic lake characterized by the recurrent cyanobacterial blooms and persistently poor water quality conditions, with an average depth of approximately 1.65m. Ongoing surface water quality monitoring by the City of Markham has documented minor improvements in recent years; however, dissolved oxygen concentrations remain low, and overall aquatic habitat conditions continue to be degraded. Reduced dissolved oxygen concentrations are common in shallow freshwater pond and lake habitats, and are often associated with enhanced eutrophication, organic matter accumulation and altered nutrient cycling processes.

The scope of this literature review includes the following:

- A review of relevant scientific literature and case studies examining the ecological, chemical, and physical effects of increased oxygenation in shallow lake systems.

- A summary of management strategies and engineered interventions designed to increase dissolved oxygen concentrations, including their short and long-term implications for system function, sediment chemistry, biological communities and overall ecosystem resilience.

2.0 Literature Review Methods

As part of NRSI's review, a range of peer-reviewed journal articles, government publications, technical manuals, and documented case studies were examined to assess the potential effects of increased oxygenation on shallow surface waterbodies. The literature search emphasized material addressing topics such as 'lake oxygenation,' 'hypolimnetic oxygenation,' 'aeration,' 'oxygenation effects,' 'eutrophication management,' and 'shallow lake response.'

Priority was given to recent publications and studies conducted under comparable surface water conditions and climatic conditions. Foundational and topic-specific works were also included where necessary to provide context and support broader interpretation. The review incorporated literature addressing both Oxygenation techniques and documented ecological outcomes to ensure a comprehensive understanding of system responses to enhanced oxygenation.

3.0 Effects of Increased Oxygenation on Shallow Surface Water Bodies

Dissolved oxygen (DO) is a Fundamental parameter influencing both the chemical and biological processes that support a healthy aquatic ecosystem.. Actively increasing dissolved oxygen concentrations, commonly known as oxygenation, can have a wide range of chemical and biological effects, many of which can be beneficial to the stability and resilience of a surface water body.

Enhanced oxygenation can improve overall water quality, promote aerobic biological activity, and support the recovery of aquatic ecosystems experiencing eutrophic or hypoxic conditions. The specific effects of increased oxygenation are described below in the following sections, with emphasis on potential implications for improving existing water conditions within Swan Lake.

3.1 Effects on Surface Water Quality

Increases in surface water Dissolved Oxygen (DO) concentrations are closely associated with measurable improvements in overall water quality. Elevated DO levels have been directly linked to reducing the rate of nutrient release from nutrient-rich sediment, particularly compounds of nitrogen, phosphorus, and certain heavy metals (Andersen et al. 2017, Borman et al. 2017, Preece et al. 2019, Shaw and Prepas 1990). This reduction in internal nutrient loading helps to mitigate the effects of organic nutrient contamination by chemically inhibiting chemical release or nutrient flux from sediments and promoting aerobic bacterial activity, which lead to an increase in the rate of organic nutrient decomposition (Borma et al. 1998, Crawshaw et al. 2018, Kirol et al. 2024, Macdonald, R.H. 1995, Preece et al. 2019).

Elevated DO concentrations have also been linked to increased rates of heavy-metal oxidation, converting metals from soluble to insoluble forms. This transformation reduces their biological availability and dissolved concentrations, resulting in improved water quality conditions (Atkinson et al. 2007, Kirol et al. 2024, Rabaev et al. 2021). Similarly, the increase in aerobic bacterial activity associated with higher DO concentrations suppresses anaerobic bacterial processes, thereby reducing the production of harmful gasses such as Hydrogen Sulfide improving overall water quality (Borma et al. 1998, Rabaev et al. 2021, Wang et al. 2025). Increased aerobic metabolism also contributes to the decomposition of organic detritus and pollutants, reducing the rate of debris accumulation and further limiting internal nutrient loading, and contributing to more stable and balanced surface water quality (Kenneth, I.A. 1983, Michael et al. 2025).

However, in systems containing sediments with significant metal-sulfide contamination, Increased DO concentrations can temporarily elevate bioavailability of heavy metals as they are oxidized and transformed between chemical states (Michael et al. 2025, Ribaudo et al. 2018). Furthermore, depending on the specific oxygenation strategy, poorly designed or implemented systems may cause sediment resuspension increasing the mobility of contaminants and organic nutrients and potentially counter acting intended improvements in water quality conditions (Kirol et al. 2024, Michael et al. 2025).

3.1.1 Reduction in Eutrophication

One key component of the improvement of overall surface water quality associated with increased DO concentration is the corresponding reduction in the risk and severity of eutrophication within shallow surface waterbodies. In systems with limited flow or vertical mixing, internal nutrient loading from accumulated organic sediments have been shown to be the dominate source of bioavailable nutrients (Andersen et al. 2017, Kenneth, I.A. 1983, Macdonald, R.H. 1995, Michael et al. 2025, Preece et al. 2019, Wang et al. 2025). Elevated DO levels have been shown to help mitigate eutrophication through several mechanisms, particularly by limiting nutrient flux across the sediment-water interface (Atkinson et al. 2007, Borman et al. 2017).

Elevated DO concentrations within the sediment-water boundary layer have been shown to suppress excessive nutrient cycling by reducing phosphorous and nitrogen release from sediments (Borman et al. 2017, Kenneth, I.A. 1983). Changes in key surface water quality conditions, notably pH, temperature, and DO, have been linked to changes in the rate of internal nutrient loading. Variations in DO changes as small as 1mg/L can alter Phosphorus release by approximately 25-37%, highlighting the sensitivity of nutrient flux to oxygen availability (Kirol et al. 2024, Shaw and Prepas 1990). Increased DO also promotes aerobic bacterial metabolism, which further reduces dissolved Phosphorus and Nitrate concentrations, two primary nutrients linked to algae bloom formation and eutrophication in shallow aquatic systems., (Atkinson et al. 2007, Macdonald, R.H. 1995, Michael et al. 2025, Shaw and Prepas 1990).

In addition, the reduction in dissolved nutrient concentrations and the enhancement of aerobic microbial activity have been linked to reductions in turbidity and improvements in water clarity and light penetration, conditions that promote natural submerged aquatic vegetation growth and enhanced overall ecological function (Andersen et al. 2017, Crawshaw et al. 2018). The establishment of a more naturalized aquatic condition can, in turn, help sustain elevated DO

levels and promote long-term stability and self-regulation of organic matter decomposition (Wang et al. 2025).

However, the extent of these benefits can be limited in systems with significant legacy nutrient loading from historically enriched or contaminated sediments. In such cases, elevated sediment nutrient concentrations may delay, reduce, or counteract the beneficial effects of increased DO concentrations on eutrophication control (Crawshaw et al. 2018, Preece et al. 2019, Ribaudo et al. 2018).

3.2 Effects on Nutrient Cycling and Sediment Chemistry

Increased dissolved oxygen (DO) concentrations play a critical role in regulating nutrient cycling and sediment chemistry within shallow aquatic systems. In oxygen-limited environments, anaerobic conditions within surface sediments promote the release of nutrients and reduced compounds—particularly phosphorus, nitrogen, and various metal ions—back into the water column. This process, known as *internal loading*, can perpetuate eutrophic conditions even when external nutrient inputs are controlled (Andersen et al. 2017; Borman et al. 2017; Preece et al. 2019).

Enhanced DO concentrations establish more oxidized conditions at the sediment–water interface, resulting in the formation of insoluble metal–phosphate complexes that effectively immobilize phosphorus within sediments (Kirol et al. 2024; Shaw and Prepas 1990). These reduction-oxidation (redox) driven transformations also promote the oxidation of reduced nitrogen compounds such as ammonium (NH_4^+) into nitrate (NO_3^-), facilitating subsequent denitrification processes and further reducing the pool of bioavailable nitrogen (Atkinson et al. 2007; Crawshaw et al. 2018; Michael et al. 2025).

The transition from anaerobic to aerobic sediment conditions also alters the mobility of metals such as iron, manganese, and zinc. Under oxygenated conditions, these elements are oxidized into less soluble forms, thereby decreasing their bioavailability and potential toxicity to aquatic organisms (Rabaev et al. 2021; Wang et al. 2025). Conversely, in oxygen-depleted sediments, the reduction of iron and manganese oxides can release bound phosphorus and trace metals, reinforcing eutrophic conditions.

Sustained oxygenation can therefore stabilize sediment chemistry and improve long-term water quality, but these effects depend on maintaining sufficient DO penetration into the sediment layer. Seasonal temperature fluctuations, organic loading, and stratification can all influence

oxygen diffusion and microbial demand, potentially limiting the persistence of oxidation processes (Macdonald 1995; Preece et al. 2019). As such, successful oxygenation programs must account for sediment composition, water depth, and hydrologic turnover rates to ensure consistent and effective redox regulation.

3.3 Biological Effects of Increased Oxygenation

Increased dissolved oxygen (DO) concentrations can have profound effects on the biological communities within shallow surface water systems. Increased DO concentrations have been widely associated with enhanced habitat suitability for aquatic organisms and is a key determinant of species composition, productivity, and overall ecosystem function (Austin et al. 2019, Beutel et al. 1999, Preece et al. 2019). These enhancements can be realized as either an increase in the range of species that can be supported within the system or as improved habitat conditions for existing species diversity, leading to greater biodiversity and ecological stability(Barry et al. 2012, Bierlein et al. 2017). In eutrophic or hypoxic conditions, the absence of adequate DO often results in habitat degradation, loss of biodiversity, and altered food web dynamics. Conversely, sustained improvements in DO concentrations promote the recovery and stabilization of biological communities across multiple trophic levels (Atkinson et al. 2007; Crawshaw et al. 2018; Michael et al. 2025). Elevated DO levels are also attributed to reducing the risk of cyanobacteria and harmful algae blooms and lower the likelihood of large-scale fish kills resulting from anoxia or prolonged hypoxic events (Kirol et al. 2024, Michael et al. 2025, Preece et al. 2019, Wang et al. 2025).

Increased sediment oxygen availability is attributed to an increase in aerobic bacterial activity supporting greater benthic macro-invertebrate density and diversity, both of which are associated with accelerating the rate of organic compound decomposition and internal nutrient loading (Bierlein et al. 2017; Borman et al. 2017; Crawshaw et al. 2018; Kirol et al. 2024). Enhanced aerobic bacterial metabolism also inhibits sulfate-reducing anerobic bacteria, decreasing the production of harmful gases such as hydrogen sulfide (H_2S) and methane (CH_4). Improvements in sediment level biodiversity, benthic macro-invertebrates and bacteria, contribute to improvements to sediment quality and promote conditions favourable for the growth of aquatic vegetation, thereby supporting natural revegetation processes (Barry et al. 2012, Beutel et al. 1999, Borman et al. 2017, Michael et al. 2025).

The increase in benthic and microbial diversity and vegetation growth is also linked to greater bioturbation, sediment mixing caused by benthic organisms, which enhances nutrient exchange

between sediment and water and reduces the bioaccumulation of toxic compounds (Andersen et al. 2017; Kenneth 1983; Shaw and Prepas 1990). This process supports the natural breakdown of previously sequestered organic material, further improving sediment health and overall system productivity. Despite these benefits, elevated DO concentrations can also result higher Biological Oxygen Demand (BOD) due to the increased metabolic activity of aerobic organisms. If oxygenation systems are interrupted or discontinued, this heightened BOD can lead to rapid DO depletion, potentially reversing short-term improvements in water quality (Crawshaw et al. 2018; Kenneth 1983; Shaw and Prepas 1990). Therefore, sustained and well-managed oxygenation is essential to maintain long-term ecological stability and prevent secondary hypoxia.

3.4 Physical and System-Level Effects of Oxygenation

Beyond the chemical and biological benefits, increased dissolved oxygen (DO) concentrations can also influence the broader physical dynamics and stability of shallow surface water systems. Oxygenation affects water column stratification, circulation, temperature gradients, and gas exchange processes that collectively govern overall system health and resilience (Austin et al. 2019; Beutel et al. 1999; Kirol et al. 2024).

3.4.1 Thermal Stratification and Mixing

In shallow lakes, such as Swan Lake, temperature-driven stratification is typically weak or transient. However, during periods of high temperature and low wind activity, thermal layering can still occur, creating a hypolimnetic zone with reduced DO availability. Artificial or mechanical oxygenation can disrupt or prevent the formation of these anoxic bottom layers by enhancing vertical mixing and diffusive oxygen transfer (Barry et al. 2012; Borman et al. 2017; Preece et al. 2019). Improved circulation increases the uniformity of oxygen distribution throughout the water column, reduces stagnation, and limits the onset of localized hypoxia near the sediment–water interface.

Mechanical mixing or diffused aeration systems also promote the release of trapped gases, including carbon dioxide (CO_2) and methane (CH_4), while simultaneously enhancing reoxygenation through increased surface turbulence (Atkinson et al. 2007; Crawshaw et al. 2018). This process contributes to a more stable water column and moderates daily oxygen fluctuations commonly observed in eutrophic systems.

3.4.2 Sediment–Water Interface and Gas Exchange

Oxygenation at or near the sediment–water interface plays a critical role in regulating benthic fluxes and maintaining sediment redox stability. Enhanced DO penetration limits anaerobic processes, reducing the upward diffusion of reduced compounds such as ammonia (NH_3), ferrous iron (Fe^{2+}), and hydrogen sulfide (H_2S) (Borman et al. 2017; Rabaev et al. 2021). Increased oxygen availability at this interface also promotes sediment consolidation, reducing resuspension and turbidity—factors that otherwise exacerbate internal nutrient loading (Kirol et al. 2024; Michael et al. 2025).

Increased turbulence and mixing further improve gas exchange efficiency at the air–water boundary, increasing atmospheric oxygen transfer and promoting the release of volatile compounds that can otherwise impair water quality or produce odours (Andersen et al. 2017; Wang et al. 2025).

3.4.3 Long-Term System Stability

By improving water column circulation, moderating stratification, and enhancing redox stability, oxygenation can substantially increase the overall resilience of shallow aquatic ecosystems. Enhanced DO levels help maintain ecological balance, prevent the re-establishment of hypoxia, and support positive feedback loops that reinforce improved biological and chemical conditions (Beutel et al. 1999; Preece et al. 2019).

However, the physical benefits of oxygenation are highly dependent on site-specific factors, including lake morphology, depth, hydrologic residence time, and organic loading. In small, shallow, and enclosed systems such as Swan Lake, oxygenation can be particularly effective, but long-term success depends on consistent operation, appropriate system design, and integration with broader watershed nutrient management strategies (Michael et al. 2025; Wang et al. 2025).

4.0 Relevance of Increased Oxygen to Swan Lake

Swan Lake is a Hyper-eutrophic, shallow waterbody characterized by recurring algae blooms and persistently low overall DO concentrations. Historic and ongoing nutrient loading attributed to Canada Geese activity and stormwater/surface water runoff has resulted in substantial sediment accumulation and ongoing internal nutrient loading, contributing to ongoing elevated Phosphorus levels and sustaining eutrophic conditions. The absence of natural inflows and outflows, coupled with limited water depths, restricts natural circulation and water stratification. These factors contribute to stagnant conditions that amplify the effects of harmful algal and cyanobacteria blooms and limit surface mixing that would otherwise support natural oxygenation.

The aquatic community within Swan Lake is currently dominated by tolerant warmwater fish species and exhibits low biodiversity, sparse aquatic vegetation, and minimal bioturbation—conditions typical of degraded habitat quality and poor surface water function. Increasing DO concentrations within Swan Lake have the potential to contribute significantly to the improvement of both overall water quality conditions and aquatic habitat conditions. Elevated DO levels are expected to enhance aerobic bacterial activity, which, in combination with chemical processes affecting Phosphorus and Organic nutrient cycling, would accelerate the decomposition of organic material and improve nutrient turnover. This, in turn would, reduce internal nutrient loading, lower surface water Phosphorus concentrations, contributing to a decrease in the risk of eutrophication and algae bloom formation. Sustained DO enhancement would be further expected to contribute to improved surface water clarity and promote natural aquatic vegetation growth, further reinforcing natural nutrient cycling and stabilization of lakebed sediments.

Higher DO concentrations would additionally improve habitat suitability for aquatic fauna by reducing the risk of hypoxia-induced stress and supporting a wide range of fish and invertebrate species. Enhanced benthic macroinvertebrate activity and vegetation establishment would provide improved substrate conditions, increased habitat complexity, and more stable ecological interactions.

Given the organic nutrient compounds found throughout Swan Lake, primarily from stormwater and surface runoff, as well as more natural sources, such as high Canada Geese populations, it is also expected that elevated DO levels will facilitate the natural oxidation and decomposition of accumulated organic and in-organic contaminants within the sediment as the oxidation of heavy

metals and organic compounds, would reduce their bioavailability and toxicity, thereby contributing to overall water quality improvements.

However, improvements in water quality may occur gradually due to substantial nutrient and contaminate load stored in the existing sediments. Moreover, increased biological activity associated with higher DO concentrations may elevate the systems biological oxygen demand if oxygenation measures were ceased abruptly, rapid DO depletion could occur, potentially reversing short-term gains in water quality.

Importantly, while increased DO concentrations can have a wide range of potential ecological benefits, oxygenation alone may not be sufficient to fully mitigate internal nutrient loading or reverse eutrophic conditions in systems with significant historical enrichment. Therefore, induced oxygenation should be implemented in conjunction with broader overall lake rehabilitation and watershed management strategies, including nutrient source control, sediment management, and habitat restoration, to ensure sustainable and long-term improvement in water quality within Swan Lake.

5.0 Summary of Oxygenation Management Approaches

A range of chemical and engineered oxygenation and aeration techniques are available to potentially enhance DO concentrations in lakes and ponds. Each strategy operates through different mechanisms and carries unique design and operational considerations that influence its suitability for a given site. The selection of an appropriate system depends on site-specific factors, including lake morphology, depth, sediment composition, nutrient sources, and hydrologic connectivity. For Swan Lake, which is a shallow, enclosed and highly eutrophic, the most feasible options are those that provide consistent oxygen delivery and promote mixing without excessive sediment disturbance.

5.1 Artificial or Engineered Aeration

One of the simplest and most commonly applied techniques to increase DO concentrations in surface water is **Artificial or Engineered Aeration**, which enhances DO through physical surface water turbulence or circulation increasing air-water gas exchange or air bubbles and diffusers to induce vertical mixing.

The most common form of engineered aeration, **Diffused Aeration**, or “bubbler”, introduces air through diffuser systems to promote gas exchange and induce vertical mixing between water layers (Austin et al. 2019). These systems can be effective at reducing localized stagnation in small surface waterbodies and can increase DO concentrations near the sediment-water interface (Barry et al. 2012). Elevated sediment DO has been shown to increase the effectiveness at controlling internal Phosphorus loading by stimulating aerobic bacterial activity within surficial sediments (Beutel et al. 1999, Bierlein et al. 2017). Hypolimnetic aeration is generally considered a relatively low-maintenance and effective method for mitigating hypoxia in systems with minimal stratification; however, its ability to affect large surface areas or substantially improve whole-lake circulation is limited (Barry et al. 2012).

5.1.1 Diffused Aeration Systems

Diffused aeration systems are among the most widely used and adaptable oxygenation techniques for improving dissolved oxygen (DO) concentrations in lakes and ponds. These systems operate by releasing compressed air or pure oxygen through diffuser heads, stones, or perforated tubing placed near the lake bottom. As air bubbles rise through the water column, they promote vertical circulation, enhance gas exchange, and facilitate oxygen diffusion throughout the system (Austin et al. 2019; Beutel et al. 1999).

Diffused aeration systems are particularly effective in small to medium-sized lakes where natural circulation is limited but complete thermal stratification is absent. The continuous release of fine air bubbles increases oxygen transfer efficiency while providing gentle water column mixing that prevents stagnation and improves DO distribution. In addition to raising DO concentrations in the water column, these systems help maintain oxidized conditions at the sediment–water interface, thereby reducing internal nutrient loading and promoting aerobic microbial activity (Barry et al. 2012; Bierlein et al. 2017; Kirol et al. 2024).

Diffused systems are less disruptive to sediments and can be operated continuously with low noise and modest energy requirements. They can also be configured for seasonal or year-round operation, allowing adjustments based on temperature, biological oxygen demand (BOD), and ice-cover conditions. However, in very shallow or irregularly shaped basins, the effectiveness of diffused aeration may be reduced due to limited vertical mixing potential and uneven bubble distribution. Careful diffuser placement is therefore critical to ensure adequate coverage and to avoid localized zones of low oxygen or excessive turbulence. If operated continuously diffused systems can enhance both surface and sediment DO, stimulate aerobic microbial activity, and gradually reduce internal nutrient loading. When used in combination with rehabilitation measures—such as sediment management, nutrient source reduction, and shoreline naturalization—can contribute to improved long-term water quality conditions.

For Swan Lake, diffused aeration represents a feasible and practical option for improving DO concentrations. Multiple diffusers positioned in the deeper and more stagnant zones could promote moderate mixing and oxygenation without disturbing fine, nutrient-rich sediments. When operated continuously at low intensity, such a system would enhance both surface and sediment DO, stimulate aerobic microbial activity, and gradually reduce internal nutrient loading. Integration with complementary rehabilitation measures—such as sediment management, nutrient source reduction, and shoreline naturalization—would maximize long-term water quality improvements.

5.1.2 Gravity (Cascade) Aeration,

Gravity Aeration, also referred to as cascade aeration, is a form of mechanical aeration that employs artificial waterfalls or stepped flow structures, along with pumping systems, to enhance oxygenation by increasing the waters exposure to the atmosphere and increase the air-water gas exchange. Gravity aeration is relatively low-tech, energy efficient, and effective at increasing DO concentrations within a localized zones while promoting increased circulation

improvements throughout the water column (Kirol et al. 2024). Gravity Aeration, remains limited in its capacity to influence large surface areas or resolve lake or system-wide oxygen defects. (Kirol et al. 2024).

While gravity aeration methods are generally effective in small or confined systems, their performance can be reduced during periods of high temperature or elevated biological oxygen demand (BOD) associated with high organic nutrient concentrations (Borman et al. 2017). In addition, improper system design or overpowered aeration can lead to sediment resuspension, releasing nutrients and contaminants and increasing turbidity.

If employed correctly gravity aeration systems have the potential to enhance surface DO conditions and induce localized mixing, contributing to increased aerobic microbial activity, and gradually reduce internal nutrient loading. When used in combination with rehabilitation measures—such as sediment management, nutrient source reduction, and shoreline naturalization—can contribute to improved long-term water quality conditions.

Gravity aeration can lead to a dramatic increase in DO concentrations within localized areas and, if properly designed and applied, can minimize sediment disturbance. However, given the overall surface area of Swan Lake, lack of both stratification and high internal nutrient loading, achieving lake-wide oxygen enhancement would require significant infrastructure investment. Long-term improvements in surface water quality are unlikely to be realized through mechanical aeration alone without complementary rehabilitation measures to address nutrient-enriched sediments and reduce ongoing stormwater nutrient inputs.

5.1.3 Fountain Aeration,

Fountain Aeration, is a form of mechanical aeration where water is pumped vertically into the air, increasing the waters exposure to the atmosphere promoting air-water gas exchange. As the oxygenated water droplets return to the water surface, they increase surface disturbance, and facilitate the diffusion of oxygen into the water column (Hao et al. 2021; Zebek 2014).

Fountain aeration systems can be effective in shallow small to medium-sized lakes where natural circulation is limited and thermal stratification is absent (Abu Hasan et al. 2025; Howley et al. 2021). The continuous fountaining of small water droplets can increase oxygen transfer efficiency and maintains surface agitation, which can disrupt algae accumulations and reduce the frequency of harmful algae blooms (Aytac et al 2024; Hoa et al. 2020). These systems are

relatively quiet, energy-efficient, and cause minimal sediment disturbance, making them suitable for both functional and aesthetic applications in urban or recreational waterbodies.

However, Fountain Aeration systems have a limited capacity to improve oxygenation at depth, and their effectiveness in addressing whole-lake oxygen deficits is constrained by their restricted mixing range and droplet dispersion (Zebek 2024). Performance can also decline during periods of high air or water temperatures, when oxygen solubility decreases (Tuna Kelestemur et al. 2024). Additionally, fountain aeration can lead to a slight increase in surface water temperatures and can only operate under ice-free conditions (Zebek 2014).

The effectiveness of fountain aeration systems is limited by the fountain size, spray pattern and pump capacity, which determines the degree of mixing and oxygenation achieved. Optimal placement and spacing is therefore critical to ensure adequate coverage and to avoid localized zones of low oxygen or excessive turbulence (Henny et al. 2019; Sinclair et al. 2020).

When operated continuously, fountain aeration systems can enhance surface DO, stimulate aerobic microbial activity, and contribute to gradual improvements to in sediment condition and reduce internal nutrient loading. However, given their limited vertical mixing, fountain systems are most effective when used in combination with broader rehabilitation measures—such as sediment management, nutrient source reduction, and shoreline naturalization—to improve long-term water quality conditions and reduce the effects of elevated biological oxygen demand (BOD) associated with high organic nutrient concentrations (Hao et al. 2021; Zebek 2014).

5.2 Chemical Oxygenation

Chemical Oxygenation is a less common but more direct method of increasing DO concentrations in stagnant or poorly circulated surface waterbodies. This approach involves oxygen-releasing compounds such as Calcium Peroxide, or oxidizing agents that influence sediment level chemical interactions and promote natural oxygenation processes (Barry et al. 2012, Borman et al. 2017). The use of Calcium Peroxide as an oxygen release agent as been proposed by the Friends of Swan Lake Park as a potential method to increase DO levels throughout Swan Lake, however widespread application to address low DO levels are still in the experimental phase and has been rejected by the City of Markham in favor of managing the root cause of nutrient loads and the opinion that the DO levels are above their internal guidelines and no further intervention is needed (Siembida-Losch 2022 and AECOM 2023).

Chemical oxygen-release agents function by slowly decomposing to elemental oxygen, which increase DO levels in the surrounding water and sediment. These materials can be highly effective in addressing prolonged hypoxic or anoxic conditions, particularly in locations with limited physical access or where continuous mechanical aeration is impractical (Kenneth, I.A. 1983). These release agents can also promote aerobic bacterial activity at the sediment-water interface, controlling the release of nutrients thereby reducing internal nutrient loading by suppressing phosphorus and nitrogen release from nutrient-enriched substrates (Barry et al. 2012, Borman et al. 2017, Preece et al. 2019, Wang et al. 2025).

However, the effectiveness and longevity of these treatments depends heavily on accurate calibration of specific dosage rates to match site-specific oxygen demand and internal nutrient loading. Over or under application can result in limited effectiveness or temporary improvements followed by rapid re-oxygen depletion and as such it can be difficult to accurately apply for larger surface water bodies (Bierlein et al. 2017, Ribaudo et al. 2018). Moreover, while chemical oxygenation can provide localized oxygenation and enhance sediment redox stability, it does not improve water column mixing or circulation.

In addition to direct oxygen-release compounds, chemical oxidants (e.g., nitrate-based amendments or other oxygen donors) can be applied to modify redox conditions within sediments, promoting aerobic microbial processes and inhibiting the release of reduced compounds and nutrients (Kenneth 1983; Preece et al. 2019). These treatments can be effective in reducing internal nutrient loading and limiting algal bloom formation; however, their successful implementation requires a detailed understanding of sediment geochemistry, nutrient cycling, and seasonal oxygen dynamics

Within Swan Lake, chemical oxygenation could provide a targeted, low-disturbance approach to increase DO concentrations, particularly in sediment-rich or inaccessible areas. This technique would avoid sediment resuspension and could sustain elevated DO levels over an extended period to time to address seasonally low DO levels. However, precise chemical and dosage calibrations would be essential to ensure long-term effectiveness. While chemical oxygenation offers broader special treatment coverage than localized mechanical systems, it does not address the lack of natural mixing or circulation within Swan Lake, nor the underlying cause of eutrophication. Consequently, chemical oxygenation would be best employed as a supplemental measure within an integrated rehabilitation program that includes nutrient management and physical oxygenation methods.

5.3 Destratification and Mixing

Destratification and induced Mixing represents a less common but potentially effective approach to improve DO levels within shallow surface water bodies (Beutel et al. 1999). At the most basic level, destratification increases DO concentrations by inducing water circulation and promoting mixing between water layers, thereby improving oxygen distribution throughout the water column, including the sediment-water interface (Crawshaw et al. 2018, Macdonald, R.H. 1995, Preece et al. 2019).

By breaking down thermal or chemical stratification, destratification reduces internal stagnation, disrupts algae blooms and minimizes the formation of anoxic zones. This allows for enhanced gas exchange at the air-water interface, promotes natural oxygenation of organic pollutants and limits internal nutrient loading from sediments (Austin et al. 2019, Beutel et al. 1999, Kirol et al. 2024). The effectiveness of destratification can be highly dependent on shoreline morphology, bathymetric contours, and rate of recirculation as these factors influence the extent of water movement and the resulting increase in dissolved oxygen (DO) concentrations. Achieving meaningful DO improvements generally requires substantial surface water agitation (Beutel et al. 1999).

Destratification is generally considered less effective at increasing DO concentrations when compared to targeted mechanical aeration systems, however it offers broader benefits in addressing stagnation, circulation deficiencies, and hypoxic zone formation (Rabaev et al. 2021). Similar to mechanical aeration improvements dependent on continuous operation, as DO levels often decline rapidly once circulation ceases. Additionally, destratification can lead to a moderate increase in overall surface water temperatures, which can have unanticipated impacts to habitat conditions for native fish and aquatic wildlife (Kenneth, I.A. 1983). The installation and operation of destratification systems in larger waterbodies can require significant infrastructure investment and energy inputs to achieve meaningful DO improvements (Macdonald, R.H. 1995).

For Swan Lake, destratification such as that potentially achieved from the circulation of surface water via the Swan Lake North Pond Channel, has the potential to increase the DO concentrations by promoting limited current flow and reducing internal lake stagnation. This may also help suppress algae bloom formation and improve localized surface water conditions. However, due to Swan Lakes overall shallow water depths, limited stratification, and high organic oxygen demand, destratification alone is unlikely to achieve substantial, system-wide

increase in DO concentrations. The expected low volume recirculation would not generate sufficient surface agitation or flow to meaningfully enhance natural oxygenation.

Within shallow weakly stratified environments, it can support additional management measure to improve water movement and reduce stagnation and if implemented alongside complementary oxygenation and nutrient management strategies result in lasting water quality improvements.

Because Swan Lake is shallow and only weakly stratified, temperature increases associated with destratification are not expected to adversely affect resident warmwater fish or aquatic invertebrate communities. Overall, destratification could serve as a supportive management measure to improve water movement and reduce stagnation but should be implemented alongside complementary oxygenation and nutrient management strategies to achieve significant and lasting water quality improvements.

6.0 Summary of Oxygenation Methods and Comparative Feasibility

A variety of oxygenation and aeration techniques are available to enhance dissolved oxygen (DO) concentrations in surface waterbodies. Each method operates through distinct physical or chemical mechanisms and presents varying levels of effectiveness depending on site-specific conditions such as depth, morphology, sediment quality, and nutrient dynamics.

For Swan Lake, with its lack of stratification and current flows, **Diffused Aeration** represents a potentially feasible option for improving DO concentrations. Multiple diffusers positioned in the deeper and more stagnant zones could promote moderate mixing and oxygenation without disturbing fine, nutrient-rich sediments. When operated continuously at low intensity, such a system would enhance both surface and sediment DO, stimulate aerobic microbial activity, and gradually reduce internal nutrient loading. Integration with complementary rehabilitation measures—such as sediment management, nutrient source reduction, and shoreline naturalization—would maximize long-term water quality improvements.

- Pros:
    - Promote moderate mixing and oxygenation without disturbing sediments;
    - Enhance both surface and sediment DO, stimulate aerobic microbial activity, and gradually reduce internal nutrient loading,
    - Effective in shallower lake environments <5m lacking stratification.
- Cons:
    - Localized benefits surrounding diffusers - adequate coverage required to avoid localized zones of low oxygen;
    - Would require complementary rehabilitation measures, and
    - Maintenance required for long-term function.

For Swan Lake with its lack of stratification and current flows, **fountain aeration** represents a potentially feasible option for improving DO concentrations. Multiple fountains positioned to cover a significant portion of the surface area could promote oxygenation without disturbing fine, nutrient-rich sediments. When operated continuously such a system would enhance surface DO, inhibit algae bloom formation, stimulate aerobic microbial activity, and gradually reduce internal nutrient loading. Integration with complementary rehabilitation measures—such as sediment management, nutrient source reduction, and shoreline naturalization—would maximize long-term water quality improvements.

- Pros:

    - Promote moderate oxygenation without disturbing sediments;
    - Enhance surface DO, stimulate aerobic microbial activity, inhibit algae bloom formation, and gradually reduce internal nutrient loading,
- Cons:
    - Localized benefits surrounding diffusers - adequate coverage required to avoid localized zones of low oxygen;
    - Would not provide year round oxygenation;
    - Would require complementary rehabilitation measures;
    - Maintenance required for long-term function.

Chemical Oxygenation represents a potentially feasible option for improving DO concentrations throughout Swan Lake. Successful implementation would require the use of carefully selected and calibrated chemical treatments to ensure adequate coverage and sustained oxygen release throughout Swan Lake while minimizing the formation of localized hypoxic or anoxic zones.

When properly applied, chemical oxygenation could promote both surface and sediment level oxygenation, stimulate aerobic microbial activity, and gradually reduce internal nutrient loading. Integration with complementary rehabilitation measures—such as sediment management, nutrient source reduction, and shoreline naturalization—would maximize long-term water quality improvements.

- Pros:
    - Promote moderate oxygenation without disturbing sediments;
    - Enhance surface and sediment DO, stimulate aerobic microbial activity, and gradually reduce internal nutrient loading;
    - Continuous oxygenation with minimal maintenance.
- Cons:
    - Requires specialist chemical blends to ensure appropriate and continuous oxygenation;
    - Would require complementary rehabilitation measures;
    - Would require repeated chemical treatments for continuous long-term function.

Destratification is a logistically complex potential beneficial strategy for improving overall water quality conditions within Swan Lake. Despite a lack of thermal stratification within Swan Lake,

this approach would primarily address stagnation, circulation deficiencies, and the formation of anoxic zones though it has a less direct influence on DO concentrations.

Circulating surface water through the Swan Lake North Pond Channel has the potential to increase the DO concentrations by promoting limited current flow, disrupting weak thermal layering, and reducing internal lake stagnation. When properly implemented, destratification can promote oxygenation at the sediment-water interface, stimulate aerobic microbial activity, and contribute to the gradual reduction of internal nutrient loading. Integration with complementary rehabilitation measures—such as sediment management, nutrient source reduction, and shoreline naturalization—would maximize long-term water quality improvements.

- Pros:
    - Minimize anoxic zone formation and address overall lake stagnation;
    - Enhance sediment level DO, stimulate aerobic microbial activity, and gradually reduce internal nutrient loading.
- Cons:
    - Logistically complicated to implement;
    - Maintenance required for long-term function
    - Minimal overall DO influences;
    - Would require complementary rehabilitation measures;

Method	Mechanism of Action	Advantages	Limitations	Feasibility for Swan Lake
Mechanical Aeration	Agitates or circulates water at the surface to enhance gas exchange and disrupt localized stagnation.	Immediate DO improvement; simple installation; visible circulation.	Limited spatial reach; energy-intensive; risk of sediment resuspension.	Effective only in localized zones; significant infrastructure needed for lake-wide benefit.
Gravity (Cascade) Aeration	Form of mechanical aeration, artificial waterfall and flow structures, disrupt localized stagnation and promote circulation.	Immediate DO improvement; low-tech, and energy efficient.	Limited spatial reach; limited ability at addressing large area; risk of sediment resuspension.	Effective only in localized zones; significant infrastructure needed for lake-wide benefit.
Diffused Aeration	Releases compressed air through submerged diffusers to promote vertical mixing and oxygen transfer.	Gentle, uniform oxygenation; low disturbance; energy-efficient; adaptable to seasonal use.	Requires careful diffuser placement; effectiveness reduced in very shallow areas.	Highly suitable; offers broad coverage and sustained oxygenation when operated continuously.
Fountain Aeriation	Pumping water through surface level diffusers into the air to promote gas exchange and surface agitation.	Uniform oxygenation; low disturbance; simple installation.	Limited spatial reach; requires careful fountain placement; non-functional during winter months.	Highly suitable; simple installation; offers sustained oxygenation when operated continuously.
Chemical Oxygenation	Introduces oxygen-releasing or oxidizing compounds that supply elemental oxygen or modify sediment redox conditions.	Direct oxygen delivery; long-lasting effect; no mechanical disturbance.	Requires precise dosing; limited circulation benefit; may provide only temporary improvement.	Moderate feasibility; useful as supplemental treatment for localized low-oxygen zones.
Destratification / Mixing	Induces circulation to break down stratification and promote natural oxygenation through gas exchange.	Reduces stagnation; minimizes hypoxic zone formation; enhances natural mixing.	Limited DO increase; potential warming; continuous operation required.	Partially feasible; could aid circulation but unlikely to raise overall DO significantly.

7.0 Conclusions and Recommendations

Within Swan Lake, any management approach intended to increase DO concentrations must be designed not only to address existing DO deficiencies but also anticipate increases in biological oxygen demand (BOD) that will result from enhanced biological and microbial activity following oxygenation. As oxygen availability improves, aerobic bacteria, benthic invertebrates, and aquatic vegetation will become more active, increasing oxygen consumption and temporarily offsetting some of the initial gains in DO. Accordingly, any oxygenation strategy must account for these feedback effects and be implemented as part of a long-term, adaptive rehabilitation program.

Importantly, effective DO enhancement within Swan Lake must also target the underlying causes of poor surface water quality, Specifically, historic and ongoing nutrient and containment loading from high Canada Geese populations, stormwater inputs and the accumulation of nutrient-rich organic sediments. High organic matter concentrations, low sediment oxygen concentrations, and anaerobic bacterial processes may work against active oxygenation programs in Swan Lake. These conditions can consume oxygen more rapidly than it is introduced, thereby slowing the realization of measurable improvements reducing the effectiveness of direct oxygenation by continuously releasing nutrients and consuming available oxygen.

While active oxygenation can be highly effective in addressing short-term hypoxia and improving localized water quality, it rarely provides lasting improvements unless combined with integrated watershed and sediment management actions. Stand-alone oxygenation systems typically require continuous operation to maintain benefits, as discontinuation can lead to a rapid decline in DO concentration, often below pre-treatment level, due to increased BOD and residual nutrient release.

Increased oxygenation in shallow, nutrient-rich systems such as Swan Lake can lead to significant improvements, including:

- Reduced internal nutrient loading and phosphorus release from sediments.
- Decreased bioavailability of heavy metals through oxidation.
- Improved surface water clarity and reduced frequency of harmful algal blooms.
- Enhanced biological diversity and productivity through improved aerobic habitat conditions.

However, these benefits are typically realized gradually, as the system responds to improved redox conditions and enhanced biological cycling. Regardless of the oxygenation strategy employed, elevated biological oxygen demand (BOD) can also lead to a sudden decline in dissolved oxygen concentrations, potentially to levels lower than those observed prior to treatment, if oxygenation programs are discontinued without addressing the underlying causes of poor water quality. Effective long-term management will therefore require sustained oxygenation, regular monitoring, and adaptive operational adjustments to maintain DO levels sufficient to counteract high BOD and sediment oxygen demand.

7.1 Oxygenation Program Considerations

Oxygenation represents a viable and effective approach to improving surface water quality and aquatic habitat conditions within Swan Lake. Diffused aeration or fountain aeration systems would likely provide the most balanced combination of performance, reliability, and cost-effectiveness for this small, shallow, and nutrient-enriched lake. When paired with watershed-level nutrient management and ecological restoration efforts, these systems can form the foundation of a long-term strategy to enhance aquatic health, reduce eutrophication, and restore more natural lake function.

However, oxygenation alone will not fully address all water quality deficiencies or the underlying causes of degradation. To improve the effectiveness and sustainability of oxygenation measures, several key factors should be considered when developing and implementing an oxygenation program for Swan Lake.

- **Address Natural Mixing Limitations**: Any oxygenation program should aim to overcome the lack of natural circulation within Swan Lake to ensure adequate exposure of all areas to elevated DO concentrations.
- **Uniform Application**: Oxygenation should be applied uniformly across the lake to prevent the formation of localized hypoxic or anoxic zones.
- **Integrated Management Approach**: Oxygenation cannot resolve the underlying causes of poor surface water quality and should be implemented in conjunction with broader rehabilitation measures that address both historical and ongoing nutrient and contaminant inputs.
- **Continuous Operation**: Consistent, low-intensity operation is preferable to intermittent high-output cycles, as sudden fluctuations in DO can destabilize the system and increase BOD demand.

- **Hydrologic Connectivity**: Recirculation of water through the north channel is expected to provide only limited improvement in DO levels unless underlying nutrient concentrations are simultaneously addressed.
- **System Design**: System layout should provide full spatial coverage, including deeper basins and areas of low circulation, while avoiding disturbance of fine, nutrient-rich sediments.
- **Operational Schedule**: Continuous, steady operation will help maintain stable oxygen levels and minimize fluctuations in BOD and redox potential.
- **Monitoring Program**: Ongoing monitoring of DO, temperature, turbidity, and phosphorus concentrations should accompany installation to evaluate system effectiveness and inform adaptive management.
- Integration with Rehabilitation Efforts: Oxygenation should complement a broader restoration plan that includes sediment nutrient management, stormwater inflow treatment, and shoreline naturalization to improve long-term system stability.

In summary, successful improvement of water quality within Swan Lake will depend on an integrated approach that combines active oxygenation with nutrient load reduction, sediment management, and ecological restoration. These combined measures will enhance dissolved oxygen concentrations, promote stable redox conditions, and foster a more balanced and resilient aquatic ecosystem.

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Appendix I
Key Findings and References

Key Finding	Summary	Source
Improvement in Surface Water Quality	• Significant surface water quality and aquatic habitat improvements have been linked to increased DO concentrations within small highly eutrophic water bodies. • Reduction in nutrient release (Nitrogen - N, Iron – Fe and P) from high concentration sediments. • Control and limit internal nutrient loading from high nutrient concentration sediments. • Increase in heavy metal mobility, the conversion from soluble to insoluble forms, and biological availability. • Increased aerobic microbial activity and organic pollutant decomposition. • Increased benthic macro-invertebrate activity and diversity. • Increased organic material decomposition and improvement in substrate suitability to support aquatic vegetation. • In areas of significant metal sulfide contamination, temporary increase in biological availability of heavy metals. • Improvements in surface water clarity and decrease in turbidity • Reduction in risk of algae bloom accumulation. • Can be linked to resuspension of contaminated sediment if not applied correctly. • Effectiveness of increased DO on improving water quality limited by historic and ongoing nutrient loading. • Not a perfect solution to offset historic high concentration organic nutrient loading.	Andersen et al. 2017 Atkinson et al. 2007 Borma et al. 1998 Borman et al. 2017 Crawshaw et al. 2018 Kenneth, I.A. 1983 Kirol et al. 2024 Macdonald, R.H. 1995 Michael et al. 2025 Preece et al. 2019 Rabaev et al. 2021 Ribaudo et al. 2018 Shaw and Prepas 1990 Wang et al. 2025
Reduction of Eutrophication	• Decreased overall risk of eutrophication. • Limits internal nutrient loading. • Limit algae bloom formation and reduce the risk of harmful algae blooms. • Reduce anaerobic bacterial activity limits accumulation and release of harmful gasses (i.e. H_2S, CH_4). • Improvement in water clarity and biological activity and natural vegetation growth. • Increased DO, pH and water temperature are all strongly linked to changes in sediment Phosphorus release, 1mg/L change in DO reflect with a corresponding 25-37% change in Phosphorus loading.	Andersen et al. 2017 Atkinson et al. 2007 Borman et al. 2017 Crawshaw et al. 2018 Kenneth, I.A. 1983 Kirol et al. 2024 Macdonald, R.H. 1995 Michael et al. 2025 Preece et al. 2019 Ribaudo et al. 2018 Shaw and Prepas 1990 Wang et al. 2025

	• Legacy Phosphorus release is strongly linked to delays (or opposition) to improvements in surface water quality following increases in DO levels.	
Enhancement of Aquatic Life	• Improved habitat suitability with increased surface water DO concentrations. • Reduced risk of fish kills or formation of hypoxic environments • Inhibition of harmful algae blooms and cyanobacteria growth. • Increased aerobic microbial activity and organic pollutant decomposition. • Increased benthic macro-invertebrate activity and diversity. • Reduce anaerobic bacterial activity limits accumulation and release of harmful gasses (i.e. H_2S, CH_4). • Increased organic material decomposition and improvement in substrate suitability to support aquatic vegetation. • Increased in bioturbation depths • Decreased bioaccumulation of toxic compounds. • Increased DO is associated with increases in Biological Oxygen Demand.	Andersen et al. 2017 Austin et al. 2019 Barry et al. 2012 Beutel et al. 1999 Bierlein et al. 2017 Borman et al. 2017 Crawshaw et al. 2018 Kenneth, I.A. 1983 Kirol et al. 2024 Michael et al. 2025 Preece et al. 2019 Ribaudo et al. 2018 Shaw and Prepas 1990 Wang et al. 2025
Mechanical Aeration	• Increased DO through surface water aeration and agitation. • Simple but effective. • Limited influence on addressing stratification and mixing. • Requires specific oxygenation strategies, Hypolimnetic aeration, to directly oxygenate substrate levels. • Increased sediment/water boundary DO levels associated with increased effectiveness at controlling Phosphorus release and improve effects on promoting aerobic bacterial activity. • Generally, less effective in high temperature areas or areas with high Biological Oxygen Demand, and high nutrient loads. • Can be effective at addressing internal Phosphorus loading over a limited geographic area, generally limited effectiveness in large surface area environments. • Limited effect on overall stagnation. • Can be linked to contaminated sediment resuspension following improper implementation.	Austin et al. 2019 Barry et al. 2012 Beutel et al. 1999 Bierlein et al. 2017 Borman et al. 2017 Kirol et al. 2024
Gravity (Cascade) Aeration	• Low-tech alternative to conventional mechanical aeration using artificial waterfalls, limited improvement on surface water mixing. • Increased DO through increased air-water gas exchange.	Austin et al. 2019 Barry et al. 2012 Beutel et al. 1999

	• Increased sediment/water boundary DO levels associated with increased effectiveness at controlling Phosphorus release and improve effects on promoting aerobic bacterial activity. • Generally, less effective in high temperature areas or areas with high Biological Oxygen Demand, and high nutrient loads. • Can be effective at addressing internal Phosphorus loading over a limited geographic area, generally limited effectiveness in large surface area environments. • Limited effect on overall stagnation. • Can be linked to contaminated sediment resuspension following improper implementation.	Borman et al. 2017 Kirol et al. 2024.
Chemical Oxygenation	• Increase DO level through direct chemical oxygen or induced oxygenation reactions. • Direct oxygen release agents (e.g. calcium peroxide) release oxygen over an extended period with a lack of ongoing infrastructure maintenance. • Increased aerobic bacterial activity and reduced internal nutrient loading. • Useful to address hypoxic conditions in difficult to access sites without the risk of sediment resuspension. • Dosage rates dependent on existing and future oxygen demands. • Difficult to accurately apply for larger surface water bodies. • Induced oxygenation addresses limiting chemical factors common to eutrophic environments. • Induces natural chemical oxygenation, highly dependent on a thorough understanding of the internal nutrient cycling processes and specific nutrient loading rates.	Barry et al. 2012 Bierlein et al. 2017 Borman et al. 2017 Kenneth, I.A. 1983 Preece et al. 2019 Ribaudo et al. 2018 Wang et al. 2025
Destratification / Mixing	• Destratification induced mixing and current flow. • Increased current flow and circulation of surface water and lake bottom water layers. • Allows natural oxygenation of surface water and circulation of higher DO water to low DO areas. • Useful to address internal lake stagnation and minimize the formation of anoxic zones. • Highly complicated to implement in large surface water bodies. • Does not directly increase DO levels. • Dependent on natural oxygenation capacity of an environment.	Austin et al. 2019 Beutel et al. 1999 Crawshaw et al. 2018 Kenneth, I.A. 1983 Kirol et al. 2024 Macdonald, R.H. 1995 Preece et al. 2019 Rabaev et al. 2021

	• Less effective in high water temperature environments. • Can increase overall surface water temperatures.	

Attachment A

Technical Review of:
Swan Lake Management Options, Swan Lake Long-Term Management Plan: Water Quality Monitoring Program Preliminary Review, Natural Resource Solutions, Inc. (NRSI), November 2025.

1. Introduction

Friends of Swan Lake Park (FOSLP) engaged Natural Resource Solutions Inc. ("NRSI") to complete a peer review of the monitoring and reporting completed to date as part of the City of Markham's 25-year water quality monitoring program preliminary (Phase 1) and provide general guidance and recommendations to support the long-term Swan Lake water quality objectives. The NRSI (2025) review *Swan Lake Management Options, Swan Lake Long-Term Management Plan: Water Quality Monitoring Program Preliminary Review, Natural Resource Solutions, Inc.* is incorporated into FOSLP's submission *Towards Sustainable Water Quality for Swan Lake*, dated December 3, 2025.

This document presents a technical review of the NRSI (2025) report, drawing on the Swan Lake Annual Monitoring Reports (2021–2024), the *Swan Lake Long-Term Management Plan* (SLMP) and supporting technical studies, and applicable provincial and federal guidance, to:

- Assess whether NRSI's interpretation of monitoring data is technically sound and appropriately framed;
- Evaluate the relevance and feasibility of recommended monitoring and management actions relative to the objectives of the SLMP; and
- Provide recommendations to support the City of Markham's decision-making on updates to the SLMP and Phase 2 implementation.

The review comments that follow are organized by section of the NRSI (2025) report in bold text, and focus on the technical accuracy, framing, and relevance of the observations and recommendations presented.

2. Technical Review

2.0 Summary of Water Quality Monitoring Components - NRSI states that the interim targets used to evaluate water quality parameters are "*general numerical guidelines intended to be used as thresholds for hyper-eutrophic conditions",* and *"that these interim targets were updated to generic thresholds for eutrophic/hyper-eutrophic conditions (Markham 2022), which are shown in Table 1."*

Review Comments:

- The values and intent of the interim water quality targets described and summarized in Table 1 are not consistent with those defined in the SLMP.
- The interim water quality targets were established in the plan as site-specific Phase 1 goals. They are not generic thresholds for eutrophic or hyper-eutrophic conditions, and they were not updated to generic trophic thresholds.
- The interim targets are quantitative, site-specific values proposed as goals to be achieved in the first five years of the plan (Phase 1) to address the primary water quality issues of eutrophication and high chloride levels. These were developed based on detailed limnological analysis of Swan Lake and represent water quality characteristics that are practically achievable through implementation of the Phase 1 management actions set out in the plan.
- Annual monitoring results are compared against the interim targets to track progress of lake management efforts.
- Results are also compared to relevant federal and provincial water quality guidelines and objectives, and the trophic state of Swan Lake is reported based observed total phosphorus concentrations, to contextualize lake condition.

- Progress toward the interim targets and updates to the targets are being evaluated through the scheduled review of the management plan this year.

2.1 Water Quality Monitoring Program Components and Recommendations - NRSI confirms that the existing core water quality monitoring program is consistent with best practice for eutrophication monitoring and supports long-term assessment of aquatic ecosystem condition and beneficial uses in Swan Lake. However, NRSI also recommends several modifications to the program, including the addition of monitoring parameters, increased sampling frequency, and expansion of monitoring locations within the lake.

Additional Parameters

NRSI characterizes Swan Lake as functioning as an "ad hoc" stormwater management facility due to the presence of multiple stormwater outfalls and contends that the omission of common stormwater management pond contaminant from the overall monitoring program limits its comprehensiveness and relevance. Several stormwater-related parameters are therefore recommended for inclusion in the core monitoring program.

Review Comments:

- While Swan Lake receives stormwater inflows, these inputs are routed through upstream stormwater management ponds and oil–grit separators (OGS) prior to discharge to the lake. As such, Swan Lake functions as a receiving waterbody rather than a stormwater management facility and plays an important role in peak flow management, but not in quality control.
- Stormwater-related inflows are appropriately considered in the context of overall lake management, but do not redefine the primary function or management objectives of the lake.
- Stormwater-related parameters (e.g., hydrocarbons, metals, oil and grease) are more effectively managed and monitored at the level of stormwater management facilities, where regulatory controls, maintenance actions, and corrective measures can be implemented, rather than through routine lake monitoring. That said, selective additional parameters may provide useful supplementary context for interpreting lake condition where they align with management objectives:
  - Inclusion of Total Suspended Solids (TSS) could be informative to support interpretation of water clarity trends and to help distinguish between phytoplankton and suspended sediments, particularly during higher-flow periods and wind mixing events.
  - Total metals monitoring could be considered as a targeted or periodic monitoring event, both to update baseline information (last assessed approximately in 2016) and to provide broader limnological context related to sediment–water interactions and potential stormwater influences. Results from such targeted monitoring could be used to determine whether ongoing metals monitoring is warranted.
  - Routine monitoring for Biochemical Oxygen Demand (BOD) is not recommended. Dissolved oxygen is already directly monitored in the lake, and recent monitoring indicates improved oxygen conditions relative to pre-management conditions. In the absence of a management objective related to organic loading or implementation of oxygenation/aeration measures—which are not proposed or feasible for Swan Lake—BOD measurements would not provide additional actionable information.
  - Monitoring for oil and grease and polycyclic aromatic hydrocarbons (PAHs) is not recommended for inclusion in the core long-term monitoring program at this time. While parking areas are present in the catchment, stormwater from these areas is treated through OGS and stormwater management ponds prior to entering the lake, and no specific source or management question has been identified that would be informed by routine PAH monitoring.
  - *E. coli* monitoring is not recommended for routine inclusion in the core lake monitoring program. Swan Lake is not intended to support contact recreation, and the management goal is to improve overall lake health to support non-contact recreational enjoyment. *E. coli* is primarily a human health indicator related to contact recreation and does not provide a meaningful indicator of aquatic ecosystem health or eutrophication status in this context. Monitoring for *E. coli* would therefore have limited relevance to the objectives of the SLMP.

Recommendation: That the core water quality monitoring program remain focused on parameters directly linked to identified management objectives for Swan Lake, with consideration given to targeted or periodic monitoring (e.g., TSS and total metals) to provide additional context. Stormwater-related parameters should continue to be addressed primarily through

stormwater management facility monitoring and maintenance programs, and additional parameters should be incorporated into lake monitoring only where a clear management question or decision would be informed by the data.

2.1.2 Water Quality Sample Collection - NRSI recommends additional spring freshet, storm-event, and winter dissolved oxygen monitoring, to provide higher-resolution characterization of water quality conditions and stormwater influences in Swan Lake.

Review Comments:

- Biweekly sampling during the open-water season is already intensive for a long-term lake management program and adequately captures seasonal variability, including spring freshet conditions through April monitoring. Storm-related conditions are also captured intermittently through the regular two-week sampling interval. In addition, the City monitors key inflows to the lake for chloride, and mass-balance modeling confirms that major phosphorus sources to the lake are well characterized under the existing program.
- While low dissolved oxygen concentrations under ice are plausible in shallow, productive systems such as Swan Lake, routine winter monitoring presents safety considerations for field staff and would provide limited management value given the lack of feasible or effective management options to address winter anoxia.
- Expanded storm-event or winter monitoring is therefore not supported at this time, as no unresolved management questions or contaminants of concern have been identified that would warrant such sampling. Moreover, Swan Lake is a shallow system where short-term storm-driven or under-ice conditions are unlikely to result in persistent or manageable impacts without being reflected in routine seasonal monitoring data.

Recommendation: That the City maintain the existing core sampling frequency, and consider targeted, limited-duration event-based or winter monitoring only if a specific hypothesis, contaminant of concern, or management decision is identified during the 5-year review of the management plan that would be informed by such data.

2.1.3 Water Quality Sampling Locations - NRSI recommends that additional monitoring sites are required because the lake is relatively stagnant increasing spatial variability and therefore potentially leading to a misinterpretation of the overall conditions of the lake by omitting areas of comparatively high or low water quality conditions.

Response:

- NRSI's characterization of Swan Lake as a "relatively stagnant lake with minimal mixing" is not supported by lake morphometry, hydrology, or observed monitoring data. Swan Lake is a shallow system (mean depth ~1.5 m) that is generally well mixed by wind, with only a small area exceeding ~2 m depth that exhibits limited and seasonal thermal stratification during peak summer conditions. Stratification is expected given the ratio of the mean depth to the surface area of the lake (i.e., a large morphometric ratio). While reduced surface mixing occurs during calm, dry periods, this does not indicate that the lake is stagnant.
- The lake has an average water residence time of approximately 1.7 years (2020-2024), which is inconsistent with a stagnant system and indicates regular water exchange and mixing at the whole-lake scale.
- The selection of the monitoring sites for the City's program was based on previous monitoring at several locations in the lake, which demonstrated that the City's dock site was representative of the nutrient and trophic state of Swan Lake. This conclusion is supported by recent monitoring data; dissolved oxygen and temperature profiles at the dock site and at the deepest area of the lake (Trent University monitoring site) are comparable, and chloride concentrations measured at the bridge, dock, and deepest location are also comparable.
- The dock site is also located near the shoreline and in proximity to two of the stormwater outfalls, and likely to capture stormwater-related impacts.
- While localized effects of stormwater outflows may occur in the immediate vicinity of discharge points, the existing monitoring locations are appropriate to characterize overall lake conditions for a lake of this size, shape, and hydrodynamic regime and are sufficient to support the objectives of the SLMP.
- Expansion of monitoring locations is not supported at this time in the absence of identified spatially distinct water quality concerns or management questions that would be addressed through increased spatial resolution.

Recommendation: That the City maintain the existing monitoring locations for long-term condition and trend monitoring, and consider targeted, short-term monitoring near outfalls only if a specific issue, hypothesis, or management decision is identified that would benefit from additional spatial resolution.

Section 2.1.4 Water Quality Guidelines and Targets – NRSI discusses provincial policies for water quality and recommends water quality guidelines for several parameters for inclusion in the analysis of the Swan Lake monitoring program results moving forward.

Review Comments:

- NRSI's discussion of Provincial Water Quality Objectives (PWQOs) does not adequately distinguish between their regulatory application (e.g., in the context of approvals for point-source discharges and compliance assessment), and their discretionary use as comparative benchmarks in ambient lake monitoring programs.
- The Swan Lake monitoring program is designed to support lake management decision-making, not regulatory compliance, and therefore appropriately emphasizes site-specific interim targets, aligned with eutrophication and chloride management objectives. While PWQOs may be used as contextual reference values, they are not mandatory compliance standards for in-lake water quality conditions in a municipally managed lake that is not subject to regulated effluent discharge or other approvals.
- The discussion of PWQO deviation policies and exemption processes is not directly applicable to the Swan Lake monitoring program, as no regulatory requirement exists to formally "attain" PWQOs or seek approval for deviations in this context. The referenced *Guidelines for Handling Requests for Deviations* are provided in the province's guidance document for point source effluents, *Deriving Receiving-Water Based, Point-Source Effluent Requirements for Ontario Waters* (MOEE 1994), which underscores that these provisions are intended for regulatory approvals, not for lake management plans.
- Where PWQOs, Canadian Environmental Quality Guidelines (CEQG), or Health Canada guidelines are directly relevant to priority concerns (e.g., dissolved oxygen, chloride, cyanobacteria density, total microcystins, chlorophyll-a), they are already included in the annual reports to provide appropriate context for interpreting observed conditions.
- PWQOs/CEQGs are not included in the annual reporting for nitrate and total ammonia (or unionized ammonia) and could be added for context.
- NRSI recommends use of a Secchi depth guideline of >1.2 m based on the *Guidelines for Canadian Recreational Water Quality* (Health Canada 2024). This value is not consistent with the cited Health Canada recommendations, either in the Summary Document (Health Canada, 2024), or the associated technical document, *Guidelines for Canadian Recreational Water Quality: Physical, Aesthetic and Chemical Characteristics* (Health Canada 2022). Health Canada recommends a guideline for water clarity as "Not significantly decreased compared to background values" with the rationale that "Individuals engaged in primary contact activities need to be able to estimate depth and see subsurface hazards. Secchi depth measurements are useful for determining clarity." The guidance document notes that Secchi depth measurements can also be used as part of a monitoring strategy for cyanobacteria blooms, consistent with its current application for Swan Lake.
- NRSI contends that "the stated water quality guidelines currently omit the total phosphorus ranges for other eutrophic conditions (from oligotrophic to hyper-eutrophic) somewhat limiting the comprehensiveness of the overall monitoring program." While the lower trophic state classes (oligotrophic and ultraoligotrophic) are not included in the annual reports, this presentation does not limit the comprehensiveness of the monitoring program and appropriately focuses interpretation on conditions that are relevant to current lake status, management progress and objectives. Inclusion of the lower trophic states could provide additional contextual information; however, these should not be presented as management targets. Trophic state classifications describe the biological productivity of an aquatic system with natural, undisturbed lakes existing across the full trophic spectrum. Lower trophic state should not be interpreted as inherently "better" water quality without explicit consideration of lake-specific ecological objectives and constraints. Given the urban setting and shallow, warm-water conditions of Swan Lake, oligotrophy is neither a realistic nor necessarily desirable condition support a health aquatic community.
- NRSI notes that the total phosphorus thresholds used to describe the trophic state of Swan Lake are generally consistent with CCME trigger ranges and recommends inclusion of additional CCME trophic ranges for context. The CCME trigger ranges provide finer-scale divisions along the trophic state spectrum; however, inclusion of these ranges would not materially change interpretation of the monitoring results. Moreover, the CCME trophic state divisions do not include values for other indicator parameters like the framework used in the SLWQMP.

- NRSI's statement that the chloride target was established to coincide with the short-term exposure guideline is not accurate. The chloride target was developed based on historical lake data and with consideration of what was practicably achievable through management actions at that time, while aiming for concentrations below the short-term exposure guideline to address the risk of acute toxicity.
- Recent monitoring indicates chloride concentrations are now well below the established target, and adjustment of the target could be considered in plan updates to reflect this change in condition. CCME short- and long-term chloride guidelines are already included in annual monitoring reports to provide appropriate context for interpreting observed conditions.

Recommendation: That the relevant PWQO, CEQG and Health Canada guidelines continue to be used as supplementary, contextual reference values where they meaningfully inform interpretation of monitoring results, while the core monitoring framework prioritize site-specific targets directly aligned with the SLMP and its defined management objectives. No changes to the guidelines are recommended as this would not materially change the interpretation of the results and to maintain consistency with past reporting.

Recommendation: That the trophic state classification used in the SLMP continue to be used for consistency in interpretation and reporting.

Recommendation: That the chloride target be revisited and revised as appropriate based on the results of recent monitoring and the City's Swan Lake Water Quality Management - Water and Chloride Budget (November, 2025), while considering management objectives and feasible chloride reduction strategies.

Section 3.0 Water Quality Monitoring Results – NRSI provides a review of water quality monitoring results from the Swan Lake Annual Monitoring Reports and provides recommendations for future reporting.

Global Statements - NRSI states that there were multiple 'omissions' of monitoring events, multiple gaps in full sampling coverage, and omissions in reporting of data that could lead to misinterpretation of the results.

Review Comments:

- NRSI provide no specific reference to dates of missing monitoring events or data to support their assertion of "multiple omissions" or how these could have led to "misinterpretation of the results".
- In practice, the number of sampling events met or exceeded the planned biweekly monitoring frequency (monthly for phytoplankton) at the designated sites, with only rare instances where there were more than two weeks between sampling events. Such occurrences are not unusual or indicative of 'omissions' given the potential for inclement weather or other issue affecting scheduling over a multi-year program. With the exception of missing phytoplankton data in the early part of the 2022 monitoring season due to lab closure during COVID, there is no evidence of omissions in reporting of data. Field data and laboratory certificates of analysis are also provided in appendices of the annual reports for transparency. Given the biweekly sampling schedule and long-term data set, any minor gaps in data collection would not materially affect interpretation of lake conditions or trends.

Recommendation: That missing data of concern, if requested, be provided to NRSI if it was unintentionally missed in the annual reports and would support NRSI's review and recommendations.

Recommendation: As recommended by NRSI, that explanations for any missing data or sampling events be included in the annual reports.

NRSI concludes that the results reported for Swan Lake appear to be generally or approximately consistent with those seen in shallow eutrophic surface water bodies for water clarity, total phosphorus, total nitrogen, and dissolved oxygen, which agrees with the conclusions of the annual monitoring reports. Certain aspects of NRSI's interpretation, particularly with respect to dissolved oxygen and cyanobacteria, would benefit from clarification to ensure results are evaluated in a manner consistent with lake-specific characteristics and the intent of applicable guidelines. These clarifications are provided below.

Dissolved Oxygen - NRSI states that the "the overall validity of the assertation that the conditions within Swan Lake are in excess of the recommended guidelines is somewhat in question based on the results of the 2024 Trent University continuous dissolved oxygen monitoring, which reported anoxic conditions within Swan Lake" and that "this suggests that the sampling coverage within Swan Lake may not adequately characterize the overall water quality conditions."

Review Comments:

- These statements are not supported by the data, and do not consider depth, duration, or spatial extent of low dissolved oxygen observations observed in the 2024 Trent University data. Such distinctions are critical for appropriate interpretation of dissolved oxygen data in shallow lakes. As described above in response to NRSI's recommendation to expand the monitoring locations, the existing monitoring sites capture lake conditions sufficient to evaluate water quality in Swan Lake to support management decisions.
- NRSI's reliance on the 2024 continuous dissolved oxygen monitoring data to question the validity of the broader dataset reflects a misunderstanding of the purpose and interpretation of the continuous monitoring and does not consider the depth of the logger near the lake bottom at 2.75 m below surface where anoxia was recorded. Continuous loggers are designed to capture short-duration and diel changes in dissolved oxygen. Detection of episodic bottom-water anoxia by continuous monitoring does not contradict discrete profile data that characterize general lake conditions within biologically active portions of the water column at the time of monitoring. It is also noted that the City's continuous logging at the dock site recorded similar near-bottom anoxic periods, which were transparently reported in the annual reports.
- Discrete profile monitoring conducted at the dock site from 2022-2024 following the 2021 PAC treatment, did not detect anoxia, and dissolved oxygen concentrations below 4 mg/L occurred on only three of 46 events and these only occurred within approximately 1 m of the sediment–water interface. The profile at the dock site in 2024 was also consistent with Trent University's profile at the deeper monitoring site. These observations are consistent with localized near-bottom oxygen depletion driven by sediment oxygen demand and respiration, and do not indicate lake-wide impairment of the mixed water column.
- Hypsometric analysis demonstrates that depths below approximately 2.5–2.75 m, where anoxia has been observed, represent only a small fraction of Swan Lake, on the order of approximately 3–5% of total lake area and 1–3% of total lake volume, based on water level at the time of monitoring. This illustrates that observed anoxia is spatially limited, volumetrically minor, and confined to a small deep-water zone, rather than indicative of widespread or persistent lake-wide conditions.
- PWQO and CCME dissolved oxygen guidelines are intended to protect aquatic life within biologically relevant habitat and are not meant to be applied uniformly throughout the entire water column at all times throughout the year. Localized or depth-limited anoxia near sediments does not constitute non-attainment of the guideline, or 'impairment'. When interpreted consistent with their intent, considering depth, habitat use, and the spatial and temporal extent of low-oxygen conditions, the observed dissolved oxygen conditions in Swan Lake meet both PWQO and CCME guidance.
- Comparison to pre-management conditions provides additional context. Prior to implementation of SLMP, anoxia was persistent and widespread with hypoxia regularly extended upward into the mixed layer during summer months. In contrast, post-2021 monitoring shows that low dissolved oxygen or anoxia is confined to near-bottom waters, occurs episodically primarily during calm and warm periods, and affects only a small portion of lake area and volume. This represents a substantial improvement in dissolved oxygen conditions and demonstrates an appropriate system response to management actions that have been implemented under the plan.
- Taking all evidence into account and with an understanding of the intent and application of relevant guidelines, it is my professional opinion that from 2022-2024:
    1. Dissolved oxygen concentrations during the open water season in Swan Lake meet PWQO for warm water fish and the CEQG for the protection of aquatic life.
    2. Anoxic conditions occur, but these are limited spatially and volumetrically and are mostly episodic during the open water season and would not pose significant widespread adverse ecological conditions for aquatic life.

Cyanobacteria and Cyanotoxins - NRSI comments on the use and interpretation of cyanobacteria-related indicators and associated Health Canada guidance in the annual monitoring reports.

Review Comments:

- The analysis of Cyanobacteria is based on cell counts and taxonomic composition, which are appropriate indicators for tracking abundance, community structure, and relative changes over time. Samples were analyzed for cyanobacteria cell density only to the level of genus.

- Health Canada guideline values for cyanobacteria biovolume and chlorophyll-a are included in the annual reports for contextual reference. These parameters are not included in the routine monitoring parameter list; no data were omitted.
- Cyanotoxins are not routinely monitored in Swan Lake. This is intentional and appropriate given the no-contact recreational use designation of the lake and the high spatial and temporal variability of toxin production, which is influenced by complex and often unpredictable environmental conditions. In this context, reliance on Health Canada guidance for cyanobacteria abundance and related indicators provides a defensible, precautionary approach to risk evaluation for cyanotoxins.
- The annual monitoring reports summarize relative abundance of cyanobacterial taxa and total cyanobacteria cell densities for each monitoring event and year. Observations regarding changes in density or community composition are presented descriptively to document conditions and trends; no claims are made attributing observed changes directly to management actions or to changes in water quality.
- Statements in the 2024 monitoring report regarding reduced cyanobacteria counts are factual summaries. The report appropriately notes that phytoplankton dominance persists despite nutrient reductions and discusses plausible ecological factors, such as warmer weather and limited submerged aquatic vegetation (SAV), that may influence lake response.

Chlorophyll a is not included as a parameter in the monitoring program. Chlorophyll-a data were provided by Trent University.

Sections 3.1 and 3.1 Adequacy of Water Quality Monitoring Program and Water Quality Monitoring Program Limitations

Review Comments:

NRSI concludes that the existing monitoring program is sufficient to characterize eutrophication risk in Swan Lake, but describes it as limited in scope and providing only a high-level assessment. While the program is intentionally focused on eutrophication and chloride, the primary water quality issues identified for Swan Lake, it is not limited in scope. It is an intensive, multi-parameter monitoring program designed to evaluate lake conditions and responses to management actions relevant to the SLMP.

Assertions that omitted monitoring events, reporting gaps, or limited spatial coverage could mischaracterize conditions or falsely suggest improvement are not supported. Monitoring frequency met or exceeded the planned biweekly schedule, no collected data were intentionally omitted from reporting, and existing sampling locations have been demonstrated to be representative of whole-lake conditions relevant to management objectives.

While additional aquatic habitat or water quality parameters could be considered in targeted studies, these have not limited the program's ability to evaluate lake condition or management effectiveness.

Section 4.0 Water Quality Monitoring Program Enhancements

Review Comments:

The monitoring program enhancements recommended by NRSI largely reiterate issues addressed elsewhere in this review and do not identify unresolved management questions that would warrant expansion of the core water quality monitoring program at this time. The existing program remains appropriate for its intended purpose and provides a scientifically-sound basis for assessing lake condition and management progress.

With respect to aquatic health, a submerged aquatic vegetation survey was completed in 2025 ahead of the planned Phase 2 schedule in response to observed phytoplankton conditions. The City has been coordinating with the MNRF to stock fish in the lake, and TRCA has been monitoring fish community with results reported in the annual reports. Fish stocking was completed in May 2025 by a private contractor to the City, adding 500 juvenile largemouth bass to the lake. No other aquatic health monitoring is recommended at this time, but could be considered in the future should a need be identified.

Section 4.1 Swan Lake Management Strategy Program Considerations – NRSI recommends several additional lake management and habitat restoration activities to further support the improvement of water quality and aquatic habitat in Swan Lake.

Comprehensive Oxygenation Program - NRSI recommends implementation of a comprehensive oxygenation program to address low dissolved oxygen conditions in Swan Lake.

Review Comments:

- The discussion of oxygenation implicitly assumes that hypoxia or anoxia represents a dominant, lake-wide management issue in Swan Lake. This assumption is not supported by the Phase 1 monitoring results, which demonstrate that observed anoxia is spatially limited, episodic, and confined to a small deep-water area, rather than indicative of a system-wide condition requiring intervention.
- Improvements in dissolved oxygen conditions observed since implementation of nutrient management actions indicate that oxygen dynamics are responding as expected to reductions in nutrient concentrations, which address the underlying cause of eutrophication-driven oxygen demand.
- While NRSI states that management actions should address underlying causes rather than symptoms, the proposed oxygenation measures, assuming these are appropriate for use in Swan Lake, would primarily function as symptom-focused interventions and are not expected to result in meaningful long-term improvements, as acknowledged in the NRSI discussion itself.

Recommendation: That, in the absence of evidence of persistent, lake-wide oxygen impairment or a clearly defined management objective that would be advanced by oxygenation, implementation of a comprehensive oxygenation program is not warranted at this time.

Sediment and Nutrient Management

Review Comments:

Several statements in this section do not accurately reflect the scientific basis, intent, or scope of the City's sediment and nutrient management program as documented in the SLMP.

The PAC/Phoslock treatment program was developed based on a comprehensive scientific assessment conducted by Freshwater Resources Inc., led by Dr. Gertrud Nürnberg, a recognized expert in lake management, eutrophication, anoxia, and internal phosphorus loading. This work included detailed limnological analysis, lake response modeling, and sediment quality evaluation, including Psenner-type sediment fractionation analysis performed at the Institut Dr. Nowak GmbH & Co. KG (Germany). Chemical dosages required to inactivate potentially mobile sediment phosphorus were scientifically determined for distinct lake zones with differing sediment characteristics and were further evaluated and refined by AECOM prior to the treatments in 2021 and 2024.

The scheduling of chemical treatments is not based on visual indicators such as algal mat formation. Treatment frequency (once every three years) was determined through evaluation of the effectiveness of the 2013 Phoslock application, sediment chemistry, observed lake phosphorus concentrations, and modeled estimates of phosphorus accumulation and release rates specific to Swan Lake. As documented in the SLMP, scenario modeling, including consideration of potential climate change impacts, demonstrated that this interval optimizes internal phosphorus load reduction and lake response. This schedule reflects a planned, proactive management strategy rather than a reactive symptoms-based approach.

NRSI's recommendations for a detailed sediment and nutrient management program largely reiterate elements already incorporated into the SLMP. The only additional element identified is the assessment of sediment conditions within upstream stormwater management facilities. Such assessments are not required to understand internal sediment and nutrient dynamics within Swan Lake and are more appropriately addressed through stormwater asset management and maintenance programs. Consideration of additional stormwater-related monitoring could be evaluated as part of a future update to the SLMP or through a focused, question-driven study, if warranted to address a specific management concern.

Finally, while chemical treatments do not directly address external nutrient sources, this distinction is well recognized in the SLMP. The purpose of PAC/Phoslock treatment is to control internal phosphorus loading, which is the dominant driver of lake eutrophication in Swan Lake. External nutrient load reduction is addressed separately and comprehensively in the Plan, with particularly effective reductions achieved through goose management and watershed controls. Internal and external load

management are complementary, not mutually exclusive, and both are necessary to achieve and sustain water quality objectives.

Recommendation: That targeted sediment characterization be considered in Phase 2 to support future PAC/Phoslock treatment planning, recognizing that the most recent comprehensive sediment assessment was completed in 2021 and that lake nutrient concentrations and biological conditions have changed substantially since that time.

Recommendation: That sediment sampling and analytical methods generally follow the established, science-based approach used in 2021, with review and refinement as appropriate based on advances in understanding and management needs.

Recommendation: That inclusion of additional sediment parameters be considered only if results from ongoing water quality monitoring indicate trends or conditions (e.g., changes in internal phosphorus release, dissolved oxygen dynamics, or biological response) where sediment characterization would meaningfully inform management decisions.

Chloride Management - NRSI notes that chloride concentrations in Swan Lake remain above the CCME long-term exposure guideline and supports and recommends the additional chloride reduction measures proposed by FOSLP as “critical to achieving any long-term improvements in surface water and aquatic ecosystems quality”.

Review Comments:

Chloride management is already a recognized priority in the SLMP and is being actively addressed by the City. In recent years, chloride concentrations in Swan Lake have declined substantially. This improvement is largely attributable to the removal of blockages at the East Pond inlet and the Swan Club oil–grit separator, which reduced untreated stormwater delivering higher chloride loads to the lake. The City continues to monitor chloride concentrations at stormwater outfalls and to refine estimates of chloride loading from these sources to improve understanding of source contributions and inform management activities. The City is currently supporting research at York University to evaluate the feasibility and effectiveness of biochar for chloride reduction. At present, this work remains at a research stage and is not yet supported for implementation.

Diversion of stormwater away from Swan Lake could reduce chloride loading from this source; however, such an intervention is not currently warranted based on observed chloride concentrations or evidence of ecological impairment. In addition, potential benefits of diverting water would require careful evaluation of potential negative impacts on lake hydrology, beneficial uses, and the observed recovery trajectory before being considered for implementation. This approach is consistent with the SLMP, which previously evaluated stormwater redirection options and identified such structural modifications as a longer-term, conditional consideration (Phase 3), subject to comprehensive technical studies, downstream infrastructure constraints, and demonstrated need. As documented in the Plan, earlier evaluations concluded that complex and costly drainage system modifications would be a low priority unless other habitat restoration efforts were shown to be unsuccessful due to chloride-related impacts.

While chloride concentrations continue to exceed the CCME long-term exposure guideline of 120 mg/L, exceedance of this guideline alone does not necessarily indicate significant impairment of aquatic habitat. This interpretation is consistent with the CCME guidance, where the guideline is derived to protect the most sensitive life stage of the most sensitive aquatic species over the long term. While concentrations below the guideline are not expected to result in adverse effects, exceedance of a CWQG does not, in itself, imply that aquatic biota are adversely affected or that a waterbody is impaired. The concentration at which effects may occur can vary depending on site-specific conditions, exposure history, and ecological context, and professional judgement is required when interpreting exceedances. Consistent with CCME guidance, chloride guidelines are intended to be applied to ambient surface water conditions rather than concentrations immediately adjacent to point sources such as stormwater outfalls, so the lake chloride monitoring approach for Swan Lake is appropriate for evaluation of chloride in the lake for aquatic health.

Recommendation: That the current chloride management approach outlined in the SLMP be continued under Phase 2, including ongoing lake and stormwater outfall monitoring and refinement of chloride loading estimates and evaluation of lake responses. Based on recent improvements and current conditions, diversion of stormwater from Swan Lake is not recommended at this time.

Recommendation: That any future consideration of stormwater diversion or other large-scale chloride reduction measures should be supported by lake-response modeling that demonstrates a clear and meaningful benefit to lake water quality, and

that explicitly evaluates potential hydrological impacts on water quality, beneficial uses, and the observed recovery trajectory of the lake.

Shoreline Habitat Enhancement - NRSI recommends shoreline restoration and planting to support aquatic ecosystem structure, stabilize nearshore conditions, and contribute to nutrient and sediment load reduction.

Review Comments:

- Shoreline enhancement is already identified as an optional management strategy in the SLMP, recognizing the multiple benefits of riparian vegetation, including habitat enhancement, shoreline stabilization, reduction of localized nutrient inputs, and deterrence of resident Canada geese.
- These measures are complementary to in-lake management actions and support broader ecosystem recovery but are not intended as a primary mechanism for addressing legacy nutrient conditions within lake sediments.
- Past removal of invasive or excessive nearshore vegetation (e.g., phragmites) has been undertaken where warranted, and any future vegetation management should be carefully targeted to balance habitat benefits, nutrient cycling considerations, and overall lake recovery objectives.

Recommendation: That shoreline planting and habitat enhancement be considered for inclusion in Phase 2, in coordination with TRCA, as a complementary measure to support aquatic habitat, shoreline stability, and ongoing ecosystem recovery, while remaining aligned with the broader nutrient management strategy outlined in the SLMP.

Responses to Section 5.0 – Conclusions

Review Comments:

NRSI's conclusions acknowledge that the Swan Lake monitoring program has documented measurable improvements in water quality and that the interim targets established by the City are attainable and reasonable. This is consistent with the findings of the annual monitoring reports and the intent of the SLMP.

However, the repeated characterization of the monitoring program as "high-level" or "limited" does not accurately reflect its design or purpose. The Swan Lake monitoring program is a focused, multi-parameter, long-term program developed to address clearly defined management questions related to eutrophication, internal nutrient loading, chloride, and lake response to implemented controls. It is not intended to serve as a comprehensive ecological inventory or regulatory compliance program, nor is such scope required to support the lake management goals.

Assertions that guideline exceedances or selective guideline application limit interpretation or obscure ecosystem health are not supported when guidelines are interpreted consistent with provincial and federal guidance. Exceedance of a guideline does not, in itself, indicate impairment, and results must be interpreted in the context of lake morphometry, exposure history, management objectives, and observed biological response. The primary causes of degraded conditions in Swan Lake, including internal phosphorus loading and key external nutrient sources, were identified through detailed limnological studies completed prior to implementation of the SLMP and are not unresolved.

Expansion of the monitoring program solely to increase "comprehensiveness" is not warranted in the absence of clearly defined management questions or evidence that existing data are insufficient to guide decisions. As demonstrated through this review, the current monitoring framework is adequate to assess lake condition, track response to management actions, and support adaptive management.

3. Summary of Recommendations

Based on this review, targeted refinements to monitoring and management are recommended for consideration by the City of Markham, where they provide clear decision value and align with the phased approach of the SLMP. These recommendations are summarized below.

Theme	Recommendation
Monitoring Program Focus	Maintain the existing core water quality monitoring program focused on eutrophication and chloride, the primary management issues identified for Swan Lake.
Supplementary Parameters	Consider targeted or periodic monitoring of Total Suspended Solids (TSS), total metals and *E. coli* to provide additional interpretive context, with results used to determine whether ongoing monitoring is warranted.
Excluded Parameters	Do not add routine monitoring for BOD, oil and grease, or PAHs, as these parameters do not align with current management objectives or provide actionable information for Swan Lake.
Sampling Frequency	Maintain the existing biweekly open-water sampling frequency (monthly for phytoplankton), which is appropriate for evaluating seasonal conditions and long-term trends.
Event-Based / Winter Sampling	Consider storm-event or winter monitoring only if a clearly defined hypothesis, contaminant of concern, or management decision is identified during the 5-year plan review.
Monitoring Locations	Maintain existing monitoring locations, which have been demonstrated to be representative of whole-lake conditions relevant to management objectives.
Spatial Expansion	Consider short-term, targeted near-outfall monitoring only if a specific issue or management question is identified that would benefit from increased spatial resolution.
Guidelines and Targets	Continue use of PWQOs, CEQGs, and Health Canada guidelines as contextual reference values rather than compliance standards, while retaining site-specific interim targets aligned with the Long-Term Management Plan.
Trophic State Framework	Continue using the trophic state classification framework defined in the SLMP for consistency in interpretation and reporting.
Chloride Target Review	Revisit and refine the chloride target as appropriate based on recent monitoring results and the Water and Chloride Budget (2025), considering feasible management actions.
Reporting Transparency	Include brief explanations for any missed sampling events or deviations from the annual work plan in future monitoring reports, where applicable.
Oxygenation	Do not implement a comprehensive oxygenation program in the absence of evidence of persistent, lake-wide oxygen impairment or a defined management objective that would be advanced by oxygenation.
Sediment Characterization	Undertake targeted sediment characterization to support future PAC/Phoslock treatment planning, recognizing changes in lake nutrient concentrations and biological conditions since the last comprehensive assessment (2020).
Sediment Methods	Apply the established, science-based sediment sampling and analytical approach used in 2020, with review and refinement as appropriate.
Additional Sediment Parameters	Include additional sediment parameters only if results from ongoing water quality monitoring indicate conditions where sediment data would meaningfully inform management decisions.
Chloride Management	Continue the current chloride management approach outlined in the SLMP, including lake and stormwater outfall monitoring and refinement of chloride loading estimates.
Stormwater Diversion	Do not pursue stormwater diversion at this time. Consider only if future lake-response modeling demonstrates a clear benefit and evaluates hydrological impacts, beneficial uses, and the lake's recovery trajectory.
Shoreline Enhancement	Consider shoreline planting and habitat enhancement as a complementary measure to support habitat quality, shoreline stability, and deterrence of resident Canada geese.

Swan Lake Long-Term Management Plan Update
Expert Consultation and Engagement

Meeting with Natural Resources Solutions Inc. (NRSI)

Environmental Services
Robert Muir, Manager, Stormwater
Zahra Parhizgari, Environmental Engineer, Stormwater
Dr. Tammy Karst-Riddoch, PhD

February 10, 2026

Agenda

- Introduction
- Purpose of Meeting
- NRSI's Scope
- Summary of Lake Conditions
- Comparisons
- Path Forward

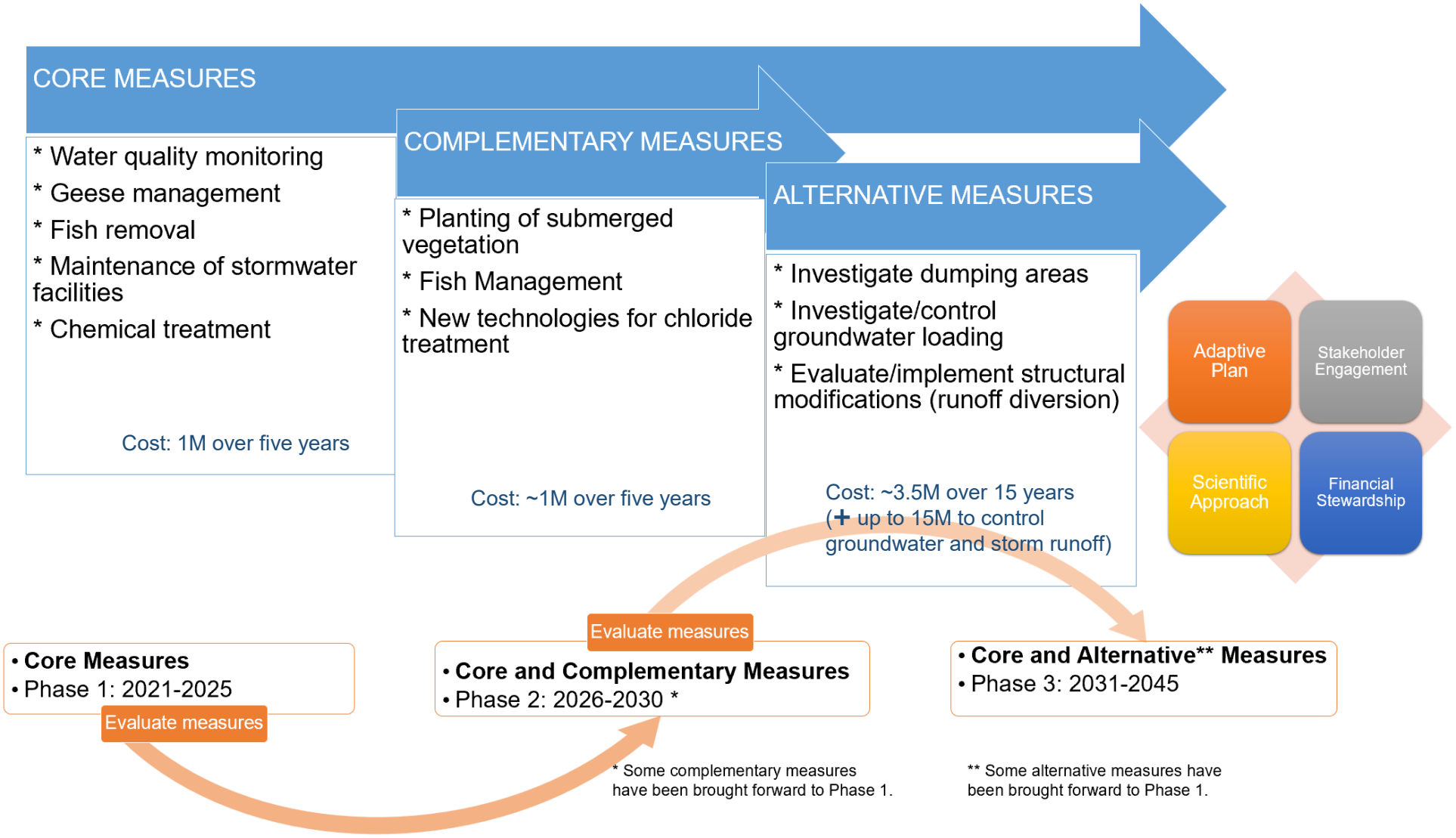
Purpose of Meeting

- Phase 1 of Swan Lake Long-Term Management Plan (SLMP- see next slide) has been completed successfully
- Consultation is a critical step in the adaptive management approach to Swan Lake Water Quality Improvement
- Expertise was solicited by Friends of Swan Lake Park (FOSLP) as part of their feedback to the SLMP five-year review
- City reviewed reports submitted through FOSLP and provided feedback

PURPOSE

- To understand how NRSI's report conclusions were developed
- To compare those conclusions with measured lake data
- To reconcile areas where statements and field results differ
- To identify opportunities for updated or refined assessments

Long Term Management Plan (2021)



Plan Review Process

Expert Consultation and Engagement

- Engage with deputants and technical stakeholders involved in the Markham Subcommittee process
- Participate in a workshop or other interactive consultation with external experts and agencies (e.g., TRCA, MNRF)
- Review of stakeholders' input

Study

- Update existing condition
- Review of management outcome
- Evaluate additional management measures
- Review and update goals, objectives and targets
- Update strategy and implementation plan

Plan Update

- Share draft report with stakeholders
- Receive feedback
- Present final report to Markham Subcommittee

NRSI Reports Scope

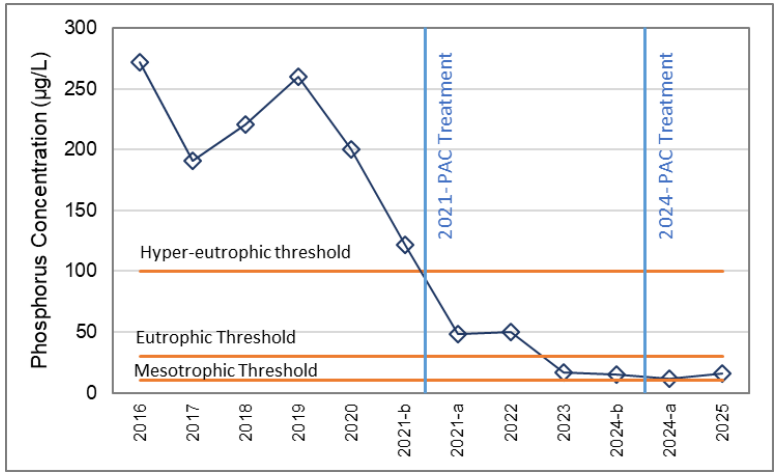
- Swan Lake Long-Term Management Plan: Water Quality Monitoring Program Preliminary Review (NRSI 2025a)
- FOSLP retained NRSI to:
  - Complete a peer review of the monitoring and reporting completed to date as part of the City of Markham's 25-year water quality monitoring program preliminary (Phase 1)
- The report also provides general guidance and recommendations to support the long term Swan Lake water quality objectives, including strategies, research areas, additional actions.

- Literature Review of Management Options and Effects of Increased Oxygenation in Swan Lake (NRSI 2025b)
- FOSLP retained NRSI to:
  - Complete a literature review examining the potential benefits of increased oxygenation on surface water quality and overall ecological conditions within Swan Lake
  - Evaluate available methods to enhance oxygenation, along with their associated impacts, feasibility, and applicability to the lake's specific conditions.

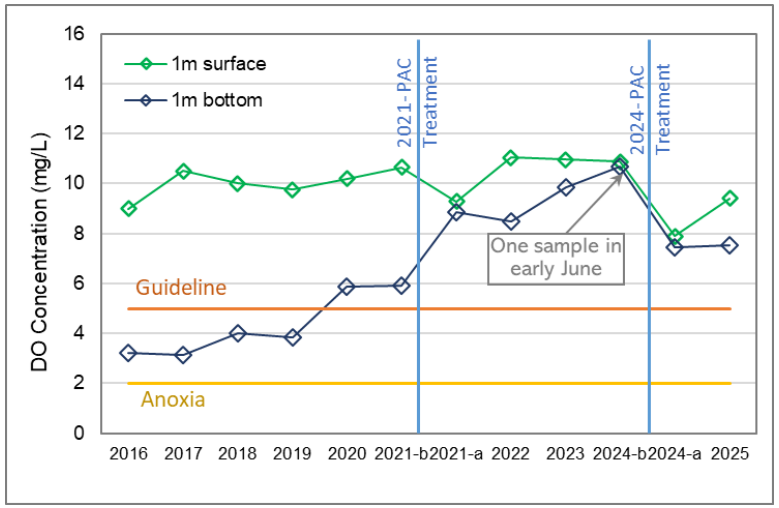
Current Lake Conditions and Trends

Water Quality- Nutrients and Oxygen

- Total Phosphorus:
  - Average under 30 µg/L during growing season (within Mesotrophic condition)
  - Decreased after each treatment
- Total Nitrogen:
  - Average below 0.65 mg/L during growing season (within Mesotrophic condition)
  - Dominant forms not bioavailable
- Dissolved Oxygen:
  - Surface concentration > 5 mg/L all year
  - Bottom concentration showed a decline during dry months
  - Observed anoxia is spatially limited, episodic, and confined to a small deep-water area



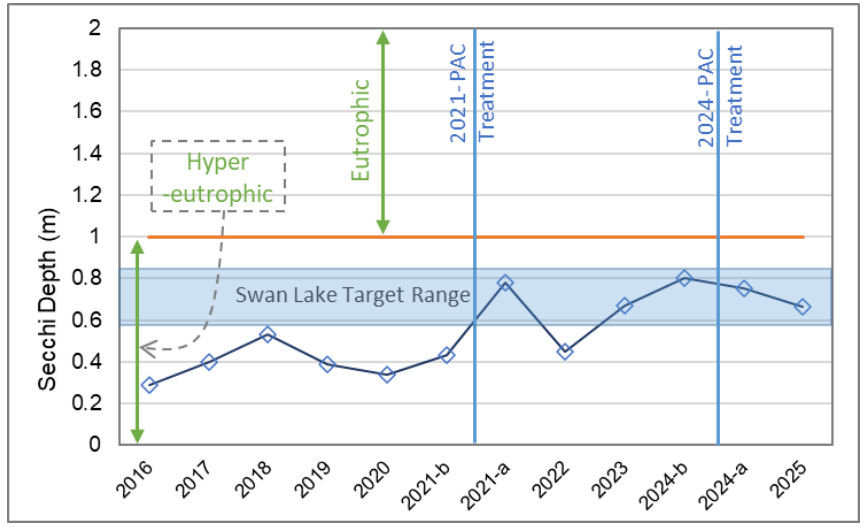
Phosphorus



Dissolved Oxygen

Water Quality- Algae and Clarity

- Algal growth:
  - Surface bloom very limited since treatment
  - Recent Cyanobacteria cell numbers declined significantly since treatment
  - Chlorophyll-a within eutrophic state, and below Health Canada chl-a indicator value used to flag possible cyanotoxin levels that exceed primary-contact recreational guidelines.
- Clarity: Mostly within target, average growing season met target

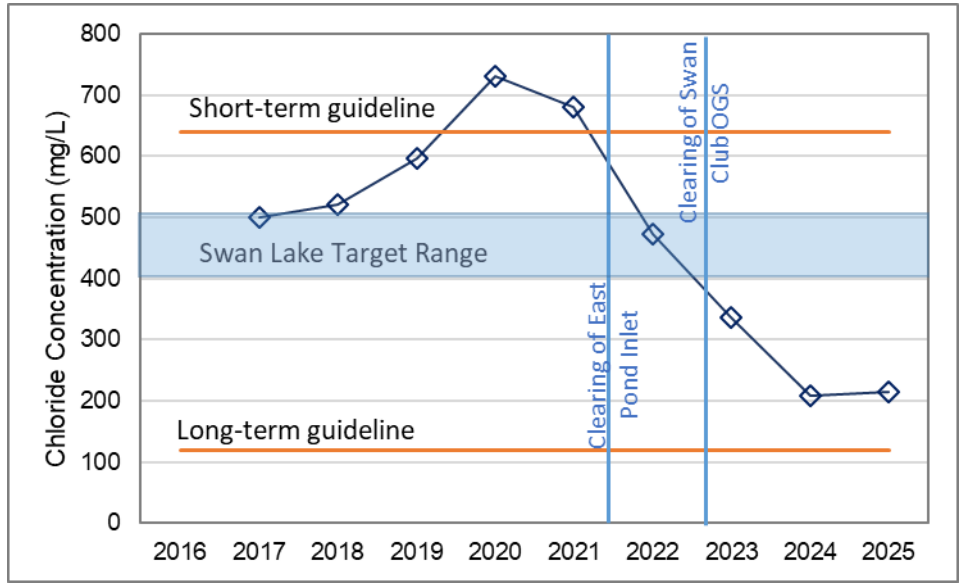


Algal bloom before treatment (photo from July 2020)

Very limited surface bloom since treatment (photo from July 2025)

Water Quality- Chloride

- Chloride enters the Lake through winter maintenance:
  - Swan Lake Village Corporation
  - City roads
  - Residents north of the Lake
  - AMICA Corporation to the south
- Previously on upward trend likely due to blockages, which resulted in untreated flows to the Lake
- Since 2021 decreased due to clearing the blockage at the East Pond inlet and Swan Club OGS
- Long-term guideline derived to protect *the most sensitive life stage of the most sensitive aquatic species* over the long term



Fish Management

- Removing bottom-dwelling fish to prevent sediment disturbance.
- Fish in the Lake included Common Carp, Brown Bullhead, and Fathead Minnow.
- 500 juvenile largemouth bass added in May 2025.

Bass stocked in May 2025

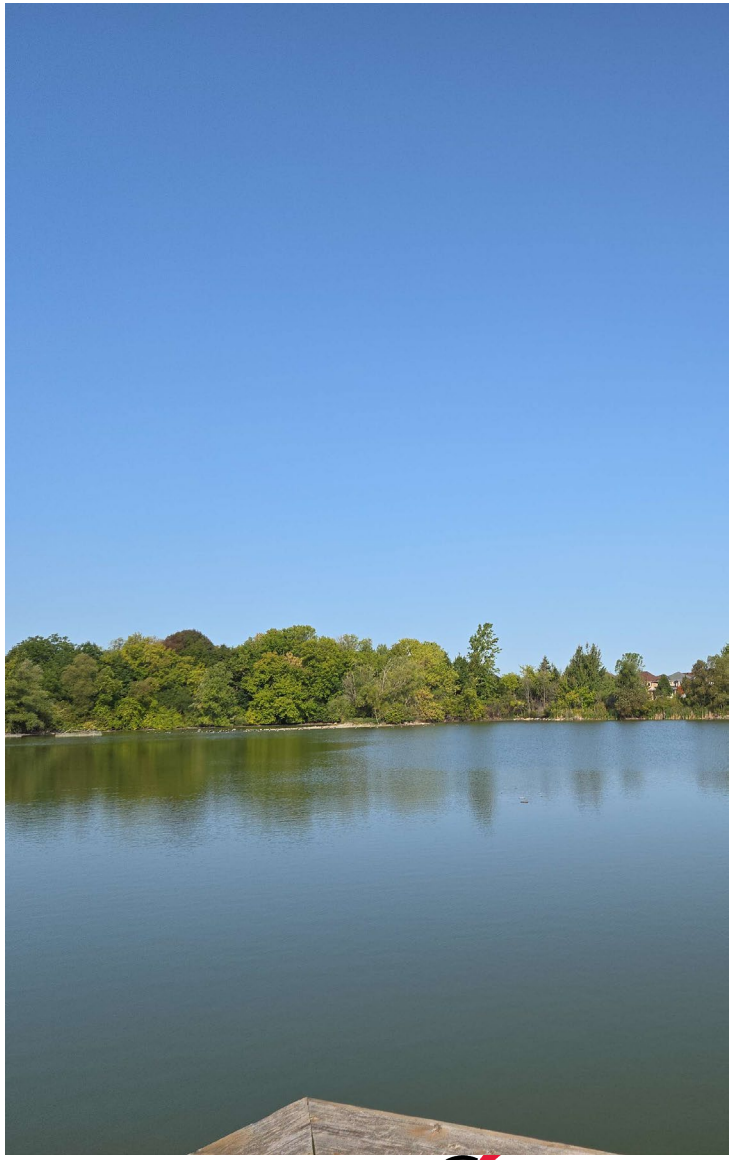
Submerged Aquatic Vegetation

- 3000 stems of wild celery planted in fenced locations on the north site in 2023 and 2024
- Naturally growing aquatic plants were also abundant in 2024 and 2025
- Further SAV planting will be assessed through the five-year review process
- 2025 survey indicated SAV was abundant throughout the lake

Aquatic Vegetation Survey in July 2025

Program Outcomes

- Significant improvements in water quality and habitat have been realized, including aquatic vegetation and fish community
- Water quality now consistently meets expectations for shallow urban water bodies
- Innovative technologies and academic research are actively being evaluated
- Phase 1 of the Long-Term Management Plan has successfully met all established goals and targets.



Comparison

Guidelines and Targets

* See next slide for chloride

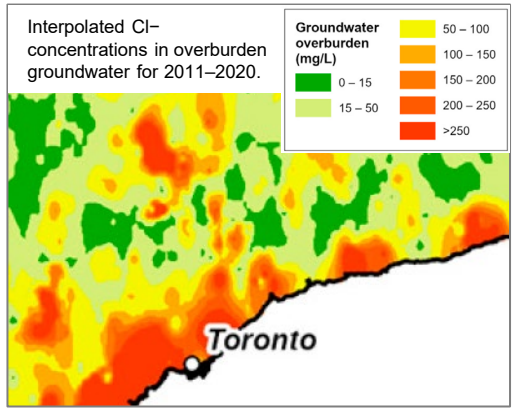
- Report Recommendations:
  - NRSI discussed provincial policies for water quality and recommends water quality guidelines for several parameters for inclusion in the analysis of the Swan Lake monitoring program results moving forward
- Review:
  - Not adequately distinguish between regulatory application of PWQOs and their optional, contextual use in non-regulatory lake monitoring programs, which is designed to support lake management decision-making, not regulatory compliance
  - PWQO deviation policies and exemption processes apply to point-source effluent approvals
  - Where PWQOs, CEQGs, or Health Canada guidelines are relevant (e.g., DO, cyanobacteria), they are already included
  - Comments on Secchi depth, and trophic-state ranges targets do not align with the relevant regulatory guidelines or Swan Lake's lake-specific objectives

Clarification:
Could you clarify why guidelines intended for regulatory compliance or point-source effluent settings are recommended for Swan Lake, which is managed under lake-specific objectives rather than compliance standards?

* PWQOs/CEQGs for nitrate and total ammonia (or unionized ammonia) could be added to the report for context.

Guidelines and Targets- Chloride

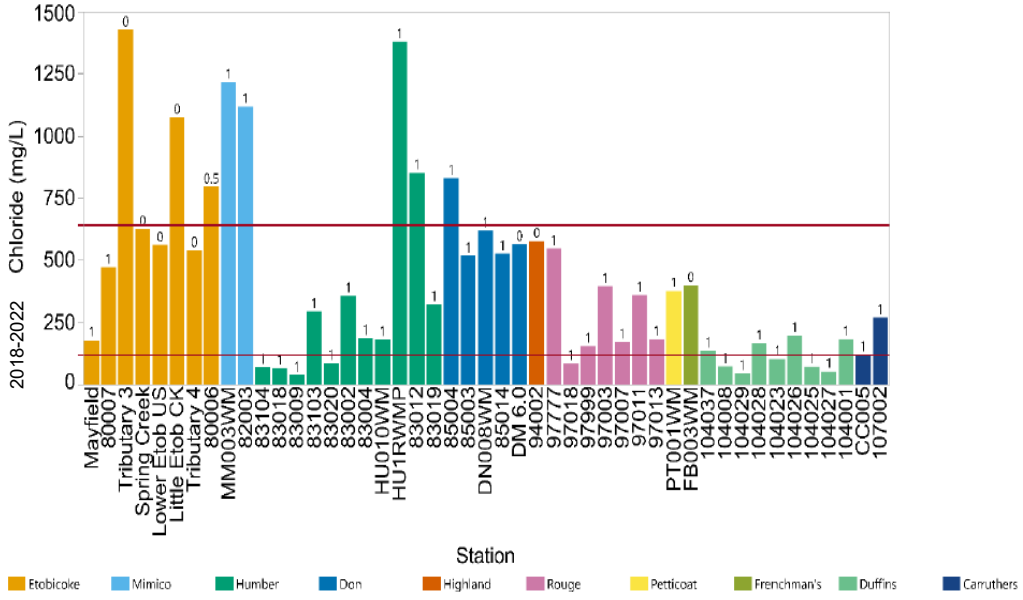
- Review:
  - Exceeding the CCME guideline does not automatically indicate habitat impairment; guideline interpretation requires consideration of site-specific conditions and exposure context.
  - Swan Lake concentrations are comparable to similar systems in this area, e.g.,:
    - Surface water concentrations in Rouge Watershed urban streams ranges from 200-500 mg/L
    - Shallow (overburden) concentrations are commonly over 200 mg/L in urban areas in the GTA
    - Groundwater concentrations in shallow formations can be high – well ID 382-1 near Milne Reservoir had concentration of 527 mg/L (2009 – 2021 data)
    - Chloride levels in the MOE Demonstration Pond study carried by MOE and the City: from 100 in summer/fall to 325 mg/L in winter



Source: Geospatial Analysis of Chloride Hot Spots and Groundwater Vulnerability in Southern Ontario, Canada Ceilidh Mackie * , Rachel Lackey and Jana Levison, 2025

Clarification:

Could you provide examples other similar lakes meeting the long-term CCME chloride guideline?



Source: Toronto Region Source Protection Area: Surface Water Quality Update, Cartwright, July 2024

Monitoring Program Scope

- Report Claims:
  - Confirms that existing monitoring program is consistent with best practice for eutrophication monitoring and supports long-term assessment of aquatic ecosystem
  - Recommends modifications, including addition of parameters, increased sampling frequency, and expansion of monitoring locations within the lake.
  - Characterizes Swan Lake as an "ad hoc" stormwater management facility and recommends several stormwater-related parameters
- Review:
  - Routine lake monitoring should remain focused on parameters tied to SLMP objectives
  - Most stormwater-related contaminants (hydrocarbons, metals, oil/grease) are more effectively monitored and managed at SWM facilities. Prior to sediment removal, samples will be collected from the ponds to meet Excess Soil Regulations.
  - Annual fish inventory is completed, and aquatic vegetation was surveyed in 2025.

Clarification:

Can you clarify how monitoring stormwater contaminants (such as hydrocarbons, oil/grease, PAHs, and general stormwater contaminants) would materially inform lake-management decisions?

* Consideration will be given to targeted or periodic monitoring of TSS, total metals and *E. coli* to provide additional interpretive context, with results used to determine whether ongoing monitoring is warranted.

Monitoring Frequency and Stations

- Report Recommendations:
  - Recommends additional spring freshet, storm-event, and winter dissolved oxygen monitoring, to provide higher-resolution characterization of water quality conditions and stormwater influences
  - Additional monitoring sites are required because the lake is relatively stagnant increasing spatial variability
- Review:
  - The current program captures key seasonal and storm-related variability, and mass-balance confirms that major phosphorus sources are well characterized.
  - Winter under-ice sampling would add safety risks and limited management value, no unresolved contaminants of concern have been identified
  - NRSI's description of Swan Lake as "stagnant" is inconsistent with its shallow, wind-mixed hydrodynamics, residence time (~1.7 years)
  - Monitoring data showing that existing stations accurately represent whole-lake conditions

Clarification:
Which specific hypotheses, contaminants of concern, or pending management decisions would warrant additional (a) event-based or winter sampling, and (b) short-term, near-outfall monitoring?

Reporting of Results

- Report Claims:
  - That there were multiple 'omissions' of monitoring events, multiple gaps in full sampling coverage, and omissions in reporting of data that could lead to misinterpretation of the results
- Review:
  - Assertions that omitted monitoring events, reporting gaps, or limited spatial coverage could mischaracterize conditions or falsely suggest improvement are not supported.
  - NRSI provide no specific reference to dates of missing monitoring events or data to support their assertion
  - Field data and laboratory certificates of analysis are also provided in appendices of the annual reports for transparency
  - Monitoring frequency met or exceeded the planned biweekly schedule
  - No collected data were omitted from reporting, and existing sampling locations have been demonstrated to be representative of whole-lake conditions relevant to management objectives.

Clarification:
Which specific monitoring events, dates, or datasets you believe were omitted or insufficiently reported?

* Very few sampling events were missed, however, they do not change the reports' conclusions. Any missed samples will be documented in future reports.

Dissolved Oxygen

- Report Claims:
  - "the overall validity of the assertation that the conditions within Swan Lake are in excess of the recommended guidelines is somewhat in question .." and that "this suggests that the sampling coverage within Swan Lake may not adequately characterize the overall water quality conditions"
- Review:
  - Low-oxygen concerns raised by NRSI overlook depth, duration, and spatial extent
  - Continuous DO logger data were misinterpreted; near-bottom anoxia is expected at 2.75 m depth and does not conflict with discrete profile data. City and Trent U data are consistent
  - Anoxia occurs only in the deepest 3–5% of lake area and 1–3% of lake volume, showing it is spatially limited and not lake-wide.
  - When interpreted according to PWQO/CCME intent, DO conditions meet guidelines, and post-management monitoring shows major improvement compared to pre-SLMP conditions.

Clarification:
Which specific aspect of the DO assessment do you feel requires further explanation?

Oxygenation Program

- Report Recommendations:
  - Implementation of a comprehensive oxygenation program to address low dissolved oxygen conditions in Swan Lake
- Review:
  - Hypoxia/anoxia is not a lake-wide issue; monitoring shows it is limited, episodic, and confined to a small deep-water area.
  - DO levels have improved following nutrient-reduction measures, indicating the system is responding as expected.
  - Proposed oxygenation measures address symptoms rather than underlying causes and are unlikely to provide lasting benefits.
  - Without evidence of persistent, lake-wide oxygen impairment, a full oxygenation program is not justified.

Clarification:
Are there any specific data points or monitoring results that led to the conclusion that lake-wide oxygenation is warranted despite evidence showing anoxia is spatially limited?

Literature Review of Oxygenation Methods (NRSI 2025b)

- Report Scope:
  - "Peer-reviewed journal articles, government publications, technical manuals, and documented case studies were examined to assess the potential effects of increased oxygenation on shallow surface waterbodies"
- Review:
  - Oxygenation methods were reviewed through the development of the Swan Lake Water Quality Strategy (Freshwater Research 2019) and further as part of the review of FOSLP reports in 2020.
  - FOSLP also solicited a proposal from Fleming College in 2021 to complete a Literature Review of Potential Engineering Solutions for the Restoration of Swan Lake, including oxygenation. This report was reviewed by FWR, and they advised against direct oxygenation. Water quality conditions have improved since the time of the Fleming College report.

Clarification:
What new information or rationale would this latest review contribute beyond the previous assessments?

Sediment and Nutrient Management

- Report Claims:
  - Chemical treatment planning is based on visual indicators such as algal mat formation
  - Need for a detailed sediment and nutrient management program
- Review:
  - The treatment program was developed through expert-led scientific assessment, modeling, and sediment analysis, with dosage refined for different lake zones. Treatment timing is science-based, not triggered by visible algal conditions.
  - Many of NRSI's recommendations repeat framework elements from SLMP, with ponds sediment assessment the only new suggestion. This assessment is not required to understand internal sediment and nutrient dynamics within Swan Lake
  - Future sediment characterization (Phase 2) will follow the established 2021 methods and only expand parameters if monitoring data indicate trends requiring deeper investigation.

Clarification:
Which specific aspects of the treatment planning process or sediment assessment methods were not fully addressed by the existing SLMP framework?

* Targeted sediment characterization will be done to support future chemical treatment planning, recognizing changes in lake nutrient concentrations and biological conditions since the last comprehensive assessment (2020).

Chloride Management

- Report Claims :
  - Recommends that additional chloride reduction measures proposed by FOSLP are "critical to achieving any long-term improvements in surface water and aquatic ecosystems quality"
- Review:
  - Chloride management is already a priority under the SLMP, and chloride levels in Swan Lake have decreased due to resolving stormwater outfall blockages
  - The City continues to monitor chloride at stormwater outfalls, refine loading estimates, and support research on potential reduction methods such as biochar (still at research stage).
  - Stormwater diversion could reduce chloride inputs but is not justified based on current concentrations compared to similar systems, and lack of ecological impairment.

Clarification:
Which specific chloride concentration trends, biological indicators, or site-specific concerns suggest the current SLMP chloride management approach may be insufficient?

Path Forward

- Will NRSI update their submissions considering City feedback?
- City will incorporate the following input in the Phase 2 Plan:
  - Targeted or periodic monitoring of TSS, total metals and *E. coli* to provide additional interpretive context
  - Documenting missing sampling events
  - Targeted sediment characterization to support future chemical treatment planning
  - Pond sediment characterization will be completed based on regulatory requirements for Excess Soil management

Swan Lake Water Quality- Meeting with NRSI

February 11, 2026

Meeting Minutes
Swan Lake Water Quality Consultation- Meeting with Natural Resources Recovery Inc. on February 10, 2026

Location:	8100 Warden Ave.
Date:	February 10, 2026
Time:	1 pm- 4:30 pm
Attendees:	City: Zahra Parhizgari (ZP) City Consultant: Tammy Karst-Riddoch (TKR) FOSLP: Fred Peters (FP) FOSLP Consultants: Blair Baldwin (BB) and Stephen Burgin (SB) from NRSI
Regrets:	City: Robert Muir

I. ZP went over the City presentation, describing the lake management long-term plan, current conditions of the lake, and comparison of observed data with the NRSI report (Swan Lake Water Quality Monitoring Program Preliminary Review, referred to as 'the report') commissioned by Friends of Swan Lake Park (FOSLP).

II. Additional parameters- In relation to NRSI's suggestion to measure more parameters and in more locations, BB said the difference is mostly the objective for Swan Lake. Is it a natural environment or a degraded urban pond, and what we want to make it. If we do not know what is in the lake, we cannot improve it.
ZP asked how that helps us. TKR asked if there was a source of PAHs in the catchment. BB said we do not know and they might be high. TKR said some suggested parameters may be useful, such as TSS to help differentiate between phytoplankton and other particulates and dissolve organic carbon that affects turbidity. Metals have been historically low but have not been analyzed for several years. *E. coli* can be an indicator of geese population. BB agreed that stormwater parameter monitoring can be seasonal. TKR noted that the position of the monitoring location at the dock would capture stormwater influence.

III. Additional station and sampling events- BB said biweekly samples do not answer the question of influences. TKR said wet weather monitoring is typically for rivers but that the biweekly sampling may capture some wet weather events (i.e., a minimum of 15 mm of rain in the previous 24 hours). Current nutrient model produces good estimates for nutrients indicating that monitoring frequency and stations capture influences of stormwater. BB agreed the Trent stations showed water quality is approximately consistent throughout the lake.

IV. Monitoring results- ZP reiterated that claiming many data points are missing and the annual report misrepresents the lake conditions are inaccurate. BB identified one missing event on the plots but will provide any other ones they identify. TKR said this is a multi-year program and missing a few events does not qualify for 'misrepresentation' and would not affect the interpretation of water quality. BB agreed that this might be strong wording.

V. Oxygenation- TKR explained the limited extent of anoxia. She presented a graph of lake elevation showing that Photosynthetically Active Radiation (PAR) can reach the sediments in most of the lake based on Secchi depth measurements. The deepest area has a tiny volume and there is physical limitation to mixing in that area because of the shape of the lake bottom, and it will go anoxic no matter what you do (oxygen will be rapidly used up in this small volume of water given the production of algae and plants in the much large volume of water above).
FP said some areas may benefit from oxygenation through a mechanical device in the deep area. He also mentioned that a core request of FOSLP is to bring the fountain back if cHAB is low. ZP explained artificially adding oxygen could cause higher Biological Oxygen Demand (BOD) which was the main reason for rejecting artificial oxygenation even when the oxygen levels were low.
TKR also explained that a depth of two meters is not enough for oxygenation by diffusion using air, and adding pure oxygen is too complex. You would also have to raise the diffuser above the sediment so the sediment-water interface would not get oxygenated, which is the main issue.
NRSI agreed that there is no DO issue in general and that the newly established vegetation could address any potential DO concern.

VI. Sediment and nutrient management- FP said that City targets are based on observation of algal mat. ZP explained that treatment is scientifically planned. Treatment is currently planned for every three years based on modeling, unless there is a large bloom, which might trigger a treatment.
BB is interested in the concentration of heavy metals in sediment for impacts on aquatic life. He expects them to be very low, but it is good to make sure they are not the limiting factor. We can ask Trent about sediment analysis they completed.

VII. Fish- FP asked if there would be more fish stocking. TKR said we will consult with TRCA and MNR after the fish inventory to prevent minnow population from collapsing with too much bass.
SB asked if we plan to have a self-sustaining bass population. This is not known given the lake depth and temperature.
BB said we may see fish kill due to harsh winter. If this happens in future, we could consider protection.

VIII. Guidelines and targets- TKR said we do not have objections to comparing results with provincial guidelines and have done so for most parameters where they were relevant. But, we do not agree that if in some cases we do not meet those guidelines, that the water is impaired. Our targets are to track success. BB said to consider those guidelines but agreed that lake objectives could be above those and still be reasonable. City agreed to show additional guidelines (e.g., for nitrate and ammonia) in annual reports.

IX. Chloride- BB said It is better to bring chloride lower to sustain more species. TKR said threshold for bass is orders of magnitude higher. BB agreed that there are very few urban lakes in Ontario that meet 120 mg/L and most are higher, up to 700 mg/L.
FP said it is possible to make chloride lower with flow diversion. ZP said this has not been established given the uncertainty about replacement water (e.g., groundwater concentration).

X. FP asked if we are doing more vegetation monitoring? TKR suggested every three years, pending the results of the management plan review. BB agreed that it is a good frequency and recommended establishing a formal monitoring program.

Action Items	Owner(s)	Deadline
To include additional guidelines in annual reports for perspective	City	Ongoing
To include additional parameters such as TSS, metals and *E. coli* on a seasonal or as-needed basis to the monitoring program	City	Ongoing
To provide a list of missing samples which could result in misinterpretation of lake conditions	NRSI	Mar 1, 2026
To update report not to imply City omits and misrepresents data in City's annual reports	NRSI	Mar 1, 2026
To update report to reflect new understanding of DO in the lake and relevant recommendations	NRSI	Mar 1, 2026
To request sediment data from Trent U.	City	Feb 20, 2026
Provide 2025 annal report	City	April, 2026
To share presentation with NRSI	City	Feb 20, 2026

BURNSIDE

Swan Lake Aquatic Conditions Review

Friends of Swan Lake Park

Swan Lake Aquatic Conditions Review

Friends of Swan Lake Park

R.J. Burnside & Associates Limited
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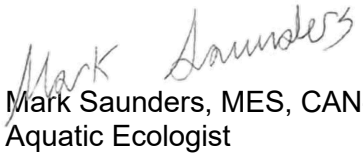
1	November 7, 2025	Draft Submission to Friends of Swan Lake Park
2	November 26, 2025	Final Submission to Friends of Swan Lake Park
3	February 26, 2026	Revisions following meeting with City of Markham on February 10, 2026

R.J. Burnside & Associates Limited

Report Prepared By:



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Executive Summary

- R.J. Burnside & Associates Limited (Burnside) reviewed aquatic habitat conditions in Swan Lake at the end of Phase 1 of the Long-Term Water Quality Management Plan, on behalf of the Friends of Swan Lake Park, to guide recommendations for Phase 2.
- Despite improvements to overall water quality, internal nutrient loads and chloride concentrations may impede current and future ecological restoration efforts if left unaddressed.
- Construction of a bioswale system in the north channel or adjacent to stormwater/ oil grit separator outlets could assist in water quality management by helping to remove and sequester internal nutrients and/or chloride loading.
- Elevated chloride concentration and predation from abundant Fathead Minnows may be suppressing zooplankton grazers (e.g., *Daphnia* spp.), although no study has yet confirmed this relationship.
- Burnside recommends assessing the present zooplankton community to determine whether the working hypothesis (i.e., low *Daphnia* spp. abundance may be contributing to elevated phytoplankton biomass) holds true. The initial survey may serve as a baseline to monitor if key zooplankton populations recover over the course of Phase 2.
- Largemouth Bass stocking in 2025 provides an opportunity to potentially reduce Fathead Minnows. Establishment of a population of bass may be supported by adding complex woody material structures. Future aquatic surveys (i.e., spring (i.e., winter kill) and summer during 2026) are recommended to determine whether current lake conditions are suitable for sustaining bass, especially to overwinter, or if further habitat modifications (e.g., deepening the pond or raising the lake level, addition of physical habitat) may be worth exploring to improve survivability.
- There are limited opportunities to use native Unionidae mussels or sunfish species to improve habitat quality.
- Due to turbidity from phytoplankton, efforts should focus on creating a sustained period of low turbidity before pursuing further submerged macrophyte restoration.

Table of Contents

1.0 Background 1
2.0 Literature Review Methods 2
3.0 General Overview of End of Phase 1 3
4.0 Turbidity and Dissolved Oxygen 6
4.1 Artificial Aeration 6
4.2 Evaluation of Proposed Bioswale 8
5.0 Chloride 11
6.0 Zooplankton and Macroinvertebrates 12
6.1 Zooplankton (*Daphnia* spp.) 12
6.2 Macroinvertebrates 13
6.3 Freshwater Mussels 14
7.0 Fish Community 14
7.1 Control of Minnows via Biomanipulation 14
7.2 Limitations to Largemouth Bass Survival in Swan Lake 16
7.3 Other Fish as a Means of Biomanipulation 18
8.0 Aquatic Vegetation 19
9.0 Recommendations 21
10.0 Conclusion 22
11.0 References 23

Tables

Table 1: Interim Water Quality Targets for the Phase 1 (2021-2025) Adapted from Parhizgari (2021) and FOSLP (2025a) 3
Table 2: Average Inorganic Water Parameters (Mean ± SD) in Swan Lake during 2025 (April 24-Sept 24, 2025) n=1-6 4
Table 3: Summary of Aeration Recommendations for Swan Lake from Anderson and Baldwin (2025a) 7
Table 4: Lake Turnover (80,000 m^3) from April-October (214 days). Adapted from FOSLP (2023) 9
Table 5: TRCA Swan Lake Fish Surveys During Phase 1. Bottom Feeding Fish (Catfish, Common Carp, and Goldfish) Were Euthanized. All Other Species Returned Alive to the Lake (FOSLP 2025b) 16
Table 6: Macrophyte Types Observed and Recommended Plantings in Swan Lake 1993 and 2024. Adapted from FOSLP (2025b) 20
Table 7: Summary of Recommendations to Improve Biological / Ecological Conditions During Phase 2 21

Figures

Figure 1: Swan Lake and Runoff Monitoring Stations. Image provided by FOSLP. Image Quality Improved through GPT-5 (OpenAI 2025a) 1
Figure 2: Proposed Route for Bioswales. Image from FOSLP (2023). Image Quality improved through GPT-5 (OpenAI 2025a)..... 8
Figure 3: Location of Three Oil Grit Separators (Red Circles) Responsible for 56% of Chloride Inputs. From FOSLP (2023).....11
Figure 4: Summary of Swan Lake Macroinvertebrate Survey (2023). Image Modified from FOSLP (2025b).....13
Figure 5: Proposed Biomanipulation to Achieve a Top-Down Trophic Cascade in Swan Lake. Created with assistance from GPT-5 (OpenAI 2025b).....15
Figure 6: Bathymetric Map of Swan Lake. Provided by FOSLP 17

Photos

Photo 1: North Channel Dry at Time of Inspection, Containing Remnants of Landfill Waste. Represents a Beautification and Bioswale Opportunity 9
Photo 2: Splitter Outlets of the East (A) and North (B) SWM Pond 10

List of Abbreviations

AI	Artificial Intelligence
BOD	Biological Oxygen Demand
DO	Dissolved Oxygen
FOSLP	Friends of Swan Lake Park
TRCA	Toronto and Region Conservation Authority
SWM	Stormwater Management
OGS	Oil Grit Separator
PAC	Poly-aluminum Chloride

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1.0 Background

Swan Lake is a 5.5 ha artificial lake in the City of Markham, created from a former gravel quarry excavated during the 1960s-1970s (FOSLP 2025a). Once dewatering operations ceased, the pit filled naturally with groundwater. During the 1970s, the site was used as a local landfill, and some illegal dumping occurred.

By the 1990s, the area surrounding Swan Lake was slated for urban development (FOSLP 2025a). The *Swan Lake Community Environmental Management Study* (December 1993) proposed converting the quarry into a public park and community feature with restored aquatic and terrestrial habitat. Markham accepted the plan in 2000.

Swan Lake has no natural surface inflows or outflows (FOSLP 2025a; Figure 1). It was incorporated into the stormwater management (SWM) system, receiving runoff from six stormwater sources and discharging through one outflow that regulates water levels at ~208.3 m above sea level, with an average depth of 1.65 m.

Figure 1: Swan Lake and Runoff Monitoring Stations. Image provided by FOSLP. Image Quality Improved through GPT-5 (OpenAI 2025a)

Persistent poor water quality and recurring algal blooms led local residents to form the Friends of Swan Lake Park (FOSLP) in 2019. Their goal is the rehabilitation of aquatic and terrestrial habitats to achieve sustainable water quality for long-term human and wildlife use. In 2020 FOSLP submitted *A Pathway to Sustainable Water Quality for Swan Lake* to City Council, prompting the 25-year *Long-Term Water Quality Management Plan* launched in 2021 (Parhizgari 2021). The plan's stated goal is "to improve the overall health of Swan Lake, which will provide opportunities for no-contact activities for the enjoyment of the community" (Parhizgari 2021).

Thus far, Phase 1 has been completed and now progressing into Phase 2:

- **Phase 1 (2021-2025)** targeted immediate water-quality improvements (chemical phosphorus reduction, geese management, invasive-species management, and pilot aquatic plantings)
- **Phase 2 (2026-2030)** is under review by Markham. FOSLP is recommending improved oxygen levels through circulation improvements, chloride reduction, sustaining nutrient levels and stronger ecological monitoring

FOSLP retained R.J. Burnside & Associates Limited (Burnside) to provide a preliminary review of aquatic habitat conditions at the end of Phase 1 and provide recommendations entering Phase 2. The following focuses on impacts and recommendations to support potential improvements for aquatic life (zooplankton, invertebrates, fish, and macrophytes).

2.0 Literature Review Methods

A literature review was conducted of the most recent reports commissioned in relation to the Swan Lake study, including those previously prepared for or by the FOSLP. Burnside visited Swan Lake with Fred Peters of FOSLP on October 15, 2025, to observe the condition of the lake, stormwater management facilities, and surrounding parklands.

Additional literature was reviewed on small, shallow, eutrophic, temperate lakes, with an emphasis on studies from North America or the northern hemisphere. While recent publications (post-2010) were prioritized, foundational and frequently cited papers were also referenced to provide context and theoretical background.

Portions of this report were edited using Artificial Intelligence (AI)-assisted editing tools in ChatGPT (OpenAI) to improve clarity and readability. AI was also used to help improve poor figure quality and to generate an illustrative figure (OpenAI 2025a; OpenAI 2025b). All research, technical analysis, writing, and interpretations are the author's own.

3.0 General Overview of End of Phase 1

Throughout Phase 1, total phosphorus and nitrogen species levels have improved from hypereutrophic conditions in 2020 to mesotrophic conditions by 2024 (Parhizgari 2025). The most recent FOSLP report indicates that the interim water-quality targets for Phase 1 were nearly achieved (Table 1). Monitoring data collected in 2025 support the continued positive trends observed during Phase 1 (Table 2). Nutrient concentrations (i.e., total phosphorus and nitrogen species) remain low and below target thresholds, indicating ongoing improvement in water quality. However, chloride concentrations and conductivity remain elevated (approximately 200 mg/L).

Table 1: Interim Water Quality Targets for the Phase 1 (2021-2025) Adapted from Parhizgari (2021) and FOSLP (2025a)

Parameter	Levels 2020	Interim Target	Objective and Rationale
Total Phosphorus (mg/L)	>0.2	0.05-0.1	Current Value: The average of the growing season TP values in the period since 2016 has been 0.2 mg/L. Interim target: will provide a low eutrophic condition in the first year after treatment increasing to eutrophic in year three.
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 Three 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 conservation target (see above)
External Phosphorus Load (kg/yr)	30	15	

Table 2: Average Inorganic Water Parameters (Mean ± SD) in Swan Lake during 2025 (April 24-Sept 24, 2025) n=1-6

Parameter	Surface (S2025)	Dock 0.5 m (S105)	Dock 1.5 m (S115)	Mid Lake (Ultrasound Transducer)	Interpretation
Total P (mg/L)	0.018±0.008	0.013±0.004	0.016±0.005	0.021±0.002	Below interim target range (<0.05)
Orthophosphate (mg/L)	0.006	ND	ND	ND	Minimal soluble P
Nitrate + Nitrite (m/L)	ND	ND	ND	0.11	Minimal Nitrogen species
Total Kjeldahl Nitrogen (mg/L)	0.59±0.13	0.56±0.05	0.56±0.10	0.53±0.06	Stable, moderate nutrient pool
Ammonia (µg/L)	0.130	0.072±0.023	0.120±0.028	0.070±0.009	Small fraction of total ammonia is the toxic un-ionized NH_3 at average Lake pH ≈8.1–8.2 (CCME 2010)
Chloride (mg/L)	213±17.1	217±17.5	200	190	Above >120 mg/L guidelines (CCME 2011)
Conductivity (µS/cm)	907±65	940±69	930	920	Elevated from road salt
Dissolved Organic Carbon (mg/L)	8.5±0.96	8.3±0.88	-	5.4±0.50	Moderate organic mat-ter
pH	8.1±0.27	8.2±0.28	-	8.1±0.01	Normal, slightly basic

ND = Not Detected at a concentration equal or greater than the indicated Detection Limit of 0.004 mg/L for Orthophosphate and 0.1 mg/L for Nitrate + Nitrite.
If a value appears without a ± SD, it indicates that dataset consisted of only one observation (n=1) or repeated identical observations

The improvements in water quality can be attributed to nutrient control measures enacted in Phase 1. Chemical treatment has been the main phosphorous control throughout the lake's history. Before the *Management Plan*, Copper-sulfate treatment was applied 1995, and a 25.2 t Phoslock® application in 2013 (FOSLP 2025a). Under Phase 1, Markham switched to poly-aluminum chloride (PAC), with a 13 t application in 2021 and 9.4 t application in 2024 (~$150,000 per application). While effective in the short-term, this approach treats symptoms rather than sources. External nutrient reduction has focused on Canada goose hazing and shoreline fencing to limit fecal loading (Parhizgari 2025; FOSLP 2025a). The underlying aquifer appears to facilitate limited flushing of nutrient-rich water, gradually improving chemistry.

Continuous dissolved oxygen (DO) monitoring began at the dock in 2023 (Parhizgari 2024). Daytime DO measurements in 2024 showed improvements, with biweekly monitoring at the bridge and dock (see Figure 1) showing surface and 1 m above the bottom near or above 6.0 mg/L (Parhizgari 2025). However, bottom-water anoxia (0 mg/L DO) continues to persist during the summer (Parhizgari 2025).

Frequent phytoplankton (i.e., algae in the water column) blooms contribute to anoxia as decomposing organic material consumes dissolved oxygen. To address elevated phytoplankton, a Water IQ Pulsar 4400+ ultrasonic unit was installed in 2024 (FOSLP 2025a). Secchi depth analysis (measure of phytoplankton-induced turbidity) showed that in 2024, Swan Lake was generally at or below the interim depth target of 0.6-0.8 m (Parhizgari 2025). However, concerns persist that the phytoplankton concentrations remain elevated, demonstrated by the fact that elevated lake turbidity likely contributed to the failed submerged aquatic macrophyte plantings (FOSLP 2025a) and chlorophyll-a (proxy for phytoplankton concentrations in water) at a depth of 1 m averaged 16 µg/L throughout 2024, indicating a eutrophic state (Parhizgari 2025).

Markham and FOSLP have diverging opinions on how to interpret the water quality results of Phase 1:

City of Markham / AECOM Position

- View surface-oxygen improvement and nutrient reduction as successes; believe nutrient control alone will maintain DO.

FOSLP Position

- Argues improvements are temporary; Swan Lake's artificial structure requires active oxygenation or circulation.
- Proposed calcium-peroxide dosing and mechanical oxygenation pilots (i.e., Fleming College 2022; University of Toronto 2023) were rejected for "unproven" or "sediment-disturbance" concerns (FOSLP 2025a).
- Maintains that controlled oxygenation could stabilize redox conditions and reduce internal P release.

In the following sections, we discuss the ecological consideration for aquatic life that could inform possible actions taken over the course of Phase 2.

4.0 Turbidity and Dissolved Oxygen

4.1 Artificial Aeration

FOSLP commissioned Natural Resource Solutions Inc. (Anderson and Baldwin 2025a) to review current oxygenation management strategies for Swan Lake. The resulting recommendations are summarized in Table 3. Overall, the report concludes that as Swan Lake recovers, its biological oxygen demand (BOD) will likely increase as aerobic organisms (e.g., bacteria, fish, and benthic invertebrates) become more active and abundant. Consequently, any aeration system must be capable of supporting both current and future BOD as the ecosystem responds to rehabilitation efforts. The report determined that diffused aeration and fountain aeration are the most suitable methods for improving oxygenation and circulation within the lake.

As detailed in the report (see reference within Anderson and Baldwin 2025a), improving DO levels may not only address the anoxia observed in the deeper portions of the lake (creating conditions that allow more characteristic aquatic life to thrive) but also help reduce the high levels of turbidity currently observed. In the presence of oxygen, phosphorus in the water binds to iron and clay particles and settles to the lake bottom, reducing its availability to phytoplankton in the water column and thereby limiting phytoplankton growth. Overtime, less phytoplankton in the water column should result in clearer water.

Table 3: Summary of Aeration Recommendations for Swan Lake from Anderson and Baldwin (2025a)

Method	Mechanism of Action	Advantages	Limitations	Feasibility for Swan Lake
Diffused Aeration	Agitates or circulates water at the surface to enhance gas exchange and disrupt localized stagnation. Releases compressed air through submerged diffusers to promote vertical mixing and oxygen transfer.	Immediate DO improvement; simple installation; visible circulation. Gentle, uniform oxygenation; low disturbance; energy-efficient; adaptable to seasonal use.	Limited spatial reach; energy-intensive; risk of sediment resuspension. Requires careful diffuser placement; effectiveness reduced in very shallow areas.	Highly suitable; offers broad coverage and sustained oxygenation when operated continuously.
Fountain Aeriation	Pumping water through surface-level diffusers into the air to promote gas exchange and surface agitation.	Uniform oxygenation; low disturbance; simple installation.	Limited spatial reach; requires careful fountain placement; non-functional during winter months.	Highly suitable; simple installation; offers sustained oxygenation when operated continuously.
Chemical Oxygenation	Introduces oxygen-releasing or oxidizing compounds that supply elemental oxygen or modify sediment redox conditions.	Direct oxygen delivery; long-lasting effect; no mechanical disturbance.	Requires precise dosing; limited circulation benefit; may provide only temporary improvement.	Moderate feasibility; useful as supplemental treatment for localized low-oxygen zones.
Destratification / Mixing	Induces circulation to break down stratification and promote natural oxygenation through gas exchange.	Reduces stagnation; minimizes hypoxic zone formation; enhances natural mixing.	Limited DO increase; potential warming; continuous operation required.	Partially feasible; could aid circulation but unlikely to raise overall DO significantly.

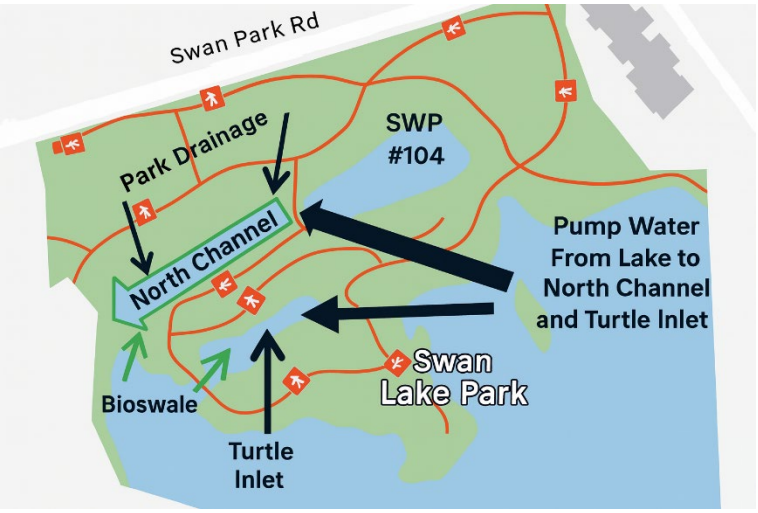
Despite the promise of mechanical aeration, recent studies suggest that such actions are not a "silver bullet." Artificial aeration in shallow, temperate lakes often have only modest effects in preventing further phosphorus release (May et al. 2020) and can be ineffective in systems with large surface areas (Kibuye et al. 2021), such as Swan Lake.

High internal phosphorus loading is a persistent challenge in shallow lake recovery (Søndergaard et al. 2003; May et al. 2020; Kibuye et al. 2021). While creating oxygenated conditions typically suppresses phosphorus availability, shallow lakes function differently than deeper systems because the distance between the sediment surface (where phosphorus is stored) and the photic zone (where phytoplankton grow) is short (Søndergaard et al. 2003). As a result, it takes little energy for nutrients to become resuspended. Wind events or the decomposition of settled organic material can quickly reintroduce phosphorus into the water column, where it becomes available for phytoplankton growth (Søndergaard et al. 2003). Therefore, mechanical aeration, if it is pursued, may not be an effective means of reducing phosphorus in Swan Lake.

4.2 Evaluation of Proposed Bioswale

In the case of Swan Lake, internal loading appears to be a more significant concern than external loading (FOSLP 2025a). With assistance from Fleming College (Siembida-Lösch 2021), FOSLP (2023) proposed investigating bioswale options, particularly within the 100 m North Channel and the Turtle Inlet (Figure 2), as a means of reducing internal nutrient loads has been investigated. Siembida-Lösch (2021) provides an extensive review of bioswale effectiveness, and a more recent study emphasizes that design should prioritize nutrient removal efficiency (Ali and Pickering 2022).

Figure 2: Proposed Route for Bioswales. Image from FOSLP (2023). Image Quality improved through GPT-5 (OpenAI 2025a)



Design outlines provided by Siembida-Lösch (2021) and FOSLP (2023) emphasize the importance of achieving a hydraulic detention time (HDT) of < 30 days to control phytoplankton growth. To meet this target for Swan Lake (80,000-102,000 m³), Siembida-Lösch (2021) recommended recirculating approximately 3,400 m³ per day. However, lower rates proposed by FOSLP (2023) could provide lower-cost alternatives while still achieving desirable outcomes, with up to 27% of the lake volume recycled (Table 4). Smaller pumps could be powered by existing on-site renewable electricity or by restoring the wind turbines currently present on-site.

Table 4: Lake Turnover (80,000 m³) from April-October (214 days). Adapted from FOSLP (2023)

Pump Size	Capacity (m³/24h)	% of Lake Volume per Day	% of Lake Volume (50% Operation)
1 HP	50	13%	7%
2 HP	200	54%	27%

It should be noted that properly designed bioswales can effectively remove particulate phosphorus but may struggle to remove dissolved phosphorus from the water column (Ali and Pickering 2022). Fortunately, dissolved phosphorus concentrations in Swan Lake appear to be very low as of 2025 (Table 2). The addition of biochar, recommended by York University as a means of aiding nutrient and chloride filtration (FOSLP 2025a); however, recent studies have demonstrated variable effectiveness at removing nutrients (Ali and Pickering 2022).

The underused North Channel, which is currently dry, may represent the most suitable location for an initial bioswale pilot, as it would minimize disturbance to the Turtle Inlet habitat. In addition, because the North Channel contains remnants of the former landfill (Photo 1), selecting this site could also present an opportunity to beautify and ecologically restore this area within the existing channel.

Photo 1: North Channel Dry at Time of Inspection, Containing Remnants of Landfill Waste. Represents a Beautification and Bioswale Opportunity

Even if a bioswale is constructed, ensuring a reduction (or current levels) of nutrient inputs will help. Migratory geese are identified as the largest contributors to external nutrient inputs into the lake (FOSLP 2025a). Geese hazing has proven effective and may be the only feasible action to deter migratory geese in an urban environment, as shoreline plantings (i.e., replacing manicured lawns with forests) are mainly targeted for residential geese (Parhizgari 2025).

Photo 2: Splitter Outlets of the East (A) and North (B) SWM Pond

A

B

In addition, or alternatively, the creation of smaller bioswale-like structures at the outlets / splitters of the two SWM ponds (North Pond #104 and East Pond #105) and/or Oil Grit Separators (OGS) that flow into Swan Lake may provide opportunities to address point-source

pollutants. Observations during October 15, 2025, showed that many of these stormwater outlets had minimal vegetation that could help to absorb pollutants (Photo 2). The stormwater inputs are not significant sources of nutrients into Swan Lake; however, interventions at these locations could help reduce chloride inputs.

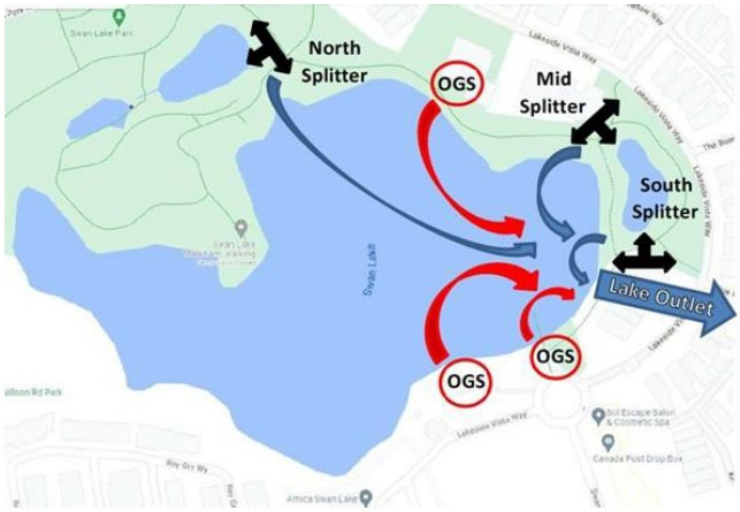
Recent studies in the Toronto area have demonstrated that select native halophytes (i.e., salt-tolerant plants) can absorb chloride runoffs from roads in urbanized ditch ways (Narwroth et al. 2025). Cordgrass (*Sporobolus michauxianus*) native to Ontario was demonstrated at removing approximately 22,000 mg/m^2 of chloride over a growing season (Narwroth et al. 2025) and may present the best-suited plant for Swan Lake. These small bioswales would be complementary to other efforts to reduce chloride concentration as they could only reduce input into Swan Lake. Biological / ecological issues surrounding chlorides are discussed in the following section.

5.0 Chloride

Chloride levels have significantly improved over Phase 1, declining from over 700 mg/L in 2020 to approximately 200 mg/L (range 180 – 270 mg/L) by 2024; a reduction of more than 70 % (Parhizgari 2025). No active measures were taken to achieve this reduction in chlorides, which is likely a result from clearing blockages at the east SWM Pond (#105) that had increased flow bypassing the pond and exchange with the underlying aquifer, combined with minimal surface outflow during the summers of 2022-2023 (FOSLP 2025a).

Three OGS units have been identified as point-source contributors responsible for roughly 56% of chloride inputs (Figure 3), as they discharge directly into the lake rather than first passing through SWM ponds (FOSLP 2025a). Debate remains whether to eliminate these discharges entirely by rerouting the stormwater.

Figure 3: Location of Three Oil Grit Separators (Red Circles) Responsible for 56% of Chloride Inputs. From FOSLP (2023)



Continuing to use Swan Lake as an ad hoc SWM pond will likely impair improvements of its water quality (see Anderson and Baldwin 2025b). The feasibility of rerouting the stormwater outlets and OGSs has been studied in a recent AECOM report (see Xu 2025). Rerouting all OGS flow and 65% of the SWM pond by-pass could reduce chloride inputs by 85% (Xu 2025). However, building on the AECOM report, FOSLP notes that alterations to the flow splitters could reduce chloride inputs by 30% ($124,767).

At the current chloride concentration (~200 mg/L), further ecological improvement is unlikely. Persistent chloride enrichment may be sustaining high phytoplankton levels by suppressing zooplankton grazers that normally control phytoplankton (Hintz et al. 2022). The following section examines this theory and related aquatic ecosystem issues.

6.0 Zooplankton and Macroinvertebrates

Often overlooked in favor of more charismatic species such as sport fishes (e.g., bass and sunfish), zooplankton, macroinvertebrates (e.g., aquatic insects, worms, and crustaceans visible with naked eye), and freshwater mussels form the base of the freshwater food web (Hintz et al. 2022), supporting fish, amphibians, and birds. Ontario has few native obligate herbivorous or planktivorous fish; thus, zooplankton, macroinvertebrates, and mussels act as the principal phytoplankton / algae grazers in these systems (Newman 1991; Sarnelle 1993). Consequently, maintaining healthy communities of these taxa may be critical for phytoplankton control.

6.1 Zooplankton (*Daphnia* spp.)

Zooplankton are more sensitive to chloride than fish (CCME 2011; Hintz et al. 2022). The current chloride concentration (~200 mg/L) is below levels harmful to most fishes but falls within, or slightly above, the chronic exposure range for key grazers such as water fleas in the *Daphnia* genus, reducing phytoplankton/algal grazing capacity (CCME 2011; Hintz et al. 2022). Even at the 120 mg/L federal target, some *Daphnia* spp. populations show reduced survival and reproduction (Hintz et al. 2022; Woodley et al. 2023).

Zooplankton, especially *Daphnia* spp., are the dominant grazers of phytoplankton in temperate freshwater lakes (Sarnelle 1993). They can help regulate cyanobacteria through grazing but do not provide a reliable or sustained means of cyanobacteria bloom elimination (May et al. 2020; Kibuye et al. 2021). Thus, *Daphnia* spp. may be uniquely suited to aid in the recovery of Swan Lake directly in a way no fish species likely could. FOSLP (2025b) has already noted the possibility of chloride-driven suppression of zooplankton, though no formal studies of Swan Lake have been completed to confirm this pattern.

Daphnia spp. stocking has been demonstrated as an effective strategy in other eutrophic temperate lakes when implemented in tandem with the introduction of piscivorous fish (see Section 7; Ha et al. 2012). However, other studies have shown that natural recovery of zooplankton communities can occur when environmental conditions improve (Albright et al. 2004; May et al. 2020; Kibuye et al. 2021). Since there is no current data available on the

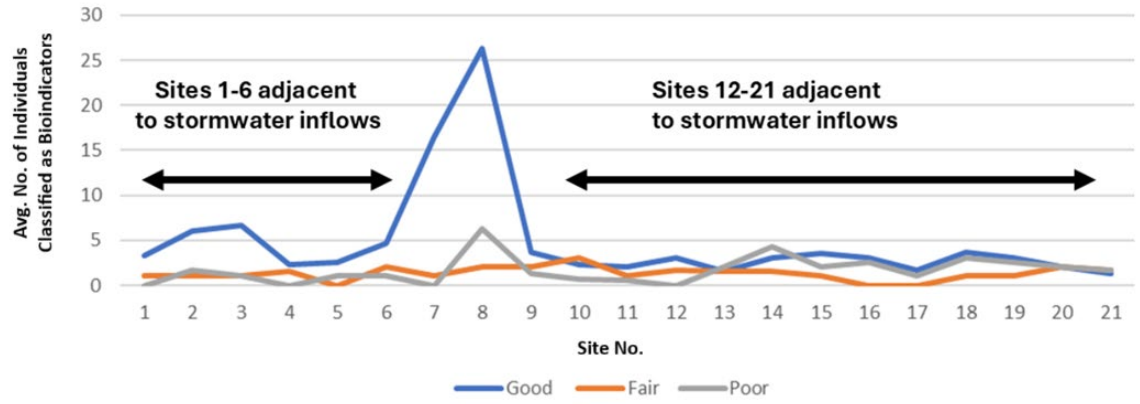
existing zooplankton community composition (i.e., whether it is dominated by inefficient grazers such as rotifers or includes effective grazers such as *Daphnia* spp.), *Daphnia* spp. stocking is not recommended at this time.

Instead, assessing the present zooplankton community is advised to determine whether the working hypothesis (i.e., low *Daphnia* spp. abundance may be contributing to elevated phytoplankton biomass) holds true. Albright et al. (2004) provide a template for an annual summer collection to determine whether the community is currently dominated by smaller-bodied, poor-grazing zooplankton (e.g., Rotifera) and whether there are any observed changes in larger-bodied grazers such as *Daphnia* spp. Such a program could be implemented over the course of Phase 2 if the initial survey suggests low abundances of key grazers.

6.2 Macroinvertebrates

Macroinvertebrates, while important benthic phytoplankton/algal grazers (Newman 1991), are strongly influenced by eutrophication but do not directly mitigate it (May et al. 2020). Many macroinvertebrates are more resilient than zooplankton and are unlikely to be severely affected by current chloride levels (CCME 2011). Instead, in a system such as Swan Lake, the macroinvertebrate composition reflects improvements in oxygen, sediment quality, and habitat during recovery (May et al. 2020). Although FOSLP requested a macroinvertebrate study, the City of Markham declined (FOSLP 2025a). In 2023, FOSLP independently commissioned Mr. Chris Reeves to conduct a macroinvertebrate survey (FOSLP 2025b). The results indicated that Swan Lake supports a fair-to-intermediate water quality community, with reduced diversity near stormwater inflows (Figure 4), suggesting that poor water quality continues to shape community structure (FOSLP 2025b).

Figure 4: Summary of Swan Lake Macroinvertebrate Survey (2023). Image Modified from FOSLP (2025b)



6.3 Freshwater Mussels

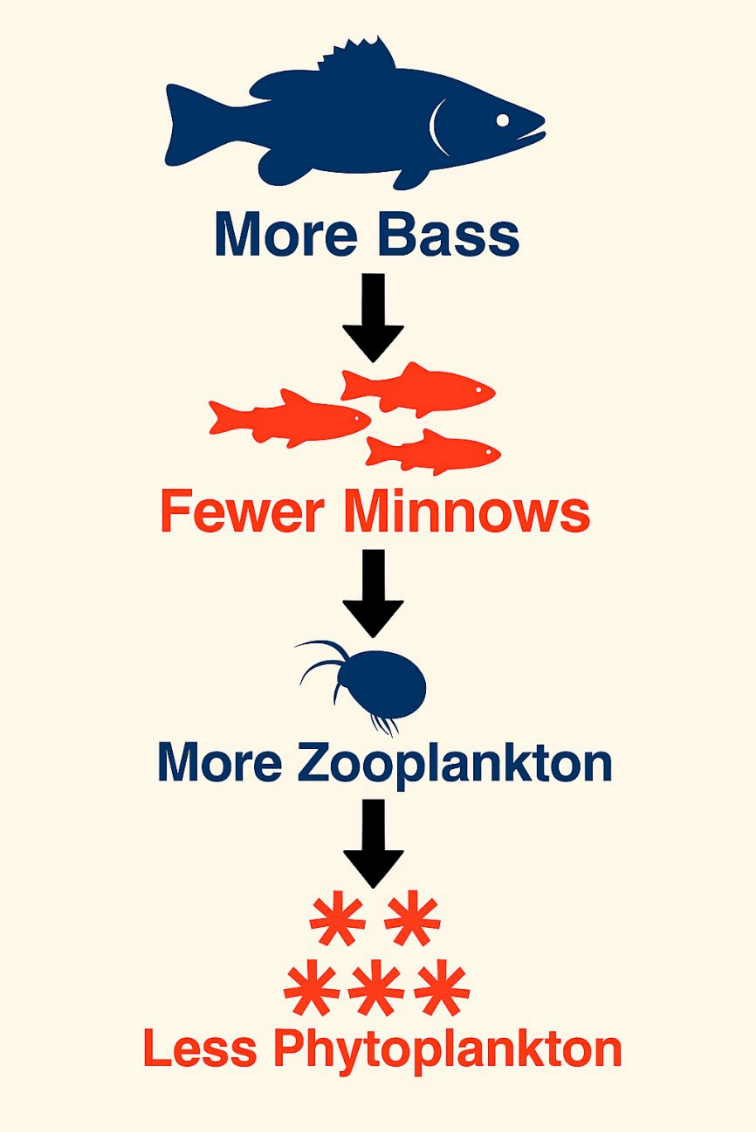
The use of freshwater mussels to control phytoplankton may be limited in Swan Lake. Although mussels have been shown to reduce phytoplankton / algal biomass, most demonstrations have involved the invasive Zebra Mussel (*Dreissena polymorpha*), making such applications undesirable (Geletu 2023). Native Unionidae mussels in Ontario have limited tolerance to polluted waters and possess complex reproductive strategies that require specific host fish (Metcalfe-Smith et al. 1998). As a result, they are generally poor colonizers of new habitats. Many species are also restricted by chloride sensitivity during their larval (glochidia) stage, with reductions to survival (EC_{10}) ranging from 24 to 789 mg/L, while adults may tolerate chloride concentrations near 200 mg/L (CCME 2011). While native floater mussels (subfamily Anodontinae) tend to be more pollution-tolerant, the Paper Pondshell (*Utterbackia imbecillis*) may represent a potential candidate species, as it is more tolerant of degraded water quality, inhabits shallow ponds, and uses readily available host fish such as Largemouth Bass (*Micropterus salmoides*) and sunfishes (*Lepomis* spp.) (Keller and Ruessler 1997; Metcalfe-Smith et al. 1998).

7.0 Fish Community

7.1 Control of Minnows via Biomanipulation

In Swan Lake, high populations of species such as Fathead Minnow (*Pimephales promelas*) may contribute to reduced zooplankton abundance and weakened phytoplankton control within the water column, consistent with a trophic cascade dynamic (Power 1992). In addition, in shallow lakes such as Swan Lake, zooplankton are more exposed to predation and thus exert weaker grazing pressure on phytoplankton than deeper systems that provide refuge zones (May et al. 2020). Adequate macrophyte coverage can offer such refuge and restore balance (Kibuye et al. 2021). Currently, submerged aquatic vegetation is observed in Swan Lake, this some physical coverage is offered.

Figure 5: Proposed Biomanipulation to Achieve a Top-Down Trophic Cascade in Swan Lake. Created with assistance from GPT-5 (OpenAI 2025b)



Introducing or enhancing piscivore populations such as Largemouth Bass, could help to improve water quality through biomanipulation via top-down trophic control (Carpenter et al. 1987; May et al. 2020; see Figure 5). A classic example of such biomanipulation is described by Albright et al. (2004), who studied a small, shallow eutrophic pond (15.6 ha, mean depth 1.8 m) in upstate New York that, prior to intervention, contained only minnows (e.g., Golden Shiner, *Notemigonus crysoleucas*) and Brown Bullhead (*Ameiurus nebulosus*). The lake exhibited high phytoplankton biomass, elevated turbidity, and a zooplankton community of low diversity, dominated by rotifers and few *Daphnia* spp. In 1999, Largemouth Bass and Smallmouth Bass (*Micropterus dolomieu*) were introduced, and by 2002 water quality visibly improved as minnow populations declined and *Daphnia* spp. increased in abundance and diversity. However, controlling planktivorous fish

populations does not always yield such clear results; some studies report that biomanipulation has little or no measurable effect on zooplankton communities (Setubal and Riccardi 2020).

Largemouth Bass are currently stocked into the lake as of 2025 (FOSLP 2025a). Bass were also stocked 1992, but fish surveys conducted by the Toronto Region Conservation Authority (TRCA) do not seem to list Largemouth Bass among species capture (Table 5).

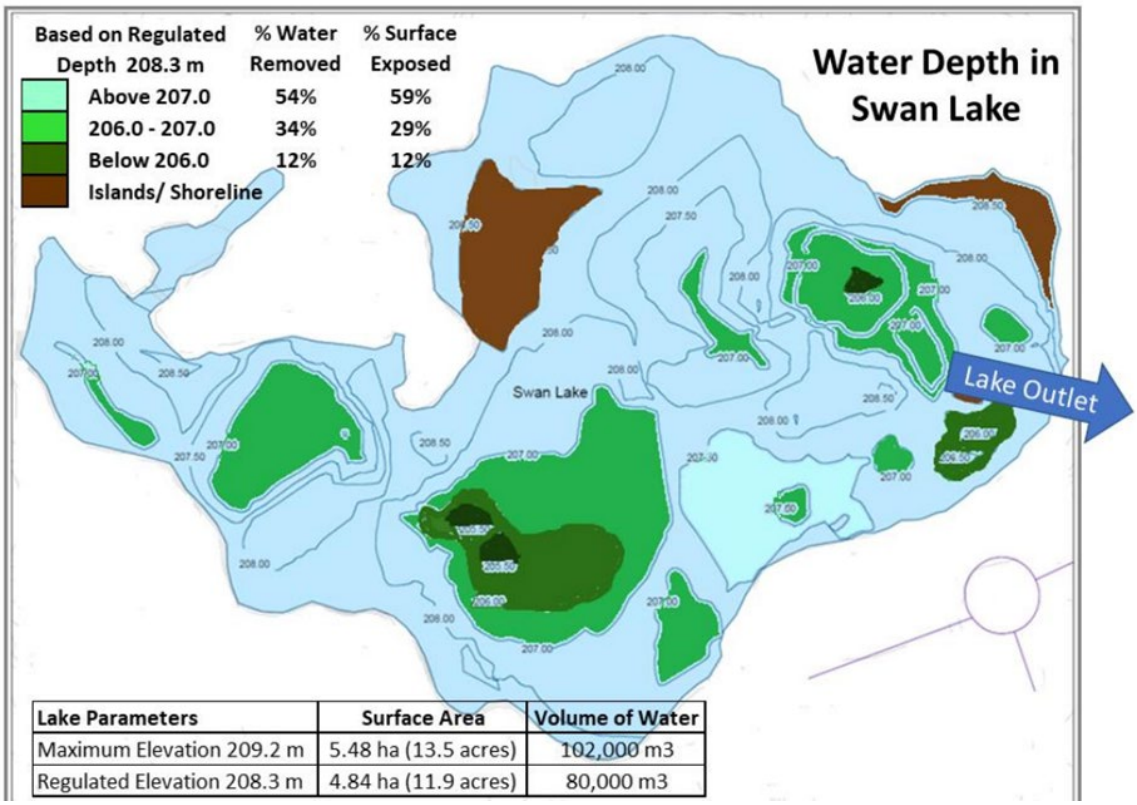
Table 5: TRCA Swan Lake Fish Surveys During Phase 1. Bottom Feeding Fish (Catfish, Common Carp, and Goldfish) Were Euthanized. All Other Species Returned Alive to the Lake (FOSLP 2025b)

Date	Fish Species	Number of Fish
April 2021 (three days electrofishing + two days nets)	Brown Bullhead	210
	Common Carp	7
	Fathead Minnow	>10,000
April 2022 (one day electrofishing + one day nets)	Brown Bullhead	80
	Common Carp	20
	Fathead Minnow	875
April 2023 (one day electrofishing)	Brown Bullhead	84
	Common Carp	103
	Fathead Minnow	14
	Goldfish	2
April 2024 (one day electrofishing + one day nets)	Brown Bullhead	193
	Common Carp	1
	Fathead Minnow	1,521
	Goldfish	13
	Common Carp X Goldfish	59
	Emeral Shiner	1

7.2 Limitations to Largemouth Bass Survival in Swan Lake

The shallow morphometry of Swan Lake, with its broad surface area and limited depth, may constrain the successful establishment of Largemouth Bass. Although Largemouth Bass occupy a wide range of depths, from very shallow (<1 m) to deeper water (~12 m) (Peat et al. 2016), they typically prefer depths of 2-3 m., especially in winter (Bunt et al. 2021). Such depths are scarce in Swan Lake, where nearly 60% of the basin is less than 1 m deep (Figure 6). Shallow lakes are especially vulnerable to meteorological variability and experience rapid temperature fluctuations in response to changes in air temperature (Piccioni et al. 2021), creating thermal instability that challenges overwintering bass. Feeding activity ceases below 6°C, making Largemouth Bass sensitive to prolonged cold periods (Fullerton et al. 2000; Bunt et al. 2021). DO is another critical factor for overwinter survival, ideally remaining within the 2-6 mg/L range (Hasler et al. 2009). Current DO measurements are limited to nearshore summer readings, but values at ~2 m depth suggest potential for winter anoxia.

Figure 6: Bathymetric Map of Swan Lake. Provided by FOSLP



Bass stocking efforts should prioritize introducing larger individuals (>100 mm total length) to improve survival and establishment (Fullerton et al. 2000; Post et al. 1998). Bass strongly prefer in-water structure provided by macrophyte beds and coarse woody material (Bunt et al. 2021). Field observations indicate that Swan Lake's littoral zone is dominated by the macroalgae *Chara* spp., but was otherwise featureless (e.g., lack of large rock or woody structure, nearly uniform depth). Installing coarse woody material (e.g., upright stumps with root mass, properly elevated logs and branches) could provide immediate cover and overwintering refuge habitat, that can be locally sourced until native vegetation recovers (Czarnecka 2016). TRCA has proposed shoreline restoration efforts that include addition of woody material and rock complexes in the littoral zone (TRCA 2022). Thus, such efforts have already been under consideration in the case of Swan Lake. Consideration of placing deeper water structures (stumps and log cover) is also required to provide refuge from predatory birds and human anglers.

Deepening portions of Swan Lake could create refuge pools suitable for overwintering Largemouth Bass, although suitable water quality needs to be confirmed during all seasons. Such modifications may also align with community goals to enhance recreational opportunities around the lake. Alternatively, modestly increasing the lake's regulated water level could expand available overwintering habitat and would be less expensive than dredging. Currently,

approximately 12% of Swan Lake offers adequate depth for overwintering, assuming the lake does not become anoxic.

Future aquatic surveys will confirm whether Largemouth Bass can successfully overwinter under current lake conditions and help determine if habitat enhancements are warranted. Spring surveys around Swan Lake may provide opportunities to note if dead fish are observable along the shoreline. If live Largemouth Bass are captured in the summer 2026 surveys, then continued stocking of larger individuals (>100 mm) is recommended, along with the placement of woody material complexes (stumps with root masses and elevated log structures) to provide habitat until macrophyte recovery occurs. Re-evaluation of the need for more extensive interventions (e.g., dredging) should be deferred until bass survival is confirmed, as the current stocking provides an opportunity to assess the effectiveness of existing conditions before pursuing additional modifications.

7.3 Other Fish as a Means of Biomanipulation

As previously noted, there are few planktivorous fish that could be introduced to control phytoplankton growth suitable to Ontario, with the most common species being the highly invasive Bighead Carp (*Hypophthalmichthys nobilis*) and Silver Carp (*Hypophthalmichthys molitrix*), which are undesirable species in most circumstances (Geletu 2023). One of the few native planktivorous fish in Ontario is the Gizzard Shad (*Dorosoma cepedianum*), but its effectiveness in controlling phytoplankton remains unclear. Although Gizzard Shad feed on phytoplankton, their high waste excretion rates rapidly recycle nutrients back into the water column, often stimulating rather than reducing algal growth (Schaus et al. 2010). In fact, removal of Gizzard Shad has been demonstrated as an effective means to reduce phytoplankton levels (Godwin et al. 2011).

Bluegill (*Lepomis macrochirus*) were also considered for stocking in Swan Lake by TRCA (Parhizgari 2025); however, smaller sunfishes such as Bluegill may not be desirable for improving the water quality of Swan Lake. Sunfishes are important zooplankton feeders in North American lakes and may therefore contribute to increased phytoplankton biomass by preferentially consuming *Daphnia* spp. or other zooplankton such as rotifers (Noda and Maruyama 2013; Bernes et al. 2015). Accordingly, the addition of sunfish species is not recommended at this stage, as it may exacerbate the elevated phytoplankton levels currently observed in Swan Lake.

8.0 Aquatic Vegetation

Macrophytes are effective at stabilizing sediments, improving water clarity, and reducing nutrient concentrations (Kibuye et al. 2021). However, the current turbid conditions in Swan Lake are likely to prevent their establishment, limiting these benefits. Previous macrophyte plantings have failed under the lake's turbid, nutrient-rich, and high-chloride conditions. Plantings of Wild Celery (*Vallisneria americana*) in 2023 and 2024 experienced >90% mortality, primarily due to light limitation and turbidity (Parhizgari 2025). However, *Chara* spp., a macroalgae, is present throughout Swan Lake as of 2025; thus, turbidity has reduced enough to allow fast growing macroalgae to establish. Considering the limited success of past plantings and supporting literature, further submerged macrophyte restoration efforts are not recommended until sustained periods of water clarity can be demonstrated.

Submerged macrophytes, not rigid emergent species such as reeds or cattails, provide superior habitat complexity for Largemouth Bass and other fish, supporting higher growth and recruitment at moderate coverage (~60 %) (Stahr and Shoup 2015; Nohner et al. 2018). Future planting should therefore focus on submerged and floating-leaved species, rather than emergent vegetation, to maximize habitat value and promote long-term ecological balance (Table 6). In fact, macrophyte recovery in similarly sized eutrophic lakes has been linked to the introduction of piscivorous fish (Albright et al. 2004). Thus, these efforts are likely to synergize.

While macrophyte beds can reduce nutrient concentrations (particularly phosphorus) by absorbing nutrients, stabilizing sediments, and increasing oxygen near the substrate, they can also, under certain conditions, contribute to internal phosphorus loading. Dense vegetation may create localized anoxia and elevated pH, both of which can enhance phosphorus release from sediments (Søndergaard et al. 2003). This potential effect should be monitored as vegetation is re-established.

Table 6: Macrophyte Types Observed and Recommended Plantings in Swan Lake 1993 and 2024. Adapted from FOSLP (2025b)

Open Waters: 0.5 m to 1.5 m Deep		Identified in 1993	Identified in 2024	Recommended
Pond Lily	*Nuphar variegata*			Yes
Water Lily	*Nymphaea odorata*			Yes
Pondweed	*Potamogeton richardsonii*			Yes
Pondweed	*Potamogeton pectinatus*			Yes

Lake Margins and Water to 0.75 m Deep		Identified in 1993	Identified in 2024	Recommended
Bur-reed	*Sparganium eurycarpum*			
Sweet Flag	*Acorus calamus*			
Soft-stem Bulrush	*Schoenoplectus tabernaemontani (*formerly *Scirpus validus)*			

Shores and Waters to 0.5 m Deep		Identified in 1993	Identified in 2024	Recommended
Narrow-leaved Cattail	*Typha angustifolia*	X	X	
Wide-leaved Cattail	*Typha latifolia*		X	
Giant Reed	*Phragmites australis*	X	X	
River Bulrush	*Bolboschoenus fluviatilis* (formerly *Scirpus fluviatillis*)			
Wild Celery[1]	*Vallisneria americana*		X	Yes

Shores and Waters to 0.25 m Deep		Identified in 1993	Identified in 2024	Recommended
Blue Flag	*Iris versicolor*			
Pickerelweed	*Pontederia cordata*			
Arrowhead	*Sagittaria latifolia*			Yes
Water Plantain	*Alisma plantago-aquatica*			
Cordgrass[2]	*Sporobolus michauxianus*			Yes

[1]Not included in original 1993 recommendations. Planted in 2023

[2]Added after Burnside's review of Nawroth et al. 2025

9.0 Recommendations

Burnside recommends the following for consideration to support aquatic life as Phase 2 rehabilitation begins.

Table 7: Summary of Recommendations to Improve Biological / Ecological Conditions During Phase 2

Biotic Group	Mechanism of Action	Effectiveness in Eutrophic Systems	Burnside Recommendations
Native Fish	Biomanipulation via top-down control	Moderate – High minnow population may be suppressing desirable zooplankton.	Largemouth Bass stocking (>100 mm) may help reduce minnows if overwintering can be demonstrated. Determine whether Largemouth Bass stocked in 2025 survive until 2026 through spring (brief walk around) and summer (fish capture) surveys.
Native Mussels	Nutrient sequestration	Low – many native mussels sensitive to poor water quality.	Paper Pondshell may provide some filtration, but unlikely to contribute significantly.
Zooplankton (esp. Daphnia spp.)	Grazing on phytoplankton	Moderate to high – if predation and chlorides are controlled.	Analysis of zooplankton community recommended before considering stocking. Initial survey could serve as baseline to monitor changes cover Phase 2 activities.
Macrophytes	Nutrient sequestration, habitat	High local effect; supports DO and stability.	Further plantings not recommended until sustained periods of water clarity can be demonstrated.
Habitat Complexity	Increase habitat complexity	High – Placement of woody material (stumps with root mass and elevated logs) or boulder complexes may enhance available habitat for Largemouth Bass.	Swan Lake currently offers limited structural habitat. Establishment of a bass population may be aided by increasing habitat complexity through addition of woody debris complexes. Deepening not recommended – evaluate after spring / summer 2026 fish surveys to determine bass survivability.

Additional comments are provided below.

Nutrient Management

- Construction of bioswale presents opportunity to further reduce internal nutrient levels
- Enhance the existing bioswale to provide opportunities to beautify section of Swan Lake

Chloride Reduction

- Maintain focus on source control (grit-separator rerouting, winter salt management, etc.)
- Target ≤120 mg/L Cl^- to aid restore zooplankton communities
- Reducing chloride inputs into Swan Lake is likely to improve biological / ecological conditions
- Creation of small bioswale-like structures at the outlets of SWM pond splitters or OGSs may provide opportunity to mitigate chloride inputs provided with the proper halophyte plantings (i.e., Cordgrass (*S. michauxianus*))
- Rerouting the stormwater outlets and OGSs present a hard-engineering option to chloride reduction

10.0 Conclusion

Success of Swan Lake's aquatic communities depends on improving water quality before attempting further biological restoration. Phase 1 has resulted in improved water quality from 2020; however, problems persist especially with elevated chlorides and internal nutrient load.

Further recovery may require

1. Nutrient stabilization via bioswale

2. Chloride control by some means of reduction

3. Improvement to *Daphnia* spp. populations through reductions in chloride concentrations and selective predator stocking

Chloride-induced suppression of *Daphnia* spp. populations is likely exacerbating Swan Lake's phytoplankton blooms. Increasing *Daphnia* spp. abundance can yield short-term improvements (< two years) in water clarity and phytoplankton control (Kibuye et al. 2021) and should be considered as part of broader lake-management planning. While some mechanism for chloride reduction is recommended, it alone will likely not resolve the issue. Creating or maintaining a population of Largemouth Bass may help to improve the *Daphnia* spp. populations through the reduction of Fathead Minnow. However, the current zooplankton community is unknown.

Improvement to the water quality of shallow, eutrophic lakes, such as the case in Swan Lake, are impeded by its slow recovery, as it is hard for people to maintain interest (May et al. 2020). However, actions for the improvements of Swan Lake are promising, and should encourage managers to maintain support and interest.

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R.J. Burnside & Associates Limited

Swan Lake Long-Term Management Plan Update
Expert Consultation and Engagement

Meeting with R.J. Burnside & Associates Limited

Environmental Services
Robert Muir, Manager, Stormwater
Zahra Parhizgari, Environmental Engineer, Stormwater
Dr. Tammy Karst-Riddoch, PhD

February 10, 2026

Agenda

- Introduction
- Purpose of Meeting
- Burnside's Scope
- Summary of Lake Conditions
- Comparisons
- Path Forward

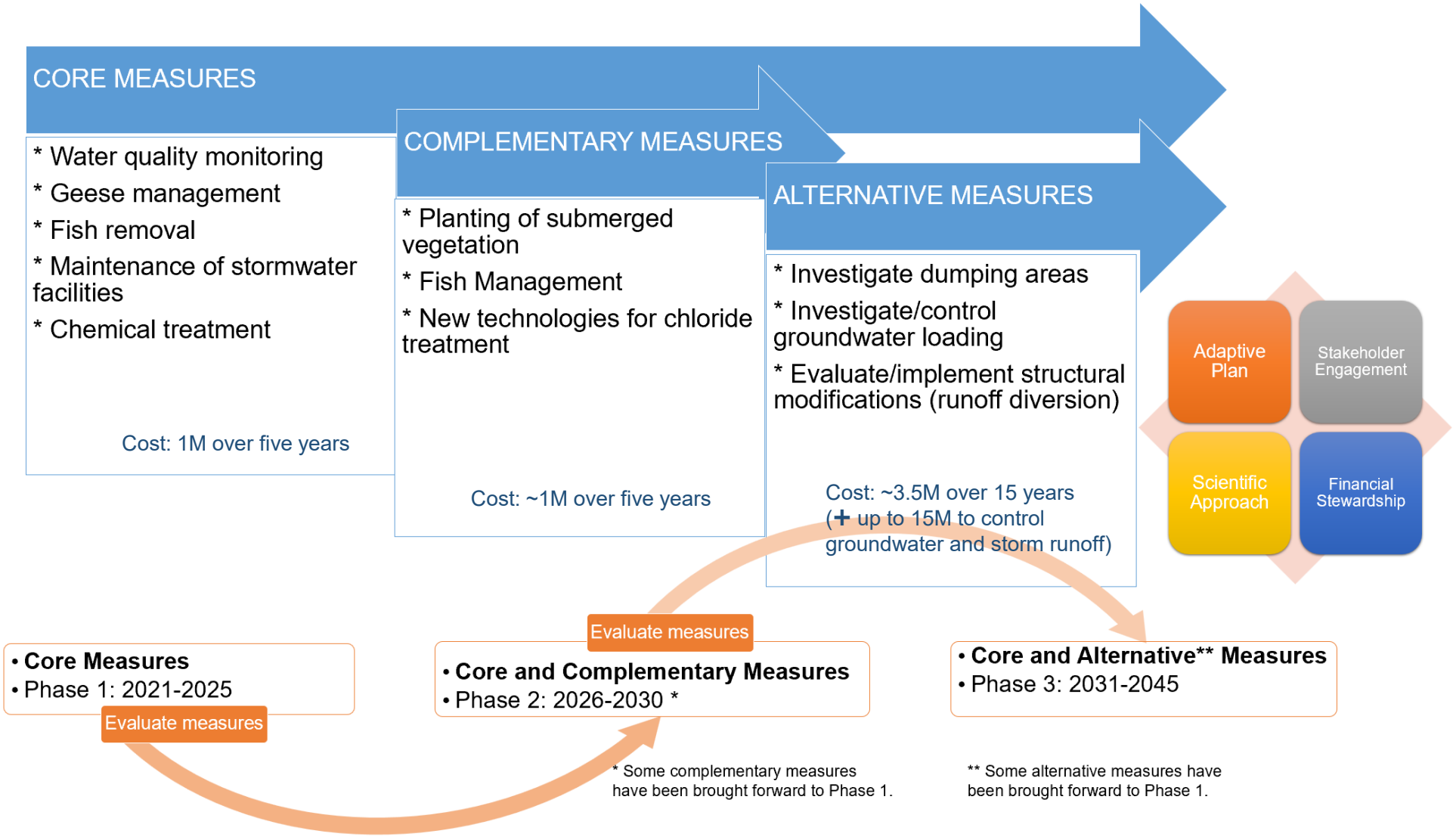
Purpose of Meeting

- Phase 1 of Swan Lake Long-Term Management Plan (SLMP- see next slide) has been completed successfully
- Consultation is a critical step in the adaptive management approach to Swan Lake Water Quality Improvement
- Expertise was solicited by Friends of Swan Lake Park (FOSLP) as part of their feedback to the SLMP five-year review
- City reviewed reports submitted through FOSLP and provided feedback

PURPOSE

- To understand how Burnside's report conclusions were developed
- To compare those conclusions with measured lake data
- To reconcile areas where statements and field results differ
- To identify opportunities for updated or refined assessments

Long Term Management Plan (2021)



Plan Review Process

Expert Consultation and Engagement

- Engage with deputants and technical stakeholders involved in the Markham Subcommittee process
- Participate in a workshop or other interactive consultation with external experts and agencies (e.g., TRCA, MNRF)
- Review of stakeholders' input

Study

- Update existing condition
- Review of management outcome
- Evaluate additional management measures
- Review and update goals, objectives and targets
- Update strategy and implementation plan

Plan Update

- Share draft report with stakeholders
- Receive feedback
- Present final report to Markham Subcommittee

Burnside's Report Scope

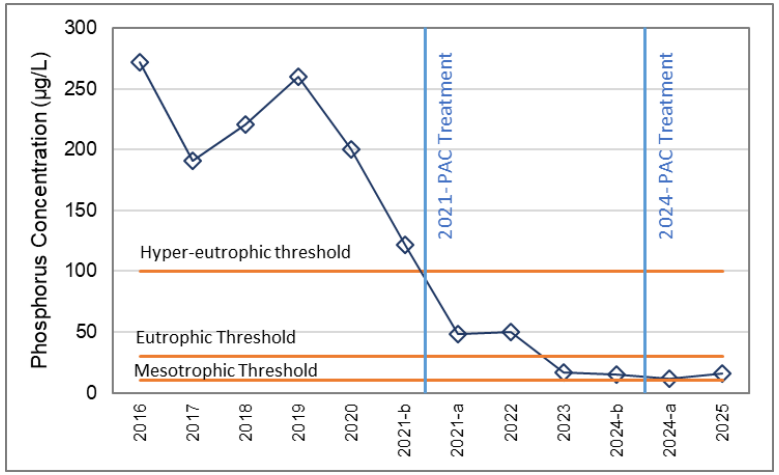
- Swan Lake Aquatic Conditions Review (Nov. 26, 2025), provided to City on Dec. 3, 2025
- FOSLP retained R.J. Burnside & Associates Limited (Burnside) to:
  - Provide a preliminary review of aquatic habitat conditions at the end of Phase 1
  - Provide recommendations entering Phase 2.
- Focus on impacts and recommendations to support potential improvements for aquatic life (zooplankton, invertebrates, fish, and macrophytes).

- *Our recent monitoring adds new information that may refine conclusions*
- *Your analysis provided helpful insight into the Lake biology*

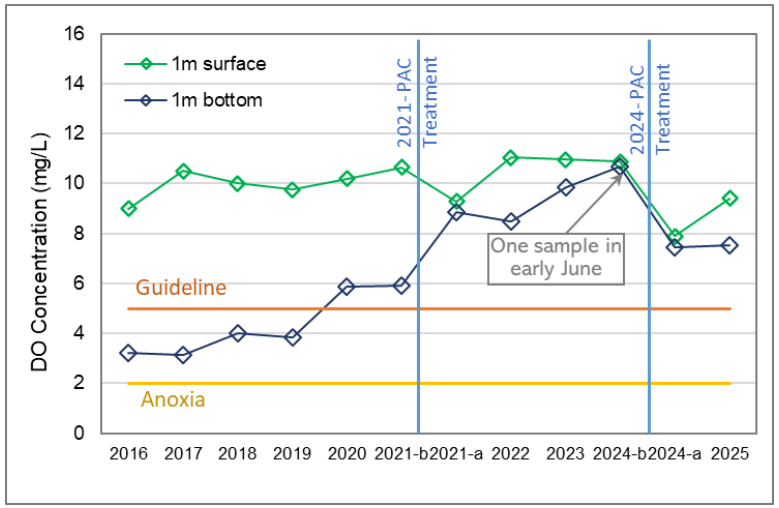
Current Lake Conditions and Trends

Water Quality- Nutrients and Oxygen

- Total Phosphorus:
  - Average under 30 µg/L during growing season (within Mesotrophic condition)
  - Decreased after each treatment
- Total Nitrogen:
  - Average below 0.65 mg/L during growing season (within Mesotrophic condition)
  - Dominant forms not bioavailable
- Dissolved Oxygen:
  - Surface concentration > 5 mg/L all year
  - Bottom concentration showed a decline during dry months
  - Observed anoxia is spatially limited, episodic, and confined to a small deep-water area



Phosphorus

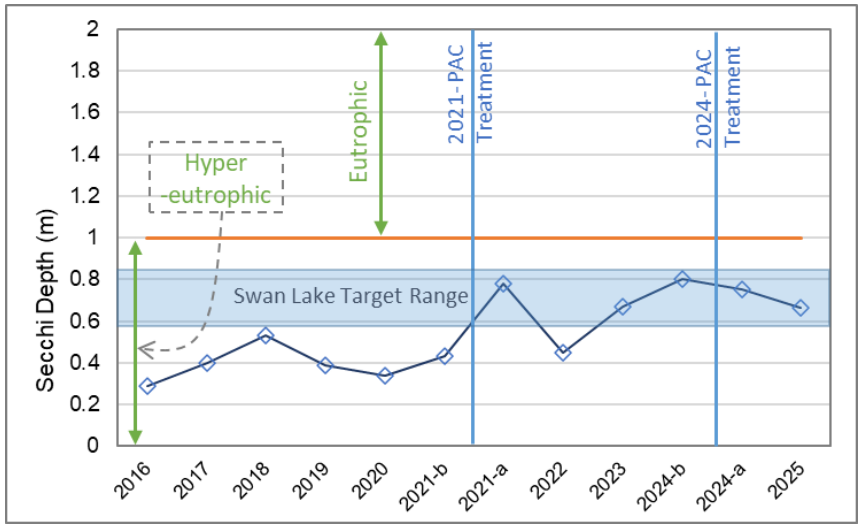


Dissolved Oxygen

Water Quality- Algae and Clarity

- Algal growth:
  - Surface bloom very limited since treatment
  - Recent Cyanobacteria cell numbers declined significantly since treatment
  - Chlorophyll-a within eutrophic state and below Health Canada chl-a indicator value for potential presence of cyanotoxins above primary contact recreational guidelines
- Clarity: Mostly within target, average growing season met target

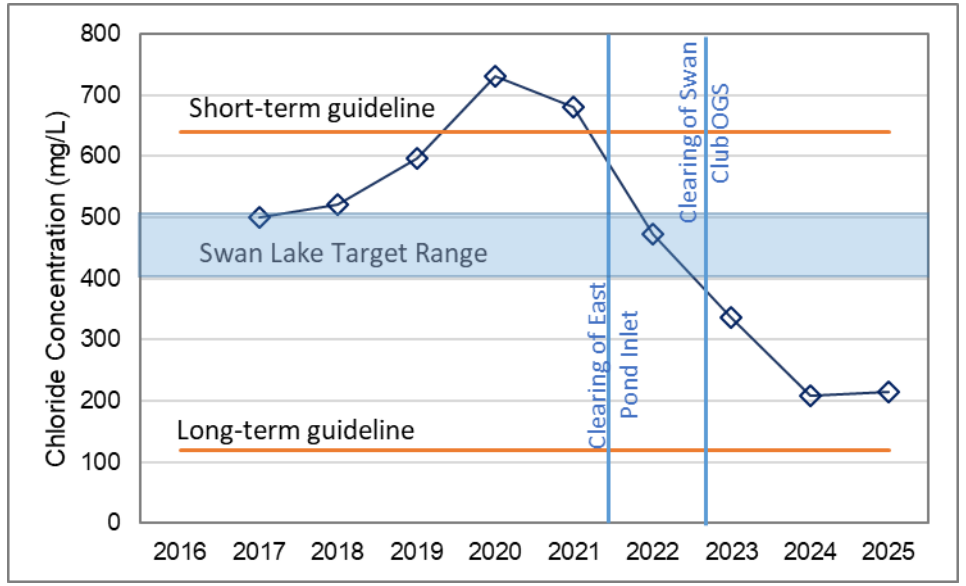
Algal bloom before treatment (photo from July 2020)



Very limited surface bloom since treatment (photo from July 2025)

Water Quality- Chloride

- Chloride enters the Lake through winter maintenance:
  - Swan Lake Village Corporation
  - City roads
  - Residents north of the Lake
  - AMICA Corporation to the south
- Previously on upward trend likely due to blockages, which resulted in untreated flows to the Lake
- Since 2021 decreased due to clearing the blockage at the East Pond inlet and Swan Club OGS
- Long-term guideline derived to protect *the most sensitive life stage of the most sensitive aquatic species* over the long term



Fish Management

- Removing bottom-dwelling fish to prevent sediment disturbance.
- Fish in the Lake included Common Carp, Brown Bullhead, and Fathead Minnow.
- 500 juvenile largemouth bass added in May 2025.

Bass stocked in May 2025

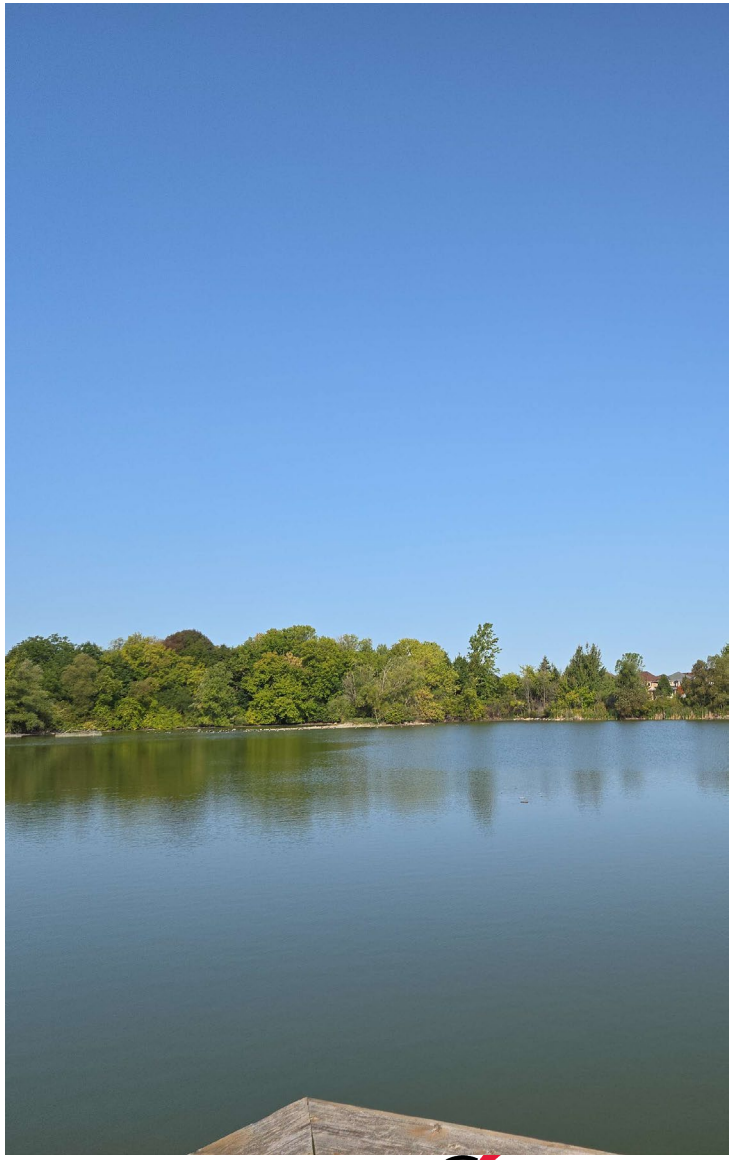
Submerged Aquatic Vegetation

- 3000 stems of wild celery planted in fenced locations on the north site in 2023 and 2024
- Naturally growing aquatic plants were also abundant in 2024 and 2025
- Further SAV planting will be assessed through the five-year review process
- 2025 survey indicated SAV was abundant throughout the lake

Aquatic Vegetation Survey in July 2025

Program Outcomes

- Significant improvements in water quality and habitat have been realized, including aquatic vegetation and fish community
- Water quality now consistently meets expectations for shallow urban water bodies
- Innovative technologies and academic research are actively being evaluated
- Phase 1 of the Long-Term Management Plan has successfully met all established goals and targets.



Comparison

Report References

- Sources used to characterize the Lake and the outcome of management activities include:
  - FOSLP. 2023. Appendix B: Recycling North Channel. In: Towards a comprehensive restoration plan for Swan Lake
  - FOSLP. 2025a. Swan Lake Water Quality Plan: Summary of Phase 1 Discussions (2021–2025) *
  - FOSLP. 2025b. Swan Lake Water Quality Plan Review (Phase 1 Review Summary and Phase 2 Preparation) *
  - Literature, Regulations, AI
- Missing Sources **:
  - City of Markham annual reports, presentations, council reports, since 2010
  - Review of previous FOSLP submissions since 2019
  - Swan Lake Water Quality Strategy (2020) and Long-Term Management Plan (2021)

Clarification:
- Have City reports and FOSLPs submission reviews been reviewed by Burnside?
- How does your submission take into account the City's previous reports, external expert assessments, and the Subcommittee and Council discussions dating back to 2010?

* These documents have not been submitted to the City.
** These documents are available on the City website, and more details would be provided upon request.

Lake Conditions and Program Outcome

- Report Claims:
  - "High abundances of phytoplankton continue to cause turbidity and low DO, which may interfere with macrophyte re-establishment ...
  - Elevated internal nutrient loading and chloride concentrations may impede current and future restoration efforts if left unaddressed.
  - At the current chloride concentration (~200 mg/L), further ecological improvement is unlikely
  - Due to high turbidity from phytoplankton preventing macrophyte growth, …
  - Chemical treatment has been the main phosphorous control throughout the lake's history. "
- Observed Data and Implemented Measures:
  - Nutrient and chloride levels have dropped significantly in recent years. An abundance of macrophyte in the Lake in 2024/2025.
  - Geese management since 2016 to control the main external source of nutrients. Removal of bottom-dwelling fish since 2021. Chemical treatment is less frequent, and it also prevents the release of internal load from sediment source.

Clarification:
Would your conclusions change if updated to include the recent monitoring record and management measures?
How would you interpret macrophyte recovery under lower nutrient/chloride conditions?

Evaluation of Proposed Bioswale

- Report Evaluation:
  - "Improving water circulation through a bioswale system and/or artificial aeration may help reduce internal nutrient loading [and] could assist in nutrient management by helping to remove and sequester internal phosphorus loading…
  - The addition of biochar, recommended by York University as a means of aiding nutrient and chloride …"
- Missing Information:
  - No independent analysis, site-specific calculations (e.g., to quantify load reduction) or similar lake applications to substantiate performance at Swan Lake
  - The fundamental premises underlying the recommendations are not supported by available evidence.
  - Characterizing Swan Lake as hydraulically stagnant, poorly mixed, and oxygen-limited is inconsistent with observed monitoring data.
  - York University is currently conducting a study on effectiveness of biochar for nutrient and chloride reduction, and the research is at early stages.

Clarification:
Please share site-specific calculations and comparable case studies that support the bioswale recommendations and indicate how your conclusions would change if the Lake's hydraulics and current oxygen concentrations are considered.

Zooplankton and Macroinvertebrates

- Report Recommendations:
  - ".. assessing the present zooplankton community is advised to determine whether the working hypothesis (i.e., low Daphnia spp. abundance may be contributing to elevated phytoplankton biomass) holds true"
  - The 2023 survey commissioned by FOSLP "indicated that Swan Lake supports a fair-to-intermediate water-quality community, with reduced diversity near stormwater inflows … suggesting that poor water quality continues to shape community structure
  - Swan Lake currently offers minimal physical habitat conducive to the recovery of zooplankton even in the absence of high chlorides."
- Responses:
  - Zooplankton monitoring is not required for the program's ability to evaluate lake condition or management effectiveness.
  - Markham's consultant reviewed the 2023 macroinvertebrate report and pointed out issues with methodology and timing.
  - Macrophytes are abundant in the lake, providing habitat for zooplankton.

Clarification:
What additional information do you expect zooplankton monitoring to provide that is not already captured through existing lake condition indicators and management effectiveness metrics?

Fish Community

- Report Observations:
  - "The shallow morphometry of Swan Lake, with its broad surface area and limited depth, may constrain the successful establishment of Largemouth Bass.
  - Bass strongly prefer in-water structure provided by macrophyte beds and coarse woody material.
  - Deepening portions of Swan Lake could create refuge pools suitable for overwintering Largemouth Bass, although suitable water quality needs to be confirmed during all seasons
- Response:
  - Bass survival will be monitored this year, and further adjustment will be made to the fish management measures as appropriate.
  - Deepening the lake will require sediment removal which is not advisable due to risk of contamination.
  - Based on lake bathymetry, a connecting trench would need to be about 1-2 m deep, which is not feasible as sediment coring indicated that the thickness of surficial organic sediments is limited to approximately 10 cm, with sandy or consolidated materials encountered immediately below.

Clarification:
How was deepening the lake evaluated as a feasible option given the contamination risks of sediment removal, and the limited depth of organic sediments identified in core samples?

Path Forward

- Will Burnside update their submissions considering City feedback?
- City will incorporate the following input in the Phase 2 Plan:
  - Habitat enhancement, e.g., woody debris if macrophytes are not sustained
  - Monitoring of bass survival and further fish management adjustment (feedback on unsuitable species will help guide fish stocking choices)

Swan Lake Water Quality- Meeting with R.J. Burnside

February 11, 2026

Meeting Minutes
Swan Lake Water Quality Consultation- Meeting with R.J. Burnside on February 10, 2026

Location: 8100 Warden Ave.

Date: February 10, 2026

Time: 10 am- 12 pm

Attendees: City: Robert Muir (RM- partial attendance), Zahra Parhizgari (ZP)
City Consultant: Tammy Karst-Riddoch (TKR)
FOSLP: Fred Peters (FP)
FOSLP Consultants: Chris Pfohl (CP) and Mark Saunders (MS) from R.J. Burnside

Regrets: NA

I. Public meeting- FP has spoken with Councillor Ho about a public meeting in February. This has not been communicated to Staff and given the timeline it does not look like there will be one.

II. RM and ZP went over the City presentation, describing the lake management long-term plan, current conditions of the lake, and comparison of observed data with the Burnside report (Swan Lake Aquatic Conditions Review, Nov. 26, 2025, referred to as 'the report') commissioned by Friends of Swan Lake Park (FOSLP).

III. References- Burnside has reviewed City reports but not listed them not to inflate references. ZP asked if they reviewed City's assessment of previous FOSLP's submissions. Not directly, but FP had provided a summary. Burnside will add any references they reviewed to their report. FP will share summaries he provided to Burnside.

IV. Lake conditions- Burnside report was based on the conditions prior to submerged aquatic vegetation (SAV) establishment and survey. MS said current plants are not desirable and could be a result of waterfowl seed dispersal from feces. He also thought 200 mg/L for chloride is a "ratchet" that limits the abundance of *Daphnia*. MS stated that chloride reduction is likely a key factor to improving ecological/biological conditions.
TKR said the plants were native species that established because of improved water clarity with lower algae levels and that chloride concentrations are high for just one species of *Daphnia.* There are others that tolerate 200 mg/L. Otherwise, the lake conditions have improved and will help establish zooplankton.
TKR asked what the management goal was to complete a zooplankton inventory. MS said to know if chloride is impacting the recovery. Burnside recommended a reduction in fathead minnow by

ensuring a top predator is in place to provide trophic balance (which the City is already doing by adding bass).

V. Zooplankton- TKR described the lake current conditions to be on a recovery trajectory.
Some of the observations made in Burnside report, e.g., those related to zooplankton, assume there is no macrophytes in the lake, which is not the case since 2024. With the abundance of aquatic plants, there is refuge for zooplankton and stocked bass will also feed on planktivorous fish, helping zooplankton population.
MS was in alignment and did not recommend stocking with zooplankton, but wanted to see if chloride concentrations are impairing zooplankton survival, for target *Daphnia* species. He mentioned an artificial lake in upstate NY, where specialists looked at zooplankton and found reduced *Daphnia*.

VI. Dissolved Oxygen- TKR discussed the limited extent of anoxia, which occurs periodically in the deepest point of the lake, comprising about 2-3% of volume when it occurs. MS said he agreed but the deeper part is the most biologically relevant area where fish seek refuge, and mechanical aeration might be an option in that area. CP stated that fish may avoid deep areas when oxygen levels are low. Fish require refuge in areas like deeper zones although they will not use them if the conditions are not suitable i.e., low oxygen.

VII. Sediment- TKR said the existing sediment was 10 cm deep in 2020, mostly from deposition of phytoplankton and other organic matter. This would make sense because the decomposition rate is so fast with shallow, warm water conditions. More recently, the decomposition of macrophyte will change the composition of sediment. Now we might have a different nutrient pulse as plants take up nutrients from sediment.

VIII. Objective for the lake- TKR said we should be realistic on what we call success for this lake, given the hard water system, naturally abundant nutrients in watershed soils, and being in an urban area. CP agreed that we cannot have a pristine lake but can improve habitat.
FP said the community sees this as a wetland system. They care about the fish because birds feed on them. The City approved development nearby, and the community wants to protect this oasis. The community wants to make the lake self-sustaining because the City will not be managing it forever.

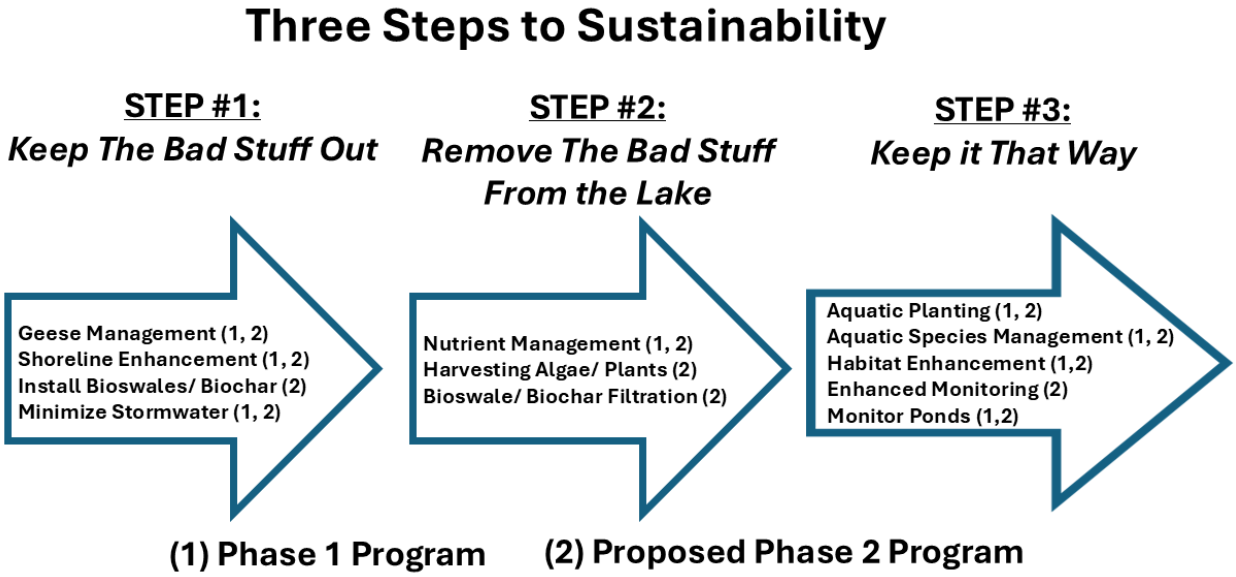
IX. Bioswale- Burnside only reviewed this concept from a biological standpoint, in general terms. TKR said there is some evidence from TRCA research that it could help with reducing high concentrations of nutrients, but concentrations in lake water are very low now, and additional reduction through a bioswale would be very minor. At these low levels, a bioswale may add nutrients in dissolved forms through geochemistry.
MS stated that the bioswale was recommended for nutrient removal not aeration. CP thought if we can rehabilitate the area that is degraded it would be a good educational and stewardship opportunity. FP has talked to Dr. Barb Zeeb, about the kind of plants that can be planted in bioswales.

X. In-lake trench- the City agreed that habitat quality could be improved by adding logs and woody material but that dredging for a trench is not feasible or advisable. MS agreed that deepening would

not be a cost-effective option for habitat improvement if the deeper areas can become anoxic. It will also be a very expensive option that can be disruptive..

Action Items	Owner(s)	Deadline
To list all references used in the report	Burnside	Mar 1, 2026
To share summaries provided to Burnside with City	FOSLP	Mar 1, 2026
To update report considering the abundance of macrophytes	Burnside	Mar 1, 2026
To update report for bioswale and trench concept	Burnside	Mar 1, 2026

TOWARDS A SUSTAINABLE NATURALIZED WETLAND



Submission for Markham's Swan Lake Water Quality Review By

Friends of Swan Lake Park

March 12, 2026

Contents

EXECUTIVE SUMMARY 3

I) FOSLP's Proposed Actions for Phase 2 7

A) Lake Management Program 7

B) Enhanced Monitoring Program 9

C) Habitat and Shoreline Enhancements 10

D) Actions to Minimize the Impact of Stormwater 10

II) Phase 2 Recommendations by FOSLP Advisory Groups 14

A) Noel: Shoreline Health and Its Role in Maintaining Water Quality 14

B) Burnside: Aquatic Environment Recommendations 16

C) NRSI: Elements of a Comprehensive Oxygenation Program 19

D) NRSI: Swan Lake Management Strategy Program Considerations 22

E) NRSI: Water Quality Monitoring Program Enhancements 26

F) References/ Links to Full Reports 27

APPENDIX A: FOSLP BACKGROUND REPORTS 28

A1): Outsourcing of Environmental Health Card 28

A2) Options For Ending Swan Lake's Stormwater Management Role 31

A3) Refinements to Flow Diversion Report 35

A4) Understanding the Role of Groundwater 39

A5) Comprehensive Oxygenation Program for Swan Lake 44

A6) Creating Overwintering Haven for Aquatic Species 48

APPENDIX B: PHASE 1 ACTIVITIES 49

B1) Lake Management Outcomes 49

B2) Phase 1 Lake Monitoring 52

B3) TRCA Phase 1 Activities and Recommendations 54

B4) Preliminary Water Quality Results (February 2026) 56

EXECUTIVE SUMMARY

Swan Lake Park is a biodiverse 14 hectare municipal park located at 25 Swan Park Road in Markham. Swan Lake, within Swan Lake Park, covers 5.4 ha and has a history of poor water quality and poor aquatic habitat. University of Toronto biologists categorized Swan Lake as a "constructed wetland " while Markham's aquatic adviser referred to it as an "open wetland".

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

In December 2021, Markham Council approved the Swan Lake Long-term Water Quality Plan which describes a phased adaptive approach with specific actions outlined for Phase 1, the initial 5 years from 2021 – 2025.

In 2025, Markham staff initiated a review of the long-term plan with a view to seeking approval from the Markham Subcommittee in April 2026 for Phase 2, (2026 – 2030).

There were significant improvements in surface water quality attributable to the Phase 1 program and all of the Phase 1 goals were met. The Phase 1 program was designed to reduce algae and improve clarity through a program focused on reducing nutrients, primarily phosphorus. Reduction in nutrient levels exceeded the interim goals. Algae levels were reduced but not to the same degree as nutrients while clarity improved only marginally.

Other benefits arising from the Phase 1 program were improvements in oxygen levels and a significant increase in submerged aquatic vegetation. Chloride levels declined significantly, likely contributing to the return of the aquatic vegetation. The decline in chloride (from road salt) is attributed to clearance of a blockage in one of the stormwater pipes, however the decline also indicates the significant influence of the groundwater system on the dynamics of the lake.

Restatement of the Long-term Goal

The stated goal of the 2021 long-term plan is:

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

It has been pointed out by several of FOSLP's advisors and by Markham's principal aquatic advisor that many of the differences between the actions within Phase 1 and those requested by FOSLP are primarily related to differences in goals.

This is substantially true. There are three differences in objectives that FOSLP would like to see addressed during Phase 2:

1) The Definition of "Health"

Swan Lake Park is one of the most biodiverse areas in Markham, largely attributable to the wetland elements within the park.

The rehabilitation of the water quality and aquatic life within Swan Lake is essential to stabilizing the park's ecosystem and preserving this naturalized oasis in light of increasing urbanization of the area. Markham Council is in the final stages of approving a redevelopment plan for the nearby Mt. Joy area that will double the local population.

FOSLP's definition of "health" includes all of the aquatic elements in the lake – in particular the lower level elements in the food chain (zooplankton etc.), that are essential components of a sustainable solution. Phase 1 monitored only selective elements of the aquatic environment. FOSLP's advisors and FOSLP believe it is essential to monitor all of the aquatic elements during Phase 2. FOSLP has outlined the scope for an "Environmental Health Card" that captures the critical aquatic elements that should be monitored during Phase 2.

2) Strive for a Sustainable Solution

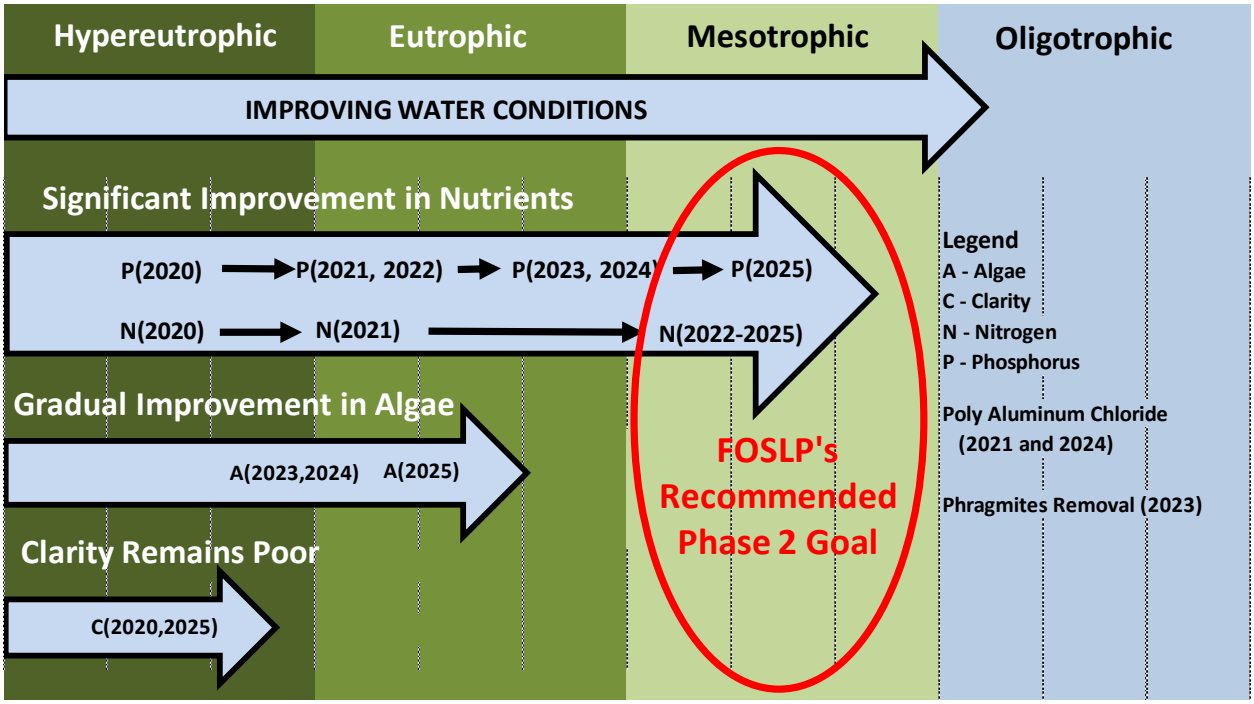
The stated objective for Phase 1 was to attain "Eutrophic" level conditions. This has been substantially accomplished. FOSLP's objective is for an ecosystem that is as self-sustainable as possible with the need for minimal future interventions. It is why we stressed in 2021 establishing the long-term goal as being the more stable "mesotrophic" state. The significant improvements during Phase 1 make this a more attainable objective.

Lake Conditions and Community Options Associated With Trophic States

TROPHIC STATE	AQUATIC ENVIRONMENT	COMMUNITY OPTIONS
Oligotrophic	Lack of plant nutrients keep productivity low, lake contains oxygen at all depths, clear water.	Swimming, paddle sports, wide range of fish options.
Mesotrophic	Moderate plant productivity, lower levels may lack oxygen in summer, moderately clear water and warm water fisheries only.	Paddle sports, swimming possible if monitored, good range of fish options.
Eutrophic	Contains excess nutrients, blue-green algae dominate during summer, algae scums are probable at times, lower levels lack oxygen in summer, poor transparency, rooted aquatic plant problems may be evident.	No swimming, paddle sports possible, limited range of fish options.
Hypereutrophic	Algal scums dominate in summer, cyanobacteria, few aquatic plants, no oxygen in lower levels, fish kills possible in summer and under winter ice.	No human interaction, potential health risk for humans and small animals.

Current results indicate that many of the critical elements, such as nutrients, are now within the definition of mesotrophic. The goal of Phase 2 should be to implement programs to further reduce algae and to improve clarity to the mesotrophic level. We recommend that Phase 2 goals target the "mesotrophic" range for all of the key metrics with the goal for chloride to be below the long-term Federal guidelines.

SWAN LAKE WATER QUALITY: PHASE 1 CHANGES 2020 - 2025



3) Return To a Naturalized State

Swan Lake has been described as a "closed-system" because it has no natural surface level streams. Evidence from Phase 1 reinforces the conclusion that the lake has a dynamic relationship with the groundwater system in the area, suggesting that it is demonstrating characteristics associated with a recharge area.

In June 2025, Markham Council agreed that as part of the Official Plan review, to consider FOSLP's request that Swan Lake and Swan Lake Park be reclassified as Natural Heritage Lands. Both satisfy the criteria due to their biodiversity and the habitat they provide to a variety of species listed at risk. Within Natural Heritage systems, major water bodies are considered significant natural sources for recharging the aquifer. Swan Lake meets the technical criteria set out in Markham's Official Plan and the Ontario guidelines for a "Key Hydraulic Feature".

FOSLP recommends that tests be undertaken during Phase 2 to understand the chemical elements within the groundwater – this will define what a "naturalized" state for the lake could look like if all stormwater sources were eliminated and other elements were brought under control.

Swan Lake existed for over 20 years as a stand-alone pond created and influenced by groundwater sources. Detailed water quality assessments in the mid-1990's indicated relatively stable aquatic conditions. Since the addition of stormwater sources, conditions have deteriorated substantially. Chloride from the road salt, undermines the most sensitive forms of zooplankton that consume algae and help maintain a natural balance. There are no known ecological benefits associated with road salt and chloride. As long as stormwater inflows are permitted, a stabilized aquatic environment may not be attainable. Actions should be undertaken to minimize the impact of stormwater inflows and to develop a plan to substantially eliminate stormwater inflows and return the lake to its naturalized state.

Stormwater flows can be substantially eliminated for $1.6 million. A large investment but one that has to be assessed in the context of the elements of the current program. The objective for Phase 2 should be develop lake conditions that are sustainable thereby minimizing the need for future interventions. This is a more likely outcome if chloride is removed from the system and the lake is allowed to go back to its natural state with the natural elements and groundwater as the primary influencers. There are some low cost efforts that can be implemented during Phase 2, including the installation of salt tolerant bioswales and once the city assumes control of the stormwater ponds, alterations to the Flow Splitters that will reduce inflows by 30% at a cost of $125,000.

> **FOSLP's Recommend Goal for Phase 2:**
> *"To improve the overall health of Swan Lake with the objective of sustaining a naturalized wetland which will provide the opportunities for no-contact activities for the enjoyment of the community."*

The following report is a revision of FOSLP's preliminary submission on December 3, 2025 to Markham staff . The revisions reflect the release by Markham of new water quality data for 2025, additional information on aquatic plants in the lake, and feedback arising from discussions with Markham staff in February 2026.

This report summarizes the analysis and recommendations by FOSLP's advisors and FOSLP's recommendations for actions to be included in the Phase 2 program reflecting this new information and the direct discussions with FOSLP and its advisors.

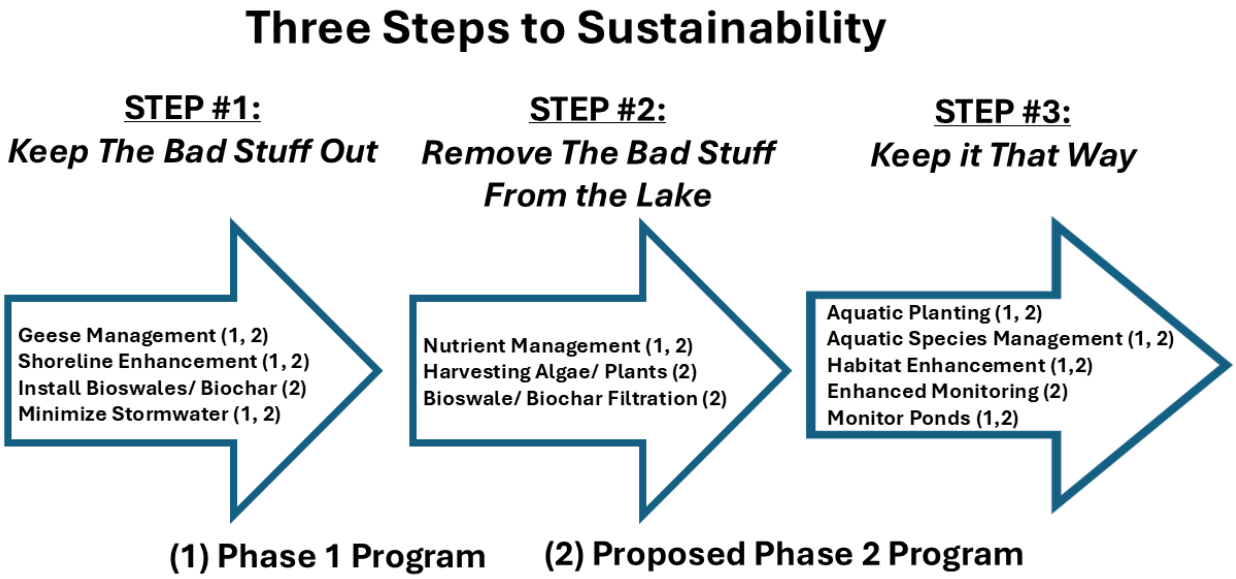
I) FOSLP's Proposed Actions for Phase 2

We recommend four core actions for Phase 2:

A) Continue the comprehensive lake management actions undertaken during Phase 1
B) Introduce an enhanced monitoring program that includes more aquatic elements
C) Implement habitat and shoreline enhancements
D) Initiate actions to minimize the impact of stormwater

A) Lake Management Program

Phase 2 should build upon the successes of Phase 1, while addressing directly continuing issues of excessive algae, poor clarity and high chloride levels. FOSLP proposes that actions during Phase 2 be structured to recognize three core steps to a sustainable ecosystem for Swan Lake:



Continue Nutrient Reduction Efforts But Introduce Direct Actions on Algae, Turbidity and Chloride

Step #1: Keep the Bad Stuff Out

1) Continue the geese hazing and relocation program to reduce external sources of phosphorus and nitrogen.
2) Enhance the shoreline areas as recommended by the TRCA, Burnside and Noel to reduce the impact of nutrients and chloride entering the lake and to absorb nutrients already in the lake.

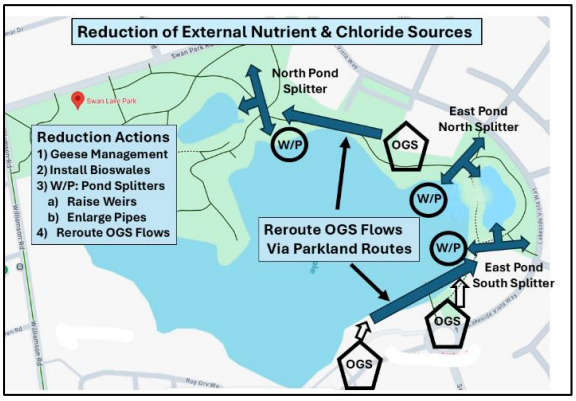
3) Minimize chloride inflows entering the lake

a) As recommended by Burnside, install bioswales at each of the six stormwater inflow sites and harvest the plants every 2-3 years.

b) Install a Biochar filtration unit at the Swan Club OGS

c) Reduce chloride inflows by 30% by altering the three splitters that control stormwater flows bypassing the ponds (Cost $125,000)

d) Monitor contaminants entering the lake via untreated stormwater.



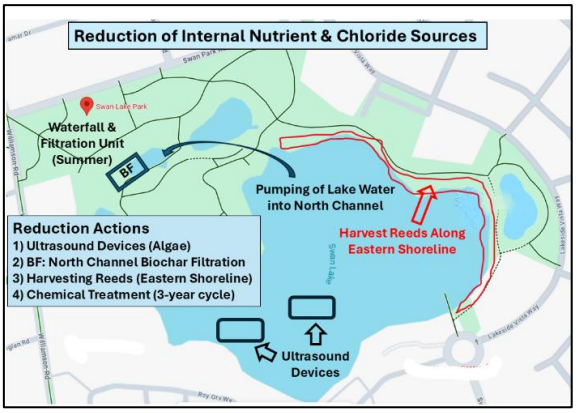
Step #2: Remove the Bad Stuff from the Lake

1) Continue with a program to remove phosphorus and nitrogen from the lake by:

a) Continue the 3-year PAC treatment program to contain phosphorus.

b) At least once during Phase 2, harvest the shoreline reeds in the fall to remove phosphorus, nitrogen and chloride from the ecosystem

c) Implement a Biochar filtration unit as a component of the recycling process through the North Channel.



2) Undertake a program to directly target algae by:

a) Continuing use of the ultrasound equipment, consider rotating locations.

b) Each spring harvest the algae that floats on the lake surface.

Step #3: Keep It That Way

1) Remove any returning phragmites and other invasive species from the shoreline
2) Continue with aquatic and shoreline planting to support aquatic and park wildlife
3) Continue with the fish management program and, if required, investigate the opportunity to stock zooplankton or mussels to support the algae management program
4) As recommended by NRSI, establish goals that align with Federal and Provincial guidelines and create triggers to address changes if conditions deteriorate.
5) As recommended by NRSI and Burnside, implement a comprehensive monitoring program that will monitor the eutrophic levels, aquatic habitat and aquatic life (zooplankton, Benthic Invertebrates), the sediments, stormwater inflows and the success of specific management actions undertaken during the rehabilitation program.

B) Enhanced Monitoring Program

A) Environmental Health Card

The Phase 1 monitoring program provided adequate monitoring of trophic levels of water quality but included only certain elements essential to an aquatic monitoring program and had very limited monitoring of contaminants (only chloride) entering the lake via stormwater.

In their reports, both R. J. Burnside[d] and Natural Resources Solutions Inc. [e,f] outline the need for a more enhanced water quality monitoring program for Phase 2 that should include monitoring trophic levels and the results from the management actions but also provide more specific information on the contaminants entering the lake from stormwater sources, the elements in the sediments and the aquatic life within the lake.

FOSLP recommends that Phase 2 monitoring include more extensive monitoring of the aquatic elements based on the following frequencies.

Frequency of Testing for Environmental Health Card

	Phase 1	Phase 2
Inorganics (P, N, etc.)	Bi-weekly	Bi-weekly
Aquatic Life		
- Phytoplanckton	Bi-weekly	Bi-weekly
- Microcystins	Bi-weekly	Bi-weekly
- Zooplanckton		Bi-weekly
- Benthic Invertebrate		Annually
- Fish	Annually	Annually
Aquatic Vegetation	Once	Annually
Stormwater Inflows (1)	Spring	Spring, major rainfall events
Sediments	Once	Annually

Note: Phase 1 stormwater testing only monitored chloride. Phase 2 testing should include Total Suspended Solids and other elements normally associated with stormwater

b) Engage University Researchers

In addition to the monitoring work undertaken by Markham and the TRCA, both Trent University and York University researchers were active during 2025. Trent undertook detailed physical water testing at 10 locations within the lake while York researchers initiated a done monitoring program. The two groups are now working to integrate their work.

We are fortunate to have two leading research teams interested in integrating Swan Lake into their research programs. Combined with Markham's needs for essential data to monitor its programs, there is an opportunity for Markham to formalize a water quality monitoring program that meets its core needs while providing baseline information for advanced

research that will provide Markham and others with critical information on the impact of lake management activities.

University researchers need data to support their advanced research programs, and the lake management activities underway in Swan Lake make it an attractive location for their research. Both the York and Trent research groups have the technical capabilities, and both have expressed an interest in participating in a co-ordinated and enhanced monitoring effort throughout Phase 2.

FOSLP is recommending that Markham undertake a co-ordinated water quality program during Phase 2 that leverages the talents of the university research teams, gives Markham the core information needed for Phase 2 while providing baseline data for the advanced research projects the university teams are undertaking.

The proposed outsourcing of the Environmental Health Card program is outlined in Appendix A1.

C) Habitat and Shoreline Enhancements

1) Re-engage the TRCA to strengthen the aquatic habitat and shoreline by:
   a) Following through on the TRCA's "Restoration Opportunities" outlined in 2022.
   b) Addressing shoreline habitat concerns raised by Noel.
   c) Implementing the aquatic habitat enhancement recommendations outlined by Burnside to support aquatic life including structural habitat (woody structures, rock clusters).
   d) Addressing the needs of park visitors and fishers by implementing the recreational shoreline enhancements recommended by TRCA in 2020 and supported by FOSLP in 2024.
2) If largemouth bass have difficulty surviving, consider Burnside's recommendation to deepen areas within the lake potentially by creating trenches linking the deeper portions of the lake. See Appendix A6.
3) Now that the cyanobacteria levels are significantly lower, FOSLP requests that the water fountain be brought back to a location near the dock.

D) Actions to Minimize the Impact of Stormwater

Friends of Swan Lake Park urges Markham to implement an action plan during Phase 2 to minimize the impact of stormwater on the lake ecosystem. During Phase 1, several important steps were completed, namely the completion of the Flow Diversion Report by AECOM and an update of the water and chloride budget. These reports confirm that there are practical solutions available to end Swan Lake's stormwater role.

We have not encountered any research that attributes positive environmental benefits to road salt while the harm caused by chloride is well documented. Little is known about the

lower-level aquatic elements within Swan Lake, such as the quantity and diversity of zooplankton, so we encourage Markham to adopt the proposed Environmental Health Card for Swan Lake. This annual report will provide meaningful information on the state of the environmental health and insight into the impact of chloride on the ecosystem and contribute to future lake management discussions.

There are four basic actions that we recommend be incorporated into Phase 2:

1) Enhanced monitoring of the stormwater infrastructure
2) Monitoring of contaminants from the stormwater sources
3) Analysis of issues arising from the Flow Diversion Report and the subsequent review related to refinements of the available flow reduction options and related costs and concerns about the potential impact, if any, on lake dynamics.
4) Development of a plan to phase out stormwater flowing into Swan Lake.

1) Enhanced Monitoring of Stormwater Facilities

It is important to continue the work started in Phase 1 to monitor the effectiveness of the existing stormwater infrastructure to avoid issues arising from future blockages.

During Phase 1, two blockages were cleared that impacted the effectiveness of the stormwater systems. The pipe at the East Pond that created the greatest bypass issue is prone to refilling through local erosion so routine monitoring is required. The two stormwater ponds, still under the control of the original developer, are 25 years old, nearing the time when a cleaning will be required. Our understanding is that a review during Phase 1 concluded that a cleaning was not required at that time.

Given the age of the ponds and the negative maintenance experience, we request annual reviews of the pond infrastructure and of the pond's effectiveness be undertaken during Phase 2 until Markham assumes control of the ponds.

2) Monitoring of Contaminants Entering the Lake

Approximately 45% of the stormwater inflow originates as untreated stormwater that has bypassed the two stormwater ponds – it is not pre-treated water from the ponds. The bypass flows have been described as the "second flush", flows that arise during heavy rainstorms or snow melts. As such, they are expected to contain lower levels of any contaminants normally associated with stormwater. The other 55% of stormwater enters through three 25-year-old OGS units designed to remove heavy contaminants but not any contaminants that are soluble.

We are not aware of any testing that has been done for contaminants other than chloride that enter the lake via the stormwater sources. We request, as NRSI has recommended, that testing of stormwater sources include measuring other contaminants entering the lake.

3) Complete Analysis of Rerouting Options and Impact on Lake Levels

The Flow Diversion Report validated that viable options exist for rerouting stormwater. There is, however, the need for further refinement to the analysis:

a) Developing revised estimates for the lower cost "Parkland" route options (Appendix A3)
b) Refining the analysis of the changes to the Flow Splitters to identify the lowest risk options. (Appendix A3)
c) Determine if there is any basis for the concern expressed about the impact of reduced stormwater inflows on lake levels. For over 20 years the lake levels were stable before any stormwater inflows were introduced. Current water flow analysis suggests that eliminating the stormwater inflows would not materially impact lake levels. (see Appendix A4). To address the concerns, we recommend further analysis of the lake dynamics be undertaken including the potential impact, if any, on eliminating stormwater inflows.
d) The significant drop in chloride levels was wonderful news. It underscores the importance of good maintenance but also indicates the apparent positive influence of groundwater on the lake system. Appendix A4 summarizes some of the current information that illustrates the impact of the groundwater on the lake dynamics. Phase 2 should include further analysis to identify the contaminants in the groundwater and quantify the impact of groundwater on the lake's system.

4) Phase 2 Actions to Minimize Impact of Stormwater Role

The Flow Diversion Report provided an estimate cost of $1.75 million to reroute the Amica and Traffic Circle OGS flows. There is however a significantly lower-cost solution to rerouting the Amica and Traffic Circle OGS flows using the "Parkland" route (see Appendix A3) which avoids the costs of restoring paved roadways.

The Water and Chloride Budget estimated total annual chloride inflows at 2.95 tonnes. Applying the flow reduction estimates provided by the Flow Diversion Report, illustrates that rerouting all OGS flows and 65% of the pond bypass flows could reduce chloride inflows by 2.52 tonnes – an 85% reduction for a cost we estimate at $1.6 million using the lower-cost Parkland routes.

		Parkland Route		
	Original Estimate	Cost Estimate	Potential Chloride Reduction	Cost Per Tonne
Rerouting Amica/TC OGS Flows	1,757,025	1,168,101	1.41	828,441
Rerouting Swan Club OGS Flows	275,072	275,072	0.25	1,100,287
Adjust Flow Splitters	124,787	124,787	0.86	145,101
Totals	**2,156,884**	**1,567,960**	**2.52**	**622,206**

The most cost-effective solution is the ability to reduce chloride inflows by 0.86 tonnes (30%) by adjusting the design of the Flow Splitters at a cost estimated by AECOM at $124,767. However, the ponds remain under the control of the developer so this is not an action that can be initiated immediately. There are some actions that could be undertaken in the meantime such as further analysis of the design considerations on the Flow Splitters and analysis to alleviate concerns about the impact on lake levels.

The York University researchers have indicated that they are working to identify a more effective form of Biochar for the filtration analysis and could be ready for an installation of a field level test in 2027. The Swan Club OGS unit would appear to be the most feasible location for this test.

We request that Phase 2 include four actions to minimize the impact of stormwater inflows:

1) Install bioswales containing chloride tolerant plants at each of the six stormwater inlets and harvest every 2-3 years to remove chloride and nutrients from the ecosystem.
2) Complete the analysis related to redesign options for the Flow Splitters and any impact on lake levels with the objective of implementing the design changes once Markham has assumed control of the ponds (see Appendix A3).
3) Undertake an assessment of the impact of rerouting the stormwater flows on the lake dynamics. (Appendix A4)
4) Work with York University researchers to implement field level testing of Biochar filtering mechanism at the Swan Club OGS unit. (Appendix A2)

II) Phase 2 Recommendations by FOSLP Advisory Groups

In 2025, FOSLP engaged two groups of aquatic biologists, R.J. Burnside & Associates Ltd. ("Burnside") and the Natural Resource Solutions Inc. ("NRSI") to review the long-term water quality plan, the actions and outcomes of Phase 1, and to provide recommendations for actions during Phase 2 that would support a long-term sustainable outcome for Swan Lake.

Kathleen Elizabeth Noel, a local naturalist and FOSLP member who has led FOSLP-sponsored birding tours of Swan Lake Park outlined the environmental sensitivity of the shoreline.

Link's to the advisors' full reports are provided in the references section but their key findings and recommendations are outlined below in italics.

A) Noel: Shoreline Health and Its Role in Maintaining Water Quality

Kathleen Elizabeth Noel, a local naturalist and FOSLP member, notes that when discussing and addressing the issue of the water quality in Swan Lake, shoreline habitat improvement and restoration should be paramount. Swan Lake's shorelines have become degraded due to several issues including the lack of emergent aquatic vegetation and terrestrial and native plants and shrubs.

Natural shorelines are known as ribbons of life for a reason and work as living filters to help improve and preserve water quality. Healthy, natural shorelines play an important role in filtering sediment and runoff, protecting against erosion, and absorbing excess nutrients. Furthermore, shorelines facilitate the exchange of resources between aquatic and terrestrial ecosystems, and therefore affect the functioning, ecological condition and health of both ecosystems.

She recommends several actions to strengthen and support the Swan Lake's shoreline:

1. **Support and Sustain the Existing Biodiversity**: Swan Lake Park is incredibly biodiverse and home to a plethora of birds and wildlife. Native birds and wildlife benefit and stabilize shoreline health and water quality through the various roles they play in regulating nutrients and maintaining ecosystems. At least 184 distinct native species of birds, aside from Canada geese (*Branta canadensis*) have been recorded in the park, 15 of which are classified as species at risk under Schedule 1 of the Government of Canada's *Species at Risk Act*. The park supports a diversity of mammals and amphibians, including two species of turtles rated as being of Special Concern under Schedule 1 of the Government of Canada's *Species at Risk Act*, all with a reliance on Swan Lake.
2. **Native Shoreline Plants**: Having native vegetation along the shoreline is crucial for healthy water quality as it acts as a living filter which helps to catch pollutants and sediments from runoff before they can reach the water, preventing them from negatively impacting water quality.

Shoreline buffers are areas along bodies of water where plants grow and are not mowed or disturbed. Many native plants have deep root systems that can help to stabilize soils and will guard against erosion and help create vital habitats for wildlife. Shoreline plants can additionally help ameliorate water quality by providing shade, aiding in the cooling of water necessary to provide a healthier aquatic environment for native species of fish and other wildlife.

3. **Harvesting**: Planting native species of salt-tolerant plants (halophytes), including switchgrass (*Pancium virgatum*), sand dropseed (*Sporobolus crytandrus*), prairie cordgrass (*Sporobolus michauxianus*), and sideoats grama (*Bouteloua curtipendula*), and employing harvesting methods to naturally manage excessive chloride levels in Swan Lake in the long-term. The harvesting process involves planting the native halophytes, allowing them to lay dormant over the winter months and flourish in the spring and summer and be cut at the base of the plant and removed from the site when they are mature the following fall. Research indicates that if this process is followed for at least three consecutive years, chloride levels in the soil drop and soil remediation is achieved. Less chloride in the soil would mean less chloride in the water, and an improvement in shoreline health and water quality as a result. This method is currently being employed to manage chloride levels at a number of parks throughout the City of Toronto, including Grenadier Pond in High Park, which has long faced issues with having excessive chloride levels that are twice the recommended level for aquatic long-term health and water quality.

Noel outlines three areas of concern.

a) **Invasive Plant Species:** Invasive plant species disturb and degrade shoreline health and the environment as a whole, which in turn has a significant negative impact on water quality. In particular, many invasive plant species including, phragmites and dog-strangling vine (DSV), can decrease water flows and nutrient transportation. Other species of concern include Garlic Mustard, Yellow Iris, Common Tansies, and Burdock. She recommends a follow-up program to remove the returning phragmites and other invasive plant species.
b) **Introduction of Biochar**: She expresses concern about the risk to the environment and native wildlife if biochar filters are employed at Swan Lake Park, noting that multiple scientific studies have detailed the health and environmental risks associated with biochar.
c) **Installation of Goose Fencing:** Noel questions the effectiveness of goose fencing as a deterrent to geese and opposed the installation of fencing along the eastern shoreline. She is concerned that the fencing can be environmentally disruptive and contribute to the degradation of shoreline health and+ water quality through fragmentating and destroying the habitat for turtles, birds and other wildlife that help to maintain ecosystem balance.

B) Burnside: Aquatic Environment Recommendations

Following are excepts from Burnside's Swan Lake Aquatic Conditions review[(d)], revised February 26, 2026. *(Italics added)*

Executive Summary

- *R.J. Burnside & Associates Limited (Burnside) reviewed aquatic habitat conditions in Swan Lake at the end of Phase 1 of the Long-Term Water Quality Management Plan, on behalf of the Friends of Swan Lake Park, to guide recommendations for Phase 2.*
- *Despite improvements to overall water quality, internal nutrient loads and chloride concentrations may impede current and future ecological restoration efforts if left unaddressed.*
- *Construction of a bioswale system in the north channel or adjacent to stormwater/ oil grit separator outlets could assist in water quality management by helping to remove and sequester internal nutrients and/or chloride loading.*
- *Elevated chloride concentration and predation from abundant Fathead Minnows may be suppressing zooplankton grazers (e.g., Daphnia spp.), although no study has yet confirmed this relationship.*
- *Burnside recommends assessing the present zooplankton community to determine whether the working hypothesis (i.e., low Daphnia spp. abundance may be contributing to elevated phytoplankton biomass) holds true. The initial survey may serve as a baseline to monitor if key zooplankton populations recover over the course of Phase 2.*
- *Largemouth Bass stocking in 2025 provides an opportunity to potentially reduce Fathead Minnows. Establishment of a population of bass may be supported by adding complex woody material structures. Future aquatic surveys (i.e., spring (i.e., winter kill) and summer during 2026) are recommended to determine whether current lake conditions are suitable for sustaining bass, especially to overwinter, or if further habitat modifications (e.g., deepening the pond or raising the lake level, addition of physical habitat) may be worth exploring to improve survivability.*
- *There are limited opportunities to use native Unionidae mussels or sunfish species to improve habitat quality.*
- *Due to turbidity from phytoplankton, efforts should focus on creating a sustained period of low turbidity before pursuing further submerged macrophyte restoration.*

Table 7: Summary of Recommendations to Improve Biological / Ecological Conditions During Phase 2

Biotic Group	*Mechanism of Action*	*Effectiveness in Eutrophic Systems*	*Burnside Recommendations*
Native Fish	*Biomanipulation via top-down control*	*Moderate – High minnow population may be suppressing desirable zooplankton.*	*Largemouth Bass stocking (>100 mm) may help reduce minnows if overwintering can be demonstrated.* *Determine whether Largemouth Bass stocked in 2025 survive until 2026 through spring (brief walk around) and summer (fish capture) surveys.*
Native Mussels	*Nutrient sequestration*	*Low – many native mussels sensitive to poor water quality.*	*Paper Pondshell may provide some filtration, but unlikely to contribute significantly.*
Zooplankton *(esp. Daphnia spp.)*	*Grazing on phytoplankton*	*Moderate to high – if predation and chlorides are controlled.*	*Analysis of zooplankton community recommended before considering stocking. Initial survey could serve as baseline to monitor changes cover Phase 2 activities.*
Macrophytes	*Nutrient sequestration, habitat*	*High local effect; supports DO and stability.*	*Further plantings not recommended until sustained periods of water clarity can be demonstrated.*
Habitat Complexity	*Increase habitat complexity*	*High – Placement of woody material (stumps with root mass and elevated logs) or boulder complexes may enhance available habitat for Largemouth Bass.*	*Swan Lake currently offers limited structural habitat. Establishment of a bass population may be aided by increasing habitat complexity through addition of woody debris complexes.* *Deepening not recommended – evaluate after spring / summer 2026 fish surveys to determine bass survivability.*

Nutrient Management

- *Construction of bioswale presents opportunity to further reduce internal nutrient levels*
- *Enhance the existing bioswale to provide opportunities to beautify section of Swan Lake*

Chloride Reduction

- *Maintain focus on source control (grit-separator rerouting, winter salt management, etc.)*
- *Target ≤120 mg/L Cl^- to aid restore zooplankton communities*
- *Reducing chloride inputs into Swan Lake is likely to improve biological / ecological conditions*

- *Creation of small bioswale-like structures at the outlets of SWM pond splitters or OGSs may provide opportunity to mitigate chloride inputs provided with the proper halophyte plantings (i.e., Cordgrass (S. michauxianus))*
- *Rerouting the stormwater outlets and OGSs present a hard-engineering option to chloride reduction*

Macrophytes Recommended by Burnside (Table 6)

Open Waters 0.5 m to 1.5 m Deep

- *Pond Lily* — *Nuphar variegata*
- *Water Lily* — *Nymphaea odorata*
- *Pondweed* — *Potamogeton richardsonii*
- *Pondweed* — *Potamogeton pectinatus*

Shores and Waters to 0.5 m Deep

- *Wild Celery* — *Vallisneria americana*

Shores and Waters to 0.25 m Deep

- *Arrowhead* — *Sagittaria latifolia*
- *Cordgrass* — *Sporobolus michauxianus*

10.0 Conclusion

Success of Swan Lake's aquatic communities depends on improving water quality before attempting further biological restoration. Phase 1 has resulted in improved water quality from 2020; however, problems persist especially with elevated chlorides and internal nutrient load.

Further recovery may require

1) *Nutrient stabilization via bioswale*
2) *Chloride control by some means of reduction*
3) *Improvement to Daphnia spp. populations through reductions in chloride concentrations and selective predator stocking*

Chloride-induced suppression of Daphnia spp. populations is likely exacerbating Swan Lake's phytoplankton blooms. Increasing Daphnia spp. abundance can yield short-term improvements (< two years) in water clarity and phytoplankton control (Kibuye et al. 2021) and should be considered as part of broader lake-management planning. While some mechanism for chloride reduction is recommended, it alone will likely not resolve the issue. Creating or maintaining a population of Largemouth Bass may help to improve the Daphnia spp. populations through the reduction of Fathead Minnow. However, the current zooplankton community is unknown.

Improvement to the water quality of shallow, eutrophic lakes, such as the case in Swan Lake, are impeded by its slow recovery, as it is hard for people to maintain interest (May et al. 2020). However, actions for the improvements of Swan Lake are promising, and should encourage managers to maintain support and interest.

C) NRSI: Elements of a Comprehensive Oxygenation Program

The following is an extract from NRSI's report on the review of management options and the effects of increased oxygenation in Swan Lake[f].

7.0 Conclusions and Recommendations

Within Swan Lake, any management approach intended to increase DO concentrations must be designed not only to address existing DO deficiencies but also anticipate increases in biological oxygen demand (BOD) that will result from enhanced biological and microbial activity following oxygenation. As oxygen availability improves, aerobic bacteria, benthic invertebrates, and aquatic vegetation will become more active, increasing oxygen consumption and temporarily offsetting some of the initial gains in DO. Accordingly, any oxygenation strategy must account for these feedback effects and be implemented as part of a long-term, adaptive rehabilitation program. Importantly, effective DO enhancement within Swan Lake must also target the underlying causes of poor surface water quality,

Specifically, historic and ongoing nutrient and containment loading from high Canada Geese populations, stormwater inputs and the accumulation of nutrient-rich organic sediments. High organic matter concentrations, low sediment oxygen concentrations, and anaerobic bacterial processes may work against active oxygenation programs in Swan Lake. These conditions can consume oxygen more rapidly than it is introduced, thereby slowing the realization of measurable improvements reducing the effectiveness of direct oxygenation by continuously releasing nutrients and consuming available oxygen.

While active oxygenation can be highly effective in addressing short-term hypoxia and improving localized water quality, it rarely provides lasting improvements unless combined with integrated watershed and sediment management actions. Stand-alone oxygenation systems typically require continuous operation to maintain benefits, as discontinuation can lead to a rapid decline in DO concentration, often below pre-treatment level, due to increased BOD and residual nutrient release.

Increased oxygenation in shallow, nutrient-rich systems such as Swan Lake can lead to significant improvements, including:

- *Reduced internal nutrient loading and phosphorus release from sediments.*
- *Decreased bioavailability of heavy metals through oxidation.*
- *Improved surface water clarity and reduced frequency of harmful algal blooms.*
- *Enhanced biological diversity and productivity through improved aerobic habitat conditions.*

However, these benefits are typically realized gradually, as the system responds to improved redox conditions and enhanced biological cycling. Regardless of the oxygenation strategy employed, elevated biological oxygen demand (BOD) can also lead to a sudden decline in dissolved oxygen concentrations, potentially to levels lower than those observed prior to treatment, if oxygenation programs are discontinued without addressing the underlying causes of poor water quality. Effective long-term management will therefore require sustained oxygenation, regular monitoring, and adaptive operational adjustments to maintain DO levels sufficient to counteract high BOD and sediment oxygen demand.

7.1 Oxygenation Program Considerations

Oxygenation represents a viable and effective approach to improving surface water quality and aquatic habitat conditions within Swan Lake. Diffused aeration or fountain aeration systems would likely provide the most balanced combination of performance, reliability, and cost- effectiveness for this small, shallow, and nutrient-enriched lake. When paired with watershed- level nutrient management and ecological restoration efforts, these systems can form the foundation of a long-term strategy to enhance aquatic health, reduce eutrophication, and restore more natural lake function.

However, oxygenation alone will not fully address all water quality deficiencies or the underlying causes of degradation. To improve the effectiveness and sustainability of oxygenation measures, several key factors should be considered when developing and implementing an oxygenation program for Swan Lake.

- ***Address Natural Mixing Limitations**: Any oxygenation program should aim to overcome the lack of natural circulation within Swan Lake to ensure adequate exposure of all areas to elevated DO concentrations.*
- ***Uniform Application**: Oxygenation should be applied uniformly across the lake to prevent the formation of localized hypoxic or anoxic zones.*
- ***Integrated Management Approach**: Oxygenation cannot resolve the underlying causes of poor surface water quality and should be implemented in conjunction with broader rehabilitation measures that address both historical and ongoing nutrient and contaminant inputs.*
- ***Continuous Operation**: Consistent, low-intensity operation is preferable to intermittent high-output cycles, as sudden fluctuations in DO can destabilize the system and increase BOD demand.*
- ***Hydrologic Connectivity**: Recirculation of water through the north channel is expected to provide only limited improvement in DO levels unless underlying nutrient concentrations are simultaneously addressed.*
- ***System Design**: System layout should provide full spatial coverage, including deeper basins and areas of low circulation, while avoiding disturbance of fine, nutrient-rich sediments.*
- ***Operational Schedule**: Continuous, steady operation will help maintain stable oxygen levels and minimize fluctuations in BOD and redox potential.*

- ***Monitoring Program****: Ongoing monitoring of DO, temperature, turbidity, and phosphorus concentrations should accompany installation to evaluate system effectiveness and inform adaptive management.*
- ***Integration with Rehabilitation Efforts****: Oxygenation should complement a broader restoration plan that includes sediment nutrient management, stormwater inflow treatment, and shoreline naturalization to improve long-term system stability.*

In summary, successful improvement of water quality within Swan Lake will depend on an integrated approach that combines active oxygenation with nutrient load reduction, sediment management, and ecological restoration. These combined measures will enhance dissolved oxygen concentrations, promote stable redox conditions, and foster a more balanced and resilient aquatic ecosystem.

In Appendix A5, FOSLP outlines a proposed configuration for a comprehensive oxygenation program that will contribute to the management of sediment-based nutrients and enhance the aquatic environment within the lake.

Recently, the submerged aquatic plants that have taken hold in Swan Lake are expected to contribute to an increase in oxygen levels in the lake. Therefore, FOSLP recommends considering the implementation of the oxygenation enhancement techniques listed in Appendix A5 only if the expected improvement in oxygenation levels does not materialize.

Now that cyanobacteria levels are considered under control, FOSLP requests that the fountain be brought back near the dock area.

D) NRSI: Swan Lake Management Strategy Program Considerations

Following is an extract from NRSI's report on Swan Lake Management Options[e] outlining their recommendations for a comprehensive oxygen, sediment and nutrient management program for Phase 2.

4.1 Swan Lake Management Strategy Program Considerations

Specific management and habitat restoration activities offer the potential to further support the improvement of water quality and aquatic habitat conditions within Swan Lake. These strategy considerations are intended to address some of the causes of degraded water quality conditions as opposed to addressing their symptoms, which support the foundation of an improved long-term strategy for Swan Lake to enhance aquatic ecosystem health, reduce eutrophication, and restore more natural lake function. Based on our understanding of the history of Swan Lake and its role in the wider stormwater system, both historic and ongoing high concentration nutrient loading is understood to be one of most significant factors contributing to the existing water quality conditions within Swan Lake. To support the enhancement of the surface water quality conditions within Swan Lake the following activities are proposed for consideration:

- ***Comprehensive Oxygenation and Aquatic Vegetation Monitoring**: It is understood that newly established aquatic vegetation communities within Swan Lake have the potential to naturally address previously identified low dissolved oxygen levels within Swan Lake. As such, supplemental oxygenation may no longer be an appropriate response to induce meaningful long-term improvements in surface water conditions. However, given the historic aquatic vegetation conditions it is important to monitor and track the establishment and overall condition of these aquatic vegetation communities and their implications to the overall dissolved oxygen conditions and generally support widespread aquatic ecosystem health.*
    - *The implementation of a standardized aquatic vegetation monitoring program would help to monitor for changes in the overall aquatic health, with dissolved oxygen condition monitoring included should aquatic vegetation communities not consistently establish. It is expected that the healthy establishment of new aquatic vegetation communities could significantly improve surface dissolved oxygen conditions and contribute to the improvement of overall surface water quality conditions.*
- ***Sediment & Nutrient Management**: Identifying and addressing the internal and external nutrient sources will directly influence long-term aquatic ecosystem condition stability. Mitigating and controlling the additional nutrient inputs that originate from stormwater and natural sources (e.g., goose droppings) is critical to addressing the underlying cause of the degraded aquatic ecosystem conditions in Swan Lake. While PAC and other phosphorus controlling chemical treatments temporarily help to mitigate surface water concentrations, it does not address the elevated concentrations within the sediment, nor does it influence long-term habitat stability. Following the*

implementation of targeted sediment and nutrient monitoring, the appropriateness of the additional chemical treatments can be further assessed.

An overall sediment and nutrient management strategy would support the characterization of overall sediment quality conditions throughout Swan Lake and support future management opportunities, including potential targeted sediment removal operations to address areas of significantly elevated sediment nutrient conditions.

While natural phosphorus loading from Canada Goose populations is understood to be short-lived, with most nutrients settling into the sediment, the Canada Goose monitoring and management operations completed to-date appear to have been effective at reducing resident goose populations, thereby helping to reduce additional external nutrient loading (Unckless and Makarewicz 2007). The continuation of these monitoring and management operations would support wider management and restoration operations and contribute to the improvement of surface water quality conditions.

A detailed sediment and nutrient management program, including the characterization of sediment conditions and the potential sediment and nutrient contributions into Swan Lake from upstream stormwater management facilities, as well as a detailed characterization of the sediment conditions throughout Swan Lake would help to direct restoration and management strategies. These would aid in addressing the underlying sources of degraded aquatic habitat conditions within Swan Lake and support the long-term improvement on surface water and aquatic ecosystem quality conditions.

  - ***Chloride Management**: Chloride concentrations have declined somewhat but remain above the long-term exposure guidelines. Addressing the inputs from upstream stormwater management, either by addressing outflow to Swan Lake or through application of targeted chloride-reducing measures (such as biochar), is critical to achieving any long-term improvements in surface water and aquatic ecosystems quality. It is understood that the overall chloride targets are to be reexamined and potentially revised as part of the City of Markham's 2025 Water and Chloride Budget program. Additional supplementary filtration and chloride reduction programs similar to those recommended by the FOSLP as part of their December 2025 submission has the potential to significantly reduce Swan Lake's annual chloride loading, contributing to the overall improvement of the surface water quality conditions.*

- ***Enhanced Monitoring Program**: It is suggested that the water quality monitoring program be expanded and/or enhanced to include sediment quality monitoring (aligned with the Sediment Quality Guidelines for the Protection of Aquatic Life) and should consider the addition of sampling locations to help support the characterization of the existing conditions within Swan Lake, and to provide additional context for supplementary treatments and rehabilitative measures (such as limited targeted removal of contaminated or high concentration sediment*

deposits). Previous sediment monitoring, completed in 2020, was in line with the assessment of the risk of eutrophication but did little to assess the overall health and suitability of the aquatic ecosystem. Ideally, this monitoring would continue an annual basis during and following any restoration and management activities to monitor changes in sediment conditions.

- ***Shoreline Habitat Enhancement**: Shoreline restoration and plantings would help to support the development of aquatic ecosystem structure, stabilize the nearshore aquatic ecosystem conditions, and contribute to the ongoing aquatic vegetation establishment program. Enhanced riparian habitats would also help to mitigate some of the natural nutrient and sediment loading. Engaging the Toronto and Region Conservation Authority to advise and support shoreline enhancements, included as part of the FOSLP's December 2025 Markham's Swan lake Water Quality Review, would strengthen the aquatic and shoreline enhancement program. But, as with other management strategies, shoreline enhancements would be most effective when implanted alongside measures that anticipated root causes of degraded water quality conditions, high nutrient concentration sediments.*

  It is understood that one management strategy being considered involves the removal of excessive nearshore invasive aquatic plants (e.g., phragmites), previously completed in 2022. Future aquatic vegetation removals have been proposed by the FOSLP to remove additional aquatic vegetation has the potential to contribute to further reducing internal organic nutrient loading going forward. However, given the high legacy concentrations of organic nutrients within the sediment, this proposed strategy would not provide a notable improvement to the overall conditions but would need to be applied along with other management strategies.

- ***Algae Management**: The continuation of ultrasonic control measures, to inhibit algae bloom formation, has the potential to support natural ecosystem stabilization, improving surface water clarity and supporting aquatic vegetation growth. Similarly, direct algae treatment chemical applications have the potential to address the risk of algae blooms but would do little to address the perceived root causes of the degraded aquatic ecosystem within Swan Lake, the historic and ongoing high concentration nutrient sediments.*

No single Swan Lake Management Strategy component will completely address the potentially degraded water quality or remove impediments to improving the conditions within the local aquatic ecosystem. However, the integration of a combination of these strategies has the potential to improve and enhance the overall sediment and water quality conditions and foster a more balanced and resilient aquatic ecosystem within Swan Lake. It is recommended that future Swan Lake Management Strategies consider the following components to enhance the effectiveness of individual management strategies and contribute to the improvement and enhancement of both sediment and water quality conditions within Swan Lake:

- *Inclusion of a sediment quality monitoring program within Swan Lake and the adjacent Stormwater Ponds to characterize the existing conditions and support wider sediment*

and nutrient management programs. It is recommended this program continues through Phase 2 and 3 to monitor for changes in sediment loading and quality conditions.

- *Implementation of an improved chloride management program, as identified as part of the City of Markham's 2025 Water and Chloride Budget program, and potential supplementary methods such as stormwater pond bypassing or filtration would help to address the elevated chloride concentrations recommendations. It is recommended this measure be implemented during Phase 2.*
- *Shoreline habitat enhancement and rehabilitation to contribute to the enhancement of aquatic habitat and nearshore aquatic ecosystem conditions, supporting the ongoing aquatic vegetation establishment program while mitigating some of the natural nutrient and sediment loading.*

5.0 Conclusions

Within Swan Lake the overall water quality monitoring program completed between 2021 and 2024 provides an appropriate, if scoped, high-level assessment of the water quality conditions as they relate to the risk of eutrophication. The parameters included as part of the overall Swan Lake Monitoring Program offer a high-level assessment of the potentially degraded surface water quality conditions and the effectiveness of the treatment and remediation activities as part of the overall Swan Lake Management Strategy. Based solely on the results of the water quality monitoring program, the existing management activities appear to have had some success at improving the water quality conditions within the lake. However, even though many of the water quality parameters met the identified guidelines/targets, several were still noted to be in exceedance. With that said, the high-level nature of the water quality parameters included as part of the monitoring program, and the guidelines applied as part of the annual analysis, limit the overall comprehensiveness of the monitoring program and the conclusions that can be drawn from observable water quality trends as they relate to the health of the aquatic ecosystem.

Given artificial nature of Swan Lake, its urbanized nature, and proximity to the local Stormwater Management Ponds, the monitoring guidelines established as thresholds for hyper-eutrophic conditions are attainable and reasonable minimum thresholds. Achieving these minimum thresholds would present an appropriate starting point to support future strategies as the management of Swan Lake moves from a restoration/mitigation to improvement/enhancement approach.

In addition, the eutrophication focus of the monitoring program limits the ability to address the effects of historic and ongoing nutrient and contaminant loading on aquatic ecosystem health or to assess the effectiveness of the treatment and remediation activities completed to-date. It is, therefore, difficult to properly identify and address the underlying sources of many of the surface water quality concerns.

The expansion and enhancement of the water quality monitoring program, including the additional sampling recommendations, would improve the comprehensiveness of the monitoring program and support greater refinement of the overall management and

restoration strategies for Swan Lake. This expansion and enhancement is recommended to include a combination of additional analysis guidelines (such as the PWQO, Recreational Water Quality Guidelines, and CCME Guidelines for the Protection of Aquatic Life), additional spring freshet and significant precipitation sampling events, and the inclusion of aquatic health-specific monitoring components (such as benthic macroinvertebrate, zooplankton, fish community composition, aquatic vegetation, or native herpetofauna)

E) NRSI: Water Quality Monitoring Program Enhancements

Following is an extract from NRSI's report on Swan Lake Management Options[(e)] outlining their recommendations for enhancements to the water quality monitoring program.

4.0 Water Quality Monitoring Program Enhancements

While the overall Swan Lake Water Quality Monitoring Program, if applied correctly, is appropriate to meet the intent of a high-level eutrophic condition characterization, the opportunity exists to expand it to provide a more comprehensive and high-resolution water quality characterization to support the overall Swan Lake Water Quality Management Plan.

The following water quality monitoring program components are recommended for consideration to further refine the water quality monitoring program. These adjustments would help provide additional context to characterize the existing aquatic ecological conditions and ecosystem health. These recommendations include:

- *Additional spring freshet and significant precipitation event (i.e., wet event) sampling to account for potential stormwater input effects on surface water conditions;*
- *Inclusion of PWQO Guidelines alongside Swan Lake Monitoring Program guidelines;*
- *Inclusion of Recreational Water Quality Guidelines for water clarity;*
  - *Inclusion of minimum and maximum water clarity readings, alongside the applicable targets/guidelines, as part of the annual water quality analysis to detail the range in conditions;*
- *Inclusion of CCME Canadian Water Quality Guidelines for the Protection of Aquatic Life guidelines for parameter analyses;*
- *Completion of all water quality monitoring components identified as part of the Swan Lake Monitoring Program on an annual basis;*
  - *A summary of omissions or alterations in monitoring from workplan components outlined as part of each annual report;*
- *Include complete bi-weekly water quality results as part of each annual report, along with explanations for any gaps in water quality sampling coverage;*
- *The inclusion of aquatic health-specific monitoring components to increase the comprehensiveness of the monitoring program.*
  - *Annual aquatic health monitoring can include the inclusion of benthic macroinvertebrate, zooplankton, and fish community composition, aquatic vegetation biomass, or composition assessment, herpetofauna nesting and overwintering assessment.*

F) References/ Links to Full Reports

a) Swan Lake Long-term Water Quality Plan, City of Markham, November 2021
Swan Lake Water Quality Management Plan

b) Consolidated Report, Swan Lake Flow Diversion Assessment, AECOM, May 2025
Agenda Package - Markham Sub-Committee_Jun18_2025.pdf

c) Swan Lake Water Flow and Chloride Analysis, Markham, November 3, 2025
Swan Lake Water Quality Management

d) Swan Lake Aquatic Conditions Review, R.J. Burnside, February 26, 2026
Swan Lake Aquatic Conditions Review

e) Swan Lake Long Term Management Plan, Natural Resource Solutions Inc. March 9, 2026
Microsoft Word - NRSI_3645_Swan Lake Water Quality Peer Review_REV2_Final_9-Mar-26.docx

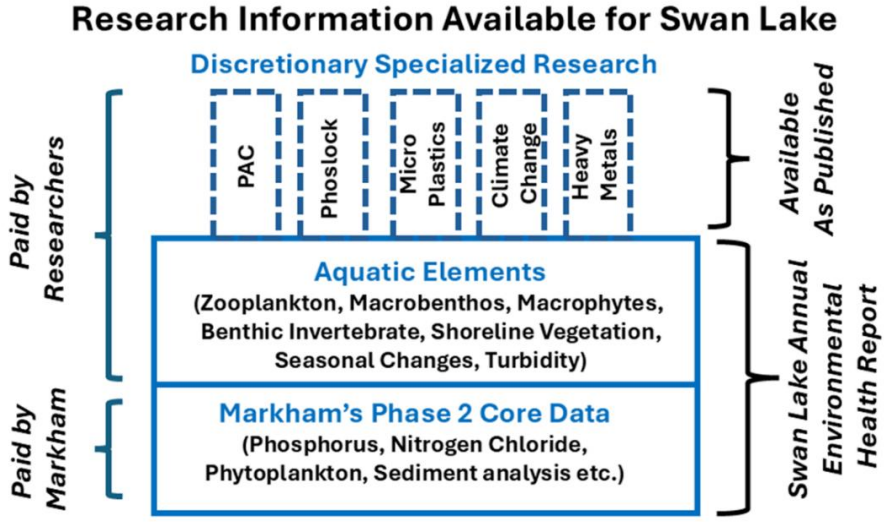
f) Literature Review of Management Options and Effects of Increased Oxygenation in Swan Lake, Natural Resource Solutions Inc. November 2025
Microsoft Word - NRSI_3645_Swan Lake Oxygenation Lit Review_7-Nov-25.docx

APPENDIX A: FOSLP BACKGROUND REPORTS

A1): Outsourcing of Environmental Health Card

Friends of Swan Lake Park has held discussions with researchers from York University and Trent University about integrating their research efforts in a manner that would address Markham's needs for monitoring of the water quality in Swan Lake through Phase 2 (2026 – 2030) of the water quality plan. This section outlines a proposal for an integrated water monitoring program for Swan Lake that would be managed by the York and Trent researchers and provide Markham with a comprehensive annual Environmental Health Card for Swan Lake.

This collaborative approach provides Markham with the opportunity to support the development of the next generation of leading Canadian researchers while addressing its needs for quality information on the water conditions in Swan Lake. The following chart illustrates the proposed relationship.



Collection of Water Quality Data During Phase 1

During Phase 1 of the Swan Lake water quality plan (2021 – 2025) Markham staff undertook physical water sampling. The samples were gathered initially biweekly and then monthly throughout Phase 1 but were physically limited to near shore areas – the dock and the bridge. The analysis included measures of inorganic elements such as phosphorus, nitrogen and chloride plus biological measures of phytoplankton and microcystins. Lab analysis was undertaken at the York-Durham Regional Environmental Laboratory in Pickering, Ontario. Markham staff documented their findings into a water quality report submitted to the Markham Subcommittee each year.

Other investigations into the aquatic health of the lake included an inventory of fish in the lake by the TRCA from 2022 – 2024 commissioned by Markham and an assessment of the Benthic Invertebrate in 2022 by an independent contractor engaged by FOSLP.

In 2025, Trent University researchers, led by Dr. Huy Dang, collected water samples to support their research on the impact on the aquatic food chain of lanthanum and aluminum originating in the Phoslock and Poly Aluminum Chloride treatments. Monthly from May to October , Scott Stebbing, a researcher from Trent, collected high-resolution vertical profiles of water quality data (pH, redox potential, oxygen level, electrical conductivity, chlorophyll-a for algal concentrations and phycocyanin as a surrogate for blue-green algae) from 10 locations throughout the lake. In addition, continuous monitoring devices were installed at a single location in the lake to collect hourly data on chlorophyll and oxygen levels from May to November 2025. They also collected samples of macrophytes, plankton, invertebrates, tadpoles, and fish for elemental analysis.

From May to December, researchers from York University undertook drone monitoring of the water quality in Swan Lake. This process provided a seasonal analysis of the changes in chlorophyll, turbidity and suspended solids throughout the growing season in all areas of the lake.

In 2026, the York and Trent researchers initiated an exercise to share data gathered via physical sampling and drone sensing to develop an integrated assessment and cross validation of the water quality measurements for 2025.

Proposed Phase 2 Environmental Health Card

The researchers from York University and Trent University have the capacity to provide Markham with an annual "Environmental Health Card" of Swan Lake based on a comprehensive monitoring program. The data collection process will be designed to meet Markham's basic needs for Phase 2 plus the elements essential to continuing research needs. Agreement amongst the parties is required but the following list illustrates some of the expected core components:

a) Periodic physical water samples, taken by drones, which would provide:
   i. Monthly or Bi-weekly drone images and physical samples. Number of locations and depths to be discussed.
   ii. Measures of Inorganic Elements consistent with Markham's previous analysis plus any additional measures required for Phase 2 monitoring.
   iii. Measures of variety and density of phytoplankton consistent with Markham's previous analysis
   iv. Measures of the variety and density of zooplankton
   v. Annual measures of diversity of Macrobenthos and Benthic Invertebrate
   vi. Annual measures of diversity and quality of fish.
b) An assessment of lake-wide patterns based on drone monitoring to provide a seasonal analysis of the changes in chlorophyll, turbidity and suspended solids, throughout the lake integrated with the findings derived from the physical samples.
c) An assessment of the coverage and density of macrophytes and shoreline vegetation.

Benefits to the Contributing Parties:

For Markham:

a) An annual analysis of the core elements essential to monitoring Phase 2 management actions.
b) Receipt of a comprehensive lake-wide Environmental Health Card on the water quality throughout the growing season, an analysis beyond Markham's current capabilities.
c) An assessment of the extent and state of the macrophytes within the lake
d) Outsourcing of a labour-intensive process to parties motivated to undertake quality driven processes.
e) An opportunity to support the development of the next generation of research talent and advance Canada's environmental research into freshwater systems.

For Researchers,

a) The opportunity to refine processes related to the integration of drone monitoring with traditional physical procedures for monitoring water quality.
b) Solid baseline water quality data required to support their advanced research on the impact of heavy metals, microplastics and other elements on aquatic life.
c) Access to a local water body to support their ongoing research that enables advanced training and global knowledge translation for the next generation of research scientists.
d) A long-term, consistent testing framework that enables research teams to train and sustain quality research staff and refine processes while providing insight into long- term factors and trends impacting the lake.

Contribution of the Parties:

The researchers will be responsible for providing the human resources, equipment and other physical resources required to:

a) Undertake the drone imagery and the collection of physical water samples
b) Analyze the contents of the water samples – either in their own labs or through external organizations such as the York-Durham Regional Environmental Lab
c) By February 28th of each year, submit an annual report to Markham summarizing the water quality findings of the previous growing season with comparisons to changes from previous years.

Markham will be required to provide:

a) An outline of expectations for the minimum data collection and related analysis required in the annual report. For Phase 2, Markham's aquatic advisor has recommended the basic testing requirements as:
    - Bi-weekly reporting on elements that monitor eutrophication and chloride
    - Monthly reporting on phytoplankton
    - Monitoring of oxygen levels
    - Periodic monitoring of Total Suspended Solids (TSS) and total metals
    - Periodic monitoring of sediments
    - Possible event-based or winter monitoring
b) An annual financial contribution to be negotiated.

A2) Options For Ending Swan Lake's Stormwater Management Role

Why High Levels of Chloride Matter

Swan Lake is a former gravel quarry with no natural surface level inflows nor outflows but there are six stormwater sources that direct almost three tonnes of chloride each year into the lake. In 2025, there were 17.4 tonnes of chloride in Swan Lake.

Chloride does not break down and will accumulate within the lake over time, impairing the health of aquatic plants and many forms of aquatic species.

The Federal government's Canadian Water Quality Guidelines ("CWQG") for chloride were established based on the sensitivity of 28 different species to chloride levels. Current levels of 200 mg/L of chloride in Swan Lake are well in excess of a safe environment for most of the species, including zooplankton, on which the federal guidelines were based.

Zooplankton are a beneficial element in freshwater because certain species consume phytoplankton (microscopic algae and microbes).

A healthy zooplankton colony would be an important contributor to controlling algal growth, but the high level of chloride is undermining the existence of zooplankton in Swan Lake.

Research by McClymont[1] concludes that the CWQ Guidelines are too high to adequately protect zooplankton communities. The study's findings were that "At the CWQG (120 mg Cl/L), zooplankton abundances and biomasses were reduced by 30% - 77% …" and notes that other studies have associated low zooplankton levels with increased phytoplankton abundance and increased frequency of harmful algal blooms and the risk of cyanobacteria.

In 2018, several Canadian environmental associations asked the Ontario government to create an Ontario water quality guideline for chlorides to address the shortcomings of the Federal guidelines.

In their report, R. J. Burnside[(d)] notes that Zooplankton, especially Daphnia app, are the dominant grazers of phytoplankton in temperate waters like Swan Lake however current levels of chloride are above the chronic exposure range for some Daphnia species. In 2020,

[1] The Effects of Increasing Chloride Concentration and Temperatures on Freshwater Zooplankton Communities, A.C. McClymont, Queen's University, 2020

a researcher from Queens University came to Swan Lake to take samples of Daphnia but was unable to detect any.

Burnside notes that it is possible to stock zooplankton species but recommends that an inventory first be taken to determine which species have survived in Swan Lake before undertaking a stocking program.

Other studies suggest high chloride levels can lead to lower oxygen levels by diminishing aquatic plant life. Controlling oxygen and chloride levels opens up more natural biomanipulation options for the management of water quality in Swan Lake.

In their study of the water quality issues in Lake Wilcox in Richmond Hill Ontario, University of Waterloo researchers identified chloride as one of the factors contributing to the release of nutrients from the sediment.

A successful rehabilitation plan requires addressing the chloride levels with the goal of restoring a healthy zooplankton community.

1) Sources of Chloride

In November 2025, Markham released the Swan Lake Water and Chloride Budget[(c)] which estimated the annual inflow of chloride for the 3-year period 2022 – 2024 from the six sources averaged 2.95 tonnes per year.

In March 2025, Markham released the Flow Diversion Assessment report[(b)] by AECOM that estimated the volumes of stormwater entering the lake from three Oil Grit Separators ("OGS") and from three inlets carrying stormwater that bypasses the two stormwater ponds.

2) Eliminating Chloride Inflows

The Flow Diversion Assessment outlined options for reducing the stormwater inflows. Approximately 85% of the chloride entering Swan Lake could be eliminated by:

- Rerouting 100% of the flows of the three Oil Grit Separators ("OGS") that account for 56% of the chloride entering the lake.
- Reducing the remaining 44% of chloride that enters the lake in stormwater bypassing the stormwater ponds by 66%.

The Flow Diversion Report estimated the total cost at $2.2 million. FOSLP estimates that by using a lower cost "parkland" route, the costs of rerouting the OGS flows could be reduced by 33%, an alternative not considered in the Flow Diversion Assessment. Details of the lower cost options are provided in Appendix A3.

The estimated combined costs of a Parkland Route and alterations to the flow splitters is $1,567,960, a reduction of $588,000 while still reducing inflows by 85%.

		Parkland Route		
	Original Estimate	Cost Estimate	Potential Chloride Reduction	Cost Per Tonne
Rerouting Amica/TC OGS Flows	1,757,025	1,168,101	1.41	828,441
Rerouting Swan Club OGS Flows	275,072	275,072	0.25	1,100,287
Adjust Flow Splitters	124,787	124,787	0.86	145,101
Totals	**2,156,884**	**1,567,960**	**2.52**	**622,206**

3) Complementary Options for Reducing Chloride Inflows:

Reducing flows bypassing the two stormwater ponds is the most cost-effective approach. At a cost of $125,000, chloride inflows could be reduced by 30%. Unfortunately, both ponds remain under the control of the original developer so Markham cannot implement these changes until they "assume" responsibility for the ponds.

Rerouting the OGS flows is expensive, and staff have recommended deferring these costs pending further assessment of the chloride levels during Phase 2.

There are, however, some low-cost options that could be implemented during Phase 2 that would reduce the impact of chloride and address some of the chloride already in the lake.

a) Bioswales at the Stormwater Inlets and the North Channel

There are shoreline plants, halophytes, that are effective at absorbing chloride and nutrients. Burnside has recommended that bioswales containing halophytes be created around the shorelines near the stormwater sources. Periodic harvesting and removal of these plants every 2 – 3 years would remove the chloride, phosphorus and nitrogen from the ecosystem.

In 2023, phragmites was removed from the eastern shoreline. It is expected that contributed to the reduction of phosphorus, nitrogen and chloride during that period.

b) Biochar Filtration

Researchers from York University are testing the use of Biochar to remove chloride and nutrients from samples of water from Swan Lake and are prepared to undertake a field test of the use of Biochar to remove chloride during Phase 2.

i. Filtration of OGS Stormwater Flows

Flows from the three Stormceptor oil grit separators release directly into the lake. Keeping the OGS units in place serves an important function by removing the heavy contaminants that would clog the filtrate. The goal is to capture flows from the OGS units and filter the flows before they enter the lake.

The lake is regulated to a depth of 208.3 m above sea level. The filtration process requires a vertical drop of the stormwater through the filtrate.

OGS Unit	Elevation	Above Lake
Amica	208.23	-0.09
Traffic Circle	208.25	-0.05
Swan Club	208.94	0.64

Only the Swan Club OGS unit appears to have the elevation needed to support a filtration chamber. Markham has estimated that the Swan Club OGS unit attributes on average 0.25 tonnes per year, or 8% of the total entering the lake. There are three options for the reducing chloride inflows the Swan Club OGS unit:

a) Reroute flows to the North Pond at cost of $234,468 - $275,072
b) Adding a Biochar filtering processes between the OGS unit and the lake to capture the chloride before it enters the lake
c) Create bioswale including halophytes, harvest periodically.

Swan Club OGS Outlet

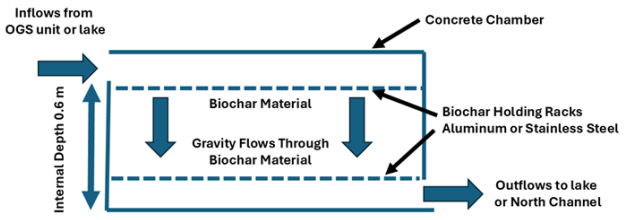
ii. Filtration of Chloride Already in the Lake

The second application of the Biochar filtration process would be to add a filtration unit as part of the process of recycling water through the North Channel. This would remove chloride, phosphorus and nitrogen from the lake water.

Water from the lake would initially be pumped into the filtration unit and then flow out to the North Channel.

A similar structure could be installed to filter flows from the Swan Club OGS unit.

Swan Lake Biochar Filtration Chamber



A3) Refinements to Flow Diversion Report

In March 2025 Markham released a Flow Diversion Report[(b)] outlining possible ways in which the stormwater flows into Swan Lake could be rerouted away from the lake. Markham staff[(c)] have estimated that each year the stormwater inflows contribute 3 tonnes of chloride (5 tonnes of road salt) each year. The Flow Diversion Report outlined viable options that could reduce inflows by 86%.

There are three scenarios outlined in the Flow Diversion Report that warrant further analysis:

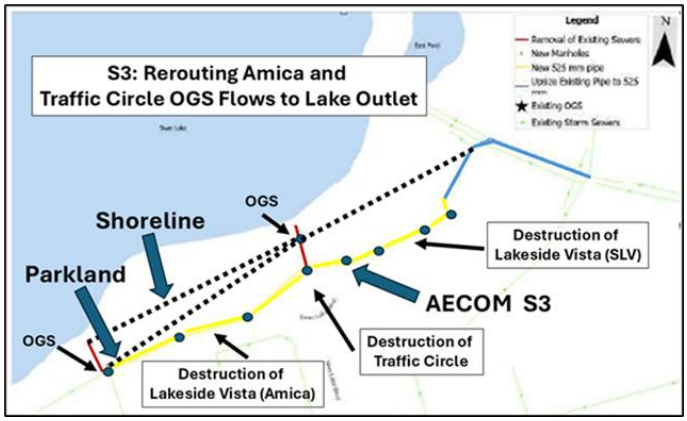
A) S3: Reviewing the route and costs of rerouting the Amica and Traffic Circle OGS flows to the lake outlet via the park, rather than along the roadways.
B) S4: Reviewing the costs related to rerouting the Swan Club OGS units to the North Pond, and
C) S5: Revising the analysis of the benefits and back flow risks associated with altering the design of the flow splitters at each pond.

A) S3: Alternative Parkland Route

FOSLP estimates that the costs of rerouting the Amica/ Traffic Circle OGS flows could be reduced by 34% by using a "Parkland Route", an alternative not considered in the Flow Diversion Assessment.

The S3 estimates for the Amica/ Traffic Circle OGS units assumes destruction and replacement of three area roadways, replacement of six manholes and relocation of related utilities.

A lower cost alternative route is available through the park area, ending at the lake outlet. It provides minimal disruption to road services, avoids area utilities and minimizes restoration costs. Assuming parkland restoration costs for parkland areas at 33% of the cost of restoring the roadways, the total costs can be reduced by $588,000.



The Amica OGS unit is in the middle of Amica's driveway. Removal of this unit will disrupt the roadway in that area and require repair. However, it is possible to avoid these costs by leaving the OGS unit intact and installing a new catch basin unit to capture the stormwater flows before it enters the lake. This would require a new collector, so while the Shoreline Route may be less disruptive, it may be only marginally cheaper.

The Traffic Circle ("TC") OGS unit is already in the park so it can be removed without significant roadway repair costs and without impacting local utilities so there would seem to be no benefit to leaving it in place. The costs of installing new catch basins, rather than replacing existing, may also result in further cost reductions.

Costs Savings Using Parkland to Reroute OGS Units

			Parkland Route	
S3: Amica OGS to Lake Outlet	**Roadway**		**Adjustment**	**Total**
Supply & Install Stormsewers	674,830	38%	100%	674,830
Supply & Install Maintenance Holes	202,449	12%	100%	202,449
Allowance for catchbasin replacements	50,612	3%	100%	50,612
Sewer Replacement Costs	**927,891**	**53%**		**927,891**
Utility Reconnection	101,225	6%	0%	-
Restoration of Roadway/Parkland	727,909	41%	33%	240,210
Total Costs	**1,757,025**	**100%**		**1,168,101**
% Original Cost				**66%**

B) S4: Swan Club to North Pond

The S4 route is already substantially within the park area. The Swan Club OGS unit is in a parking lot, so removal will require repair to the paved area. It may be possible to leave the OGS unit in place and pick up the stormwater inflows before they enter the lake to minimize repair costs. Again, the savings may not be material.

The S4 estimate included costs for relocating utilities etc. that are not relevant, but the estimate may require an adjustment to reflect repair costs to the park pathways and parkland areas.

			Parkland Route	
S4: Swan Club OGS to North Pond	**Original**		**Adjustment**	**Total**
Supply & Install Stormsewers	180,375	66%	100%	180,375
Supply & Install Maintenance Holes	54,113	20%	100%	54,113
Allowance for catchbasin replacements	13,528	5%	100%	13,528
Sewer Replacement Cost	**248,016**	90%		**248,016**
Utility Reconnection	27,056	10%	0%	-
Restoration of Roadway/Parkland	-	0%		27,056
Total Costs	**275,072**	100%		**275,072**

Revised Cost Estimates

The estimated combined cost of a Parkland Route and alterations to the flow splitters is $1,567,960, a reduction of $588,000 while still reducing inflows by 85%.

		Parkland Route		
	Original Estimate	**Cost Estimate**	**Potential Chloride Reduction**	**Cost Per Tonne**
Rerouting Amica/TC OGS Flows	1,757,025	1,168,101	1.41	828,441
Rerouting Swan Club OGS Flows	275,072	275,072	0.25	1,100,287
Adjust Flow Splitters	124,787	124,787	0.86	145,101
Totals	**2,156,884**	**1,567,960**	**2.52**	**622,206**

C) S5: Addressing Potential Flow Splitter Concerns

The issues arising from the report related to adjusting the flow splitters is not related to costs, rather a review of ways to mitigate any risks associated with the various options. Our request is that certain scenarios be run to ensure that any changes to the design minimizes back flow risks.

The report notes that raising only the weirs may introduce some "basement flooding risk" in the East Pond area but did not indicate which inlet was of concern. There was no similar concern expressed about the North Pond area. As noted on pg. 53 (S5b), upsizing of the pond inflow pipes "reduces the backwater caused by the limit of the 450 mm pipe", suggesting that the basement flooding risk is avoided.

Three aspects of the S5 analysis be revisited to identify the options that will minimize risks.

a) Confirm that the Model Appropriately Reflects the Existing Configuration

It is not clear from the report that the analysis reflects the differences in the design of the three inflow strictures for the three splitters. The North Pond Splitter and South Splitter in the East Pond have comparable designs, just differences in the size of the circular inflow pipes. However, the North Splitter in the East Pond, which serves the largest catchment area, has a materially different box culvert inflow structure.

The 2.4 m x 0.9 m Box Culvert is comparable to a 1650 mm diameter circular pipe in terms of area, though the flow management impact is likely different. Our request is to confirm that the Box Culvert structures were appropriately reflected in the analysis.

Dimension of System Serving Inflows to Flow Splitters

	North Pond	East Pond	
Catchment Area	**12.6 ha**	**19.3 ha**	
Splitter Details		**South**	**North**
Inflow System to Splitter	1050 mm	675 mm	Box Culvert 2.4 m x 0.9 m
Outlet to Pond	450 mm	450 mm	450 mm
Outlet to Lake	1050 mm	675 mm	1.8 m x 0.9 m
Current Flows to Lake (m3)	2,573	1,360	4,310
Potential Reduction	65%	45%	74%
Estimated Flows (m3)	892	750	1,107

b) Alter the Sequence of Changes

The analysis assumed a sequence of first raising the weirs and then enlarging the pipes. An analysis of the reverse sequence should be undertaken.

Only enlarging the inflow pipes to the pond should not add to backflow pressures so an assessment of the benefits of increasing the pipes sizes as the initial step, without raising the weir height, would provide a benchmark of the benefits arising from the lowest risk option.

The additional benefits or additional risks associated with increasing the weir height can then be assessed.

c) Assess the Benefits/Risks of Incremental Changes to the Weir

The North Pond weir could be raised by 0.2 m, but the analysis only increased the weir by 0.1 m. The design of the East Pond will support an increase in the weir height by 0.3 m but that was the only option considered. An analysis of the impact for each splitter of increases in weir height by increments of 0.1 m to the maximum height should highlight the safest options.

Other Areas That May Require Further Analysis

i. East Pond and Foundation Collector System ("FDC").

It is our understanding that the FDC system upstream from the East Pond serves homes in the immediate area adjacent to the East Pond and operates independently of the collector systems that feed into the East Pond. Therefore, we question the concerns about the impact of raising the weirs on basements in the immediate area but agree that a "connectivity test" should be undertaken before implementing the changes.

ii. North Pond

On pg. 41, the report notes that "it remains uncertain whether the surcharge conditions in the downstream sewer of the North Pond, along Williamson Road, would impose any restrictions on pond outflows. Such restrictions could potentially impact the effectiveness of the upgrade options. The capacity of the downstream sewer on Willamson Road is not analyzed in the study, further investigation is required to confirm the downstream condition."

The outflow mechanism from the North Pond will not be altered and it is not clear that any of the proposed changes would impact the conditions or issues downstream nor impact the effectiveness of the proposed changes. During a heavy rainfall event, a deterioration of the effectiveness of the proposed changes should not be a material concern since bypass flows are expected under those conditions.

Determine if any additional analysis is warranted related to the North Pond before proceeding with changes.

A4) Understanding the Role of Groundwater

Historical documentation attributes the creation and maintenance of lake levels at approximately 208.0 MASL from the mid-1970's to the mid-1990's to local groundwater sources.

In June 2025, Markham Council agreed that as part of the Official Plan review, to consider FOSLP's request that Swan Lake and Swan Lake Park be reclassified as Natural Heritage Lands. Both satisfy the criteria due to their biodiversity however Swan Lake also meets the technical criteria set out in Markham's Official Plan and the Ontario guidelines for "Key Hydraulic Features".

Within Natural Heritage systems, major water bodies are considered significant natural sources for recharging the aquifer.

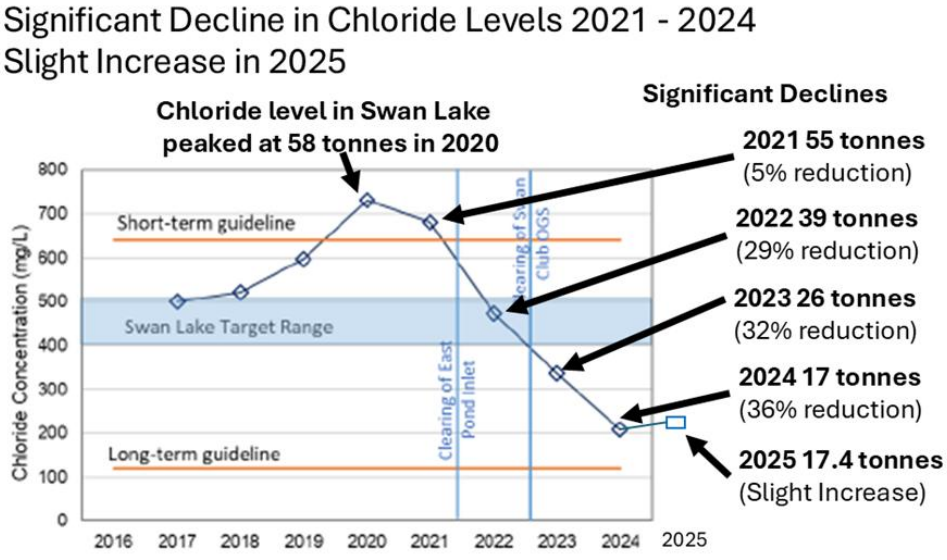
Evidence gathered during Phase 1, indicates that the groundwater may be a significant factor that should be factored into lake management discussions. Three factors need to be investigated;

a) The impact of "flushing" by groundwater.
b) The chemical elements in the groundwater.
c) The Impact, if any, of rerouting stormwater flows away from the lake on lake levels.

a) Impact of Flushing

Chloride levels in Swan Lake rose dramatically from 2018 – 2020. This was attributed to a blockage in one of the pipes in the North Splitter in the East Pond which prevented stormwater flows from entering the East Pond which resulted in a significant increase in untreated stormwater flows directed into the lake. Since this blockage was cleared, chloride levels have declined significantly and have levelled off but there are still over 17 tonnes of chloride active in the water column.

Even after the blockage was cleared, the annual chloride inflows are estimated at 3 tonnes. Despite significant annual additions in chloride, there was a material drop in chloride levels from 2020 through 2024 with a slight increase in 2025.



Inflows reduced once blocked pipe cleared. Reasons for reductions are not clear.

The decline in chloride levels illustrates the dynamics of the factors influencing the lake.

The 2024 water monitoring report attributes the decline to a reduction of inflows of road salt due to unclogging of input sources plus “dilution by cleaner water”.

Two factors need to be considered in understanding “dilution”:

i) Where did the chloride already in the lake go?
ii) Where did the “freshwater “ come from.

i. Where Did Chloride Already in the Lake Go?

Water leaves the lake three ways:

- Evaporation (no impact on chloride)
- Lake outlet (will remove chloride)
- Groundwater (will remove chloride)

During 2022 and 2023 chloride levels declined approximately 30% each year. However, the lake levels during the late spring and summers of 2022 and 2023 were very low and there was very little outflow through the stormwater outlet. The chloride laden water had to go somewhere so the groundwater was the only outflow option that could account for such a significant decline during those years.

Figure 9: Lake Elevation Records and Precipitation in 2022

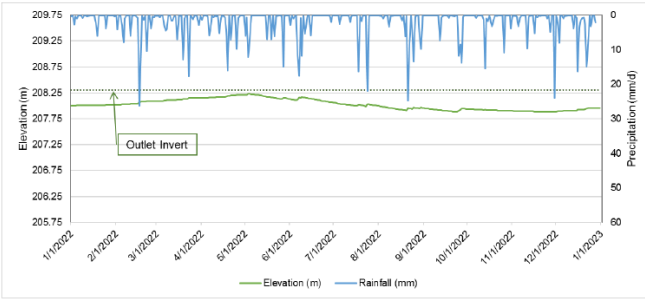
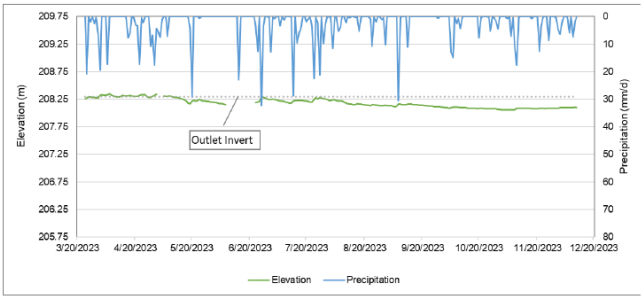


Figure 10: Lake Elevation Records and Precipitation in 2023



The summer of 2024 was cooler with greater levels of precipitation and higher lake levels than in 2022 and 2023, but chloride levels continued to decline, suggesting the impact of both groundwater and loss through the lake outlet.

ii) Where Did the Freshwater Come From?

“Dilution” requires that the outflow be replaced by freshwater. In November 2025, Markham staff released a “Water and Chloride Budget”[c] model for Swan Lake that indicates that water loss to evaporation from the lake exceeded the volume attributable to direct precipitation.

For the period 2009 – 2024, the lake lost on average 17% more to evaporation than it gained from direct precipitation.

In the hot, dry summers of 2022 and 2023, precipitation minus evaporation was unlikely the source of freshwater.

Impact of Natural Elements 2009 - 2024			
	Direct Precip	Evaporation	Precip less Evap
Annual	**37,302**	**- 46,887**	**- 9,585**
Dec - May	16,802	- 15,992	810
June - Nov.	20,500	- 30,895	-10,395
Percent of Lake Volume	33%	-49%	-17%

The water budget analysis calculated the average water flows for the period 2009 – 2024. The "balancing" entry incorporates amounts not directly attributable to identified sources and implicitly incorporates the impact attributable to groundwater ("Balance"). The Flow Diversion Report estimated the lake volume at 62,640 m^3, so the net inflows attributed to groundwater (and other factors) represents on average a net inflow of 16% of the lake volume.

		Balance		
Month	Balance	Inflows	Outflows	Precip less Evap
Jan	- 2,082		- 2,082	1,677
Feb	- 1,037		- 1,037	1,277
Mar	- 174		- 174	8
Apr	846	846		- 312
May	4,917	4,917		- 4,206
Jun	5,297	5,297		- 4,060
Jul	4,212	4,212		- 5,159
Aug	2,490	2,490		- 3,356
Sep	1,109	1,109	-	- 1,186
Oct	- 1,756		- 1,756	1,810
Nov	- 1,663		- 1,663	1,556
Dec	- 2,300		- 2,300	2,366
Annual	**9,859**	**18,871**	**- 9,012**	**- 9,585**
Dec - May	170	5,763	- 5,593	810
June - Nov.	9,689	13,108	- 3,419	- 10,395
Percent of Lake Volume	16%	30%	-14%	-15%

The net monthly groundwater ("Balance") inflows occur during the summer months when water is lost to evaporation. It appears the lake levels are stabilized by groundwater inflows during the summer.

A breakdown of the "Balance" values indicates that groundwater inflows were averaging 30% of the lake volume while groundwater outflows averaged 14% supporting a conclusion of the "flushing" impact of groundwater on the lake system.

These monthly numbers reflect the net changes in water flows per month. We do not know the gross inflows into the lake, nor the gross outflows each month So, the "flushing" action is likely significantly greater than 30%.

The outflow portion will take the chloride and other elements away from the lake while the groundwater inflows may contribute other elements, including chloride.

During Phase 2, an analysis of the groundwater elements and flow impacts is required to determine the potential "balance" between lake elements and elements inflowing from groundwater sources.

b) Contents of Groundwater

It has been suggested that the levelling off of chloride levels in the lake in 2024 and 2025 may reflect an "equilibrium" point between external sources and groundwater sources.

The lake was created naturally by groundwater but there is no data on the contents of contaminants in the groundwater entering Swan Lake. An analysis of the contents will help determine what is the natural "equilibrium" point attainable through lake management options. This is particularly relevant in relation to the contaminants being directed into the lake by the stormwater system. Chloride is the most notable, but there may be other elements as well.

Two activities are required to understand the natural equilibrium of the lake:

1) More information on the contaminants entering the lake via the stormwater system
2) Testing of groundwater sources to determine what are the natural influences on the lake. This will help understand the "floor" values that are attainable through lake management activities.

c) Impact on Lake Levels

Concern has been expressed that rerouting 35,000 m^3 of stormwater away from the lake may have a negative impact on lake levels.

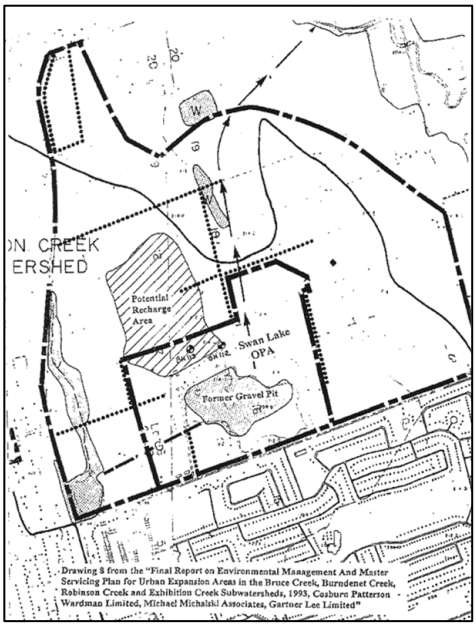
Markam's recent water flow analysis provides estimates that suggest lake outflows consistently exceed any inflows from the stormwater system.

Month	Stormwater System	Lake OutFlow	Net Inflows (Outflows)	Perrcent of Lake Volume
Annual	**35,121**	**- 38,644**	**- 3,523**	-6%
Dec - May	14,546	- 17,153	- 2,607	-4%
June - Nov.	20,575	- 21,491	- 916	-1%

Historical Assessment of the Impact of Groundwater

The lake filled naturally in the 1970's and existed in a stabilized state for more than 20 years before the stormwater system was introduced.

The adjacent chart was included in a Peto MacCallum report identifying the "potential recharge area" which extends into the north-west portion of the park.



Drawing 8 from the "Final Report on Environmental Management And Master Servicing Plan for Urban Expansion Areas in the Bruce Creek, Burndenet Creek, Robinson Creek and Exhibition Creek Subwatersheds, 1993, Cosburn Patterson Wardman Limited, Michael Michalski Associates, Gartner Lee Limited"

The following section, extracted from a November 1993 report by Peto MacCallum Ltd., outlines the natural state of the lake prior to the introduction of the stormwater system.

2.1.1 Site Settings and Land Use History

The site is located within a broad physiographic region known as the Peel Plain, a level-to-undulating tract of clay soils. Its principal physiographic feature is the Markham-Pickering till plain, a bevelled, partly drumlinized and fluted plain. The Pleistocene geology of the area has been shaped by glacial activity. The native soils consist of a sandy to clay bouldery till locally underlain by sand and gravel deposits. Historically, these deposits have been extracted as a source of road base granular out of the Groves gravel pit which formerly operated on the site.

Locally, the physiography of the site has been altered by relatively large volumes of fill materials stockpiled around the lake. Geodetic ground surface elevations range between approximately 205 and 221 m over the site.

Surface drainage in the area generally occurs through the Little Rouge Creek tributaries of the Rouge River which flow southeastwards. However, there are no obvious surface drainage outlets from the lake. Surface flows are generally directed southwestwards and away from the site. ***Hydrogeological records of water wells on the site indicate static groundwater table elevations ranging between 207 and 209 m. The elevation of the water level of the lake is approximately 208 m, confirming that the lake probably originated from groundwater within the kame aquifer.*** An analysis of static water level elevations indicates that the regional groundwater flow is directed southwestwards or southwards with an average hydraulic gradient of about 1%. ***[Emphasis added]***

Historically, gravel extraction operations on the site began as early as the 1850s. However, the operations were phased out during the 1870s when the site was acquired by the Grove family. In 1962, the gravel operations resumed out of the Grove Pit under the ownership of Warnock and Johnson. Groundwater was struck around 1970 and the pit became a lake. Shortly thereafter the gravel pit operations discontinued.

2.2.2 Groundwater

Seepages of groundwater were observed in boreholes 3,4,5 and 6 during drilling. Groundwater, probably regional, was encountered in all of the boreholes with the exception of boreholes 7, 8, 9 and 13 and observation well 4. Groundwater water was encountered in test pits 5, 9,10, 11, 12, 17, 18, 33, 39, 40, 43 and 44. Depths to groundwater/wet cave ranged between 1.0 and 7.6 m below grade. ***By November 3, 1993, approximately five weeks after installation, the groundwater levels stabilized at 2.7 to 5.7 m below grade, elevation 208.0 +/- , in observation wells 2,3,4 and 5. In observation well 1, the water level was noted to be close to the ground surface on that date.*** An analysis of the static water level elevations indicated that in November, 1993, the regional groundwater flow was directed southwestwards with an average hydraulic gradient of about 1%. ***[Emphasis added]***

A5) Comprehensive Oxygenation Program for Swan Lake

In its report[f] on oxygenation options for Swan Lake, Natural Resource Solutions Inc. ("NRSI") outlined the potential benefits of a comprehensive oxygenation process for Swan Lake.

NRSI noted that oxygenation represents a viable and effective approach to improving surface water quality and aquatic habitat conditions within Swan Lake. When paired with watershed- level nutrient management and ecological restoration efforts, these systems can form the foundation of a long-term strategy to enhance aquatic health, reduce eutrophication, and restore more natural lake function.

NRSI concluded that increased oxygenation in shallow, nutrient-rich systems such as Swan Lake can lead to significant improvements, including:

- Reduced internal nutrient loading and phosphorus release from sediments.
- Decreased bioavailability of heavy metals through oxidation.
- Improved surface water clarity and reduced frequency of harmful algal blooms.
- Enhanced biological diversity and productivity through improved aerobic habitat conditions.

Within Swan Lake, NRSI stated that any management approach intended to increase Dissolved Oxygen ("DO") concentrations must be designed not only to address existing DO deficiencies but also anticipate increases in biological oxygen demand (BOD) that will result from enhanced biological and microbial activity following oxygenation.

NRSI outlined key factors to consider in the design of a comprehensive oxygenation system:

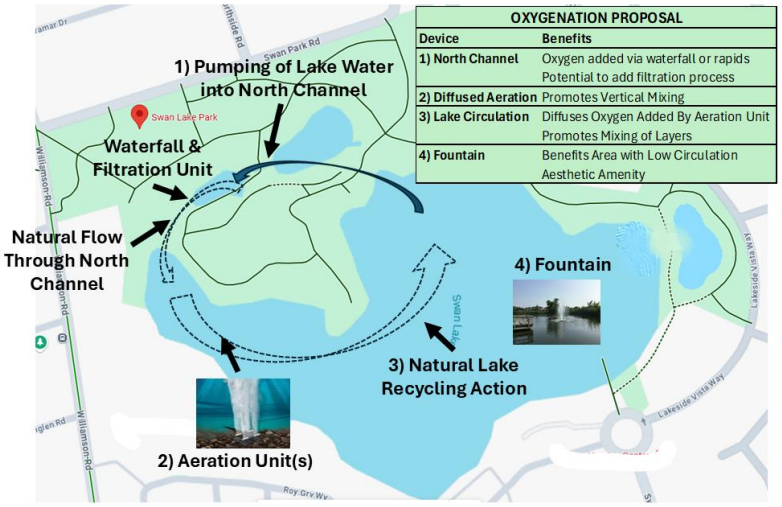
- **System Design**: System layout should provide full spatial coverage, including deeper basins and areas of low circulation, while avoiding disturbance of fine, nutrient-rich sediments.
- **Uniform Application**: Oxygenation should be applied uniformly across the lake to prevent the formation of localized hypoxic or anoxic zones.
- **Continuous Operation**: Consistent, low-intensity operation is preferable to intermittent high-output cycles, as sudden fluctuations in DO can destabilize the system and increase BOD demand.

The following section outlines a proposed configuration for a comprehensive oxygenation program based on NRSI's analysis that will contribute to the management of sediment-based nutrients and enhance the aquatic environment within the lake.

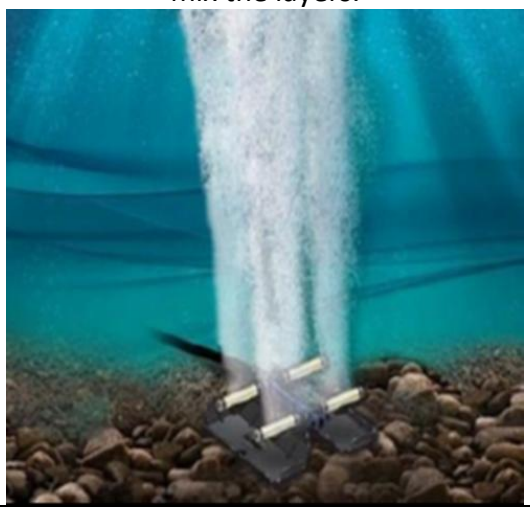
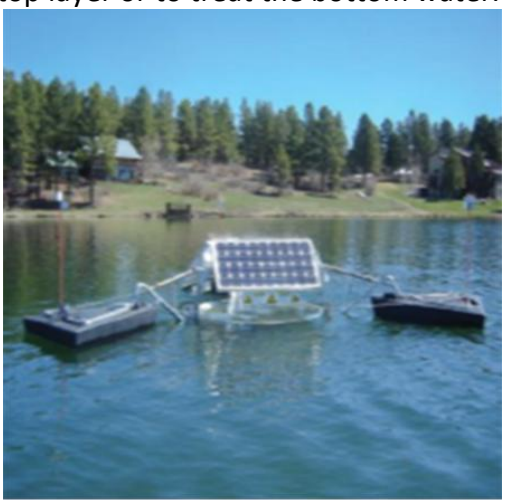
The submerged aquatic plants that have recently taken hold in Swan Lake are expected to contribute to an increase in oxygen levels in the lake. Therefore, FOSLP recommends considering the implementation of the following oxygenation enhancement techniques only if the expected improvement in oxygenation levels does not materialize.

Based on NRSI's guidance, FOSLP's comprehensive oxygenation system contains four components that will incorporate the critical design recommendations.

Four Components	Benefits
1) Recycling Lake Water Through the North Channel	a) Oxygen added through the North Channel b) Potential to add filtration mechanism using Biochar or Chlorocel in the North Channel to remove nutrients and chloride.
2) 1 – 2 Aeration units near the deeper areas in the lake	a) Primary source for new oxygen b) Mixing of the layers locally
3) Circulation throughout the lake created by North Channel recycling	a) Disperses oxygen from the aeration units b) Mixes layers within the lake
4) Fountain Near the Dock	c) Adds oxygen in an area not likely impacted by North Channel circulation d) Returns a popular lake amenity



Examples of Aeration Options

Bubblers	Solar Bee® Lake Circulators
Bubblers add oxygen and will mix the layers.	Active lake circulation can be limited to only the top layer or to treat the bottom water.
	

The units would be operational consistently from April through November powered by the new solar panel complex on the Amica shoreline and repurposed windmill.

Solar Panel Units Powering Ultrasound Devices	Existing Windmill

Recycling through the North Channel

The North Channel, about 100 metres long, is designed as an emergency spillway for overflow from the north stormwater pond (SWP #104); however, it has rarely been used. The channel is typically dry, though during wet periods it will hold water from the runoff from the surrounding parkland.

Removing water from the lake and returning it through the North Channel to the lake oxygen enhanced with possibly fewer nutrients could provide a natural enhancement to the water quality in the lake and reduce the dependency on future chemical treatments. A small portion of the channel is a bioswale which it may be possible to extend. It also may be feasible to circulate water from the lake into Turtle Inlet, creating a decorative waterfall. Turtle Inlet is a small, shallow inlet that has potential to be enhanced as a bioswale.

Pumping Options

It is essential to clarify the primary objectives of recycling water via the North Channel and Turtle Inlet:

a. If the emphasis is primarily oxygenation of the lake, then a high-volume pump may be required.
b. If the emphasis is a combination of filtration and oxygenation, then pumping lower volumes in line with the capabilities of the filtration process will be needed.
c. If the bioswale is the primary tool for filtration then very low flow rates may be required.

Swan Lake contains approximately 80,000 m^3 of water. To recycle that volume over the 7-month period from April – October period would require a pump capable of pumping 360 m^3 /24 hour.

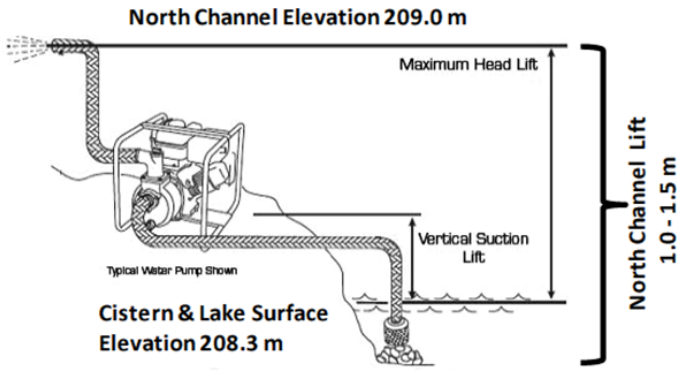
A small "cottage" style pump (1.0 – 1.5 hp), connected to a continuous power source, could recycle 13% - 54% of the lake water through the North Channel.

Driven by either solar sources or by repurposing the existing windmill on the north pond, assuming 50% efficiency, the small pumps would have the capability to recycle 7% - 27% of the 80,000 m^3 of lake water over the summer months which may be sufficient for a filtration process.

Greater lake circulation and improved levels of oxygenation could be achieved if industrial scale pumps, such as those used by Markham's stormwater management department, were deployed. With more powerful pumps, it may be possible to recycle more than 100% of the lake water through the North Channel each season.

To reduce the energy required for the pumps it may be feasible to create cisterns at the start of the North Channel and near Turtle Inlet. The distance from the edge of the lake to the North Channel or Turtle Inlet is approximately 50 - 100 m. A downward sloping pipe from the lake to the cistern could provide a gravity-fed mechanism for getting lake water to the North Channel or Turtle Inlet without pumping. Water in the cistern will rise to the level of the lake water. Pumps would be required to raise the water from the cistern to the North Channel or to a waterfall.

It may be possible to install a filtering process as the lake water enters the cistern.



The eastern end of the North Channel is at an elevation of 209.0 m. or 0.7 m. above the regulated lake level.

Depending on the location of the intake head within the cistern, the maximum head lift height to the North Channel surface is expected to be 1.0 – 1.5 m.

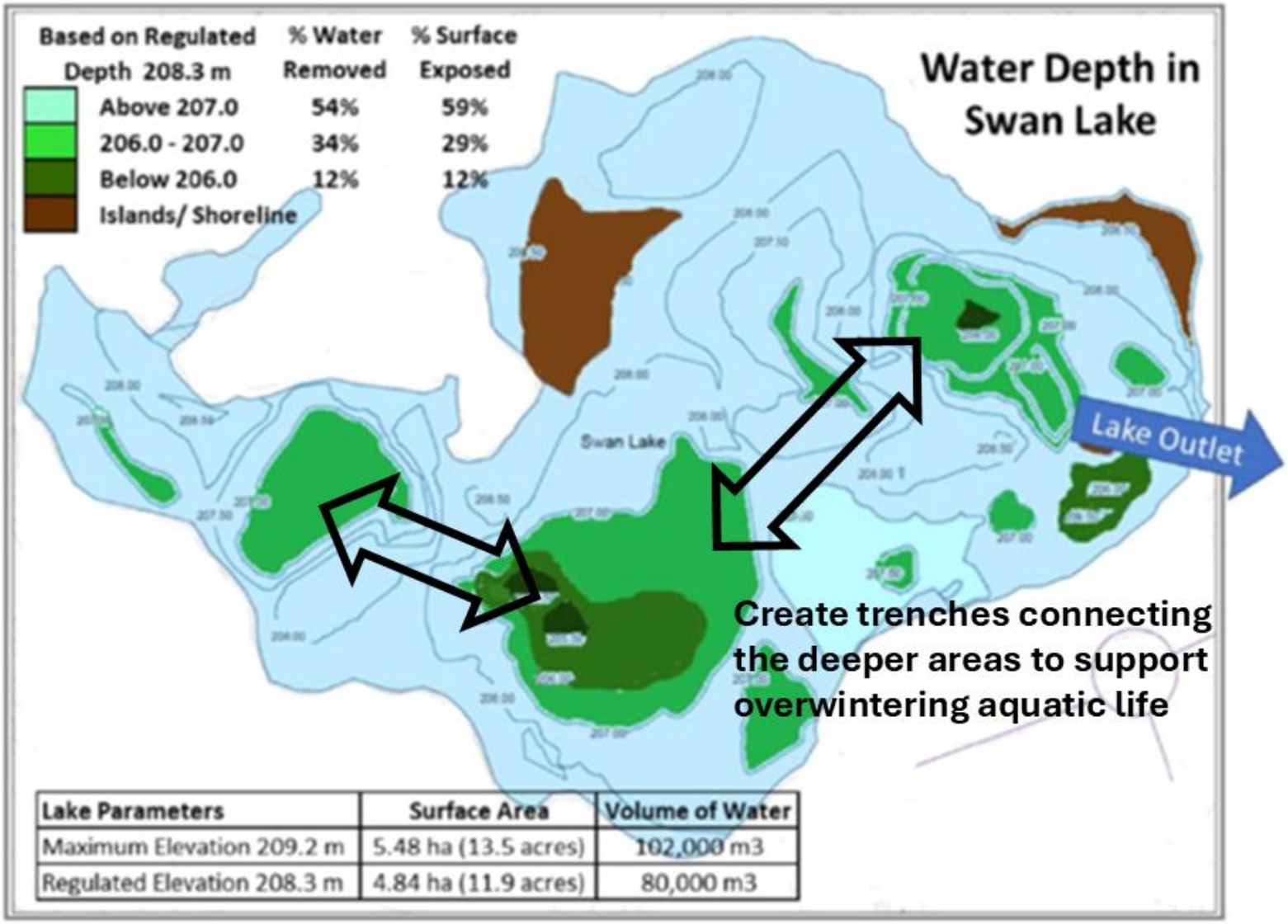
Creation of a decorative waterfall into Turtle Inlet may provided a means for increasing oxygenation content and could be accomplished by pumping the water 5 m higher to approximately 214.0 m.

Regulating Rates of Flow To Minimize Disruption of Sediments

In discussions during Phase 1, concern had been raised that circulation through the lake would stir up the sediments, causing the release of more nutrients from the sediments and increasing turbidity. Any potential impact of flows disrupting sediments can be minimized in two ways:

1) By dispersing the inflow sources. Water can be picked up in 2-3 different locations in the north-east area of the lake, dispersing the inflow.
2) The rate of flow through the North Channel can be regulated by the pumping actions. In the initial year of operation, a low rate of flow to would minimize any possible disruption. The flow action may initially alter the pattern of the sediments. Flow rates can be increased in subsequent periods based on any observed impact on turbidity.

A6) Creating Overwintering Haven for Aquatic Species



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

APPENDIX B: PHASE 1 ACTIVITIES

B1) Lake Management Outcomes

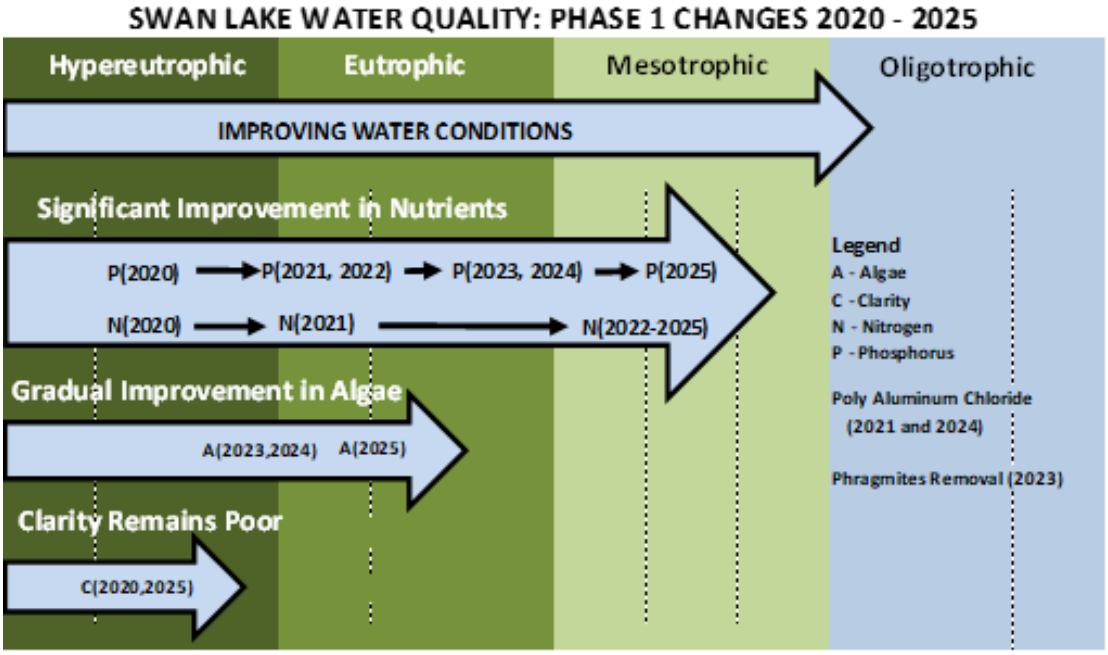
Swan Lake has a history of algal blooms and in 2020 a high level of cyanobacteria was reported. Phase 1 actions were primarily focussed on reducing algae and cyanobacteria through a program targeted to reduce two nutrients essential to the growth of algae, phosphorus and nitrogen. It was stated that the reduction in phosphorus and nitrogen would lead to a reduction in algae and improvement in oxygen levels.

Through their droppings, Canada geese were considered to be the primary "external" source of phosphorus and nitrogen entering the lake. A geese management program was implemented to reduce both the summer resident geese population and to reduce the number of geese staying on the lake during the migration season.

The sediments were considered to be the primary storehouse of nutrients already in the lake. Two treatments of polyaluminum chloride ("PAC") were applied in 2021 and 2024 to reduce the "Internal" source of phosphorus.

In 2022, the TRCA was engaged to remove phragmites from the eastern shoreline of the lake and the North Pond. It is likely that the harvesting of these reeds contributed to the reduction of phosphorus, nitrogen and chloride in the ecosystem during this period.

Phase 1 activities resulted in a significant decline in phosphorus, nitrogen and cyanobacteria; however, only limited progress was made in reducing algal levels in the lake. Clarity and turbidity remain poor.



FOSLP is recommending that Phase 2 actions be focussed on sustaining the improved nutrient levels but with additional actions that will directly reduce the high levels of chloride, algae and improve turbidity with enhancements to support the aquatic habitat.

Aquatic Plants

During the review discussions, Markham provided the following summary of aquatic plants identified during the past two years. The full report has yet to be released.

“During the second PAC application in 2024, significant amounts of aquatic vegetation comprised primarily of Small Pondweed (Potamogeton pusillus) were observed and at times hindered the movement of the application boat. This was the first observation of any significant amounts of submerged aquatic vegetation in the lake. In 2025, a comprehensive survey was conducted to characterize the existing aquatic plant community. The survey found that SAV was abundant throughout the lake with generally moderate to high robustness (cover) at depths less than 2 m, and variable cover from high robustness to absent at depths greater than 2 m. The plants were dominated by the native species including Muskgrass (Chara spp.) and Canada Waterweed (Elodea canadensis) and lower abundances of Small Pondweed and Curly-leaved Pondweed (Potamogeton crispus). The newly established SAV community is consistent with improved water clarity and reduced algae levels in recent years. "

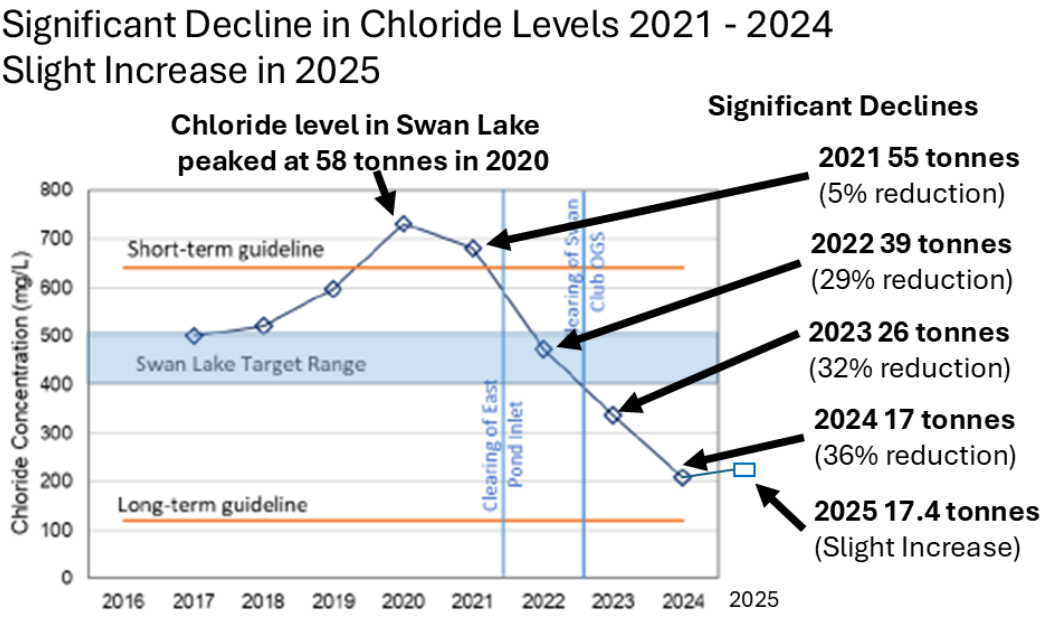
In 2024 the TRCA was engaged to plant wild celery (Vallisneria americana) to establish a test base for macrophytes. The program has had limited success with only 30% of the plants taking hold and only those in shallow water. The TRCA attributes the poor results to fluctuating water levels and poor clarity in the water.

Significant Decline in Chloride Due to Flushing Action

Swan Lake has no natural surface level inflows nor outflows but there are six stormwater sources that direct almost three tonnes of chloride into the lake each year. Chloride does not break down and will accumulate within the lake over time, impairing the health of aquatic plants and many forms of aquatic species.

The other notable change during Phase 1 was a significant decline in chloride levels in the lake. The chloride levels in Swan Lake rose dramatically from 2018 – 2020. This was attributed to a blockage in one of the pipes preventing stormwater flows from entering the East Pond and resulting in a significant increase in flows directed into the lake. Since this blockage was cleared, chloride levels have declined significantly and have levelled off but there are still over 17 tonnes active in the water column and more stored in the sediments.

Though reduced, chloride levels remain well above the Federal guidelines for safe aquatic life.



Inflows reduced once blocked pipe cleared. Reasons for reductions are not clear.

The decline in chloride levels illustrates the ability of the stormwater outflows and the groundwater system to flush chloride from the lake. Markham's Flow Diversion Assessment[(b)] has identified actions that could reduce stormwater inflows into the lake by 85%. If implemented, it is possible that the flushing action could reduce the existing chloride levels below the Federal guidelines, an essential step in stabilizing aquatic life in the lake.

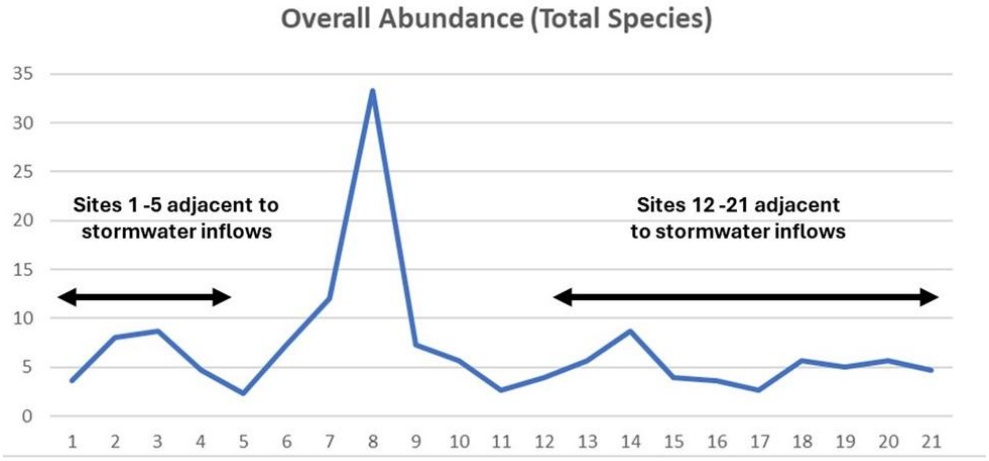
FOSLP is requesting that Phase 2 include an analysis of the natural chloride levels in the groundwater entering Swan Lake. This information will provide a baseline as to what level of chloride would be sustainable if external stormwater sources were removed.

B2) Phase 1 Lake Monitoring

Throughout Phase 1, there were several groups with different perspectives involved in monitoring the water quality and habitat in Swan Lake.

Markham took physical water samples on a routine basis throughout Phase 1. Initially tests were taken bi-weekly and lately monthly at two near-shore locations at the dock and bridge. The focus was on monitoring the nutrients, oxygen, phytoplankton and other organic elements with the goal of assessing the eutrophication level of the water and the success of various management actions. The Markham program included an annual fish inventory program undertaken by the TRCA but did not attempt to monitor aquatic elements such as zooplankton and Benthic Invertebrate. There was some testing of the sediments in 2020 to help with the design of the chemical applications.

Presence of Ephemeroptera (Mayfly), Plecoptera (Stonefly) and Trichoptera (Caddisfly), or EPT, are indicators of good water quality and overall ecosystem health, In 2022, FOSLP engaged Chris Reeves to undertake an inventory of the Benthic Invertebrate. He observed that significantly fewer species were identified in areas adjacent to the stormwater sources but overall concluded that given the taxa found and percentage of EPT species identified, Swan Lake could be rated as fair or intermediate water quality based on his findings.



Dr. Huy Dang of Trent University provides oversight into work by researchers from Trent, Laval University and the Institut National de la Recherche Scientifique (Quebec City) who have been active in Swan Lake over the past three years. Their focus has been on the impact of the heavy metal elements in the chemicals used to reduce phosphorus (Phoslock and Polyaluminum Chloride) on aquatic life.

In 2025, researchers from Trent gathered extensive data including temperature, oxygen (two depths) and chlorophyll over time with very high resolution and have compiled vertical profiles of various parameters (pH, temperature, oxygen, redox, and electrical conductivity) at 10 sites around the lake. This data will be released in 2026 once the research is published.

In 2025, researchers from York University partnered with Friends of Swan Lake Park to form the Swan Lake Citizen Science Lab ("SLCSL").

The objective was to bring advanced technical capabilities of drone monitoring, artificial intelligence, Virtual Reality and simulation to bear on the environmental elements in Swan Lake and Swan Lake Park.

Throughout the growing season, SLCSL project leader, Dr. Ali Asgary collected drone-based multispectral imagery of Swan Lake. The drone imagery provides the basis for three water quality measures:

1) Normalized Difference Chlorophyll Index (NDCI)
2) Normalized Difference Turbidity Index (NDTI)
3) Normalized Difference Water Index (NDWI)

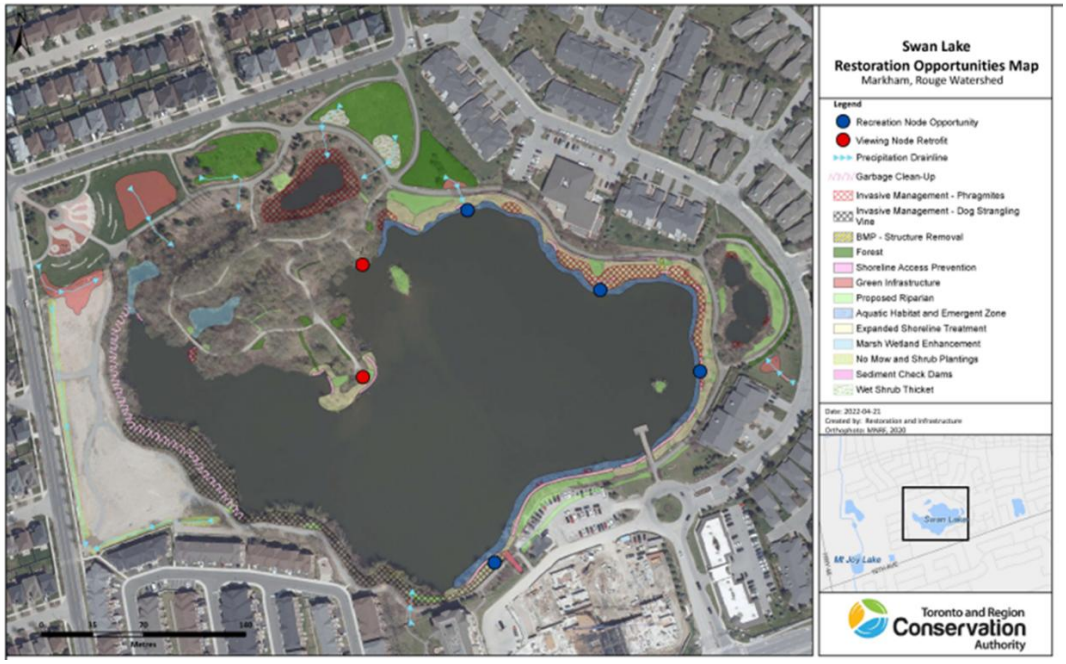
The drone imagery can detect chlorophyll, but it cannot differentiate whether the source is algae or aquatic plants. The researchers from Trent and York undertook to work to integrate their physical and drone imagery to align the drone techniques with the physical monitoring program.

B3) TRCA Phase 1 Activities and Recommendations

The Toronto and Region Conservation Authority ("TRCA") was involved in three core lake management activities during Phase 1:

a) The TRCA undertook a fish inventory program that included the removal of certain "bottom feeding" and invasive species that were considered to be undermining the Phase 1 program.
b) Phragmites was removed in the fall of 2022 along the eastern shoreline and at the North Pond. It is likely that the removal of these reeds also resulted in the removal of phosphorus, nitrogen and chloride from the lake system. No estimate has been made of the potential reductions.
c) The TRCA was engaged to plant wild celery (Vallisneria americana) to establish a test base for macrophytes. The program has had limited success with only 30% of the plants taking hold and only those in shallow water. The TRCA attributes the poor results to fluctuating water levels and poor clarity in the water. No mention was made of the potential impact of chloride levels.

In addition, Markham engaged the TRCA to advise on shoreline enhancements. The TRCA outlined their recommendations for shoreline enhancements and "Restoration Opportunities" at a public meeting on April 26, 2022.



The TRCA's 2022 recommendations included:

a) An invasive plant species removal program for phragmites and dog-strangling vine.
b) An outline of shoreline restoration opportunities that would address the lack of emergent aquatic, terrestrial native plants, shrubs and shallow water habitat.
c) Revegetation of the shoreline to create a diverse naturalized shoreline.
d) Recommendations for the installation of additional stonework along the shoreline to limit geese access.

e) Recommendations for reducing degradation of the shoreline by park users by controlling park visitors access to the lake by installing recreational nodes.

As part of the program to constrain access for the geese, Markham staff proposed the installation of permanent fencing as a geese deterrent, rather than the more costly stone work program proposed by the TRCA.

At the June 2025 meeting of the Markham Subcommittee, Kathleen Elizabeth Noel outlined her concerns about the impact of the fencing on the habitat and staff agreed to discuss the issue with the TRCA before proceeding.

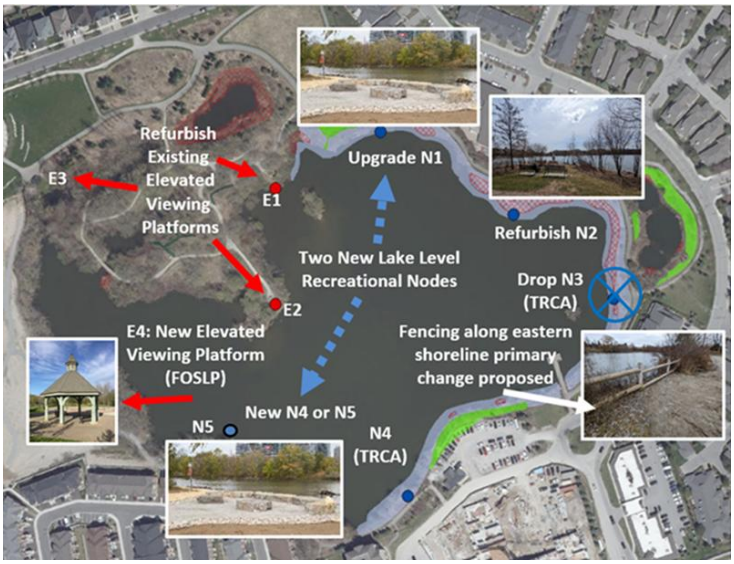
Photo courtesy of Cindy Fowler

Subsequently, staff proceeded with the installation of cedar post and paddle board fencing in 2025 noting that design provisions were made regarding wildlife concerns. The project will also entail the planting of approximately 200 native plants to form a low-growing natural border.

In 2024, FOSLP requested that Markham proceed with a scaled down version of the TRCA recommendations for recreational nodes, requesting that two (N1 & N5) rather than four nodes be added to the shoreline, plus requested an additional viewing area (E4) on the western shoreline be added to serve park visitors in the western section of the park.

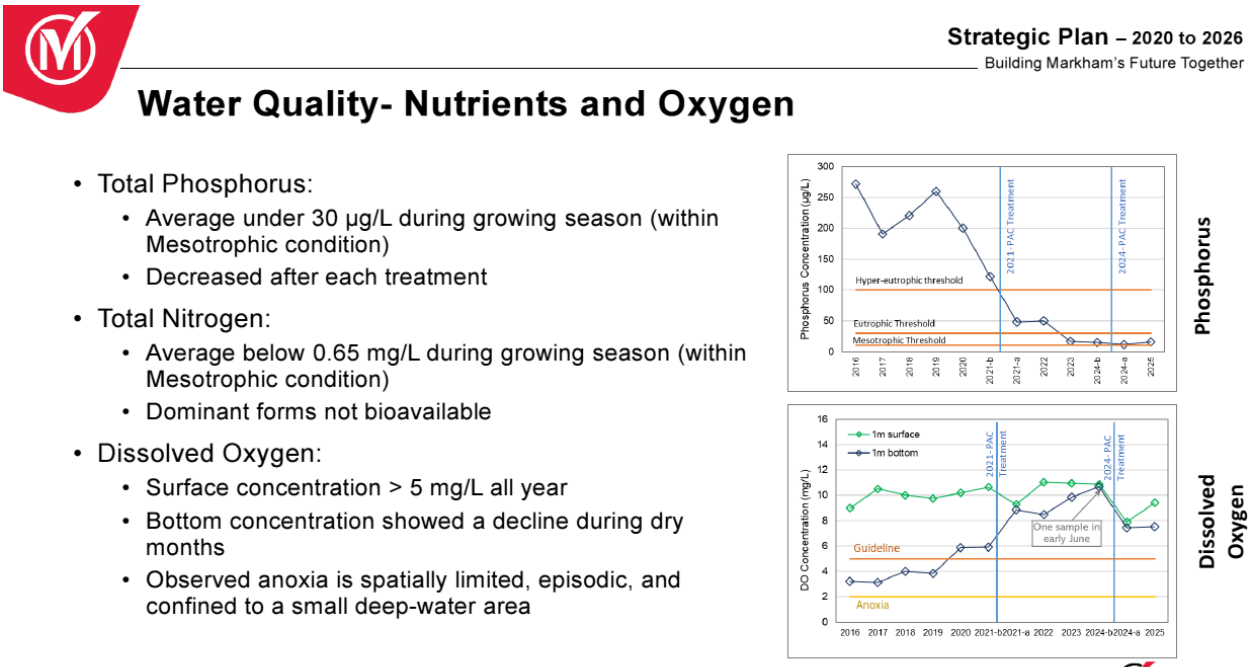
Markham staff recommended against the installation of recreational nodes due to equity with other parks. There are, however, only two other parks containing a major water body. FOSLP is requesting that these additional enhancements be implemented during Phase 2.

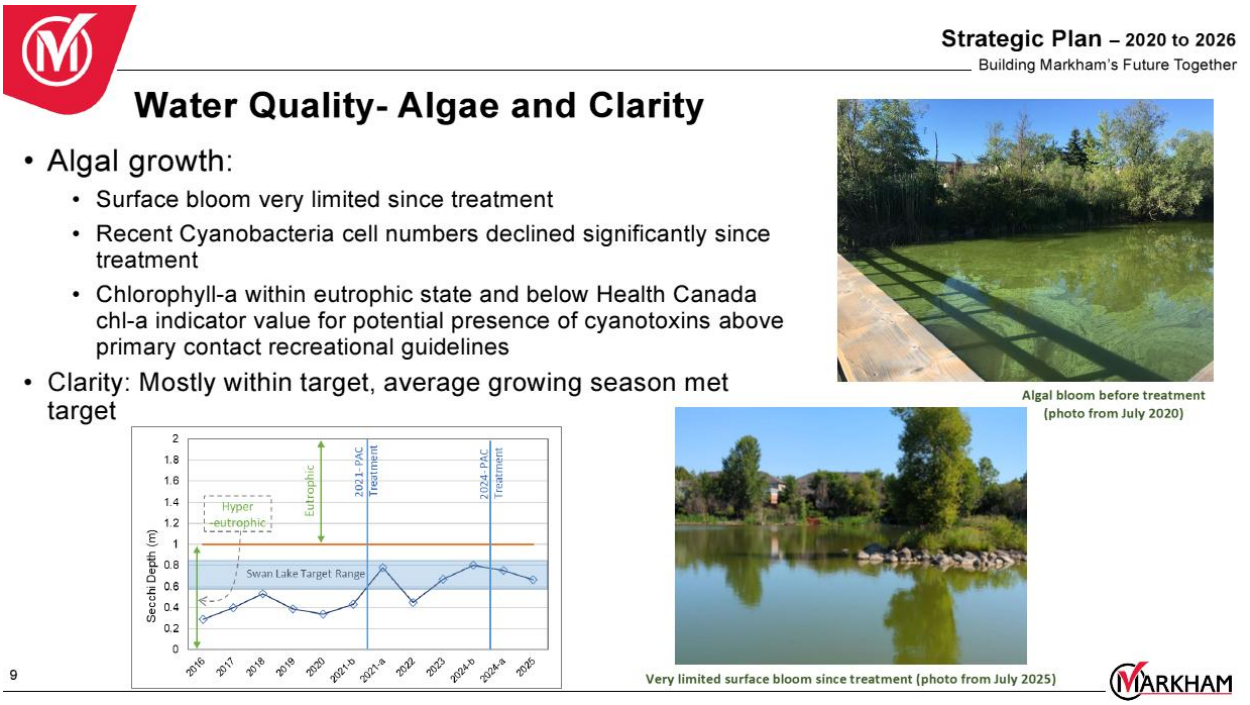
FOSLP Proposed Shoreline Amenities May 2024



B4) Preliminary Water Quality Results (February 2026)

The following details preliminary water quality results were released by Markham staff during discussions on Phase 2 plans.

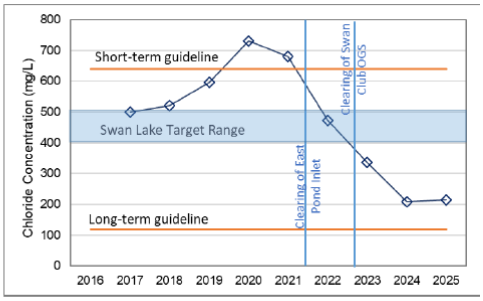




Strategic Plan – 2020 to 2026
Building Markham's Future Together

Water Quality- Chloride

- Chloride enters the Lake through winter maintenance:
  - Swan Lake Village Corporation
  - City roads
  - Residents north of the Lake
  - AMICA Corporation to the south
- Previously on upward trend likely due to blockages, which resulted in untreated flows to the Lake
- Since 2021 decreased due to clearing the blockage at the East Pond inlet and Swan Club OGS
- Long-term guideline derived to protect *the most sensitive life stage of the most sensitive aquatic species* over the long term



Strategic Plan – 2020 to 2026
Building Markham's Future Together

Fish Management

- Removing bottom-dwelling fish to prevent sediment disturbance.
- Fish in the Lake included Common Carp, Brown Bullhead, and Fathead Minnow.
- 500 juvenile largemouth bass added in May 2025.

Bass stocked in May 2025

Submerged Aquatic Vegetation

- 3000 stems of wild celery planted in fenced locations on the north site in 2023 and 2024
- Naturally growing aquatic plants were also abundant in 2024 and 2025
- Further SAV planting will be assessed through the five-year review process
- 2025 survey indicated SAV was abundant throughout the lake

Aquatic Vegetation Survey in July 2025

Strategic Plan – 2020 to 2026
Building Markham's Future Together

Program Outcomes

- Significant improvements in water quality and habitat have been realized, including aquatic vegetation and fish community
- Water quality now consistently meets expectations for shallow urban water bodies
- Innovative technologies and academic research are actively being evaluated
- Phase 1 of the Long-Term Management Plan has successfully met all established goals and targets.

12

MARKHAM

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Project name:
Swan Lake Technical Reviews

Project ref:
60705384

From:
Tammy Karst-Riddoch

Date:
February 2, 2026

To:
Zahra Parhizgari, , M.Sc., P.Eng., PMP
Environmental Engineer | Stormwater | Environmental Services
Community Services Commission | City of Markham

CC:
Robert J. Muir, M.A.Sc., P.Eng.
Manager, Stormwater | Environmental Services
Community Services Commission | City of Markham

Memo

Subject: Review of Towards Sustainable Water Quality for Swan Lake, Friends of Swan Lake Park

AECOM Canada ULC (AECOM) was engaged by the City of Markham to conduct an independent technical review of the report Towards Sustainable Water Quality for Swan Lake, prepared by the Friends of Swan Lake Park (FOSLP) and dated December 3, 2025. The report summarizes analyses prepared by FOSLP's advisors and presents recommendations for management actions proposed for Phase 2 (2026–2030) of the Swan Lake Long-Term Water Quality Plan (SLMP).

Markham Council approved the SLMP in December 2021, establishing a phased, adaptive management framework with specific actions identified for Phase 1 (2021–2025). City staff have initiated a review of the plan in advance of seeking approval to proceed with Phase 2 in April 2026.

This memorandum presents AECOM's technical review of the FOSLP submission and supporting advisor reports, focusing on interpretation of monitoring results, characterization of lake conditions, and the technical basis for the Phase 2 recommendations, with emphasis on consistency with observed conditions and alignment with the intent of the approved SLMP.

1. Technical Review

FOSLP asserts that the Phase 1 measures of the SLPM focused primarily on reducing algal biomass indirectly through nutrient reduction and that these have had limited effect. On this basis, FOSLP concludes that continued nutrient management must be complemented by measures that directly address oxygen conditions, turbidity, algae, and chloride. The proposed FOSLP management actions to address those concerns include:

1. Keep the bad stuff out and add oxygen
    a. Geese management
    b. Shoreline enhancement
    c. End stormwater role
    d. Oxygenation program
2. Remove the bad stuff from the lake
    a. Nutrient Management
    b. Harvesting Algae/Plants

c. Selective removal of sediments
d. Biochar filtration

3. Keep it that way

a. Aquatic planting
b. Aquatic Species Management
c. Enhanced Monitoring

The following technical review is organized by the above proposed management actions and considers comments and recommendations of FOSLP and their advisors. Recommendations regarding each of the proposed actions are provided for consideration by the City of Markham in the five year review of the SLMP.

1a. Geese Management - Continue the geese hazing program to reduce external sources of phosphorus and nitrogen.

Goose management is a core component of the SLMP and is proposed to continue through Phases 2 and 3. Action taken by the City in Phase 1 have successfully reduced geese and resultant total phosphorus loads by an average of ~65%, significantly contributing to reduced total phosphorus concentrations in the lake.

Recommendation: That goose management continue as a core component of the SLMP.

1b. Shoreline Enhancement - Enhance the shoreline areas as recommended by the TRCA, Burnside and Noel to reduce the impact of nutrients entering the lake and to absorb nutrients already in the lake.

Native shoreline plantings are a recognized best management practice that provide bank stabilization, habitat enhancement, moderation of overland runoff, and potential deterrence of waterfowl. However, their nutrient management benefit is limited. While vegetation may reduce particulate nutrient inputs from runoff, it does not remove nutrients already present in the lake, and nutrients assimilated into plant biomass are largely recycled back to the system with die-back in the fall.

Recommendation: That the City consider targeted native shoreline plantings in areas where riparian cover is lacking in Phase 2 as a complementary measure, but not as a core component in lake nutrient reduction.

1c. End Stormwater Role - Minimize chloride inflows entering the lake (see Appendix B) a. Eliminate 56% of the chloride flows from the three Oil Grit Separator units using a low-cost parkland route at a cost FOSLP estimates at $1.1 million. b. Reduce chloride inflows by 29% by altering the three splitters that control stormwater flows bypassing the ponds (Cost $125,000).

The recommendation to eliminate or reduce stormwater inputs to Swan Lake to address chloride loading was also advanced in NRSI's report, *Swan Lake Management Options, Swan Lake Long-Term Management Plan: Water Quality Monitoring Program Preliminary Review,* November 2025. A detailed review of the NRSI report is included as Attachment A to this memo, and the response from that review regarding chloride management is reproduced below. Additional comments on stormwater diversion follow.

- Responses to NRSI Recommendations for Chloride Management (reproduced from Attachment A):

Chloride management is already a recognized priority in the SLMP and is being actively addressed by the City. In recent years, chloride concentrations in Swan Lake have declined substantially. This improvement is largely attributable to the removal of blockages at the East Pond inlet and the Swan Club oil–grit separator, which reduced untreated stormwater delivering higher chloride loads to the lake. The City continues to monitor chloride concentrations at stormwater outfalls and to refine estimates of chloride loading from these sources to improve understanding of source contributions and inform management activities. The City is currently supporting research at York University to evaluate the feasibility and effectiveness of biochar for chloride reduction. At present, this work remains at a research stage and is not yet supported for implementation.

Diversion of stormwater away from Swan Lake could reduce chloride loading from this source; however, such an intervention is not currently warranted based on observed chloride concentrations or evidence of ecological impairment. In addition, potential benefits of diverting water would require careful evaluation of potential negative impacts on lake hydrology, beneficial uses, and the observed recovery trajectory before being considered for implementation. This approach is consistent with the SLMP, which previously evaluated stormwater redirection options and identified such structural modifications as a longer-term, conditional consideration (Phase 3), subject to comprehensive technical studies, downstream infrastructure constraints, and demonstrated need. As documented in the Plan, earlier evaluations concluded that complex and costly drainage system modifications would be a low priority unless other habitat restoration efforts were shown to be unsuccessful due to chloride-related impacts.

While chloride concentrations continue to exceed the CCME long-term exposure guideline of 120 mg/L, exceedance of this guideline alone does not necessarily indicate significant impairment of aquatic habitat. This interpretation is consistent with the CCME guidance, where the guideline is derived to protect the most sensitive life stage of the most sensitive aquatic species over the long term. While concentrations below the guideline are not expected to result in adverse effects, exceedance of a CWQG does not, in itself, imply that aquatic biota are adversely affected or that a waterbody is impaired. The concentration at which effects may occur can vary depending on site-specific conditions, exposure history, and ecological context, and professional judgement is required when interpreting exceedances. Consistent with CCME guidance, chloride guidelines are intended to be applied to ambient surface water conditions rather than concentrations immediately adjacent to point sources such as stormwater outfalls, so the lake chloride monitoring approach for Swan Lake is appropriate for evaluation of chloride in the lake for aquatic health.

- Additional Comments

FOSLP asserts that recent observed declines in lake chloride concentrations reflect effective “flushing” by stormwater outflows and groundwater and that if stormwater diversion is implemented, “flushing action could reduce the existing chloride levels below the Federal guidelines”.

The observed pattern of chloride concentrations in Swan Lake is consistent with the removal of a discrete, high-chloride surface load rather than enhanced “flushing” by stormwater outflows or groundwater, as suggested by FOSLP. A stormwater conveyance blockage caused first-flush runoff to be directed to the lake rather than bypassing it as intended resulting in high chloride loads. Once the blockage was cleared and normal stormwater routing was restored, chloride loads were significantly reduced. An initial relatively rapid decline in lake concentrations was followed by a more gradual decrease, with concentrations now appearing to stabilize. This response is consistent with a step change in chloride loads and suggests that the lake has reached, or is approaching, an equilibrium condition under the current hydrologic regime and chloride loading.

The potential for additional chloride reduction through groundwater “flushing” is not supported by available data at this time. The effect of groundwater exchange depends on both exchange rates and groundwater chloride concentrations. While the recent water budget for Swan Lake suggests groundwater interaction is likely, existing data are insufficient to quantify the magnitude or direction of exchange. Chloride concentrations in groundwater have not been characterized. Without this information, it cannot be assumed that groundwater inflow would reduce lake chloride concentrations.

Stormwater diversion could also provide only limited benefit and may result in adverse effects, including:

- Reduced lake levels and outlet discharge if groundwater inflow does not fully replace diverted stormwater, particularly during the open-water season when evapotranspiration is highest.
- Increased in-lake chloride concentrations under reduced discharge conditions, as chloride export declines and chloride mass is retained within a smaller water volume.
- Limited or no chloride reduction even if groundwater inflow replaces diverted stormwater, as lake concentrations would be expected to converge toward groundwater chloride levels.
- Adverse effects on nearshore habitat, nutrient cycling, and dissolved oxygen dynamics resulting from changes in water level and hydraulic residence time.

These limitations and potential adverse effects are not addressed in FOSLP’s recommendation.

Based on existing data, stormwater diversion is not supported as a means of achieving further meaningful chloride reduction in Swan Lake. Substantial uncertainty remains regarding potential long-term benefits, seasonal concentration responses, and hydrologic impacts on water quality and aquatic habitat.

The SLMP appropriately identifies investigation of groundwater contributions as a complementary Phase 3 measure, to be advanced if additional information is needed to support further water-quality improvements.

Recommendation: That the current chloride management approach outlined in the SLMP be continued under Phase 2, including ongoing lake and stormwater outfall monitoring, refinement of chloride loading estimates and evaluation of lake responses. Based on recent improvements and current conditions, diversion of stormwater from Swan Lake is not recommended at this time.

Recommendation: That any future consideration of stormwater diversion or other large-scale chloride reduction measures should be supported by lake-response modeling that demonstrates a clear and meaningful benefit to lake water quality, and that explicitly evaluates potential hydrological impacts on water quality, beneficial uses, and the observed recovery trajectory of the lake.

Recommendation: That the investigation of groundwater contributions planned for Phase 3 be considered for advancement to Phase 2 to support water balance calculations and the role of groundwater in chloride loads.

1d. Oxygenation Program - Implement a comprehensive oxygenation program.

FOSLP cites recommendations by NRSI in support of implementing a comprehensive oxygenation program for Swan Lake. The proposed program includes multiple interventions, including recycling lake water through the North Channel, installation of one to two aeration units in deeper areas of the lake, circulation induced by North Channel recycling, and a fountain near the dock.

The fundamental premises underlying the recommendations are not supported by available evidence. Characterizing Swan Lake as hydraulically stagnant, poorly mixed, and oxygen-limited is inconsistent with observed monitoring data. These issues are addressed in detail in the review of NRSI's report provided in Attachment A. Pertinent excerpts from that review, refuting the assertion that Swan Lake is impaired by low dissolved oxygen requiring additional oxygenation measures, are reproduced below, followed by comments specific to the current proposal.

- Responses to NRSI Conclusions on Dissolved Oxygen and Oxygenation Requirements (reproduced from Attachment A):
  - NRSI's reliance on the 2024 continuous dissolved oxygen monitoring data to question the validity of the broader dataset reflects a misunderstanding of the purpose and interpretation of the continuous monitoring and does not consider the depth of the logger near the lake bottom at 2.75 m below surface where anoxia was recorded. Continuous loggers are designed to capture short-duration and diel changes in dissolved oxygen. Detection of episodic bottom-water anoxia by continuous monitoring does not contradict discrete profile data that characterize general lake conditions within biologically active portions of the water column at the time of monitoring. It is also noted that the City's continuous logging at the dock site recorded similar near-bottom anoxic periods, which were transparently reported in the annual reports.
  - Discrete profile monitoring conducted at the dock site from 2022-2024 following the 2021 PAC treatment, did not detect anoxia, and dissolved oxygen concentrations below 4 mg/L occurred on only three of 46 events and these only occurred within approximately 1 m of the sediment–water interface. The profile at the dock site in 2024 was also consistent with Trent University's profile at the deeper monitoring site. These observations are consistent with localized near-bottom oxygen depletion driven by sediment oxygen demand and respiration, and do not indicate lake-wide impairment of the mixed water column.
  - Hypsometric analysis demonstrates that depths below approximately 2.5–2.75 m, where anoxia has been observed, represent only a small fraction of Swan Lake, on the order of approximately 3–5% of total lake area and 1–3% of total lake volume, based on water level at the time of monitoring. This illustrates that observed anoxia is

spatially limited, volumetrically minor, and confined to a small deep-water zone, rather than indicative of widespread or persistent lake-wide conditions.

- PWQO and CCME dissolved oxygen guidelines are intended to protect aquatic life within biologically relevant habitat and are not meant to be applied uniformly throughout the entire water column at all times throughout the year. Localized or depth-limited anoxia near sediments does not constitute non-attainment of the guideline, or 'impairment'. When interpreted consistent with their intent, considering depth, habitat use, and the spatial and temporal extent of low-oxygen conditions, the observed dissolved oxygen conditions in Swan Lake meet both PWQO and CCME guidance.
- Comparison to pre-management conditions provides additional context. Prior to implementation of SLMP, anoxia was persistent and widespread with hypoxia regularly extended upward into the mixed layer during summer months. In contrast, post-2021 monitoring shows that low dissolved oxygen or anoxia is confined to near-bottom waters, occurs episodically primarily during calm and warm periods, and affects only a small portion of lake area and volume. This represents a substantial improvement in dissolved oxygen conditions and demonstrates an appropriate system response to management actions that have been implemented under the plan.
- Taking all evidence into account and with an understanding of the intent and application of relevant guidelines, it is my professional opinion that from 2022-2024:
  - Dissolved oxygen concentrations during the open water season in Swan Lake meet PWQO for warm water fish and the CEQG for the protection of aquatic life.
  - Anoxic conditions occur, but these are limited spatially and volumetrically and are mostly episodic during the open water season and would not pose significant widespread adverse ecological conditions for aquatic life.
- The discussion of oxygenation implicitly assumes that hypoxia or anoxia represents a dominant, lake-wide management issue in Swan Lake. This assumption is not supported by the Phase 1 monitoring results, which demonstrate that observed anoxia is spatially limited, episodic, and confined to a small deep-water area, rather than indicative of a system-wide condition requiring intervention.
- Improvements in dissolved oxygen conditions observed since implementation of nutrient management actions indicate that oxygen dynamics are responding as expected to reductions in nutrient concentrations, which address the underlying cause of eutrophication-driven oxygen demand.
- While NRSI states that management actions should address underlying causes rather than symptoms, the proposed oxygenation measures, assuming these are appropriate for use in Swan Lake, would primarily function as symptom-focused interventions and are not expected to result in meaningful long-term improvements, as acknowledged in the NRSI discussion itself.

Recommendation: That, in the absence of evidence of persistent, lake-wide oxygen impairment or a clearly defined management objective that would be advanced by oxygenation, implementation of a comprehensive oxygenation program is not warranted at this time.

- Additional Comments

As noted in the detailed review of the NRSI report, characterization of Swan Lake as a "relatively stagnant lake with minimal mixing" is not supported by lake morphometry, hydrology, or observed monitoring data. Swan Lake is a shallow system (mean depth ~1.5 m at average water levels) that is generally well mixed by wind, with only a small area exceeding ~2 m depth that exhibits limited and seasonal thermal stratification during peak summer conditions. Stratification is expected given the ratio of the mean depth to the surface area of the lake (i.e., a large morphometric ratio). While reduced surface mixing occurs during calm, dry periods, this does not indicate that the lake is stagnant. The lake has an average water residence time of approximately 1.7 years (2020-2024), which is inconsistent with a stagnant system and indicates regular water exchange and mixing at the whole-lake scale.

The need for additional water circulation or mixing is therefore not well founded. Moreover, given the very shallow nature of the lake, physical interventions intended to induce circulation or mixing would be difficult to implement without causing sediment resuspension. Sediment resuspension can have multiple adverse effects, including increased turbidity, mobilization of sediment-bound nutrients, and disruption of internal nutrient cycling, particularly phosphorus retention and settling processes.

In conclusion, available evidence does not support the need for a comprehensive oxygenation program in Swan Lake. Dissolved oxygen conditions meet applicable guidelines within biologically relevant habitat, and observed anoxia is limited, episodic, and confined to a small deep-water area. Implementing oxygenation under these conditions would not address a demonstrated lake-wide impairment and would represent a symptom-focused intervention with limited expected benefit and potential adverse effects that could undermine the water quality improvements achieved over the last several years.

Recommendation: That the comprehensive oxygenation program proposed by FOSLP and their advisors not be considered for implementation, and that future consideration of the proposal should be contingent on new evidence demonstrating persistent, lake-wide oxygen impairment or a clearly articulated management objective requiring such intervention and supported by data.

2a. Nutrient Management - Scheduling another PAC treatment 3-5 years after the latest treatment to contain phosphorus.

The PAC treatments have effectively controlled the release of phosphorus from sediments, which was the primary source of phosphorus contributing to nutrient concentrations in the lake. The effectiveness of the treatments are well supported by lake water quality monitoring data. This management action is already including as a core measure in the SLMP with plans to continue in Phase 2.

Recommendation: That the chemical treatments to manage phosphorus loads from lake sediments continue as a core measure and be implemented in accordance with the SLMP.

2b. Harvesting Algae/Plants - At least once during Phase 2, harvest the shoreline reeds in the fall to remove phosphorus, nitrogen and chloride from the ecosystem.

Harvesting of invasive shoreline vegetation (e.g., Phragmites) is a recognized best practice for shoreline management and habitat maintenance and may provide localized benefits, including aesthetic improvement and limited removal of nutrients stored in plant biomass. However, the potential for meaningful reductions in lake-wide phosphorus, nitrogen, or chloride concentrations through plant harvesting is likely limited under current conditions.

Nutrient concentrations in Swan Lake have declined substantially since implementation of nutrient management actions, with current total phosphorus concentrations generally below approximately 20 µg/L, compared to historical concentrations exceeding 100 µg/L. Under these conditions, the mass of phosphorus removed through periodic shoreline vegetation harvesting is expected to be small relative to total lake loads, and the water-quality benefit may be marginal.

Accordingly, harvesting of shoreline vegetation should be considered for the SLMP where it can be demonstrated to provide a clear benefit, either through measurable nutrient or chloride removal or through shoreline management and habitat objectives. Given its maintenance-oriented nature, this activity may be more appropriately addressed through routine parks or shoreline management programs rather than as a water-quality control measure within the SLMP.

Recommendation: That harvesting of shoreline vegetation be considered as a shoreline management or maintenance activity, and that its inclusion as a nutrient or chloride management measure be contingent on demonstration of a clear benefit relative to cost and scale of removal.

2c. Selective Removal of Sediments - Identify the primary areas where sediments are storing nutrients and chloride, and selectively remove those sediments, in sync with deepening areas to provide a haven for overwintering species.

Sediment removal was evaluated during development of the Swan Lake Management Plan (SLMP) and was not recommended due to multiple, well-founded concerns, including the potential disturbance of contaminants associated with former gravel pit operations and historical dump sites, as well as the high cost and complexity of sediment removal and disposal. These constraints remain unchanged. Moreover, sediment removal would represent a major physical disturbance that risks undermining the substantial water-quality improvements achieved through recent management actions.

Chemical treatment has successfully reduced internal phosphorus loading from sediments, and the primary driver of sediment phosphorus release, persistent anoxia, is no longer a significant lake-wide condition. Under current conditions, there is no technical rationale for sediment removal as a nutrient management measure. As defined in the SLMP, chemical treatment remains the most effective and least disruptive approach for managing sediment-derived phosphorus. Given the substantial reduction in lake phosphorus concentrations, it is anticipated that the pool of mobile sediment phosphorus will continue to decline over time, potentially reducing the frequency or dosage of future chemical treatments.

FOSLP's submission also repeatedly suggests that sediments represent a meaningful long-term source of chloride to the water column. This interpretation is not supported by established chloride behavior in freshwater systems. Chloride is highly mobile and does not bind strongly to sediments. While sediment porewater chloride concentrations may reflect historical loading, observed lake chloride trends are more consistently explained by hydrologic processes including inflow and outflow routing, evaporative concentration, and groundwater exchange, rather than by sediment storage or release. Accordingly, sediment-focused management actions are unlikely to result in meaningful or sustained reductions in lake chloride concentrations unless they fundamentally alter the lake's hydrologic or chloride mass balance. Sediment-associated chloride should therefore not be interpreted as justification for sediment removal as a chloride control measure.

The proposal to excavate trenches to deepen portions of the lake to provide overwintering habitat would necessarily require sediment removal and is not advisable for the reasons outlined above. In addition, this approach is unlikely to be technically feasible. Based on lake bathymetry, a connecting trench would need to be on the order of approximately 1-2 m deep. However, sediment coring conducted in 2020 indicates that the thickness of surficial organic sediments is limited to approximately 10 cm, with sandy or consolidated materials encountered immediately below. These materials are likely associated with former gravel pit substrates or engineered caps and should not be disturbed. The limited thickness of organic sediment is consistent with the relatively young age of the lake (early 1990s), expected depositional rates, and rapid organic matter cycling typical of shallow, warm-water systems.

Given these constraints, sediment excavation for habitat enhancement is neither technically justified nor environmentally prudent. As previously recommended, overwintering habitat suitability should be evaluated through targeted biological monitoring before any consideration of physical modification to lake sediments.

Recommendation: That selective sediment removal, including excavation for nutrient, chloride, or habitat management purposes, not be considered for implementation, as it is not supported by current data, poses unnecessary environmental risk, and is inconsistent with the management framework and demonstrated success of the SLMP.

2d. Biochar Filtration - Implement a Biochar filtration unit as a component of the recycling process through the North Channel.

The North Channel recycling process proposed by FOSLP, as a component of the comprehensive oxygenation program, is not recommended (see response to Recommendation 1d). As such, implementation of a biochar filtration unit dependent on this recycling process is also not supported at this time.

The City is currently supporting research at York University to evaluate the feasibility and effectiveness of biochar for nutrient and chloride reduction. Pending the outcomes of this research, biochar may warrant future consideration where it can be demonstrated to provide a measurable benefit, particularly for controlling nutrient and chloride loads associated with stormwater inputs.

Recommendation: That implementation of biochar filtration as proposed by FOSLP not be considered for Phase 2 of the SLMP, with any future consideration contingent on the results of ongoing research and demonstrated applicability to stormwater load management.

3a. Aquatic Planting - Continue with aquatic and shoreline planting to support aquatic and park wildlife.

Recent monitoring indicates that Swan Lake is undergoing natural recovery of aquatic vegetation. An aquatic plant survey originally planned for Phase 2 of the SLMP was advanced in 2025 following observations of submerged aquatic plants during

the 2024 PAC treatment. Results from the 2025 aquatic vegetation survey show that the lakebed is now colonized by submerged aquatic vegetation, with *Chara* and *Potamogeton pusillus* present as dominant species at water depths up to approximately 2 m, and lower coverage, but still present at greater depths. This represents a substantial improvement from earlier conditions when little to no SAV was present and indicates improving habitat quality and system stability.

In contrast, pilot planting of Wild Celery (*Vallisneria americana*) conducted in 2023 and 2024 by TRCA demonstrated limited establishment success, with overall survival rates of approximately 30% or less, likely influenced by turbidity, fluctuating water levels, and site conditions. These observations suggest that natural colonization is currently the dominant and more effective mechanism for SAV recovery.

Given the demonstrated natural establishment of submerged vegetation and the limited success of active plantings to date, further SAV planting is not warranted at this time.

Recommendation: That additional planting of submerged aquatic vegetation not be pursued at this time, and that vegetation recovery continue to be monitored. Targeted planting (e.g., floating-leaved or emergent species) may be considered in the future only if monitoring indicates a clear need and demonstrates that such actions would provide a measurable ecological benefit beyond ongoing natural recovery.

3b. Aquatic Species Management - Continue with the fish management program and investigate the opportunity to stock zooplankton or mussels to support the algae management program.

Continuation of the fish management program as set out in the SLMP is supported. Recent monitoring confirms that fish community management and invasive species control are progressing as intended. Results from the 2025 electrofishing and netting program showed continued presence of native and forage species, a notable absence of Common Carp. Largemouth bass were also stocked in the lake in 2025. Consistent with TRCA's recommendations, annual monitoring and continued removal of invasive species should proceed, along with evaluation of bass survival and spawning success in 2026. Consideration of returning some native benthic species (e.g., Brown Bullhead) is also appropriate to maintain balanced ecosystem function.

While zooplankton and benthic filter feeders (e.g., mussels) are important components of aquatic food webs and can influence algal dynamics, active stocking of these organisms is not recommended at this time. Ongoing recovery of submerged aquatic vegetation, reductions in nutrient concentrations, and ongoing fish community management, particularly stocking of largemouth bass and reduction of planktivorous and benthic-disturbing species, are expected to support natural recovery of zooplankton populations through trophic interactions and improved habitat conditions. Zooplankton communities may also have been previously suppressed by elevated chloride concentrations prior to 2021, conditions that have since improved.

Given these factors, direct stocking of zooplankton or mussels is not warranted under current conditions and would introduce additional uncertainty without clear evidence of benefit.

Recommendation: That the fish management program continue, including annual monitoring, invasive species control, and evaluation of bass stocking success; and that stocking of zooplankton or mussels not be pursued at this time. Future consideration of such measures should be contingent on monitoring evidence demonstrating a clear ecological need that cannot be addressed through ongoing habitat recovery and fish community management.

3c. Enhanced Monitoring - As recommended by NRSI, implement a comprehensive monitoring program in conjunction with university researchers that will monitor the eutrophic levels, aquatic habitat and aquatic life (zooplankton, Benthic Invertebrates), the sediments, and the success of specific management actions undertaken during the rehabilitation program. As recommended by NRSI, establish goals that align with Federal and Provincial guidelines and create triggers to address changes if conditions deteriorate.

A detailed technical review of the NRSI report and associated recommendations is provided in Attachment A. Recommendations for the City's consideration with respect to enhanced monitoring are included therein.

2. Closing

This review has focused on the key management actions proposed by FOSLP and has sought to evaluate each recommendation in the context of available monitoring data, system understanding, and the objectives of the Swan Lake Management Plan. I would be pleased to discuss the findings and recommendations further or to clarify any aspects of this review as needed.

Attach.

Attachment A

Technical Review of:
Swan Lake Management Options, Swan Lake Long-Term Management Plan: Water Quality Monitoring Program Preliminary Review, Natural Resource Solutions, Inc. (NRSI), November 2025.

1. Introduction

Friends of Swan Lake Park (FOSLP) engaged Natural Resource Solutions Inc. ("NRSI") to complete a peer review of the monitoring and reporting completed to date as part of the City of Markham's 25-year water quality monitoring program preliminary (Phase 1) and provide general guidance and recommendations to support the long-term Swan Lake water quality objectives. The NRSI (2025) review *Swan Lake Management Options, Swan Lake Long-Term Management Plan: Water Quality Monitoring Program Preliminary Review, Natural Resource Solutions, Inc.* is incorporated into FOSLP's submission *Towards Sustainable Water Quality for Swan Lake*, dated December 3, 2025.

This document presents a technical review of the NRSI (2025) report, drawing on the Swan Lake Annual Monitoring Reports (2021–2024), the *Swan Lake Long-Term Management Plan* (SLMP) and supporting technical studies, and applicable provincial and federal guidance, to:

- Assess whether NRSI's interpretation of monitoring data is technically sound and appropriately framed;
- Evaluate the relevance and feasibility of recommended monitoring and management actions relative to the objectives of the SLMP; and
- Provide recommendations to support the City of Markham's decision-making on updates to the SLMP and Phase 2 implementation.

The review comments that follow are organized by section of the NRSI (2025) report in bold text, and focus on the technical accuracy, framing, and relevance of the observations and recommendations presented.

2. Technical Review

2.0 Summary of Water Quality Monitoring Components - NRSI states that the interim targets used to evaluate water quality parameters are "*general numerical guidelines intended to be used as thresholds for hyper-eutrophic conditions",* and *"that these interim targets were updated to generic thresholds for eutrophic/hyper-eutrophic conditions (Markham 2022), which are shown in Table 1."*

Review Comments:

- The values and intent of the interim water quality targets described and summarized in Table 1 are not consistent with those defined in the SLMP.
- The interim water quality targets were established in the plan as site-specific Phase 1 goals. They are not generic thresholds for eutrophic or hyper-eutrophic conditions, and they were not updated to generic trophic thresholds.
- The interim targets are quantitative, site-specific values proposed as goals to be achieved in the first five years of the plan (Phase 1) to address the primary water quality issues of eutrophication and high chloride levels. These were developed based on detailed limnological analysis of Swan Lake and represent water quality characteristics that are practically achievable through implementation of the Phase 1 management actions set out in the plan.
- Annual monitoring results are compared against the interim targets to track progress of lake management efforts.
- Results are also compared to relevant federal and provincial water quality guidelines and objectives, and the trophic state of Swan Lake is reported based observed total phosphorus concentrations, to contextualize lake condition.

- Progress toward the interim targets and updates to the targets are being evaluated through the scheduled review of the management plan this year.

2.1 Water Quality Monitoring Program Components and Recommendations - NRSI confirms that the existing core water quality monitoring program is consistent with best practice for eutrophication monitoring and supports long-term assessment of aquatic ecosystem condition and beneficial uses in Swan Lake. However, NRSI also recommends several modifications to the program, including the addition of monitoring parameters, increased sampling frequency, and expansion of monitoring locations within the lake.

Additional Parameters

NRSI characterizes Swan Lake as functioning as an "ad hoc" stormwater management facility due to the presence of multiple stormwater outfalls and contends that the omission of common stormwater management pond contaminant from the overall monitoring program limits its comprehensiveness and relevance. Several stormwater-related parameters are therefore recommended for inclusion in the core monitoring program.

Review Comments:

- While Swan Lake receives stormwater inflows, these inputs are routed through upstream stormwater management ponds and oil–grit separators (OGS) prior to discharge to the lake. As such, Swan Lake functions as a receiving waterbody rather than a stormwater management facility and plays an important role in peak flow management, but not in quality control.
- Stormwater-related inflows are appropriately considered in the context of overall lake management, but do not redefine the primary function or management objectives of the lake.
- Stormwater-related parameters (e.g., hydrocarbons, metals, oil and grease) are more effectively managed and monitored at the level of stormwater management facilities, where regulatory controls, maintenance actions, and corrective measures can be implemented, rather than through routine lake monitoring. That said, selective additional parameters may provide useful supplementary context for interpreting lake condition where they align with management objectives:
  - Inclusion of Total Suspended Solids (TSS) could be informative to support interpretation of water clarity trends and to help distinguish between phytoplankton and suspended sediments, particularly during higher-flow periods and wind mixing events.
  - Total metals monitoring could be considered as a targeted or periodic monitoring event, both to update baseline information (last assessed approximately in 2016) and to provide broader limnological context related to sediment–water interactions and potential stormwater influences. Results from such targeted monitoring could be used to determine whether ongoing metals monitoring is warranted.
  - Routine monitoring for Biochemical Oxygen Demand (BOD) is not recommended. Dissolved oxygen is already directly monitored in the lake, and recent monitoring indicates improved oxygen conditions relative to pre-management conditions. In the absence of a management objective related to organic loading or implementation of oxygenation/aeration measures—which are not proposed or feasible for Swan Lake—BOD measurements would not provide additional actionable information.
  - Monitoring for oil and grease and polycyclic aromatic hydrocarbons (PAHs) is not recommended for inclusion in the core long-term monitoring program at this time. While parking areas are present in the catchment, stormwater from these areas is treated through OGS and stormwater management ponds prior to entering the lake, and no specific source or management question has been identified that would be informed by routine PAH monitoring.
  - *E. coli* monitoring is not recommended for routine inclusion in the core lake monitoring program. Swan Lake is not intended to support contact recreation, and the management goal is to improve overall lake health to support non-contact recreational enjoyment. *E. coli* is primarily a human health indicator related to contact recreation and does not provide a meaningful indicator of aquatic ecosystem health or eutrophication status in this context. Monitoring for *E. coli* would therefore have limited relevance to the objectives of the SLMP.

Recommendation: That the core water quality monitoring program remain focused on parameters directly linked to identified management objectives for Swan Lake, with consideration given to targeted or periodic monitoring (e.g., TSS and total metals) to provide additional context. Stormwater-related parameters should continue to be addressed primarily through

stormwater management facility monitoring and maintenance programs, and additional parameters should be incorporated into lake monitoring only where a clear management question or decision would be informed by the data.

2.1.2 Water Quality Sample Collection - NRSI recommends additional spring freshet, storm-event, and winter dissolved oxygen monitoring, to provide higher-resolution characterization of water quality conditions and stormwater influences in Swan Lake.

Review Comments:

- Biweekly sampling during the open-water season is already intensive for a long-term lake management program and adequately captures seasonal variability, including spring freshet conditions through April monitoring. Storm-related conditions are also captured intermittently through the regular two-week sampling interval. In addition, the City monitors key inflows to the lake for chloride, and mass-balance modeling confirms that major phosphorus sources to the lake are well characterized under the existing program.
- While low dissolved oxygen concentrations under ice are plausible in shallow, productive systems such as Swan Lake, routine winter monitoring presents safety considerations for field staff and would provide limited management value given the lack of feasible or effective management options to address winter anoxia.
- Expanded storm-event or winter monitoring is therefore not supported at this time, as no unresolved management questions or contaminants of concern have been identified that would warrant such sampling. Moreover, Swan Lake is a shallow system where short-term storm-driven or under-ice conditions are unlikely to result in persistent or manageable impacts without being reflected in routine seasonal monitoring data.

Recommendation: That the City maintain the existing core sampling frequency, and consider targeted, limited-duration event-based or winter monitoring only if a specific hypothesis, contaminant of concern, or management decision is identified during the 5-year review of the management plan that would be informed by such data.

2.1.3 Water Quality Sampling Locations - NRSI recommends that additional monitoring sites are required because the lake is relatively stagnant increasing spatial variability and therefore potentially leading to a misinterpretation of the overall conditions of the lake by omitting areas of comparatively high or low water quality conditions.

Response:

- NRSI's characterization of Swan Lake as a "relatively stagnant lake with minimal mixing" is not supported by lake morphometry, hydrology, or observed monitoring data. Swan Lake is a shallow system (mean depth ~1.5 m) that is generally well mixed by wind, with only a small area exceeding ~2 m depth that exhibits limited and seasonal thermal stratification during peak summer conditions. Stratification is expected given the ratio of the mean depth to the surface area of the lake (i.e., a large morphometric ratio). While reduced surface mixing occurs during calm, dry periods, this does not indicate that the lake is stagnant.
- The lake has an average water residence time of approximately 1.7 years (2020-2024), which is inconsistent with a stagnant system and indicates regular water exchange and mixing at the whole-lake scale.
- The selection of the monitoring sites for the City's program was based on previous monitoring at several locations in the lake, which demonstrated that the City's dock site was representative of the nutrient and trophic state of Swan Lake. This conclusion is supported by recent monitoring data; dissolved oxygen and temperature profiles at the dock site and at the deepest area of the lake (Trent University monitoring site) are comparable, and chloride concentrations measured at the bridge, dock, and deepest location are also comparable.
- The dock site is also located near the shoreline and in proximity to two of the stormwater outfalls, and likely to capture stormwater-related impacts.
- While localized effects of stormwater outflows may occur in the immediate vicinity of discharge points, the existing monitoring locations are appropriate to characterize overall lake conditions for a lake of this size, shape, and hydrodynamic regime and are sufficient to support the objectives of the SLMP.
- Expansion of monitoring locations is not supported at this time in the absence of identified spatially distinct water quality concerns or management questions that would be addressed through increased spatial resolution.

Recommendation: That the City maintain the existing monitoring locations for long-term condition and trend monitoring, and consider targeted, short-term monitoring near outfalls only if a specific issue, hypothesis, or management decision is identified that would benefit from additional spatial resolution.

Section 2.1.4 Water Quality Guidelines and Targets – NRSI discusses provincial policies for water quality and recommends water quality guidelines for several parameters for inclusion in the analysis of the Swan Lake monitoring program results moving forward.

Review Comments:

- NRSI's discussion of Provincial Water Quality Objectives (PWQOs) does not adequately distinguish between their regulatory application (e.g., in the context of approvals for point-source discharges and compliance assessment), and their discretionary use as comparative benchmarks in ambient lake monitoring programs.
- The Swan Lake monitoring program is designed to support lake management decision-making, not regulatory compliance, and therefore appropriately emphasizes site-specific interim targets, aligned with eutrophication and chloride management objectives. While PWQOs may be used as contextual reference values, they are not mandatory compliance standards for in-lake water quality conditions in a municipally managed lake that is not subject to regulated effluent discharge or other approvals.
- The discussion of PWQO deviation policies and exemption processes is not directly applicable to the Swan Lake monitoring program, as no regulatory requirement exists to formally "attain" PWQOs or seek approval for deviations in this context. The referenced *Guidelines for Handling Requests for Deviations* are provided in the province's guidance document for point source effluents, *Deriving Receiving-Water Based, Point-Source Effluent Requirements for Ontario Waters* (MOEE 1994), which underscores that these provisions are intended for regulatory approvals, not for lake management plans.
- Where PWQOs, Canadian Environmental Quality Guidelines (CEQG), or Health Canada guidelines are directly relevant to priority concerns (e.g., dissolved oxygen, chloride, cyanobacteria density, total microcystins, chlorophyll-a), they are already included in the annual reports to provide appropriate context for interpreting observed conditions.
- PWQOs/CEQGs are not included in the annual reporting for nitrate and total ammonia (or unionized ammonia) and could be added for context.
- NRSI recommends use of a Secchi depth guideline of >1.2 m based on the *Guidelines for Canadian Recreational Water Quality* (Health Canada 2024). This value is not consistent with the cited Health Canada recommendations, either in the Summary Document (Health Canada, 2024), or the associated technical document, *Guidelines for Canadian Recreational Water Quality: Physical, Aesthetic and Chemical Characteristics* (Health Canada 2022). Health Canada recommends a guideline for water clarity as "Not significantly decreased compared to background values" with the rationale that "Individuals engaged in primary contact activities need to be able to estimate depth and see subsurface hazards. Secchi depth measurements are useful for determining clarity." The guidance document notes that Secchi depth measurements can also be used as part of a monitoring strategy for cyanobacteria blooms, consistent with its current application for Swan Lake.
- NRSI contends that "the stated water quality guidelines currently omit the total phosphorus ranges for other eutrophic conditions (from oligotrophic to hyper-eutrophic) somewhat limiting the comprehensiveness of the overall monitoring program." While the lower trophic state classes (oligotrophic and ultraoligotrophic) are not included in the annual reports, this presentation does not limit the comprehensiveness of the monitoring program and appropriately focuses interpretation on conditions that are relevant to current lake status, management progress and objectives. Inclusion of the lower trophic states could provide additional contextual information; however, these should not be presented as management targets. Trophic state classifications describe the biological productivity of an aquatic system with natural, undisturbed lakes existing across the full trophic spectrum. Lower trophic state should not be interpreted as inherently "better" water quality without explicit consideration of lake-specific ecological objectives and constraints. Given the urban setting and shallow, warm-water conditions of Swan Lake, oligotrophy is neither a realistic nor necessarily desirable condition support a health aquatic community.
- NRSI notes that the total phosphorus thresholds used to describe the trophic state of Swan Lake are generally consistent with CCME trigger ranges and recommends inclusion of additional CCME trophic ranges for context. The CCME trigger ranges provide finer-scale divisions along the trophic state spectrum; however, inclusion of these ranges would not materially change interpretation of the monitoring results. Moreover, the CCME trophic state divisions do not include values for other indicator parameters like the framework used in the SLWQMP.

- NRSI's statement that the chloride target was established to coincide with the short-term exposure guideline is not accurate. The chloride target was developed based on historical lake data and with consideration of what was practicably achievable through management actions at that time, while aiming for concentrations below the short-term exposure guideline to address the risk of acute toxicity.
- Recent monitoring indicates chloride concentrations are now well below the established target, and adjustment of the target could be considered in plan updates to reflect this change in condition. CCME short- and long-term chloride guidelines are already included in annual monitoring reports to provide appropriate context for interpreting observed conditions.

Recommendation: That the relevant PWQO, CEQG and Health Canada guidelines continue to be used as supplementary, contextual reference values where they meaningfully inform interpretation of monitoring results, while the core monitoring framework prioritize site-specific targets directly aligned with the SLMP and its defined management objectives. No changes to the guidelines are recommended as this would not materially change the interpretation of the results and to maintain consistency with past reporting.

Recommendation: That the trophic state classification used in the SLMP continue to be used for consistency in interpretation and reporting.

Recommendation: That the chloride target be revisited and revised as appropriate based on the results of recent monitoring and the City's Swan Lake Water Quality Management - Water and Chloride Budget (November, 2025), while considering management objectives and feasible chloride reduction strategies.

Section 3.0 Water Quality Monitoring Results – NRSI provides a review of water quality monitoring results from the Swan Lake Annual Monitoring Reports and provides recommendations for future reporting.

Global Statements - NRSI states that there were multiple 'omissions' of monitoring events, multiple gaps in full sampling coverage, and omissions in reporting of data that could lead to misinterpretation of the results.

Review Comments:

- NRSI provide no specific reference to dates of missing monitoring events or data to support their assertion of "multiple omissions" or how these could have led to "misinterpretation of the results".
- In practice, the number of sampling events met or exceeded the planned biweekly monitoring frequency (monthly for phytoplankton) at the designated sites, with only rare instances where there were more than two weeks between sampling events. Such occurrences are not unusual or indicative of 'omissions' given the potential for inclement weather or other issue affecting scheduling over a multi-year program. With the exception of missing phytoplankton data in the early part of the 2022 monitoring season due to lab closure during COVID, there is no evidence of omissions in reporting of data. Field data and laboratory certificates of analysis are also provided in appendices of the annual reports for transparency. Given the biweekly sampling schedule and long-term data set, any minor gaps in data collection would not materially affect interpretation of lake conditions or trends.

Recommendation: That missing data of concern, if requested, be provided to NRSI if it was unintentionally missed in the annual reports and would support NRSI's review and recommendations.

Recommendation: As recommended by NRSI, that explanations for any missing data or sampling events be included in the annual reports.

NRSI concludes that the results reported for Swan Lake appear to be generally or approximately consistent with those seen in shallow eutrophic surface water bodies for water clarity, total phosphorus, total nitrogen, and dissolved oxygen, which agrees with the conclusions of the annual monitoring reports. Certain aspects of NRSI's interpretation, particularly with respect to dissolved oxygen and cyanobacteria, would benefit from clarification to ensure results are evaluated in a manner consistent with lake-specific characteristics and the intent of applicable guidelines. These clarifications are provided below.

Dissolved Oxygen - NRSI states that the "the overall validity of the assertation that the conditions within Swan Lake are in excess of the recommended guidelines is somewhat in question based on the results of the 2024 Trent University continuous dissolved oxygen monitoring, which reported anoxic conditions within Swan Lake" and that "this suggests that the sampling coverage within Swan Lake may not adequately characterize the overall water quality conditions."

Review Comments:

- These statements are not supported by the data, and do not consider depth, duration, or spatial extent of low dissolved oxygen observations observed in the 2024 Trent University data. Such distinctions are critical for appropriate interpretation of dissolved oxygen data in shallow lakes. As described above in response to NRSI's recommendation to expand the monitoring locations, the existing monitoring sites capture lake conditions sufficient to evaluate water quality in Swan Lake to support management decisions.
- NRSI's reliance on the 2024 continuous dissolved oxygen monitoring data to question the validity of the broader dataset reflects a misunderstanding of the purpose and interpretation of the continuous monitoring and does not consider the depth of the logger near the lake bottom at 2.75 m below surface where anoxia was recorded. Continuous loggers are designed to capture short-duration and diel changes in dissolved oxygen. Detection of episodic bottom-water anoxia by continuous monitoring does not contradict discrete profile data that characterize general lake conditions within biologically active portions of the water column at the time of monitoring. It is also noted that the City's continuous logging at the dock site recorded similar near-bottom anoxic periods, which were transparently reported in the annual reports.
- Discrete profile monitoring conducted at the dock site from 2022-2024 following the 2021 PAC treatment, did not detect anoxia, and dissolved oxygen concentrations below 4 mg/L occurred on only three of 46 events and these only occurred within approximately 1 m of the sediment–water interface. The profile at the dock site in 2024 was also consistent with Trent University's profile at the deeper monitoring site. These observations are consistent with localized near-bottom oxygen depletion driven by sediment oxygen demand and respiration, and do not indicate lake-wide impairment of the mixed water column.
- Hypsometric analysis demonstrates that depths below approximately 2.5–2.75 m, where anoxia has been observed, represent only a small fraction of Swan Lake, on the order of approximately 3–5% of total lake area and 1–3% of total lake volume, based on water level at the time of monitoring. This illustrates that observed anoxia is spatially limited, volumetrically minor, and confined to a small deep-water zone, rather than indicative of widespread or persistent lake-wide conditions.
- PWQO and CCME dissolved oxygen guidelines are intended to protect aquatic life within biologically relevant habitat and are not meant to be applied uniformly throughout the entire water column at all times throughout the year. Localized or depth-limited anoxia near sediments does not constitute non-attainment of the guideline, or 'impairment'. When interpreted consistent with their intent, considering depth, habitat use, and the spatial and temporal extent of low-oxygen conditions, the observed dissolved oxygen conditions in Swan Lake meet both PWQO and CCME guidance.
- Comparison to pre-management conditions provides additional context. Prior to implementation of SLMP, anoxia was persistent and widespread with hypoxia regularly extended upward into the mixed layer during summer months. In contrast, post-2021 monitoring shows that low dissolved oxygen or anoxia is confined to near-bottom waters, occurs episodically primarily during calm and warm periods, and affects only a small portion of lake area and volume. This represents a substantial improvement in dissolved oxygen conditions and demonstrates an appropriate system response to management actions that have been implemented under the plan.
- Taking all evidence into account and with an understanding of the intent and application of relevant guidelines, it is my professional opinion that from 2022-2024:
    1. Dissolved oxygen concentrations during the open water season in Swan Lake meet PWQO for warm water fish and the CEQG for the protection of aquatic life.
    2. Anoxic conditions occur, but these are limited spatially and volumetrically and are mostly episodic during the open water season and would not pose significant widespread adverse ecological conditions for aquatic life.

Cyanobacteria and Cyanotoxins - NRSI comments on the use and interpretation of cyanobacteria-related indicators and associated Health Canada guidance in the annual monitoring reports.

Review Comments:

- The analysis of Cyanobacteria is based on cell counts and taxonomic composition, which are appropriate indicators for tracking abundance, community structure, and relative changes over time. Samples were analyzed for cyanobacteria cell density only to the level of genus.

- Health Canada guideline values for cyanobacteria biovolume and chlorophyll-a are included in the annual reports for contextual reference. These parameters are not included in the routine monitoring parameter list; no data were omitted.
- Cyanotoxins are not routinely monitored in Swan Lake. This is intentional and appropriate given the no-contact recreational use designation of the lake and the high spatial and temporal variability of toxin production, which is influenced by complex and often unpredictable environmental conditions. In this context, reliance on Health Canada guidance for cyanobacteria abundance and related indicators provides a defensible, precautionary approach to risk evaluation for cyanotoxins.
- The annual monitoring reports summarize relative abundance of cyanobacterial taxa and total cyanobacteria cell densities for each monitoring event and year. Observations regarding changes in density or community composition are presented descriptively to document conditions and trends; no claims are made attributing observed changes directly to management actions or to changes in water quality.
- Statements in the 2024 monitoring report regarding reduced cyanobacteria counts are factual summaries. The report appropriately notes that phytoplankton dominance persists despite nutrient reductions and discusses plausible ecological factors, such as warmer weather and limited submerged aquatic vegetation (SAV), that may influence lake response.

Chlorophyll a is not included as a parameter in the monitoring program. Chlorophyll-a data were provided by Trent University.

Sections 3.1 and 3.1 Adequacy of Water Quality Monitoring Program and Water Quality Monitoring Program Limitations

Review Comments:

NRSI concludes that the existing monitoring program is sufficient to characterize eutrophication risk in Swan Lake, but describes it as limited in scope and providing only a high-level assessment. While the program is intentionally focused on eutrophication and chloride, the primary water quality issues identified for Swan Lake, it is not limited in scope. It is an intensive, multi-parameter monitoring program designed to evaluate lake conditions and responses to management actions relevant to the SLMP.

Assertions that omitted monitoring events, reporting gaps, or limited spatial coverage could mischaracterize conditions or falsely suggest improvement are not supported. Monitoring frequency met or exceeded the planned biweekly schedule, no collected data were intentionally omitted from reporting, and existing sampling locations have been demonstrated to be representative of whole-lake conditions relevant to management objectives.

While additional aquatic habitat or water quality parameters could be considered in targeted studies, these have not limited the program's ability to evaluate lake condition or management effectiveness.

Section 4.0 Water Quality Monitoring Program Enhancements

Review Comments:

The monitoring program enhancements recommended by NRSI largely reiterate issues addressed elsewhere in this review and do not identify unresolved management questions that would warrant expansion of the core water quality monitoring program at this time. The existing program remains appropriate for its intended purpose and provides a scientifically-sound basis for assessing lake condition and management progress.

With respect to aquatic health, a submerged aquatic vegetation survey was completed in 2025 ahead of the planned Phase 2 schedule in response to observed phytoplankton conditions. The City has been coordinating with the MNRF to stock fish in the lake, and TRCA has been monitoring fish community with results reported in the annual reports. Fish stocking was completed in May 2025 by a private contractor to the City, adding 500 juvenile largemouth bass to the lake. No other aquatic health monitoring is recommended at this time, but could be considered in the future should a need be identified.

Section 4.1 Swan Lake Management Strategy Program Considerations – NRSI recommends several additional lake management and habitat restoration activities to further support the improvement of water quality and aquatic habitat in Swan Lake.

Comprehensive Oxygenation Program - NRSI recommends implementation of a comprehensive oxygenation program to address low dissolved oxygen conditions in Swan Lake.

Review Comments:

- The discussion of oxygenation implicitly assumes that hypoxia or anoxia represents a dominant, lake-wide management issue in Swan Lake. This assumption is not supported by the Phase 1 monitoring results, which demonstrate that observed anoxia is spatially limited, episodic, and confined to a small deep-water area, rather than indicative of a system-wide condition requiring intervention.
- Improvements in dissolved oxygen conditions observed since implementation of nutrient management actions indicate that oxygen dynamics are responding as expected to reductions in nutrient concentrations, which address the underlying cause of eutrophication-driven oxygen demand.
- While NRSI states that management actions should address underlying causes rather than symptoms, the proposed oxygenation measures, assuming these are appropriate for use in Swan Lake, would primarily function as symptom-focused interventions and are not expected to result in meaningful long-term improvements, as acknowledged in the NRSI discussion itself.

Recommendation: That, in the absence of evidence of persistent, lake-wide oxygen impairment or a clearly defined management objective that would be advanced by oxygenation, implementation of a comprehensive oxygenation program is not warranted at this time.

Sediment and Nutrient Management

Review Comments:

Several statements in this section do not accurately reflect the scientific basis, intent, or scope of the City's sediment and nutrient management program as documented in the SLMP.

The PAC/Phoslock treatment program was developed based on a comprehensive scientific assessment conducted by Freshwater Resources Inc., led by Dr. Gertrud Nürnberg, a recognized expert in lake management, eutrophication, anoxia, and internal phosphorus loading. This work included detailed limnological analysis, lake response modeling, and sediment quality evaluation, including Psenner-type sediment fractionation analysis performed at the Institut Dr. Nowak GmbH & Co. KG (Germany). Chemical dosages required to inactivate potentially mobile sediment phosphorus were scientifically determined for distinct lake zones with differing sediment characteristics and were further evaluated and refined by AECOM prior to the treatments in 2021 and 2024.

The scheduling of chemical treatments is not based on visual indicators such as algal mat formation. Treatment frequency (once every three years) was determined through evaluation of the effectiveness of the 2013 Phoslock application, sediment chemistry, observed lake phosphorus concentrations, and modeled estimates of phosphorus accumulation and release rates specific to Swan Lake. As documented in the SLMP, scenario modeling, including consideration of potential climate change impacts, demonstrated that this interval optimizes internal phosphorus load reduction and lake response. This schedule reflects a planned, proactive management strategy rather than a reactive symptoms-based approach.

NRSI's recommendations for a detailed sediment and nutrient management program largely reiterate elements already incorporated into the SLMP. The only additional element identified is the assessment of sediment conditions within upstream stormwater management facilities. Such assessments are not required to understand internal sediment and nutrient dynamics within Swan Lake and are more appropriately addressed through stormwater asset management and maintenance programs. Consideration of additional stormwater-related monitoring could be evaluated as part of a future update to the SLMP or through a focused, question-driven study, if warranted to address a specific management concern.

Finally, while chemical treatments do not directly address external nutrient sources, this distinction is well recognized in the SLMP. The purpose of PAC/Phoslock treatment is to control internal phosphorus loading, which is the dominant driver of lake eutrophication in Swan Lake. External nutrient load reduction is addressed separately and comprehensively in the Plan, with particularly effective reductions achieved through goose management and watershed controls. Internal and external load

management are complementary, not mutually exclusive, and both are necessary to achieve and sustain water quality objectives.

Recommendation: That targeted sediment characterization be considered in Phase 2 to support future PAC/Phoslock treatment planning, recognizing that the most recent comprehensive sediment assessment was completed in 2021 and that lake nutrient concentrations and biological conditions have changed substantially since that time.

Recommendation: That sediment sampling and analytical methods generally follow the established, science-based approach used in 2021, with review and refinement as appropriate based on advances in understanding and management needs.

Recommendation: That inclusion of additional sediment parameters be considered only if results from ongoing water quality monitoring indicate trends or conditions (e.g., changes in internal phosphorus release, dissolved oxygen dynamics, or biological response) where sediment characterization would meaningfully inform management decisions.

Chloride Management - NRSI notes that chloride concentrations in Swan Lake remain above the CCME long-term exposure guideline and supports and recommends the additional chloride reduction measures proposed by FOSLP as “critical to achieving any long-term improvements in surface water and aquatic ecosystems quality”.

Review Comments:

Chloride management is already a recognized priority in the SLMP and is being actively addressed by the City. In recent years, chloride concentrations in Swan Lake have declined substantially. This improvement is largely attributable to the removal of blockages at the East Pond inlet and the Swan Club oil–grit separator, which reduced untreated stormwater delivering higher chloride loads to the lake. The City continues to monitor chloride concentrations at stormwater outfalls and to refine estimates of chloride loading from these sources to improve understanding of source contributions and inform management activities. The City is currently supporting research at York University to evaluate the feasibility and effectiveness of biochar for chloride reduction. At present, this work remains at a research stage and is not yet supported for implementation.

Diversion of stormwater away from Swan Lake could reduce chloride loading from this source; however, such an intervention is not currently warranted based on observed chloride concentrations or evidence of ecological impairment. In addition, potential benefits of diverting water would require careful evaluation of potential negative impacts on lake hydrology, beneficial uses, and the observed recovery trajectory before being considered for implementation. This approach is consistent with the SLMP, which previously evaluated stormwater redirection options and identified such structural modifications as a longer-term, conditional consideration (Phase 3), subject to comprehensive technical studies, downstream infrastructure constraints, and demonstrated need. As documented in the Plan, earlier evaluations concluded that complex and costly drainage system modifications would be a low priority unless other habitat restoration efforts were shown to be unsuccessful due to chloride-related impacts.

While chloride concentrations continue to exceed the CCME long-term exposure guideline of 120 mg/L, exceedance of this guideline alone does not necessarily indicate significant impairment of aquatic habitat. This interpretation is consistent with the CCME guidance, where the guideline is derived to protect the most sensitive life stage of the most sensitive aquatic species over the long term. While concentrations below the guideline are not expected to result in adverse effects, exceedance of a CWQG does not, in itself, imply that aquatic biota are adversely affected or that a waterbody is impaired. The concentration at which effects may occur can vary depending on site-specific conditions, exposure history, and ecological context, and professional judgement is required when interpreting exceedances. Consistent with CCME guidance, chloride guidelines are intended to be applied to ambient surface water conditions rather than concentrations immediately adjacent to point sources such as stormwater outfalls, so the lake chloride monitoring approach for Swan Lake is appropriate for evaluation of chloride in the lake for aquatic health.

Recommendation: That the current chloride management approach outlined in the SLMP be continued under Phase 2, including ongoing lake and stormwater outfall monitoring and refinement of chloride loading estimates and evaluation of lake responses. Based on recent improvements and current conditions, diversion of stormwater from Swan Lake is not recommended at this time.

Recommendation: That any future consideration of stormwater diversion or other large-scale chloride reduction measures should be supported by lake-response modeling that demonstrates a clear and meaningful benefit to lake water quality, and

that explicitly evaluates potential hydrological impacts on water quality, beneficial uses, and the observed recovery trajectory of the lake.

Shoreline Habitat Enhancement - NRSI recommends shoreline restoration and planting to support aquatic ecosystem structure, stabilize nearshore conditions, and contribute to nutrient and sediment load reduction.

Review Comments:

- Shoreline enhancement is already identified as an optional management strategy in the SLMP, recognizing the multiple benefits of riparian vegetation, including habitat enhancement, shoreline stabilization, reduction of localized nutrient inputs, and deterrence of resident Canada geese.
- These measures are complementary to in-lake management actions and support broader ecosystem recovery but are not intended as a primary mechanism for addressing legacy nutrient conditions within lake sediments.
- Past removal of invasive or excessive nearshore vegetation (e.g., phragmites) has been undertaken where warranted, and any future vegetation management should be carefully targeted to balance habitat benefits, nutrient cycling considerations, and overall lake recovery objectives.

Recommendation: That shoreline planting and habitat enhancement be considered for inclusion in Phase 2, in coordination with TRCA, as a complementary measure to support aquatic habitat, shoreline stability, and ongoing ecosystem recovery, while remaining aligned with the broader nutrient management strategy outlined in the SLMP.

Responses to Section 5.0 – Conclusions

Review Comments:

NRSI's conclusions acknowledge that the Swan Lake monitoring program has documented measurable improvements in water quality and that the interim targets established by the City are attainable and reasonable. This is consistent with the findings of the annual monitoring reports and the intent of the SLMP.

However, the repeated characterization of the monitoring program as "high-level" or "limited" does not accurately reflect its design or purpose. The Swan Lake monitoring program is a focused, multi-parameter, long-term program developed to address clearly defined management questions related to eutrophication, internal nutrient loading, chloride, and lake response to implemented controls. It is not intended to serve as a comprehensive ecological inventory or regulatory compliance program, nor is such scope required to support the lake management goals.

Assertions that guideline exceedances or selective guideline application limit interpretation or obscure ecosystem health are not supported when guidelines are interpreted consistent with provincial and federal guidance. Exceedance of a guideline does not, in itself, indicate impairment, and results must be interpreted in the context of lake morphometry, exposure history, management objectives, and observed biological response. The primary causes of degraded conditions in Swan Lake, including internal phosphorus loading and key external nutrient sources, were identified through detailed limnological studies completed prior to implementation of the SLMP and are not unresolved.

Expansion of the monitoring program solely to increase "comprehensiveness" is not warranted in the absence of clearly defined management questions or evidence that existing data are insufficient to guide decisions. As demonstrated through this review, the current monitoring framework is adequate to assess lake condition, track response to management actions, and support adaptive management.

3. Summary of Recommendations

Based on this review, targeted refinements to monitoring and management are recommended for consideration by the City of Markham, where they provide clear decision value and align with the phased approach of the SLMP. These recommendations are summarized below.

Theme	Recommendation
Monitoring Program Focus	Maintain the existing core water quality monitoring program focused on eutrophication and chloride, the primary management issues identified for Swan Lake.
Supplementary Parameters	Consider targeted or periodic monitoring of Total Suspended Solids (TSS), total metals and *E. coli* to provide additional interpretive context, with results used to determine whether ongoing monitoring is warranted.
Excluded Parameters	Do not add routine monitoring for BOD, oil and grease, or PAHs, as these parameters do not align with current management objectives or provide actionable information for Swan Lake.
Sampling Frequency	Maintain the existing biweekly open-water sampling frequency (monthly for phytoplankton), which is appropriate for evaluating seasonal conditions and long-term trends.
Event-Based / Winter Sampling	Consider storm-event or winter monitoring only if a clearly defined hypothesis, contaminant of concern, or management decision is identified during the 5-year plan review.
Monitoring Locations	Maintain existing monitoring locations, which have been demonstrated to be representative of whole-lake conditions relevant to management objectives.
Spatial Expansion	Consider short-term, targeted near-outfall monitoring only if a specific issue or management question is identified that would benefit from increased spatial resolution.
Guidelines and Targets	Continue use of PWQOs, CEQGs, and Health Canada guidelines as contextual reference values rather than compliance standards, while retaining site-specific interim targets aligned with the Long-Term Management Plan.
Trophic State Framework	Continue using the trophic state classification framework defined in the SLMP for consistency in interpretation and reporting.
Chloride Target Review	Revisit and refine the chloride target as appropriate based on recent monitoring results and the Water and Chloride Budget (2025), considering feasible management actions.
Reporting Transparency	Include brief explanations for any missed sampling events or deviations from the annual work plan in future monitoring reports, where applicable.
Oxygenation	Do not implement a comprehensive oxygenation program in the absence of evidence of persistent, lake-wide oxygen impairment or a defined management objective that would be advanced by oxygenation.
Sediment Characterization	Undertake targeted sediment characterization to support future PAC/Phoslock treatment planning, recognizing changes in lake nutrient concentrations and biological conditions since the last comprehensive assessment (2020).
Sediment Methods	Apply the established, science-based sediment sampling and analytical approach used in 2020, with review and refinement as appropriate.
Additional Sediment Parameters	Include additional sediment parameters only if results from ongoing water quality monitoring indicate conditions where sediment data would meaningfully inform management decisions.
Chloride Management	Continue the current chloride management approach outlined in the SLMP, including lake and stormwater outfall monitoring and refinement of chloride loading estimates.
Stormwater Diversion	Do not pursue stormwater diversion at this time. Consider only if future lake-response modeling demonstrates a clear benefit and evaluates hydrological impacts, beneficial uses, and the lake's recovery trajectory.
Shoreline Enhancement	Consider shoreline planting and habitat enhancement as a complementary measure to support habitat quality, shoreline stability, and deterrence of resident Canada geese.

Swan Lake Long-Term Management Plan Update
Public Consultation and Engagement

Meeting with Friends of Swan Lake Park (FOSLP)

Environmental Services
Robert Muir, Manager, Stormwater
Zahra Parhizgari, Environmental Engineer, Stormwater

March 25, 2026

Agenda

- Introduction
- Purpose of Meeting
- Summary of Lake Conditions
- Comparisons
- Path Forward

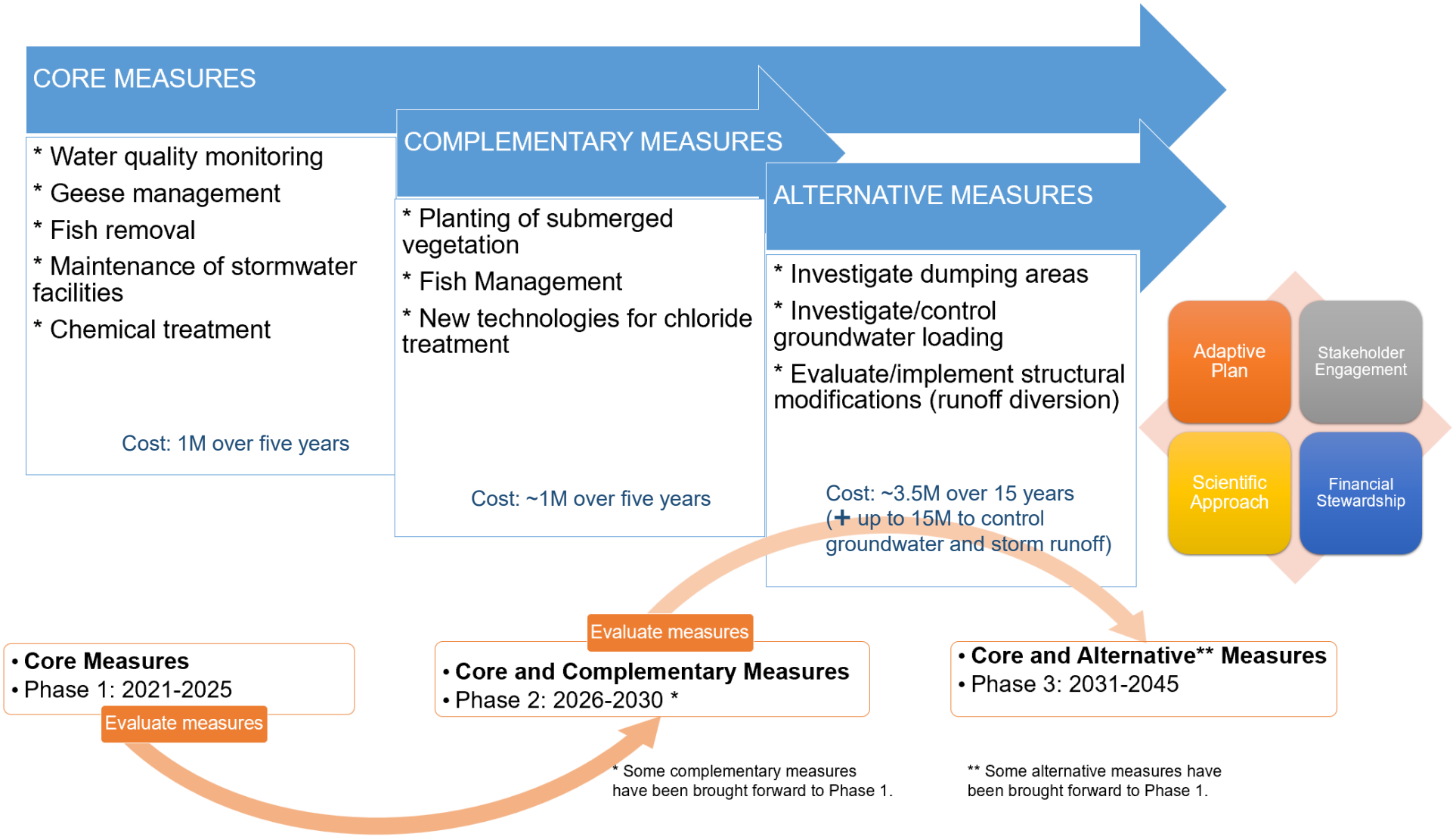
Purpose of Meeting

- Phase 1 of Swan Lake Long-Term Management Plan (SLMP- see next slide) has been completed successfully
- Consultation is a critical step in the adaptive management approach to Swan Lake Water Quality Improvement
- Friends of Swan Lake Park (FOSLP) submitted a report on December 3, 2025
- Staff and consultant reviewed the report and provided feedback
- Meetings were held with FOSLP and its consultants in February 2026, and Staff and City consultant provided feedback on the submissions
- FOSLP submitted an updated report on March 12, 2026

PURPOSE

- To understand how FOSLP's report conclusions were developed
- To reconcile areas where statements differ from empirical data and/or science
- To identify opportunities for updated or refined assessments

Long Term Management Plan (2021)



Plan Review Process

Expert Consultation and Engagement

- Engage with deputants and technical stakeholders involved in the Markham Subcommittee process
- Participate in a workshop or other interactive consultation with external experts and agencies (e.g., TRCA, MNRF)
- Review of stakeholders' input

Study

- Update existing condition
- Review of management outcome
- Evaluate additional management measures
- Review and update goals, objectives and targets
- Update strategy and implementation plan

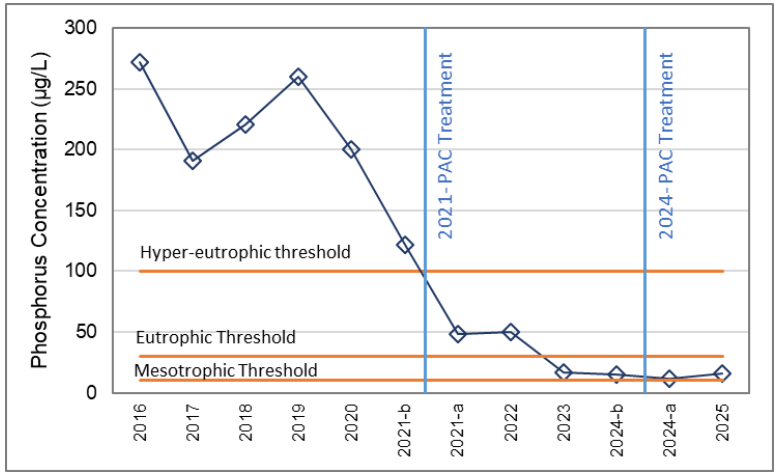
Plan Update

- Share draft report with stakeholders
- Receive feedback
- Present final report to Markham Subcommittee

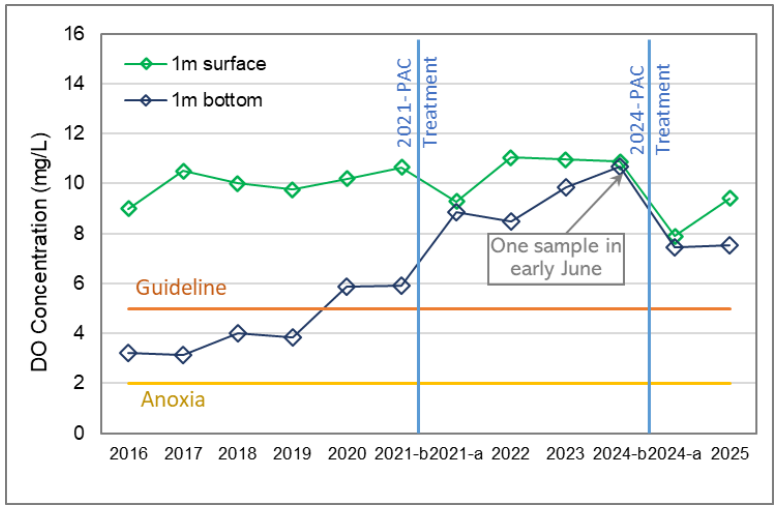
Current Lake Conditions and Trends

Water Quality- Nutrients and Oxygen

- Total Phosphorus:
  - Average under 30 µg/L during growing season (within Mesotrophic condition)
  - Decreased after each treatment
- Total Nitrogen:
  - Average below 0.65 mg/L during growing season (within Mesotrophic condition)
  - Dominant forms not bioavailable
- Dissolved Oxygen:
  - Surface concentration > 5 mg/L all year
  - Bottom concentration showed a decline during dry months
  - Observed anoxia is spatially limited, episodic, and confined to a small deep-water area



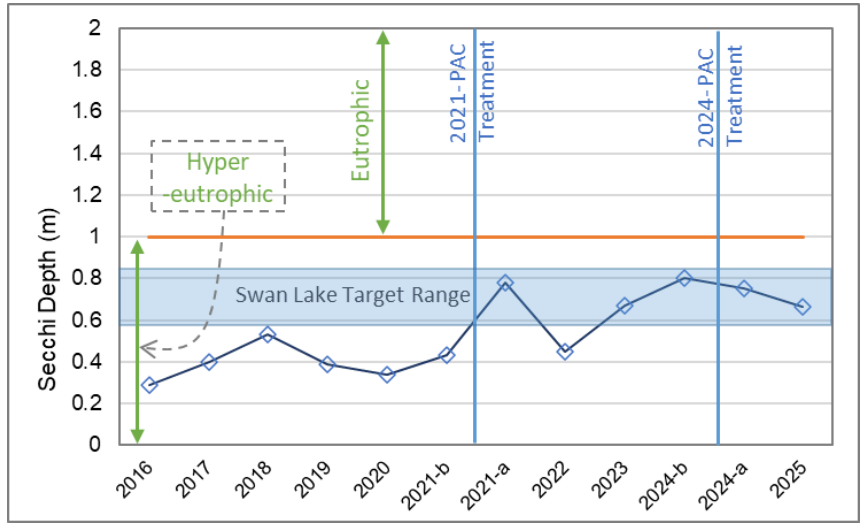
Phosphorus



Dissolved Oxygen

Water Quality- Algae and Clarity

- Algal growth:
  - Surface bloom very limited since treatment
  - Recent Cyanobacteria cell numbers declined significantly since treatment
  - Chlorophyll-a within eutrophic state, and below Health Canada chl-a indicator value used to flag possible cyanotoxin levels that exceed primary-contact recreational guidelines.
- Clarity: Mostly within target, average growing season met target

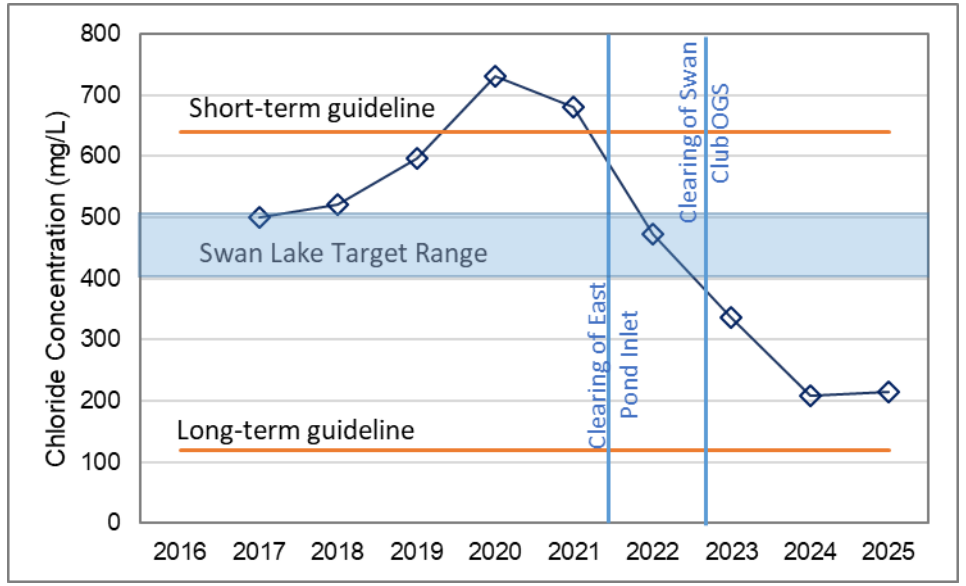


Algal bloom before treatment (photo from July 2020)

Very limited surface bloom since treatment (photo from July 2025)

Water Quality- Chloride

- Chloride enters the Lake through winter maintenance:
  - Swan Lake Village Corporation
  - City roads
  - Residents north of the Lake
  - AMICA Corporation to the south
- Previously on upward trend likely due to blockages, which resulted in untreated flows to the Lake
- Since 2021 decreased due to clearing the blockage at the East Pond inlet and Swan Club OGS
- Long-term guideline derived to protect *the most sensitive life stage of the most sensitive aquatic species* over the long term



Fish Management

- Removing bottom-dwelling fish to prevent sediment disturbance.
- Fish in the Lake included Common Carp, Brown Bullhead, and Fathead Minnow.
- 500 juvenile largemouth bass added in May 2025.

Bass stocked in May 2025

Submerged Aquatic Vegetation

- 3000 stems of wild celery planted in fenced locations on the north site in 2023 and 2024
- Naturally growing aquatic plants were also abundant in 2024 and 2025
- Further SAV planting will be assessed through the five-year review process
- 2025 survey indicated SAV was abundant throughout the lake

Aquatic Vegetation Survey in July 2025

Program Outcomes

- Significant improvements in water quality and habitat have been realized, including aquatic vegetation and fish community
- Water quality now consistently meets expectations for shallow urban water bodies
- Innovative technologies and academic research are actively being evaluated
- Phase 1 of the Long-Term Management Plan has successfully met all established goals and targets.

Comparison

FOSLP Report Scope

- Lake Management Objectives
- FOSLP's Proposed Actions for Phase 2
- FOSLP Advisors' Proposed Actions for Phase 2

Updates in FOSLP Report (March 2026) in Agreement with Staff

- Overall Lake Conditions:
  - Significant improvements in surface water quality attributable to the Phase 1 program
- Oxygen & Need for Oxygenation:
  - FOSLP report discusses a comprehensive oxygenation program, but recognizes that evidence does not support the need for such a program
- Sediment Removal:
  - There is no technical rationale for sediment removal
- Drone Monitoring:
  - Withdrawn

Management Objective

- FOSLP Objectives:
  1) The Definition of "Health" includes all of the aquatic elements in the lake – in particular the lower-level elements in the food chain.
  2) Strive for a Sustainable Solution by implementing programs to further reduce algae and to improve clarity to the mesotrophic level
  3) Return To a Naturalized State by minimizing the impact of stormwater inflows
- City Objectives:
  - Use a science-based, evidence-driven framework
  - Consider Swan Lake's hydrology, morphology, and external influences
  - Prioritize actions with demonstrated benefit
  - Advance improvements through phased, adaptive management
  - Achieve the best practicable outcome while ensuring responsible use of public resources

Staff Position:

- Monitoring of lower-level biota does not address any unresolved management questions
- Maintaining mesotrophic clarity is not sustainable in Swan Lake given its physical setting
- Groundwater interaction is not well defined, and removal of stormwater inflows is premature

Chloride Impact

- FOSLP Claim:
  - Recommends that Phase 2 target for chloride to be below the long-term Federal guidelines.
  - "chloride concentrations may impede current and future ecological restoration efforts"
  - "Reducing chloride inputs into Swan Lake is likely to improve biological / ecological conditions"
- Review:
  - There is no evidence of ecological impairment due to chloride.
  - Exceedance of guidelines does not, in itself, indicate impairment and should be interpreted in the context of lake-specific objectives and conditions.
  - Historical evidence shows Swan Lake was treated for algae as early as 1995 using copper sulphate (Michalski Nielson, 2008), indicating a natural propensity for algal growth even in the absence of stormwater runoff.

Staff Position:

- Establishing Phase 2 chloride targets below long-term Federal guidelines is not supported by evidence of demonstrated need or expected ecological benefit at this time.
- We will continue to monitor chloride and lake trajectory

Chloride Treatment

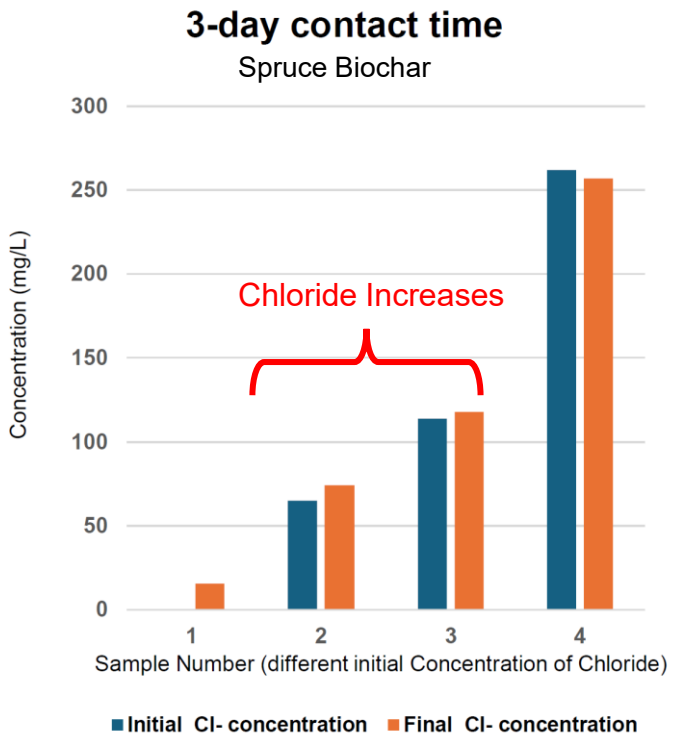
- FOSLP Proposal:
  - Install bioswales at each of the six stormwater inflow sites and harvest the plants every 2-3 years.
  - Install a Biochar filtration unit at the Swan Club OGS
  - Implement a Biochar filtration unit as a component of the recycling process through the North Channel.
- Review:
  - Bioswales are designed for low-flow, distributed runoff and are not suitable for the high-volume, episodic stormwater discharges at Swan Lake inflows. As a result, they would not provide reliable chloride removal and would pose operational and maintenance risks.
  - Research into chloride removal using biochar by York U has not shown any measurable removal even after 3-day contact (i.e., runoff would need to be stored for three days for a possible treatment if a suitable material is found).
  - The Swan Club OGS has a residence time of only 3-4 minutes (9 L/s peak flow rate and 1780 L storage)

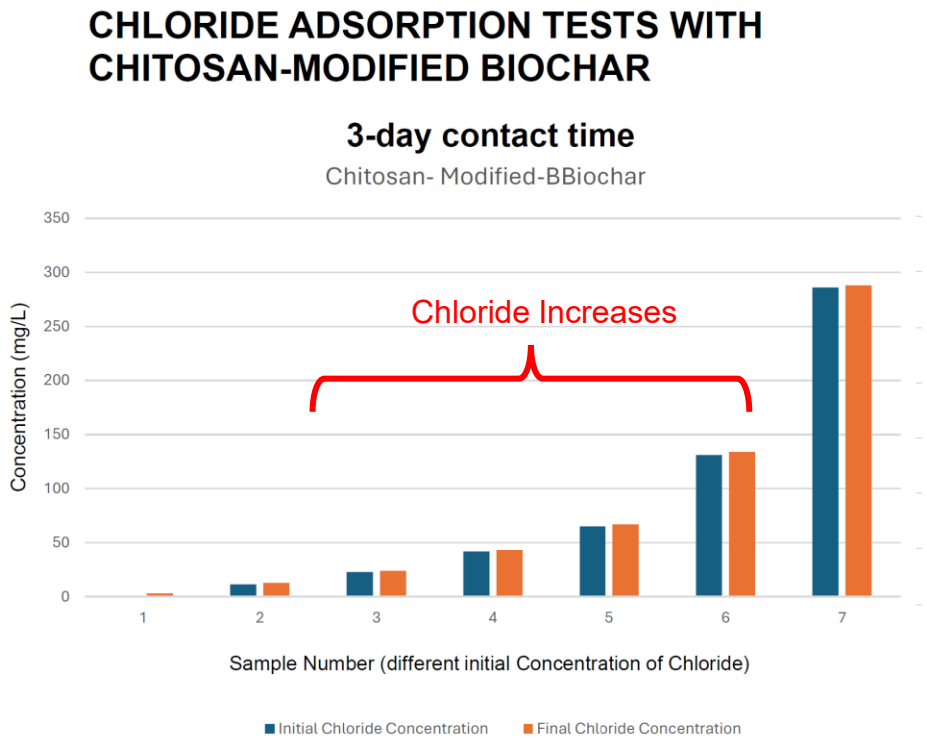
Staff Position:

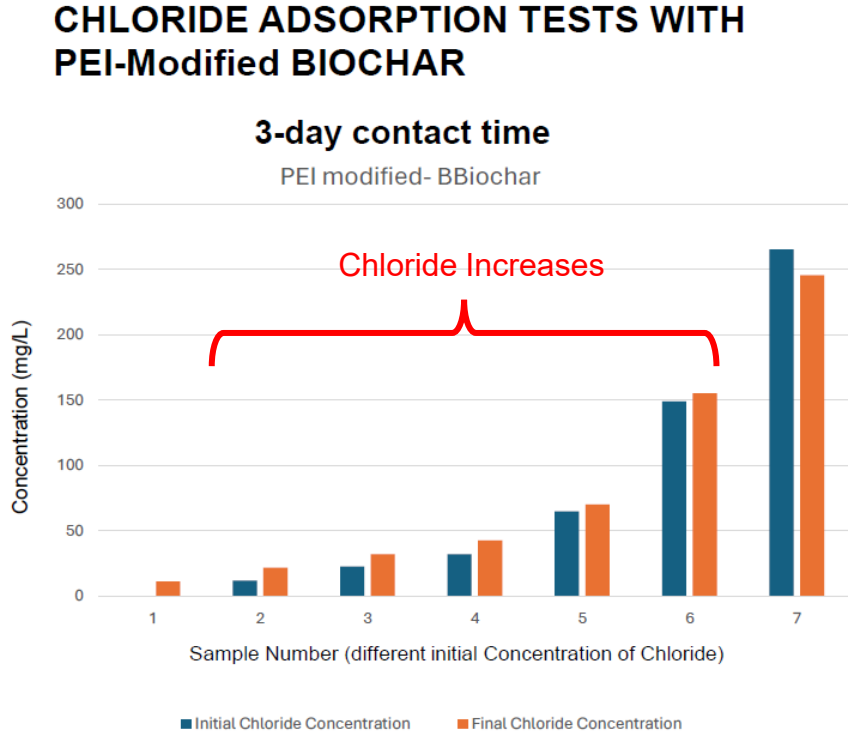
We do not support bioswales or biochar filtration as chloride treatment measures for Swan Lake stormwater inflows, as neither approach has demonstrated effectiveness or suitability under site-specific conditions (see lab results next slide).

Chloride Treatment – Biochar lab research (York U.)

- Spruce Biochar, Bella Biochar, Chitosan-Modified Biochar, PEI-Modified Biochar and Nanoflower media **increases chloride concentrations in low concentration samples**. Limited reduction in higher concentration samples:



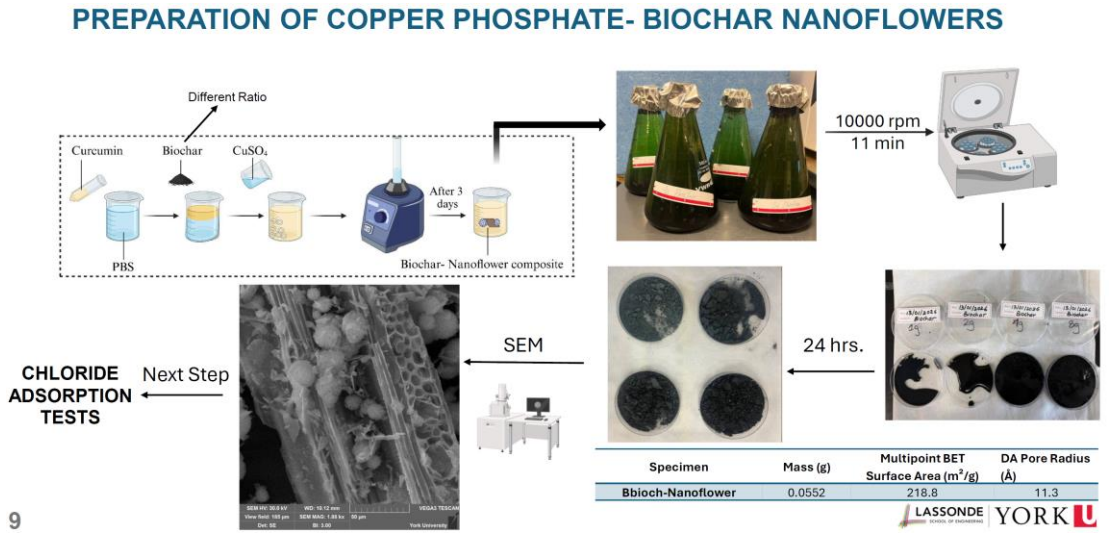




York U. Progress Report (March 13, 2026) Biochar-nanoflower-based Column Filtration System for the Removal of Nutrients (N and P) and chlorides from Swan Lake Water

Chloride Treatment – Biochar lab research (York U.)

- York U. is continuing **lab-scale research** which includes on-going activities related to developing and testing new materials:
  - Testing Biochar-Nanoflower composite media developed
  - Testing Super-Absorbent Polymer (SAP)-Eggshell media developed



Staff Position:
- Research will continue through 2026.
- Staff will report on final research findings in the 2026 annual report to the Markham Subcommittee and comment on feasibility for any type of local field-scale implementation considering effectiveness and cost.

York U. Progress Report (March 13, 2026) Biochar-nanoflower-based Column Filtration System for the Removal of Nutrients (N and P) and chlorides from Swan Lake Water

Regulatory and Industry Perspectives on Chloride Treatment

Ministry of Environment, Conservation and Parks:

MECP advised that "chloride removal, this is not easy to do even for drinking water, so for stormwater, this is not practical". (per A. Ahmed, Manager, Municipal Water and Wastewater)

OGS Manufacturer

Swan Club OGS manufacturer Rinker advised that "We ourselves do not have any specific examples of this. For a Stormceptor, it would not be possible to retrofit with a treatment system. We do not have any technologies that provide chloride removal …" (per B. O'Leary, P.Eng., Stormwater Specialist).

Staff has also requested additional comments from TRCA on treatment options through their Sustainable Technologies Evaluation Program and baseline chloride levels through their research group.

Stormwater Diversion

- FOSLP Recommendations:
  - "Actions should be undertaken to minimize the impact of stormwater inflows and to develop a plan to substantially eliminate stormwater inflows and return the lake to its naturalized state."
  - Reduce chloride inflows by 30% by altering the three splitters that control stormwater flows bypassing the ponds
- Review:
  - Diversion of stormwater away from Swan Lake could reduce chloride loading from this source; however, such intervention is not currently warranted based on:
    - Observed chloride concentrations, and
    - Lack of evidence of ecological impairment attributable to stormwater inflows.
  - Potential benefits of stormwater diversion would require careful evaluation of potential adverse impacts, including:
    - Changes to lake hydrology and water levels
    - Effects on beneficial uses
    - Disruption of the lake's observed recovery trajectory

Staff Position:

- Stormwater diversion is not recommended, as current monitoring shows no ecological impairment related to chloride.
- Flow diversion is a significant structural intervention with potential risks to lake hydrology, water levels, and the lake's recovery trajectory.
- Need to consider diversions can be revisited in Phase 3 as recommended by Markham Subcommittee in 2025 if required based on chloride concentrations.

Groundwater Flushing Hypothesis

- FOSLP Claim:
  - "The decline in chloride levels illustrates the ability of the stormwater outflows and the groundwater system to flush chloride from the lake."
  - "Phase 2 should include further analysis to identify the contaminants in the groundwater."
- Review:
  - The potential for additional chloride reduction through groundwater 'flushing' is not supported by available data.
  - Historical evidence shows Swan Lake was treated for algae as early as 1995 using copper sulphate (Michalski Nielson, 2008), indicating a natural propensity for algal growth even in the absence of stormwater runoff.
  - Available groundwater chemistry data presented at FOSLP / NRSI meeting indicated chlorides in shallow groundwater are above Swan Lake concentrations (see following slides).

Staff Position:

- Groundwater flow and chemistry are not sufficiently defined to support assumptions of further chloride reduction or ecological benefit.
- Evaluating groundwater impacts would require extensive, multi-year studies that would not inform near-term decisions.
- Given the lake's positive recovery trajectory, such studies are not warranted at this time.

Review of Groundwater "Key Hydraulic Feature"

- FOSLP Claim / Recommendation:
  - ".. Swan Lake also meets the technical criteria set out in Markham's Official Plan and the Ontario guidelines for "Key **Hydraulic** Features."
  - "Within Natural Heritage systems, major water bodies are considered **significant** natural source for **recharging** the aquifer."
  - Three factors need to be investigated: flushing by groundwater, chemical elements in groundwater, impact of stormwater rerouting (diversion).
- Review – OP on Key **Hydrologic** (not Hydraulic) Features:

  [3.1.2.9] "Key natural heritage features and key hydrologic features are the principal features of the Natural Heritage Network **that are identified by the Province for protection**."

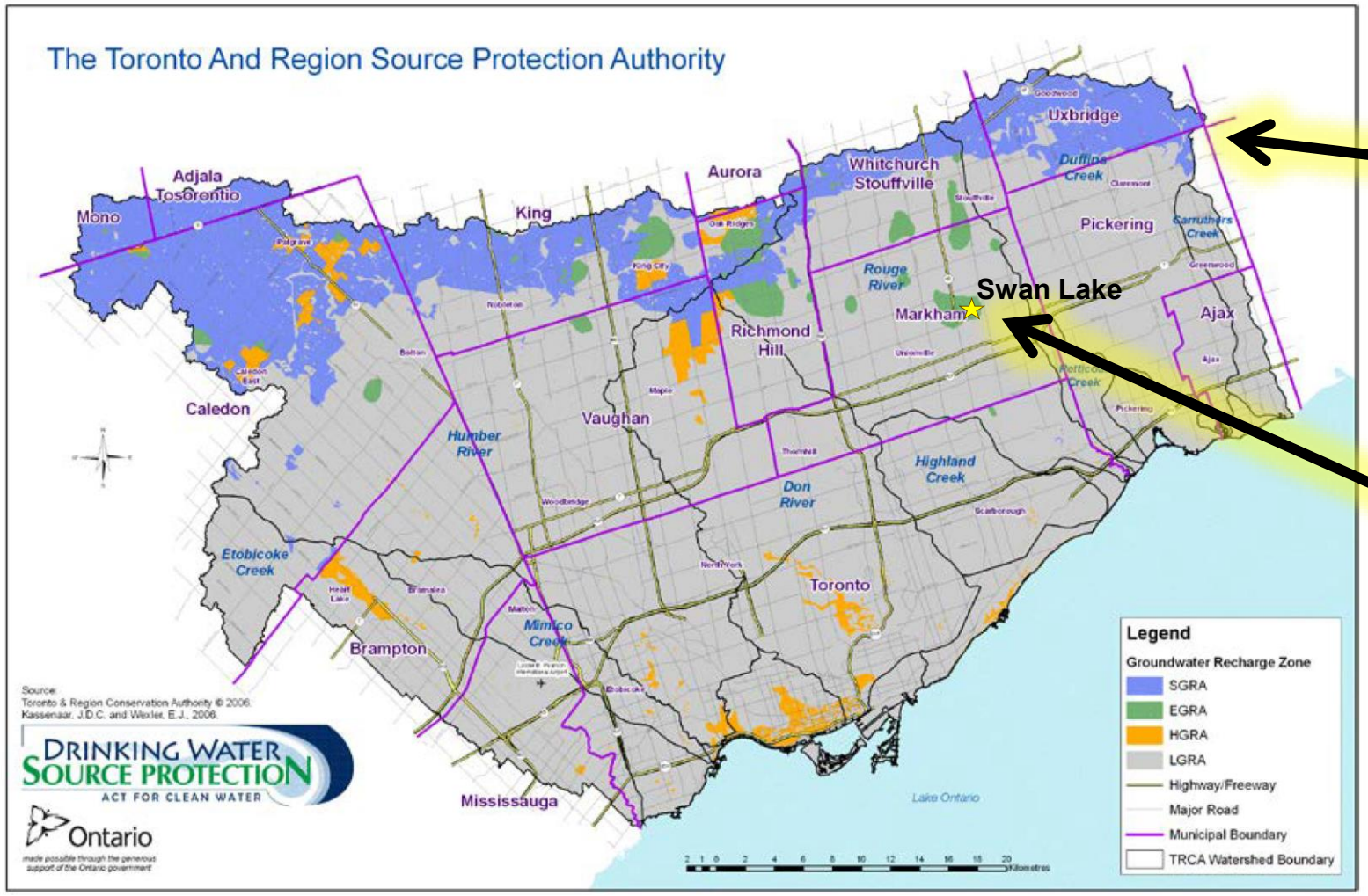
  [3.1.2.12] ".. shall be precisely delineated on a site-by-site basis using procedures established by the Region, Toronto and Region Conservation Authority and the Province…"

  [3.3.2.1] "That development, redevelopment and site alteration be designed with the goal of protecting ground and surface water quality and quantity through the identification of strategies and techniques to maintain and where appropriate restore the function of key hydrologic features demonstrated through master environmental servicing plans or other equivalent studies."

Staff Position: Identified Key Hydrologic Features are a resource for protection during the development process. The presence of groundwater interaction with Swan Lake as a component of the water balance does not constitute a significant aquifer recharge function for study and management outside the already-completed development review process. See TRCA (stormwater management) & Province (Clean Water Act) mapping of management areas on next slides.

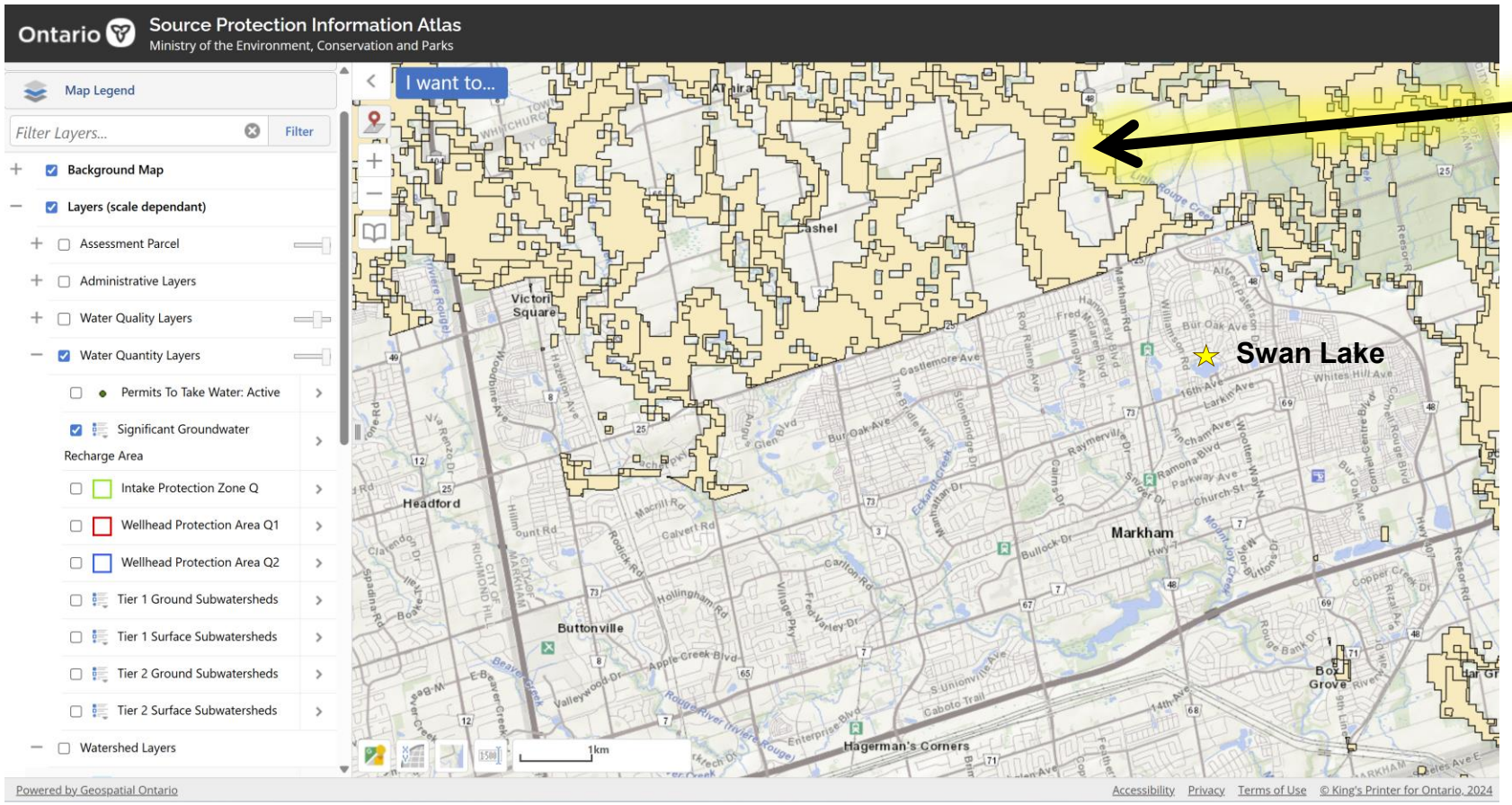
TRCA Local Groundwater Features

Figure C 10: Recharge Area Classification



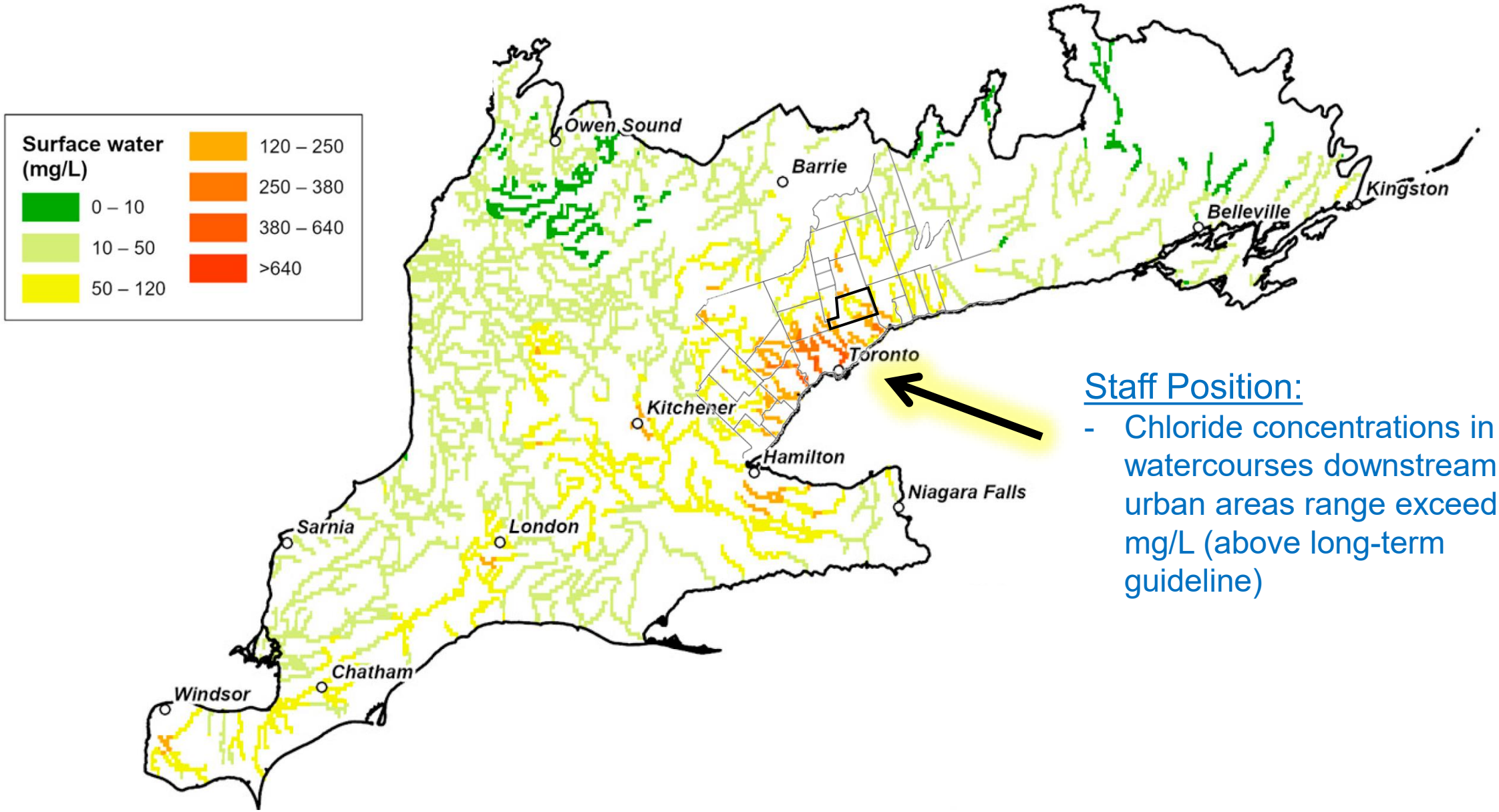
- TRCA 2012 criteria mapping for development stormwater management does not identify Swan Lake area as a Significant Groundwater Recharge Area, or High Groundwater Recharge
  - Local recharge is a common function ("potential recharge area" (Peto MacCallum))
- TRCA identifies Environmentally Significant Recharge Areas (EGRAs) that requires analysis and design **to maintain pre-development recharge to protect hydrologic functions**.
  - Completed for surrounding development
- EGRA's are not included in the Markham OP

Provincial Groundwater Features



- Source Protection Plan (SPP) under the Clean Water Act for drinking water source protection identifies **Significant Groundwater Recharge Areas** where recharge is to be maintained or best efforts are required to maintain recharge after development.
- Clean Water Act SGRAs apply to undeveloped areas as shown on the Ontario Source Protection Information Atlas (i.e., north of major Mackenzie Drive).
- Markham considers Clean Water Act SPP requirements in review of new development stormwater management plans, and not to manage groundwater in existing development areas.

Watercourse Chloride 2011-2020

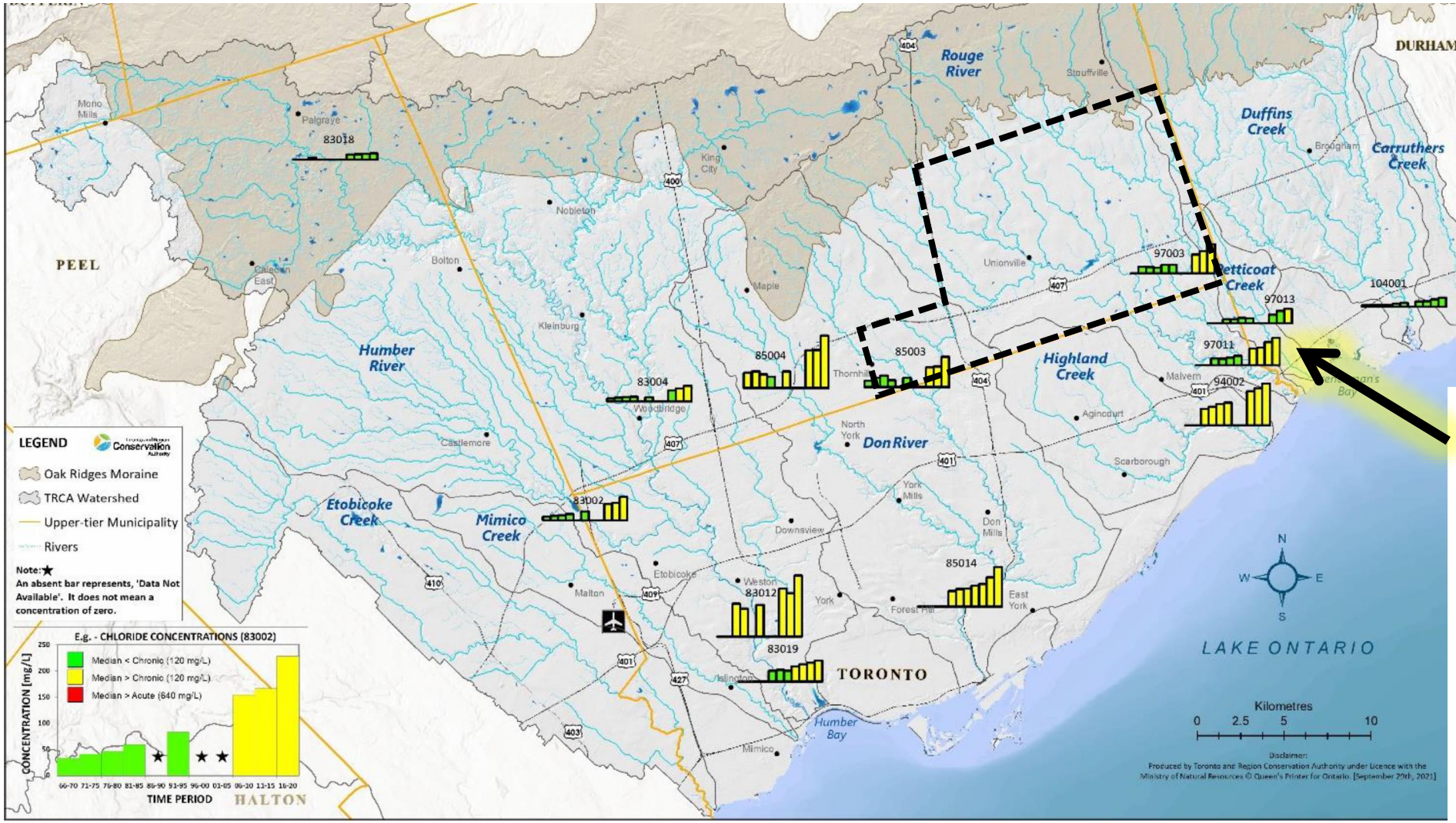


Staff Position:

- Chloride concentrations in watercourses downstream of urban areas range exceed 120 mg/L (above long-term guideline)

Source: Figure 8b) - Geospatial Analysis of Chloride Hot Spots and Groundwater Vulnerability in Southern Ontario, Canada Ceilidh Mackie * , Rachel Lackey and Jana Levison, published in Water (2025)

Changes In Chloride 1966-2020

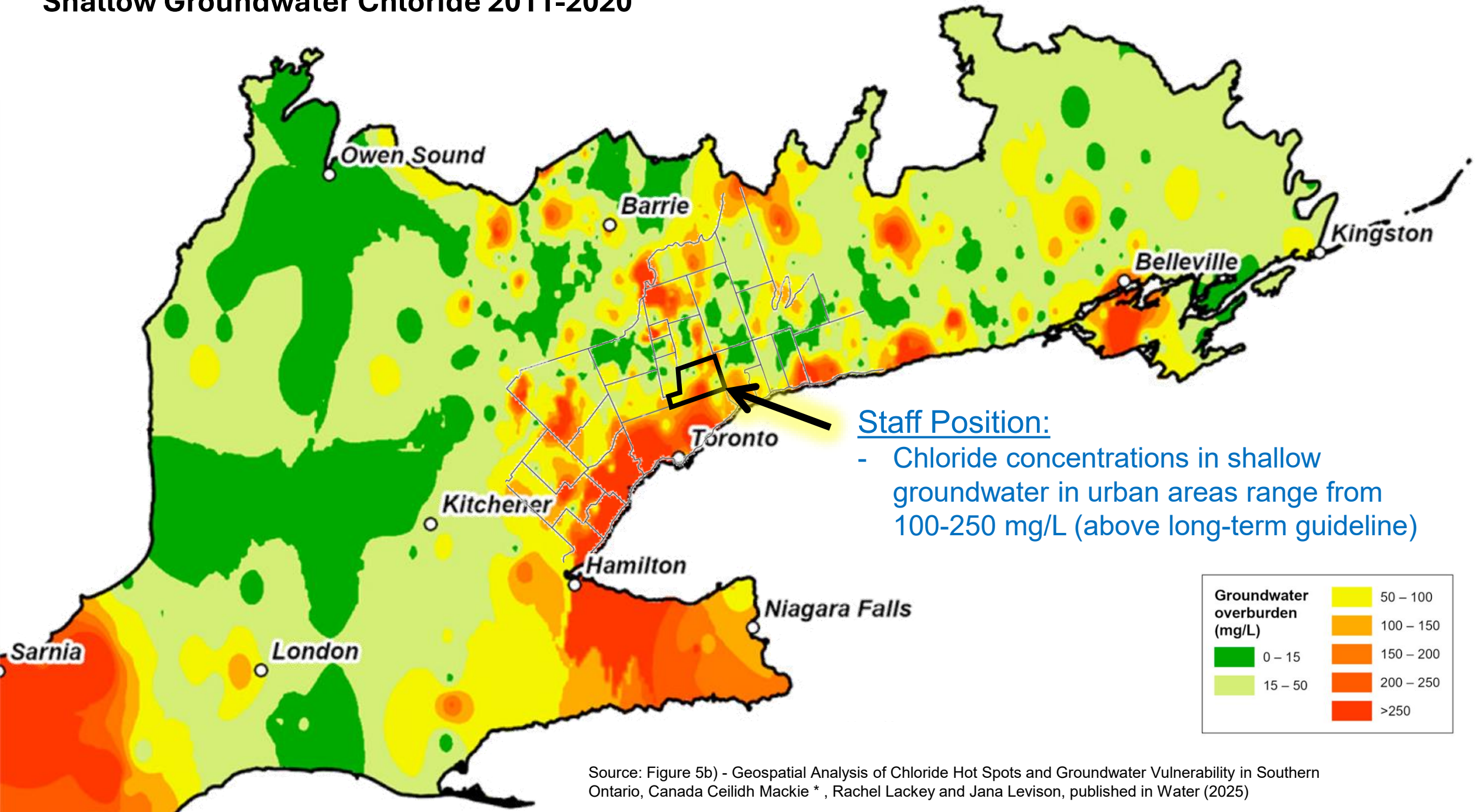


Staff Position:

- Chloride concentrations in the Rouge River watershed increased over time with more development
- Past conditions are not reflective of current conditions

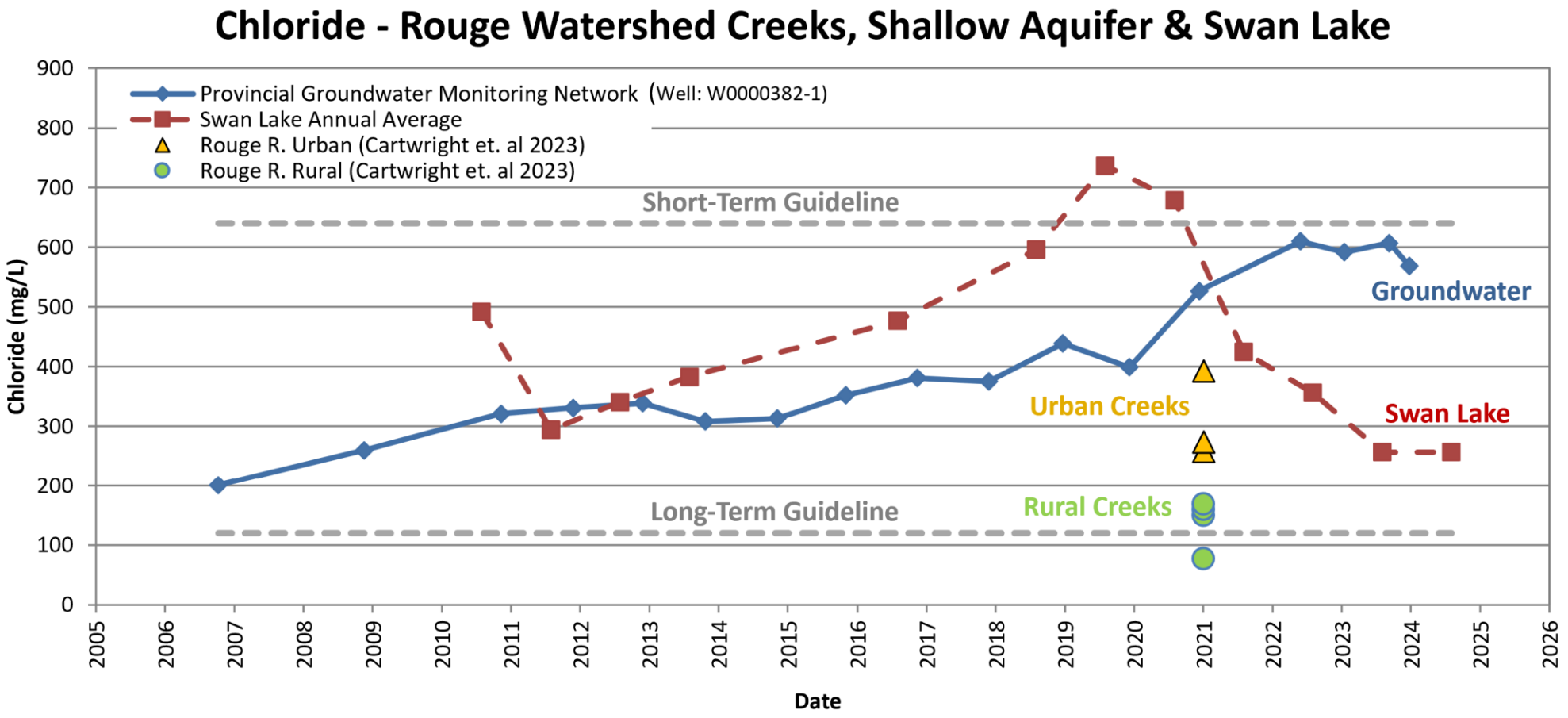
Spatial Patterns (2016-2020) and Temporal Trends (1966-2020) in Stream Water Quality across TRCA's Jurisdiction (TRCA, 2021)

Shallow Groundwater Chloride 2011-2020



Source: Figure 5b) - Geospatial Analysis of Chloride Hot Spots and Groundwater Vulnerability in Southern Ontario, Canada Ceilidh Mackie * , Rachel Lackey and Jana Levison, published in Water (2025)

Should or can Phase 2 chloride goal be below 120 mg/L, relying on high-cost diversions and groundwater input (per FOSLP, 2026)? No.



Staff Position:

- Lake chloride already below shallow ground water and many urban streams
- 120 mg/L guideline not met in urban water systems nor many rural creeks
- FOSLP goals and interventions are not realistic or practical

Monitoring Program

- FOSLP Recommendations:
  - "FOSLP's definition of 'health' includes all of the aquatic elements in the lake – in particular the lower-level elements in the food chain."
  - "FOSLP recommends an annual Environmental Health Card for Swan Lake."
  - "undertake a coordinated water quality program during Phase 2 that leverages the talents of the university research teams,"
- Review:
  - The Phase 2 monitoring framework is defined to assess lake condition and management effectiveness.

Staff Position:

- Phase 2 monitoring program will be designed to inform management decisions and to evaluate lake condition, trends, and effectiveness of implemented actions.
- Monitoring will be led and delivered by City staff to ensure continuity and consistency across years and phases
- University researchers are welcome to undertake complementary research aligned with their specific scientific interests

Path Forward

- Staff do not recommend any chloride management interventions, e.g., flow diversion based on current concentrations and considering local surface and groundwater reference data
- Biochar research is ongoing but does not appear viable for short-term implementation. The staff will update the Subcommittee on the research outcome
- Flow diversion was reviewed last year and was deferred to consider in Phase 3, if required. Current conditions do not warrant advancing it to Phase 2.

Swan Lake Water Quality- Meeting with FOSLP

March 25, 2026

Meeting Minutes
Swan Lake Water Quality Consultation- Meeting with Friends of Swan Lake Park on March 25, 2026

Location:	8100 Warden Ave.
Date:	March 25, 2026
Time:	2 pm- 5 pm
Attendees:	City: Anthony Obtinario (AO), Rober Muir (RM), Zahra Parhizgari (ZP) FOSLP: Fred Peters (FP)
Regrets:	NA

I. RM and ZP went over the City presentation, describing the lake management long-term plan, current conditions of the lake, and comparison of observed data and staff objectives for the Lake with FOSLP's report (Towards a Sustainable Natural Wetland, first draft on December 3, 2025, and updated on March 12, 2026, referred to as 'the report').

II. This year, FOSLP is focusing on the wetland elements, wildlife and also invasive species. FP thinks a lot of good stuff is going on, and he was positively surprised by the outcome of Phase 1 activities.

III. ZP observed that FOSLP's perspective on oxygenation and north channel changed after February meetings with the three groups FOSLP had engaged in various studies about Swan Lake. FP indicated that his initial position came from his layman perspective and his advisors, as well as his experience with farm ponds. But his mind has changed significantly, as he thinks there is a significant groundwater impact on flushing. Therefore, he does not see the Lake as closed system, but rather as a system with active groundwater exchange.

IV. FP referred to discussions in the February meetings, when differences in objectives were discussed. FP elaborated that FOSLP's objectives for the health of the lake include indicators and targets for 'lower-level aquatic elements', such as zooplankton. RM explained that there is no benchmark for zooplankton and such a survey does not provide any missing information on the Lake's trajectory. ZP added that potential impact of chloride on the most sensitive species of daphnia is well-documented, and monitoring of Swan Lake does not add new information for decision-making. FP indicated that he had read about this information, and he had spoken with researchers from Queens University who collected samples from six lakes, including Swan Lake, and they did not find daphnia in Swan Lake.

V. FB indicated that in his mind, a big breakthrough in Phase 1 was the drop in chloride, and the significance of groundwater. RM explained that the City has done extensive analysis on water

balance and chloride for the Lake. These studies have included far more details that any water balance study done, e.g., for development projects. There is no existing groundwater model for this area, and completing a study would be very complex and expensive. FP agreed that building a groundwater model was not warranted, however, he would like to see investigation of groundwater concentrations.

VI. RM indicated that staff have started collecting some samples from Foundation Drain Collectors (FDC) around the Lake. FP said there are test holes around the lake, and he thinks we cannot get the information from FDCs. RM said that wells are usually decommissioned after a study is complete to avoid contamination. FP suggested that the City establishes new boreholes. RM explained that multiple boreholes will be required for collecting meaningful data and given the current lake concentrations, this might not be warranted.

VII. RM asked about the sequence that FP was asking. FP listed measuring chemistry of groundwater from boreholes, zooplankton survey to see what can survive, and then make decision about diverting runoff away from the Lake.

VIII. ZP talked about flow diversion, and that it can be looked at in Phase 3 if the Lake trajectory is not in the right direction. RM said that the detailed design of flood remediation in Markham Village Phase 2 (area downstream of Swan Lake) is starting in 2026, and the scope does not include Swan Lake diversion. FP said that his proposed option (i.e., raising the pond inlet weir) does not impact downstream flooding. RM indicated that the stormwater ponds have not been assumed by the City, and the assumption timeline is not known. He also mentioned that the developers would not do any extra work through the pond assumption process (beyond what is the subdivision agreement).

IX. RM also explained that diverting more flow from Swan Lake would mean discharging more of the salt-laden runoff (which also contains other contaminants) directly into Mount Joy Creek. Diverting flow could also impact Lake hydrology and water level, potentially affecting the ecosystem, if there is not enough clean groundwater replacing this source.

X. On the concept of using bioswale at the six Lake inlets and planting and harvesting salt-tolerant plants, FP said these have been researched in the military college, and have been successful in absorbing nutrients, oil, and other contaminants. FP indicated that one such pilot project has been implemented at Lake Wilcox. RM explained there isn't enough contact time for bioswale at the inflows to meaningfully treat runoff. FP said this is something that could be considered around the whole lake to passively remove chloride from water.

XI. RM shared that based on staff meeting with York U, the biochar research has yet to identify a suitable media for chloride adsorption. The researchers are also looking at 3-day contact time, and therefore, this would not be feasible for implementation in an Oil and Grit Separator (OGS) but will instead require building large containments downstream of the OGSs. Staff have also contacted MECP, TRCA, and an OGS manufacturer, and they were not aware of any other practical means for treating chloride in runoff.

XII. RM explained the meaning of Significant Groundwater Recharge Area (SGRA) and its relevant for development. The designation does not give the Lake priority or extra resources for water quality management. Swan Lake is not a SGRA, but it is within an Ecologically Significant Groundwater Recharge Area (ESGRA), a designation used by the TRCA, also to inform development-related decisions. FP indicated that he brought up the SGRA designation earlier when he asked the Parks department for further studies on the terrestrial habitat of the Lake, and they responded that the Park is not designated as a Natural Heritage feature.

XIII. RM discussed current and trends in chloride concentrations in surface water and groundwater in the area, showing both are on an upward trend and are above the CCME long-term objective of 120 mg/L. FP thought that surface water levels were not relevant for Swan Lake as it could be disconnected from road salt through manageable options.

XIV. RM shared plots of groundwater chloride concentrations. We agreed to do more FDC testing. FP asked for boreholes in the north. RM said that flow paths are not defined, and excavating multiple boreholes will be expensive and not required given the current lake concentrations.

XV. FP indicated that the drone work was pulled back, but York U and Trent U are working on it to distinguish between algae and plant chlorophyl. FP was not aware if York U was going ahead with publishing the respective paper.

XVI. On the FOLSP's monitoring proposal, ZP indicated that for continuity and reliability, staff will run the City's water quality monitoring program, and university researchers are welcome to collect additional data for their specific research purposes. The City has cooperated with them before and even agreed to host a Trent student in the office when they conduct their research. FP has spoken with the universities, and they can commit to five years. RM explained that the City's procurement process has not been followed, and staff do not believe that this arrangement is in the best interest of the City.

XVII. FP shared the document FOSLP's Proposed Actions for Phase 2 (Check List) that included a comparison of FOSLP and City external advisor AECOM's recommendations (see attached). FP also shared a summary document PHASE 2: Three Core Objectives (attached) that included an amended goal on sustainable biodiversity, understanding groundwater and minimizing stormwater impacts. RM noted that the City's program already supports biodiversity by improving water quality, that the City initiated collection of FDC groundwater to help characterize quality, and that Staff could review research on chloride removal of through plant harvesting to assess merits and is awaiting York's findings on Biochar treatment.

XVIII. FP inquired on timing of sharing Phase 2 plan recommendations and RM stated that senior staff consultation is scheduled through mid-April, so that plan recommendations that will go to the Markham Subcommittee will be available to share the third week of April.

XIX. FP noted that he will be organizing a public meeting before the April 30th Markham Subcommittee, e.g., on April 28th. RM indicated that the April 30th Markham Subcommittee is the City's public meeting for presenting and discussing Phase 2 plan.

Action Items	Owner(s)	Deadline
Provide references or contact information for using bioswale in removing chloride from runoff, including a pilot project at Lake Wilcox	FOSLP	April 10, 2026
Share meeting slide presentation	City	March 27,2026

Swan Lake Long-Term Management Plan Update
Expert Consultation and Engagement

Meeting with Swan Lake Citizen Science Lab

Environmental Services
Robert Muir, Manager, Stormwater
Zahra Parhizgari, Environmental Engineer, Stormwater
Dr. Tammy Karst-Riddoch, PhD

February 11, 2026

Agenda

- Introduction
- Purpose of Meeting
- Swan Lake Citizen Science Lab's Scope
- Summary of Lake Conditions
- Comparisons
- Path Forward

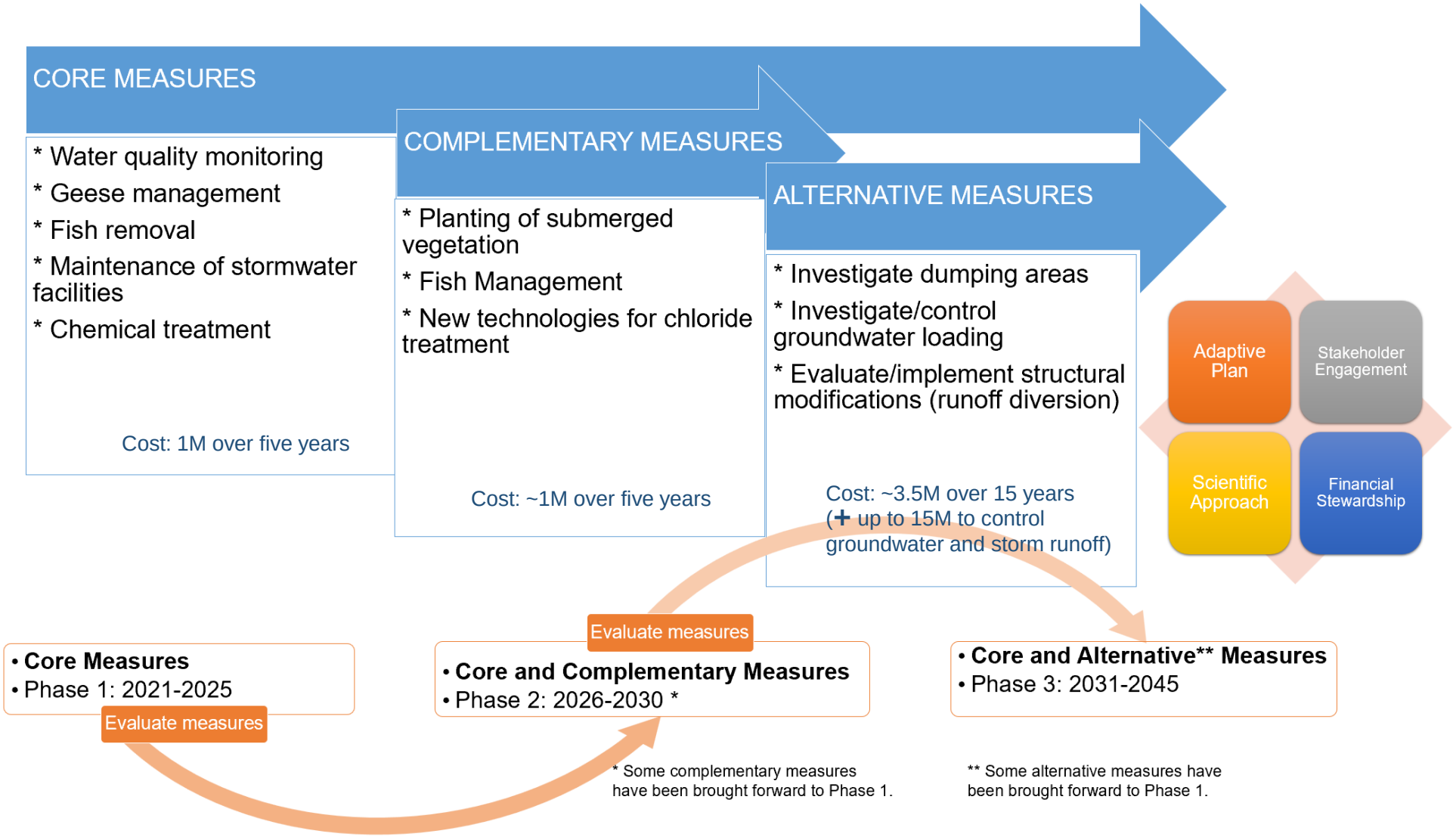
Purpose of Meeting

- Phase 1 of Swan Lake Long-Term Management Plan (SLMP- see next slide) has been completed successfully
- Consultation is a critical step in the adaptive management approach to Swan Lake Water Quality Improvement
- Expertise was solicited by Friends of Swan Lake Park (FOSLP) as part of their feedback to the SLMP five-year review
- City reviewed reports submitted through FOSLP and provided feedback

PURPOSE

- To understand how SL CSL's report conclusions were developed
- To compare those conclusions with measured lake data
- To reconcile areas where statements and field results differ
- To identify opportunities for updated or refined assessments

Long Term Management Plan (2021)



Plan Review Process

Expert Consultation and Engagement

- Engage with deputants and technical stakeholders involved in the Markham Subcommittee process
- Participate in a workshop or other interactive consultation with external experts and agencies (e.g., TRCA, MNRF)
- Review of stakeholders' input

Study

- Update existing condition
- Review of management outcome
- Evaluate additional management measures
- Review and update goals, objectives and targets
- Update strategy and implementation plan

Plan Update

- Share draft report with stakeholders
- Receive feedback
- Present final report to Markham Subcommittee

Swan Lake Citizen Science Lab's Scope

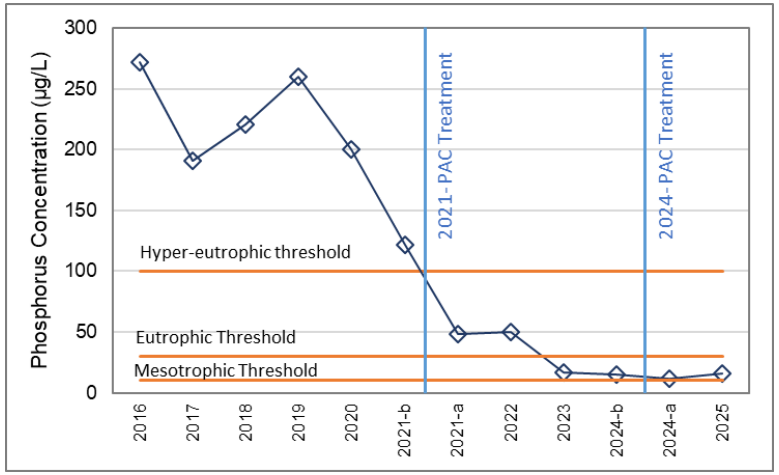
- SL CSL was established in 2024 for research on Swan Lake, and is a partnership between:
  - Researchers from York University (CIFAL York, ADERSIM, and One Water), and
  - Friends of Swan Lake Park (FOSLP)
- Study goals:
  - Goal 1: High-Resolution Water Quality Mapping (distribution of chlorophyll-a and algal blooms (cyanobacteria), TSS, Submerged aquatic vegetation (SAV)
  - Goal 2: Monitor Ecosystem Restoration Success (establishment, growth, and health of the newly planted SAV, extent and spread of invasive vegetation)

- Drone-Based Monitoring Swan Lake Water Quality Report # 1: Multispectral Data
- *Drone-Based Water Quality Monitoring of a Small Urban Lake: Case of Swan Lake in the Greater Toronto Area, Canada (paper submitted to the Environmental Monitoring and Assessment journal- not reviewed)*
- *Proposal for an Environmental Health Card for Swan Lake, Discussion Paper (received Feb 3)*

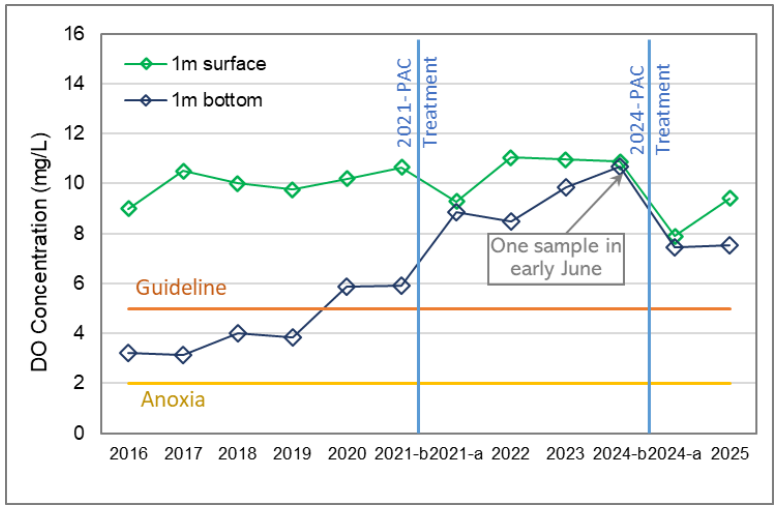
Current Lake Conditions and Trends

Water Quality- Nutrients and Oxygen

- Total Phosphorus:
  - Average under 30 µg/L during growing season (within Mesotrophic condition)
  - Decreased after each treatment
- Total Nitrogen:
  - Average below 0.65 mg/L during growing season (within Mesotrophic condition)
  - Dominant forms not bioavailable
- Dissolved Oxygen:
  - Surface concentration > 5 mg/L all year
  - Bottom concentration showed a decline during dry months
  - Observed anoxia is spatially limited, episodic, and confined to a small deep-water area



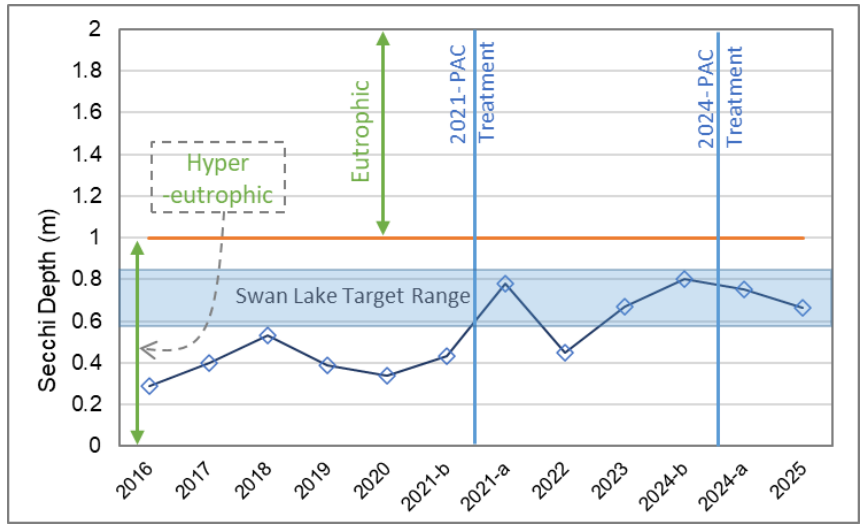
Phosphorus



Dissolved Oxygen

Water Quality- Algae and Clarity

- Algal growth:
  - Surface bloom very limited since treatment
  - Recent Cyanobacteria cell numbers declined significantly since treatment
  - Chlorophyll-a within eutrophic state and below Health Canada chl-a indicator value for potential presence of cyanotoxins above primary contact recreational guidelines
- Clarity: Mostly within target, average growing season met target

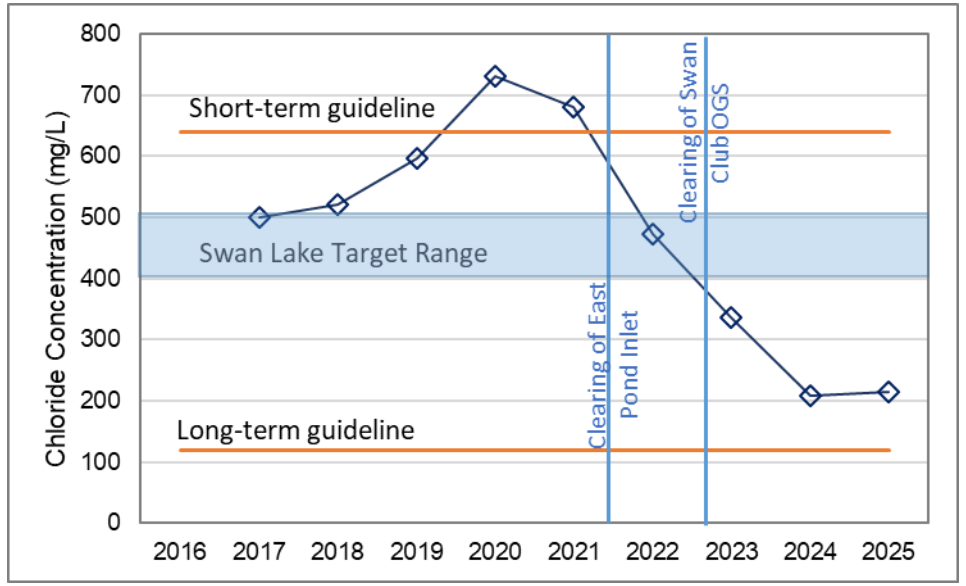


Algal bloom before treatment (photo from July 2020)

Very limited surface bloom since treatment (photo from July 2025)

Water Quality- Chloride

- Chloride enters the Lake through winter maintenance:
  - Swan Lake Village Corporation
  - City roads
  - Residents north of the Lake
  - AMICA Corporation to the south
- Previously on upward trend likely due to blockages, which resulted in untreated flows to the Lake
- Since 2021 decreased due to clearing the blockage at the East Pond inlet and Swan Club OGS
- Long-term guideline derived to protect *the most sensitive life stage of the most sensitive aquatic species* over the long term



Fish Management

- Removing bottom-dwelling fish to prevent sediment disturbance.
- Fish in the Lake included Common Carp, Brown Bullhead, and Fathead Minnow.
- 500 juvenile largemouth bass added in May 2025.

Bass stocked in May 2025

Submerged Aquatic Vegetation

- 3000 stems of wild celery planted in fenced locations on the north site in 2023 and 2024
- Naturally growing aquatic plants were also abundant in 2024 and 2025
- Further SAV planting will be assessed through the five-year review process
- 2025 survey indicated SAV was abundant throughout the lake

Aquatic Vegetation Survey in July 2025

Program Outcomes

- Significant improvements in water quality and habitat have been realized, including aquatic vegetation and fish community
- Water quality now consistently meets expectations for shallow urban water bodies
- Innovative technologies and academic research are actively being evaluated
- Phase 1 of the Long-Term Management Plan has successfully met all established goals and targets.

Comparison

About the Swan Lake Citizen Science Lab

- Report Claims:
  - "the lab coordinates regular fieldwork, water sampling, chemical testing, and biodiversity surveys, ensuring that drone data are grounded in real-world observations."
  - "it provides hands-on workshops and training sessions-covering topics from water sampling and drone piloting to data analysis"
  - "Drone-based mapping visually captures and geolocates all monitoring stations and inflow sites, which is vital for accurate chloride and water budget calculations. "
- Review:
  - We understand in 2025, only one sample was collected using a drone, and no analysis was completed; drone imagery interpretation not corroborated with real-world observations
  - For safety reasons, we do not encourage residents to work around water (e.g., to collect samples)

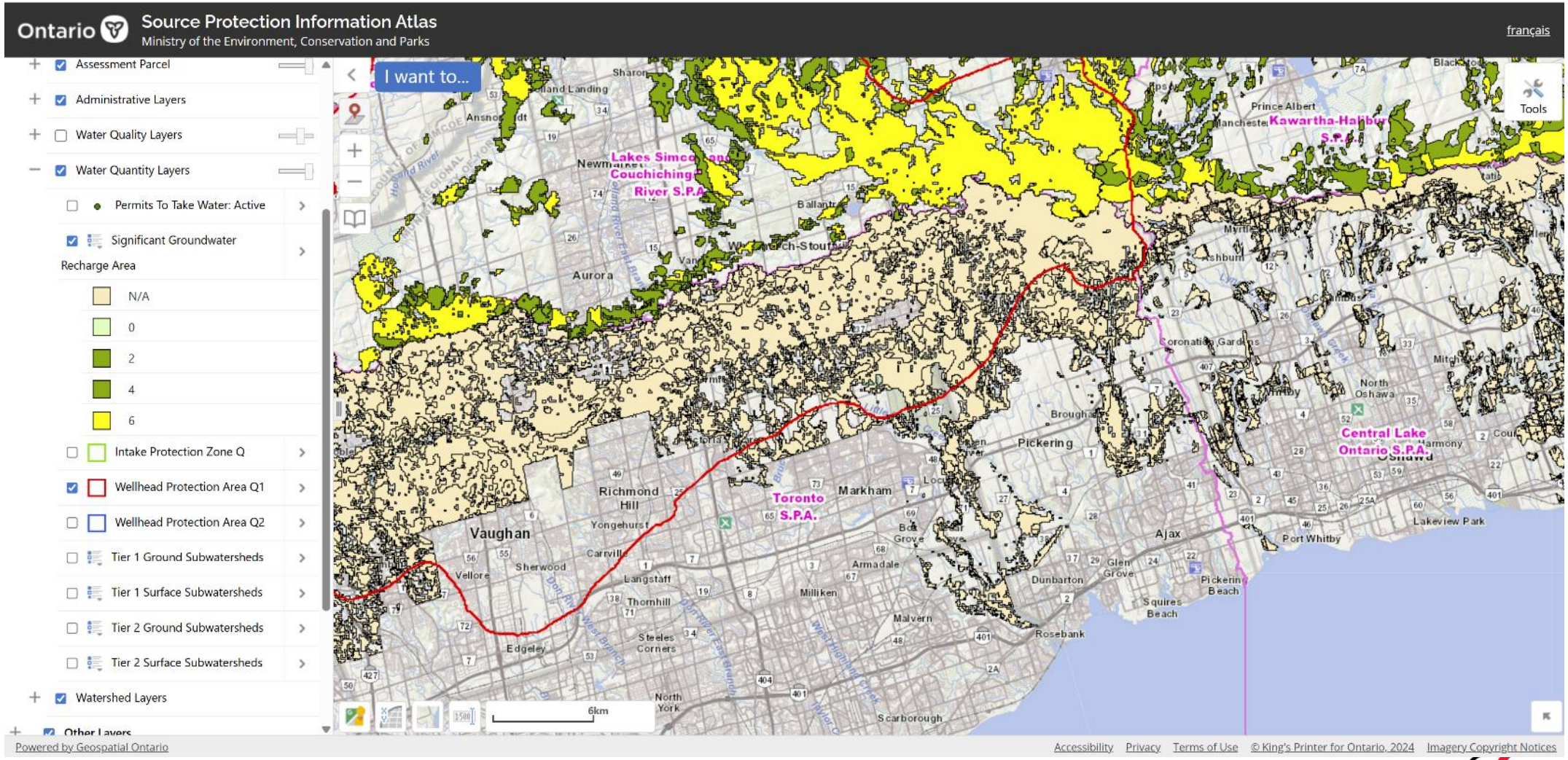
Clarification:
What is the Citizen Lab's plan for verification of drone imagery interpretation using field data?
What information does drone imagery provide for accurate chloride and water budget calculations?

Lake Conditions

- Report Claims:
  - "… This history makes Swan Lake not just a surface feature but also an important groundwater recharge zone for the local aquifer."
  - "Chloride contamination remains a significant environmental concern for Swan Lake, primarily due to de-icing road salt used during winter (City of Markham, 2024)"
  - "… DO has dropped to anoxic levels for several days in late summer and mid-fall in the deeper parts of the lake. This lack of oxygen accelerates nutrient release from the sediment."
- Review:
  - The role of Swan Lake as an important groundwater recharge zone has not been established previously, or in this report. The TRCA and MECP map groundwater features in terms of their significance for recharge and this area is not a SGRA (see next slide).
  - The statement on chloride concentration misrepresents Markham report. Current chloride concentrations are in line with similar urban systems, and there is no evidence of impairment of aquatic health due to chloride.
  - Hypoxia/anoxia is not a lake-wide issue; monitoring shows it is limited, episodic, and confined to a small deep-water area. There is no evidence of nutrient release from sediment due to localize anoxia.

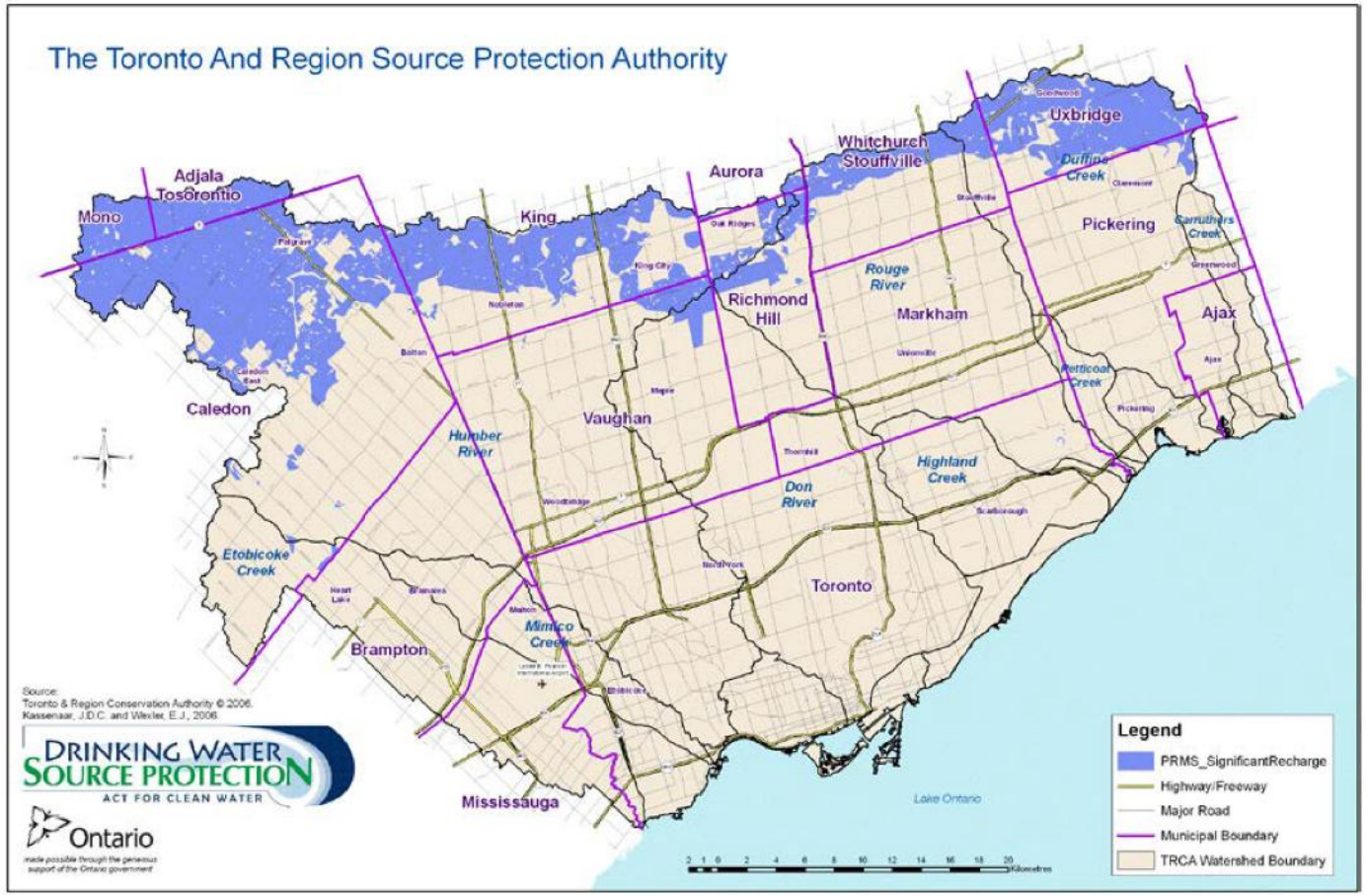
Clarification:
-What evidence exists on Swan Lake functioning as a groundwater recharge zone,
-What evidence exists on chloride contamination posing a significant environmental concern, and anoxia causing nutrient release?

Significant Groundwater Recharge Areas



Significant Groundwater Recharge Areas, Cont'd

Figure C 7: Significant Groundwater Recharge Areas (SGRA)



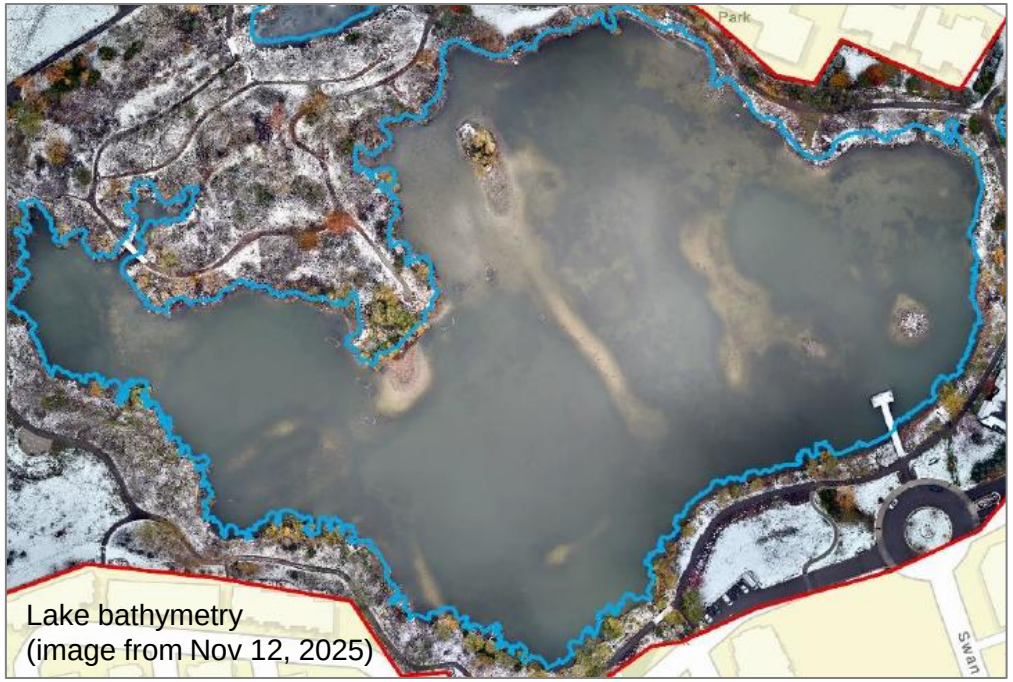
Use of Indicators

- Report Definitions:
  - Normalized Difference Water Index (NDWI): used to differentiate water from non-water features such as soil, vegetation, and urban areas
  - Normalized Difference Chlorophyll Index (NDCI): tracks the levels of Chlorophyll-a (Chl-a), the main pigment involved in photosynthesis in algae and phytoplankton
  - Normalized Difference Turbidity Index (NDTI): estimates water turbidity
- Review:
  - NWDI has been used to indicate turbidity
  - NDCI has been used to indicate cyanobacteria levels
  - NDTI has been used to indicate TSS levels*

* Converting turbidity to TSS requires site-specific calibration. We can have low TSS but high turbidity if particles are very fine or if there's a lot of colored organic matter (e.g., algae blooms).

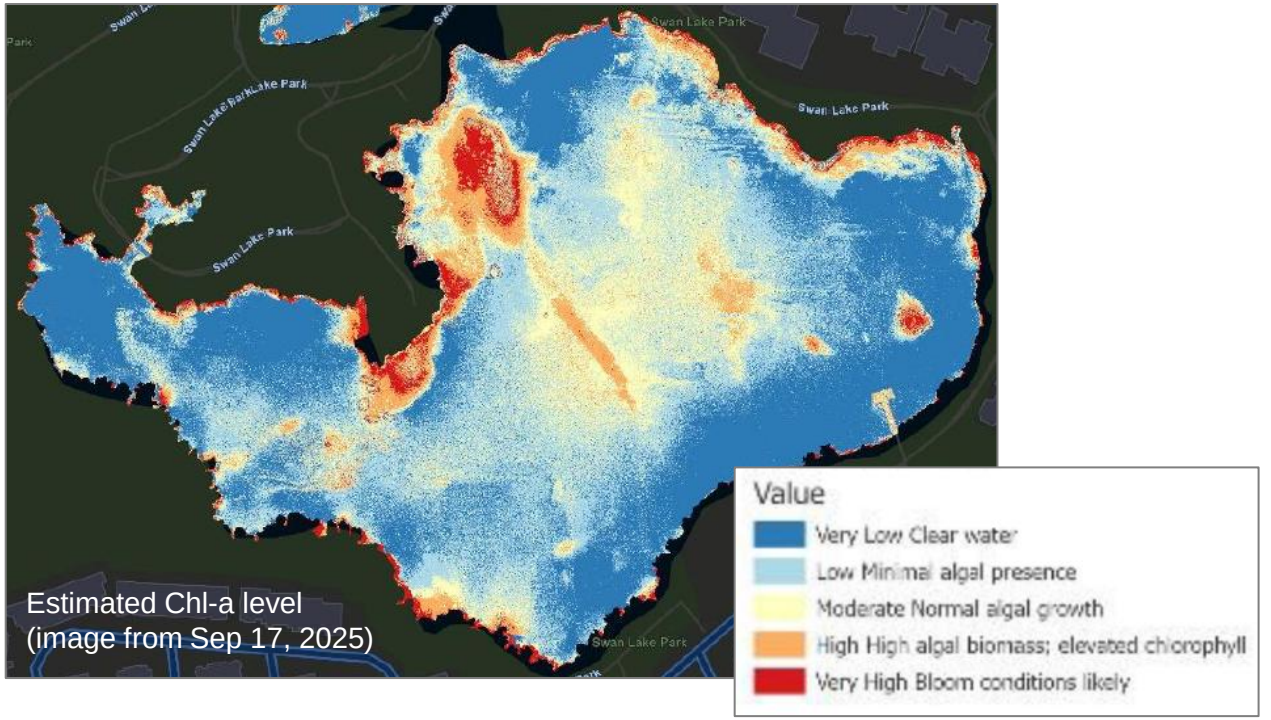
Clarification:
- Were any calibration or validation data used to support these alternative interpretations of Indicators for Swan Lake?
- How is chl-a in macrophytes being distinguished from chl-a in algae?
- How are cyanobacteria distinguished from other types of phytoplankton?
- Were any visual observations of macrophyte conducted during the surveys?

Lake Bathymetry



Lake bathymetry
(image from Nov 12, 2025)

Clarification:
How are the underwater features cover being considered in terms of effects on indicators?

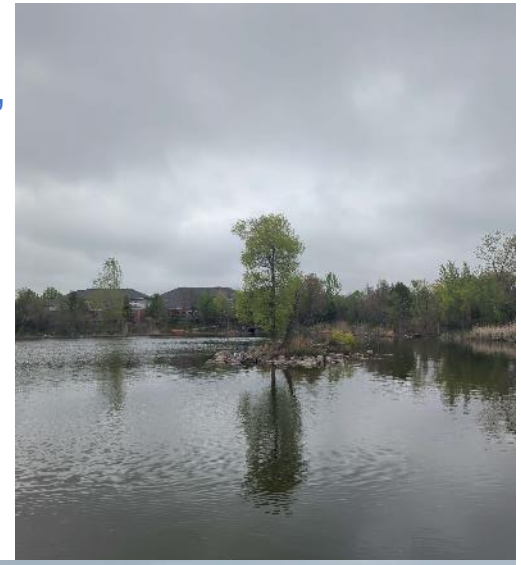


Estimated Chl-a level
(image from Sep 17, 2025)

Eutrophic Conditions and Cyanobacteria Blooms

- Report Claims:
  - "… This color and density indicate a significant algal bloom, as shown by the NDCI measurements. The green hue suggests a high concentration of green algae or possibly a cyanobacterial (blue-green) bloom that looks green when very dense."
  - "… On May 20th and throughout the summer is so densely green that it suggests conditions consistent with a severe hypereutrophic state, where light penetration is minimal due to the sheer volume of algal biomass."
  - "… The pale, dense patches on the surface in the summer maps visually confirm the low-NDWI, high-concentration surface scums that are a significant feature of the lake's water quality problem."
- Review:
  - Claiming that the lake is hypereutrophic and there is high concentration of surface scum and possibly a cyanobacterial (blue-green) bloom based on a green hue is speculative and not supported by field data and site observations (e.g., on May 14, total cell count was 50,000).

Clarification:
What field measurements, or validated remote-sensing analyses were used to support the conclusion that Swan Lake was in a hypereutrophic state or experiencing cyanobacterial blooms?

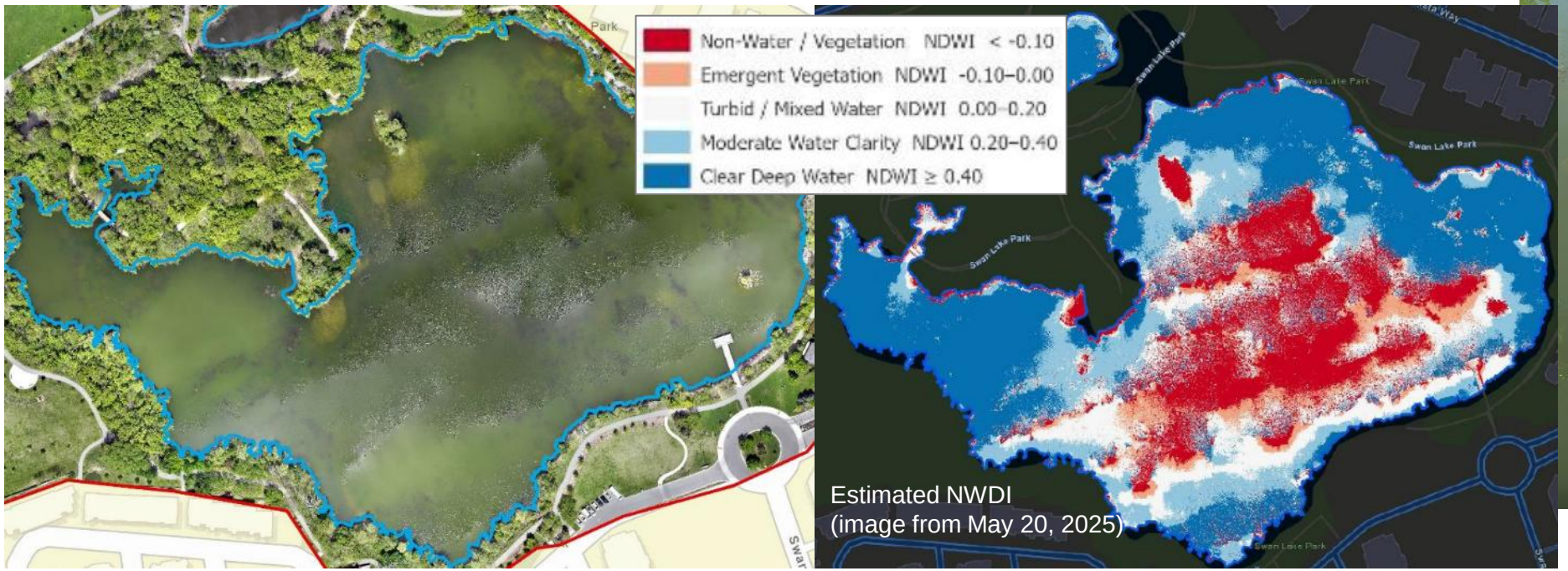


Swan Lake, May 14, 2025

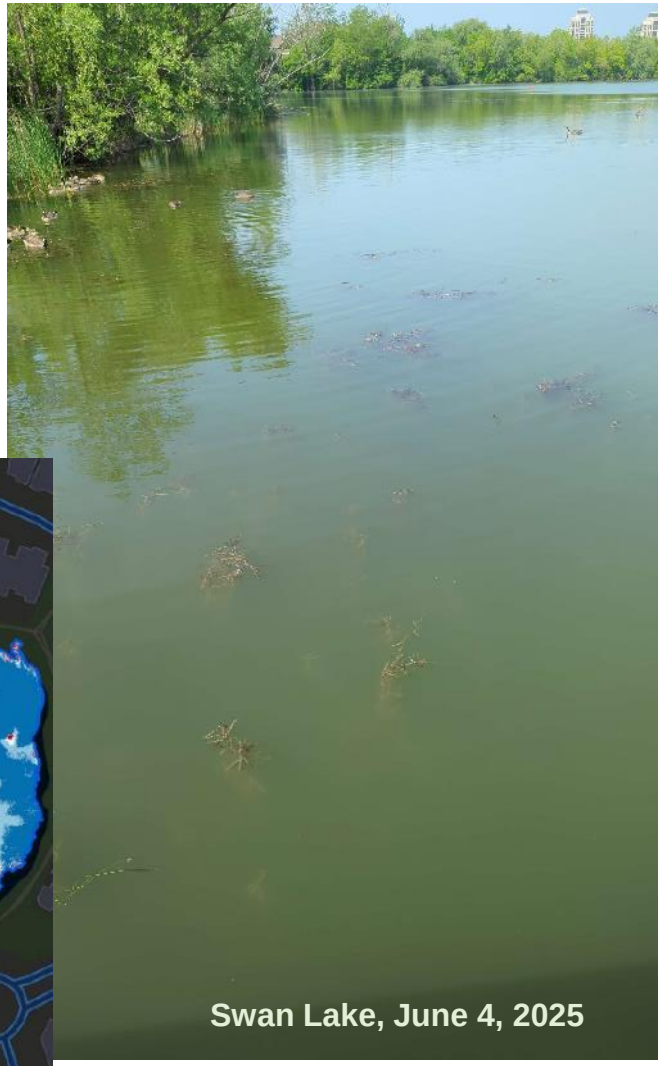
Phytoplankton vs. Aquatic Vegetation

- Report Claims:
  - On May 20, 2025, ..NDWI readings, typically associated with land or vegetation, confirm the presence of dense, floating algal scums or mats on the lake surface during the peak bloom period."

Clarification:
How does NDWI differentiate between algae and aquatic vegetation?



Estimated NWDI
(image from May 20, 2025)



Swan Lake, June 4, 2025

Path Forward

- Will SL CSL update their submissions considering City feedback?
- What other applications of the drone imagery can be used to support Swan Lake management and park improvements, e.g., geese counts during the migratory period when there are high counts.

Swan Lake Water Quality- Meeting with SL Citizen Science Lab- February 12, 2026

Meeting Minutes
Swan Lake Water Quality Consultation- Meeting with Swan Lake Citizen Science Lab. on February 11, 2026

Location:	8100 Warden Ave.
Date:	February 10, 2026
Time:	1 pm- 4 pm
Attendees:	City: Zahra Parhizgari (ZP) City Consultant: Tammy Karst-Riddoch (TKR) FOSLP: Fred Peters (FP) Swan Lake Citizen Science Lab: Dr. Ali Asgary (AA) from CIFAL York, and Dr. Satindar Kaur Brar (SKB) from One Water Institute
Regrets:	City: Robert Muir

I. ZP went over the City presentation, describing the lake management long-term plan, current conditions of the lake, and comparison of observed data with the SL CSL report (Drone-Based Monitoring Swan Lake Water Quality Report # 1: Multispectral Data, referred to as 'the report').

II. The City has not reviewed a paper submitted to the Environmental Monitoring and Assessment journal on Drone-Based Water Quality Monitoring of a Small Urban Lake: Case of Swan Lake in the Greater Toronto Area, Canada (referred to as 'the paper').

III. Algae counts- SKB asked about cHAB counts, and TKR explained that the cell counts have dropped significantly but are not below our targets. She explained the alternative equilibrium theory, and that the lake is in a state of transition from a turbid, phytoplankton-dominated state to a clear-water state with aquatic plants. You should expect this lake to be productive and green given watershed soils, lake depth and its urban setting, but we just don't want to see harmful algal blooms.

IV. Cyanotoxins- SKB asked about how Chl-a is an indicator of cyanotoxin, what about other algae? TKR explained that this is valid for water that is dominated by cyanobacteria (HC 2022 guidelines). SKB was skeptical of the correlation and mentioned that EU adopted cyanotoxins as parameter and not replaced by an indicator. TKR said we use HC guidelines and the approach is widely recognized (WHO) for risk assessment.

V. Verification- In response to the question on the type and extent of verification of imagery with site data, AA indicated that he did not mean this report to be submitted to the City as the interpretation of imagery was preliminary. They have since submitted a journal paper (under review) and resolved many of the issues discussed. They are also comparing Trent data over different locations with their

imagery for validation. It is understood that the report would not be updated and resubmitted in the current form.
TKR said this document is public facing and will raise a question why it is different from City reporting.
SKB agreed that these images need to be verified with test results. She said the drone imagery is very positive long-term, and going forward we should have field samples and correlate them. AA agreed.

VI. Lake bathymetry- AA indicated that they have excluded all underwater features and vegetation in the paper. They also removed tree overlaps but have not removed underwater features just below surface (like the sediment bar).

VII. Eutrophic conditions- AA indicated that the paper would give an accurate description. He presented other imagery indicating variability over the lake surface. TKR said in terms of variability, the Dock area is most often the worst place for algal growth.
Images, indices and data from May 20 were discussed. While the report and calculated indices imply sever hyper-eutrophic condition, and widespread blooms, these were not observed on site. Trent data also showed Chl-a at about 5 µg/L. AA said the indices are not insignificant. City suggested that images need to be calibrated with field data to be useful.

VIII. ZP explained that any interpretation should be differentiating between macrophytes and phytoplankton. AA noted that the imagery does not differentiate between these sources of chlorophyll-a.

IX. Other applications of drone imagery were discussed, e.g., geese count, through flying the drone in the evening and using thermal imagery.

X. Ultrasound pilot project- SKB asked about potential impact of pulsar on animals and humans. Were there any confirmatory tests on the release of toxins after ultrasound application. Does your monitoring include death and natural decomposition of algae?
TKR explained that ultrasound collapses the gas vacuoles not the cell walls, so toxins remain in the cells, which sink. Toxins would then be released through decomposition of the dead cells, as it would for cells that die naturally. Low power ultrasound used in the lake does not result in cavitation, which can be harmful. It was also explained that ultrasound is not directed on the mats, and rather it is a proactive measure to prevent mats from forming.
SKB shared reports and papers on the effect of ultrasound on zooplankton. TKR noted the paper indicated that low power ultrasound without cavitation is unlikely to harm zooplankton.

XI. Biochar update- A short discussion was had on biochar with more to come. York has had different strategies, trying to functionalize the application while not adding toxicity.
FP said it would be a good application to add them to OGS at Swan club.

XII. On the ‘Proposal for an Environmental Health Card for Swan Lake, Discussion Paper’ submitted by FOSLP, ZP indicated that it does not follow the City purchasing by-law and procedures and cannot be discussed at the moment.

Action Items	Owner(s)	Deadline
To update any reference to Drone report considering discussions in this meeting	FOSLP	Mar 1, 2026
To share the long-term management plan with AA	City	Feb 20, 2026