Swan Lake

Annual Meeting with Markham Subcommittee

May 11, 2022

Environmental Services
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Agenda

- Background
- 2021 Water Quality Results and Evaluation of Implemented Core Measures
- High Level Water Flow and Chloride Analysis
- Review of FOSLP's Holistic Approach to Realizing Community Goals
- Recommendations

Background

2021 Council Resolutions

MINUTES AND NOTES OF THE NOVEMBER 16, 2021 MARKHAM SUB-COMMITEE (16.0)

1. That the minutes and notes of the November 16, 2021 Markham Sub-Committee meeting be received for information purposes; and,
2. That the report entitled "Swan Lake Water Quality Management Plan" be received; and,
3. That Staff implement the Plan presented as Option 1 including proposed Core and new Complementary measures beginning in 2023; and,
4. That an additional $2.35M over 25 years be reflected in the 2022 Lifecycle Reserve Update; and,
5. That an additional $10K be added to the 2022 Budget for geese relocation, and fish management at Swan Lake; and,
6. That staff be given discretion to advance three low-cost programs (<$90k) into Phase 1 (initial 5 years), including:
   i) Research into chloride solutions
   ii) planting submerged plants
   iii) incorporation of the fish management plan and fish stocking
7. That Staff report back annually on water quality results and evaluation of adapted Core and Complementary measures for consideration in Phase 2 of the strategy through the Markham Sub Committee with the participation of the Friends of Swan Lake Park in today's presentation and other concerns, including high level lake water flow analysis; and,
8. That staff report back to the Markham Sub Committee within the next 6 months (before the end of June) to discuss suggestions in Friends of Swan Lake Park in today's presentation and other concerns that have arisen; and further,
9. That staff be directed to consider longer-term actions to achieve and maintain restoration; and further,
10. That Staff be authorized and directed to do all things necessary to give effect to this resolution.

Option 1 - Expanded Core & Complementary Measures

and Evaluate the need for Alternative Measures

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

Core Measures Implemented in 2021

Activity	Phase 1 Core Measures (Years 1-5)
Water quality monitoring and annual reporting to Subcommittee	☑
Geese management *and explore enhanced methods*	☑
Remove benthic-dwelling fish	☑
Maintenance of stormwater management facilities (by developers then City)	☑
Community Engagement	☑
Chemical treatment	☑
Shoreline planting / Improvements	☑ underway
Chemical oxygenation pilot project (by research institute)	pending more data collection (planned for 2024/2025)
Fish management plan and fish stocking (by MNDMNRF)	
Planting of submerged plants	
New technologies for chloride treatment	

Enhanced hazing (fall)
Geese relocation (73)
Nest and egg removal (13 nests and 52 eggs)
Reduced the number to half

Fish inventory (Common Carp, Brown Bullhead, and Fathead Minnow)
Removal of bottom dwelling fish (to avoid disturbance of sediment)

Clearing of the blocked inlet to the East Pond to prevent untreated runoff from being discharged to the Lake (completed by developer)

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

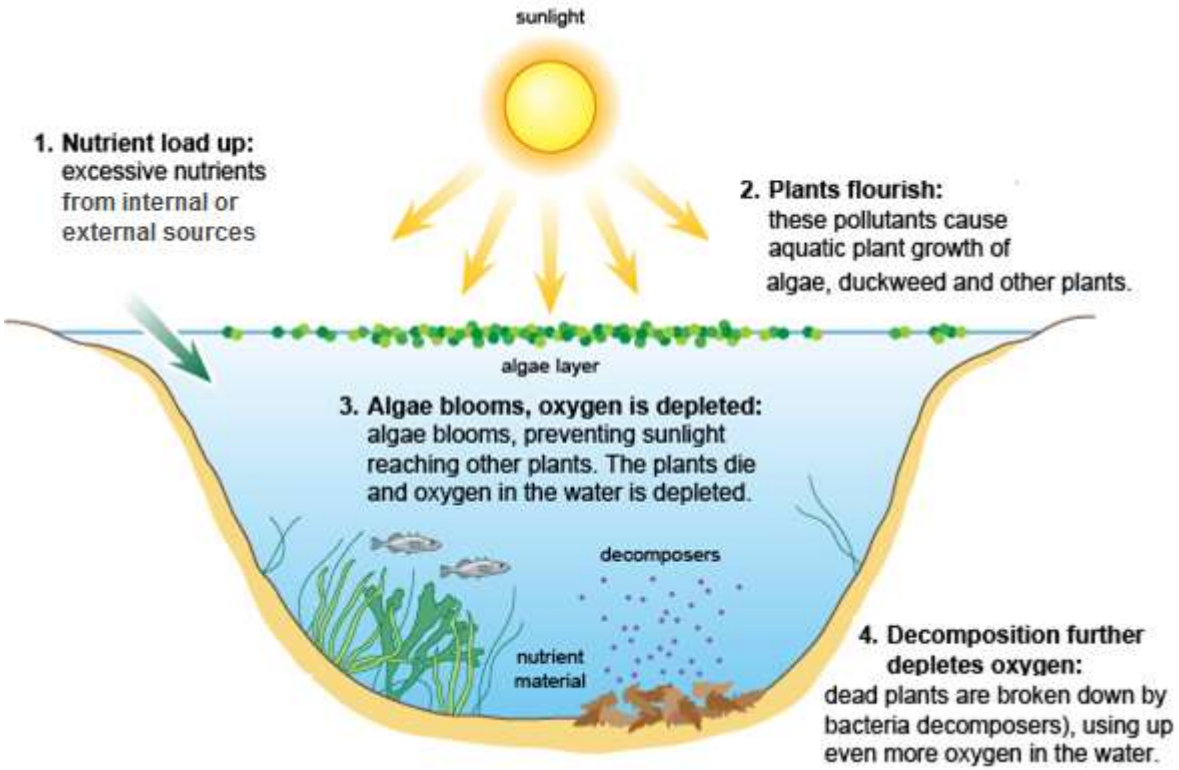
2021 Water Quality Results
and
Evaluation of Implemented Core Measures

Water Quality Monitoring

- Dissolved oxygen, clarity,
- Dissolved organic carbon, color
- Nutrients (phosphorus and nitrogen)
- Phytoplankton
- Chloride
- Water level
- Geese count

Water Quality Processes

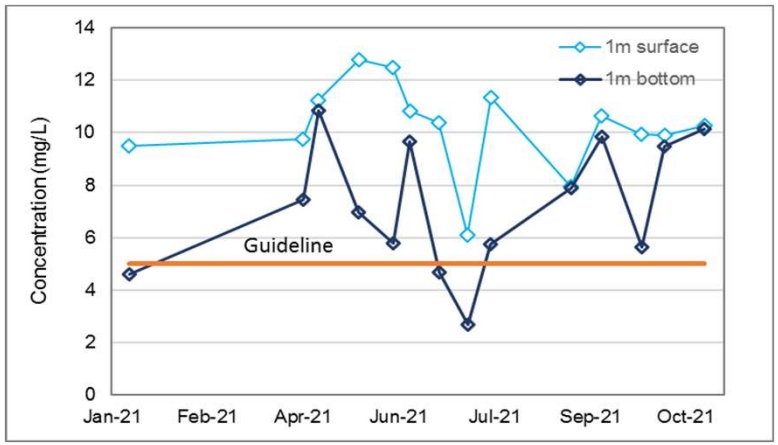
- Excessive amount of phosphorus and nitrogen results in algae growth
- As the algae die and decompose, the process consumes dissolved oxygen (DO)
- Die-off and decomposition of submerged plants also contributes to low DO

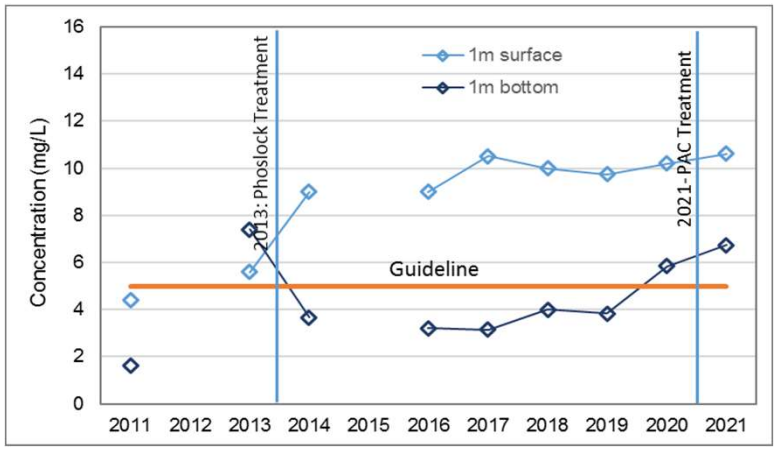


Eutrophic Classifications (based on DO, phosphorus, clarity):
Oligotrophic: pristine
Mesotrophic: clear with some submerged plants
Eutrophic: somewhat unclear, lots of planktonic plant growth
Hypereutrophic: unclear, with frequent algal blooms

Water Quality Results- Dissolved Oxygen

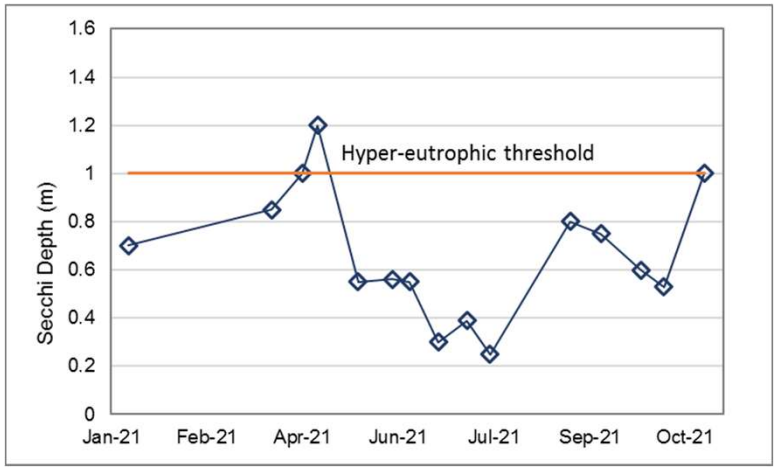
- Minimum required DO for the protection of warm water fish is 4-5 mg/L
- In 2021:
  - Surface concentration >5mg/L all year
  - Bottom concentration >5mg/L after treatment
- Increased compared to pre-treatment years

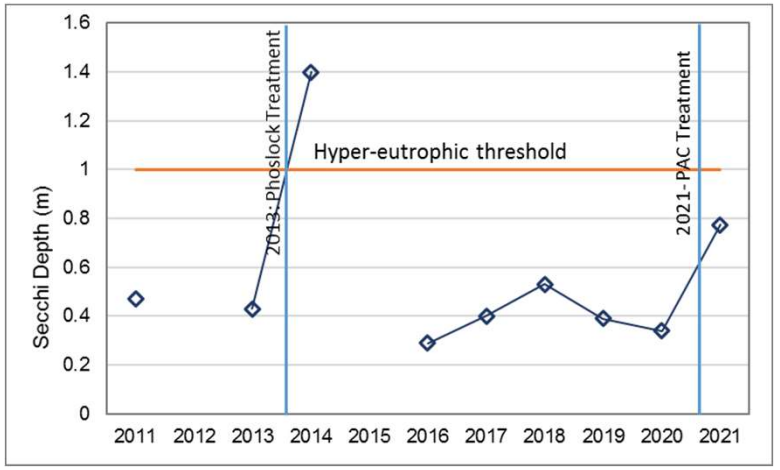




Water Quality Results- Clarity

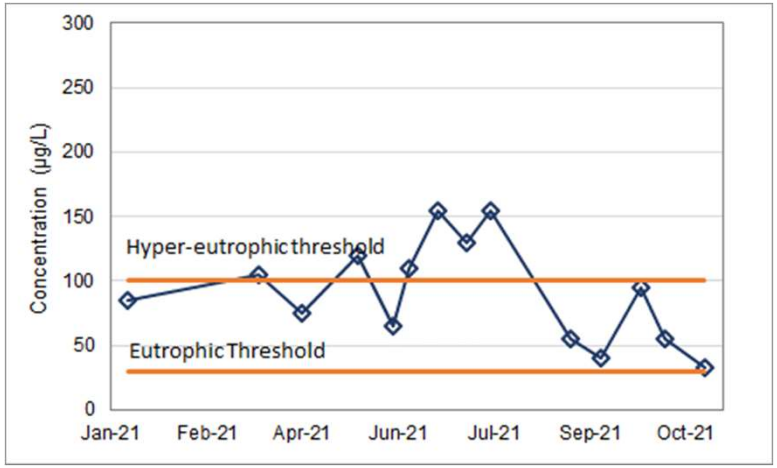
- Below 1 m represents hyper-eutrophic, but 1m a good target for shallow lakes due to low depth and sediment impact
- In 2021:
  - Increased to >1m after treatment
- Increased compared to pre-treatment years

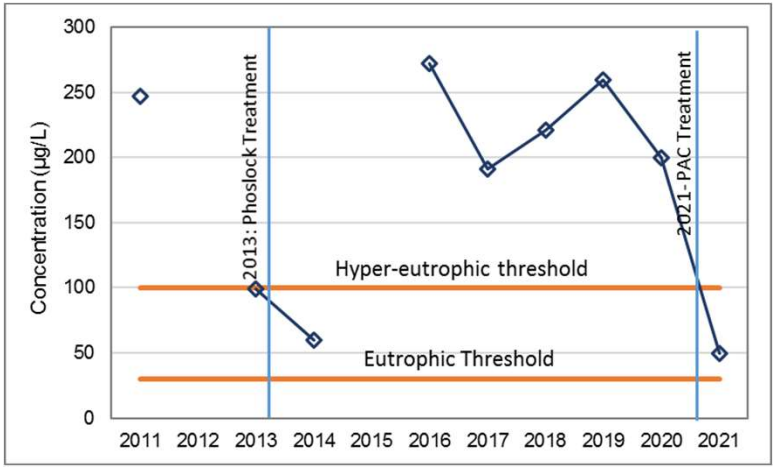




Water Quality Results- Total Phosphorus

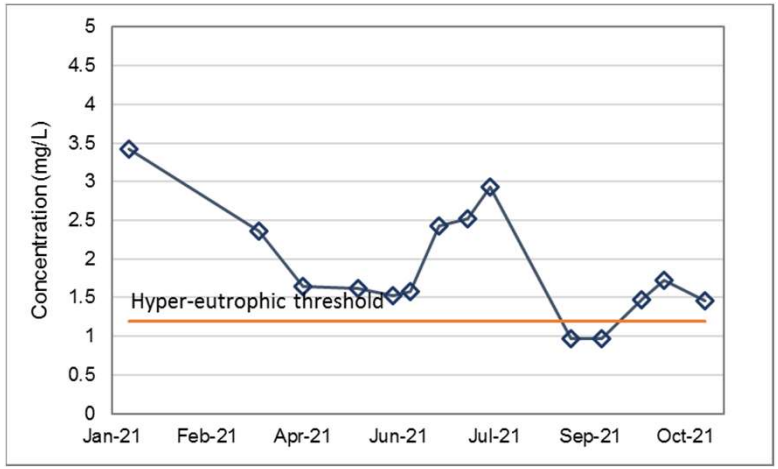
- Above 100 µg/L represent hyper-eutrophic conditions
- Above 30 µg/L eutrophic
- In 2021:
  - Average after treatment: 50 µg/L
- Decreased compared to pre-treatment years

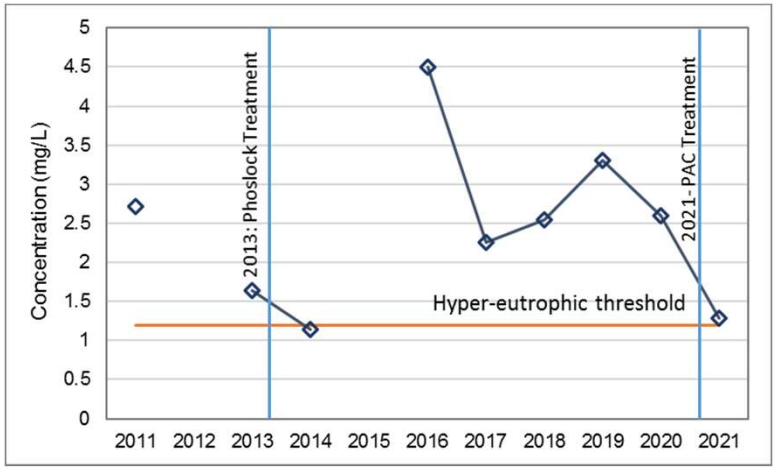




Water Quality Results- Total Nitrogen

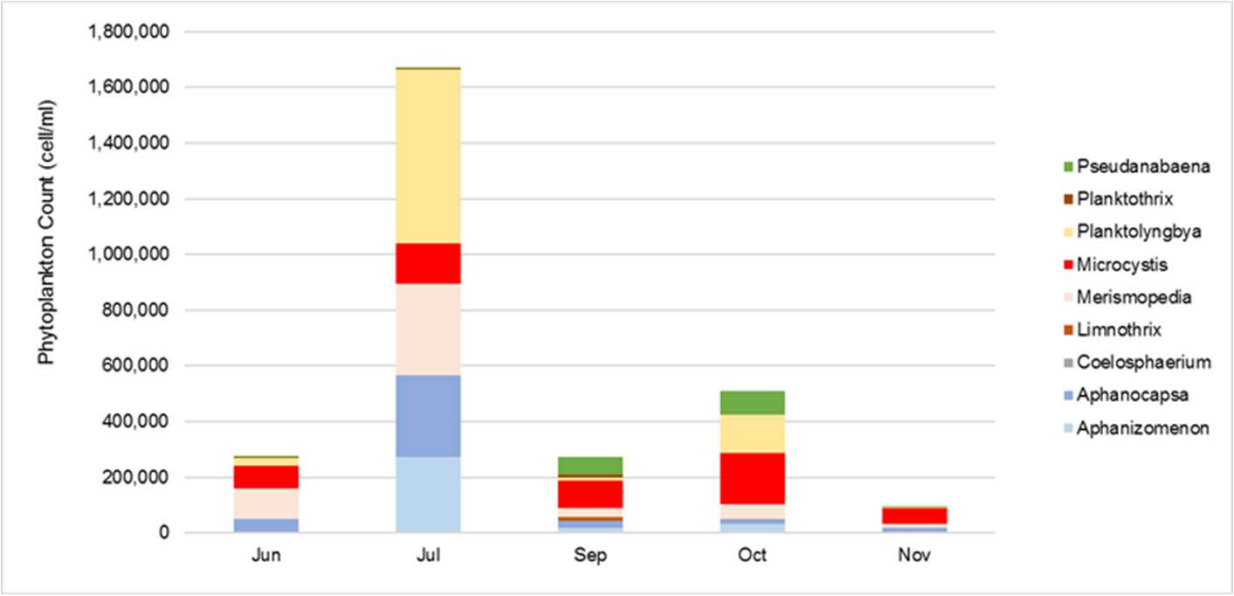
- Above 1.2 mg/L represents hyper-eutrophic conditions
- In 2021:
  - Dropped to 1 mg/L after treatment
  - Dominant forms not bioavailable
- Decreased compared to pre-treatment years





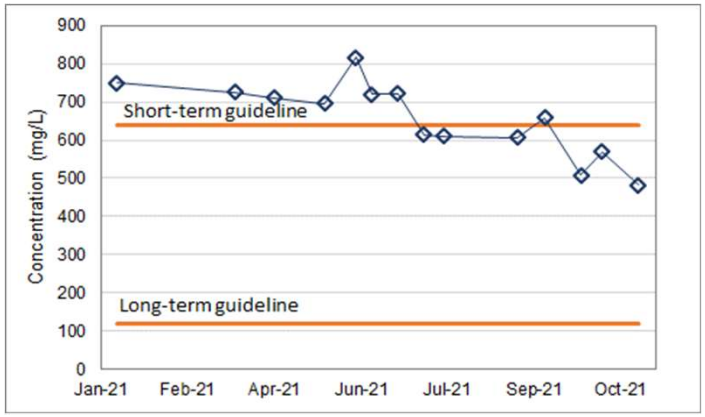
Water Quality Results- Phytoplankton

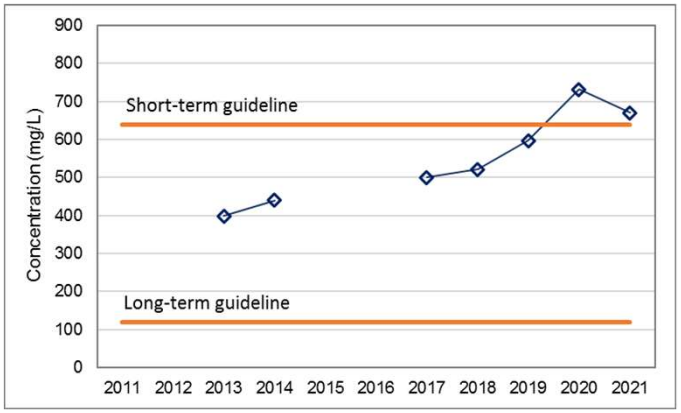
- Phytoplankton (cell count and cyanobacteria) was measured before and after treatment.
- Cell numbers decreased immediately after the treatment.
- Microcystis (toxin producing algae) also decreased after treatment, but increased about 5 weeks later, potentially due to the high load of nutrients from the blocked inlet to the East Pond.



Water Quality Results- Chloride

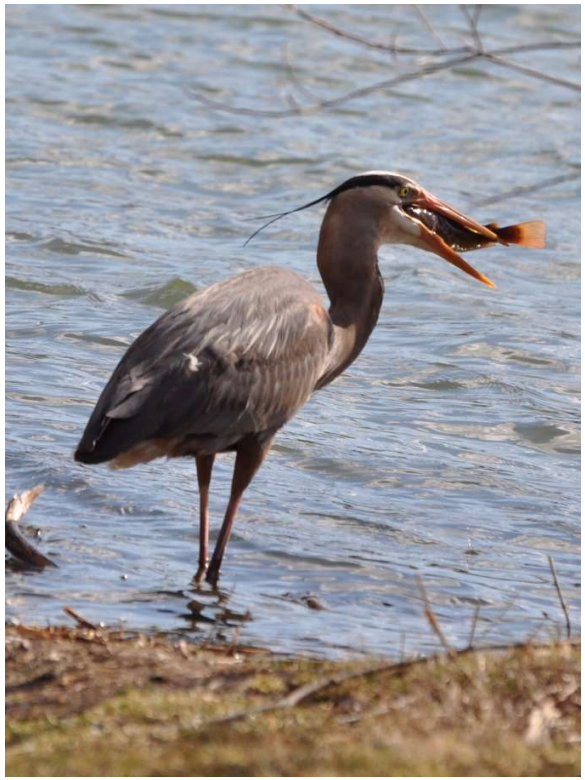
- Chloride concentration increasing in urban lakes as a result of de-icer application
- Chloride does not biodegrade, readily precipitate, volatilize, or bioaccumulate
- Chloride guidelines include a long-term guideline (chronic exposure) of 120 mg/L and a short-term guideline (sudden spike) of 640 mg/L
- Chloride concentrations have been increasing in Swan Lake





Aquatic Habitat

- Supports minnows (present in 1000's)
- Larger fish also observed



Photos courtesy of Mark Henschel

Summary- Water Quality

- Management activities in 2021 focused on the significant nutrient loadings:
  - PAC treatment was used to reduce internal loads
  - Geese management was used to reduce external loads
- These activates were effective at improving water quality:
  - reduce phosphorus concentrations
  - Improved water clarity
  - Increased dissolved oxygen levels
  - reduction of cyanobacteria

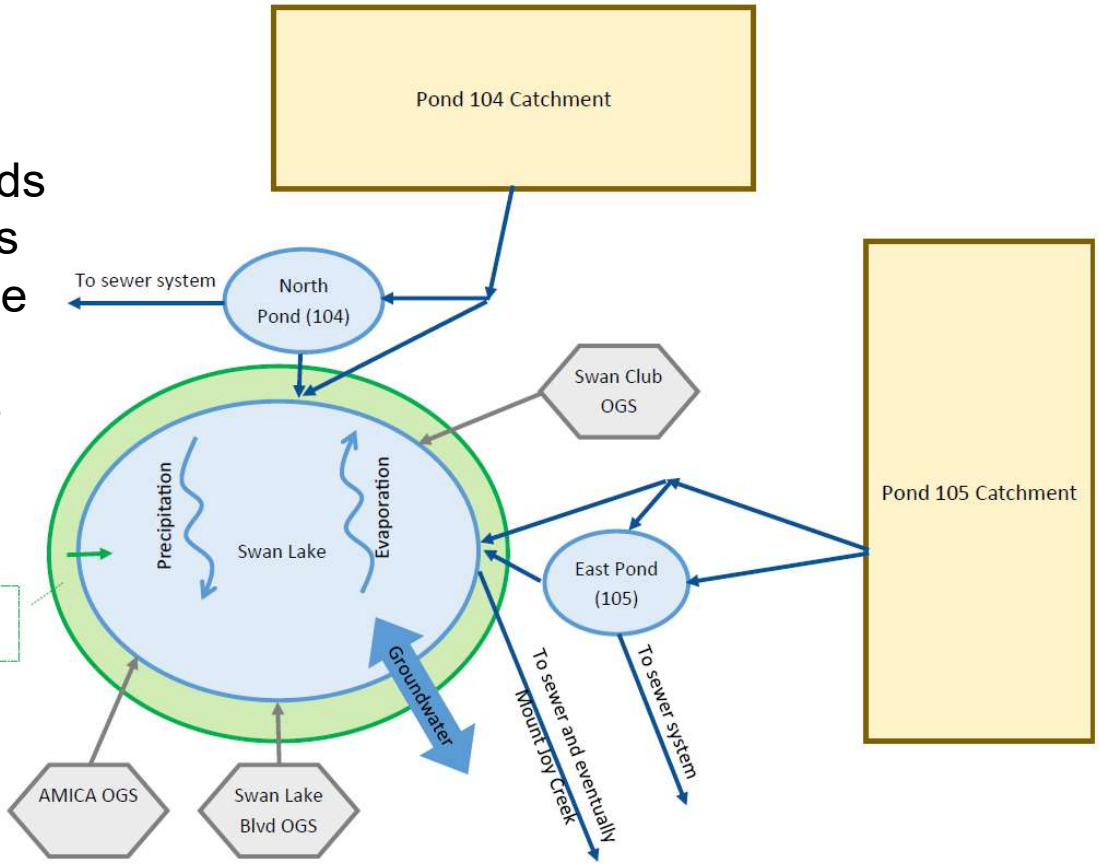

Swan Lake, August 2021

- Monitoring in 2022 (first complete post-treatment year) will provide more conclusive information about the efficacy of PAC treatment and clearing of the blocked inlet.

High Level Water Flow and Chloride Analysis

Conceptual Model

- Flows to the Lake include:
  - flows bypassing the ponds
  - overflows from the ponds
  - discharges from the three OGS
  - runoff from the shoreline area
  - direct precipitation
- Outflows include:
  - evaporation
  - flow through Lake outlet
  - groundwater exchange



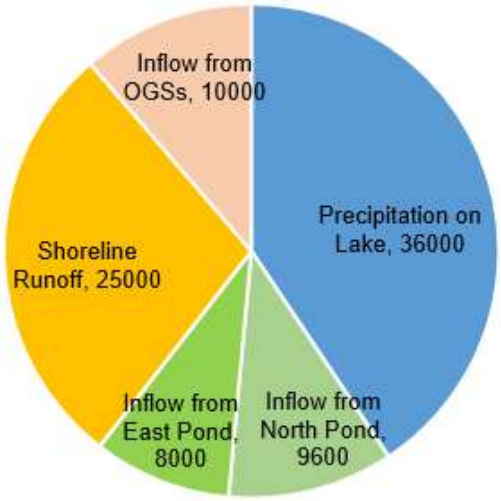
Modelling Approach

- Reviewed drainage plans and delineated catchments
- Reviewed stormwater controls
- Compiled precipitation data and calculated evaporation
- Developed a continuous model for 2009-2021
- Estimated runoff from each catchment and through each pathway
- Used water level data to estimate outflow
- Collected salt usage data (with help from FOSLP)
- Collected runoff samples for chloride analysis
- Estimated chloride contribution from each source

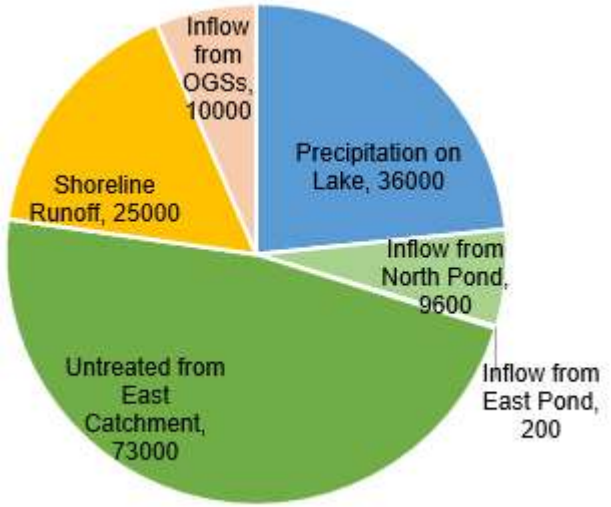
Water Flow Result

- Most of the runoff from the developed catchment is treated in two ponds, and the treated runoff is discharged to the storm sewer system
- During the period when the northern inlet to the Ease Pond was blocked (~2018-2021), a significant amount of untreated runoff discharged to the Lake.

Annual inflows (m^3, as designed)



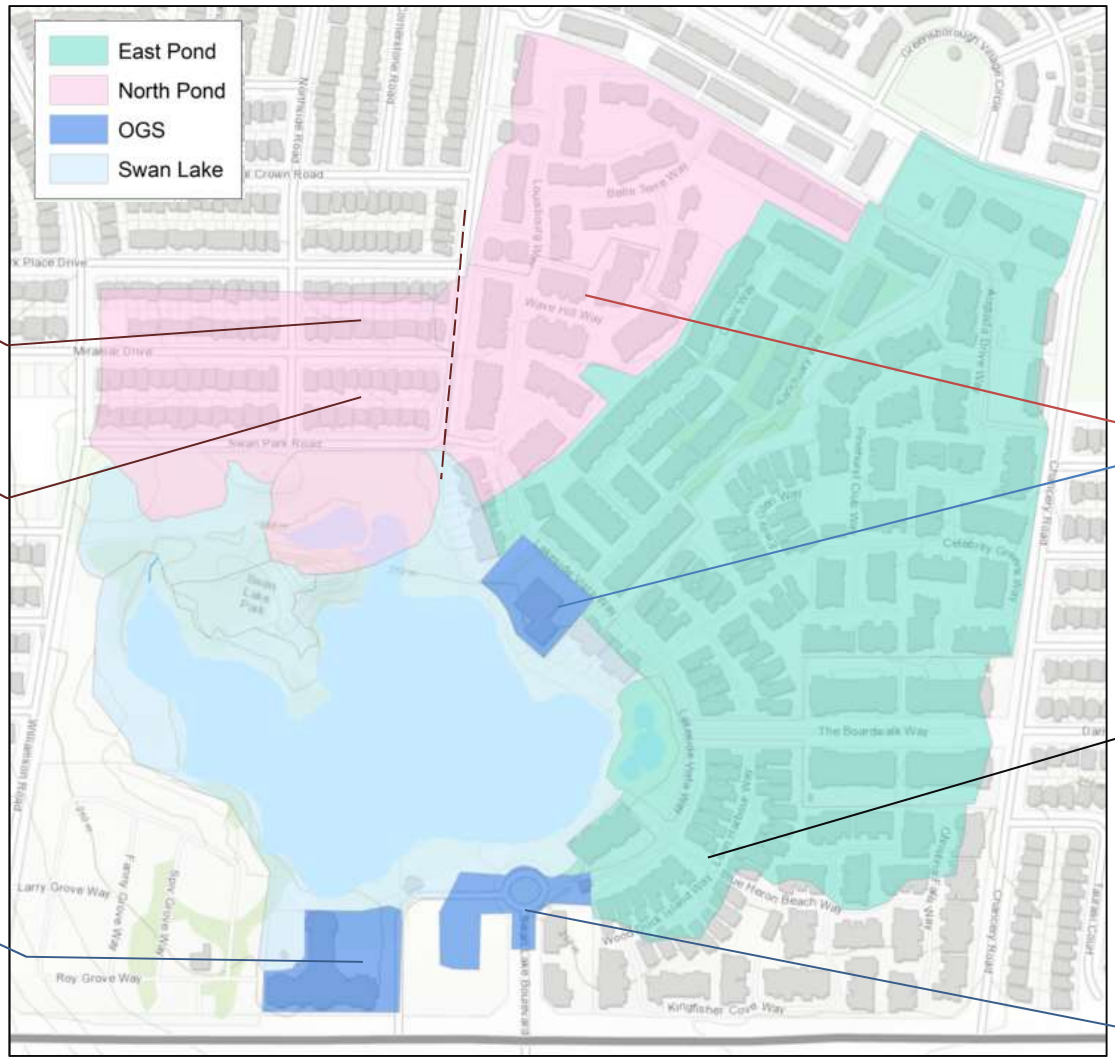
Annual inflows (m^3, blocked inlet)



Chloride Monitoring

- Data availability:
  - Limited in-Lake data before 2017
  - Concentration at Dock and Bridge measured since 2017 from April to Nov
  - No runoff data until 2021
  - No snow melt data until 2022
- Additional data collection in 2021/2022:
  - Runoff data (inlet to ponds and to the Lake from ponds/OGSs/shoreline)
  - Concentration at Lake outlet (maybe more representative of the overall condition than the Dock)

Winter Maintenance and Salt Usage



City:
1 km roads
2200 kg salt/yr

Residents:
driveways/
walkways

Swan Lake Village Corporation:
14 km road
~ 30 tonnes/yr
&
driveways/
walkways/parking
70 tonnes/yr

AMICA Corporation

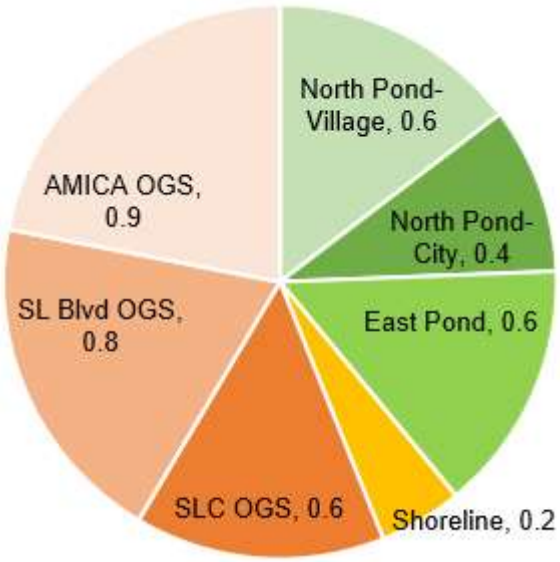
City
130 m roads
900 kg salt/yr

*salt usage from driveways/parkways on the north and AMICA property was estimated.

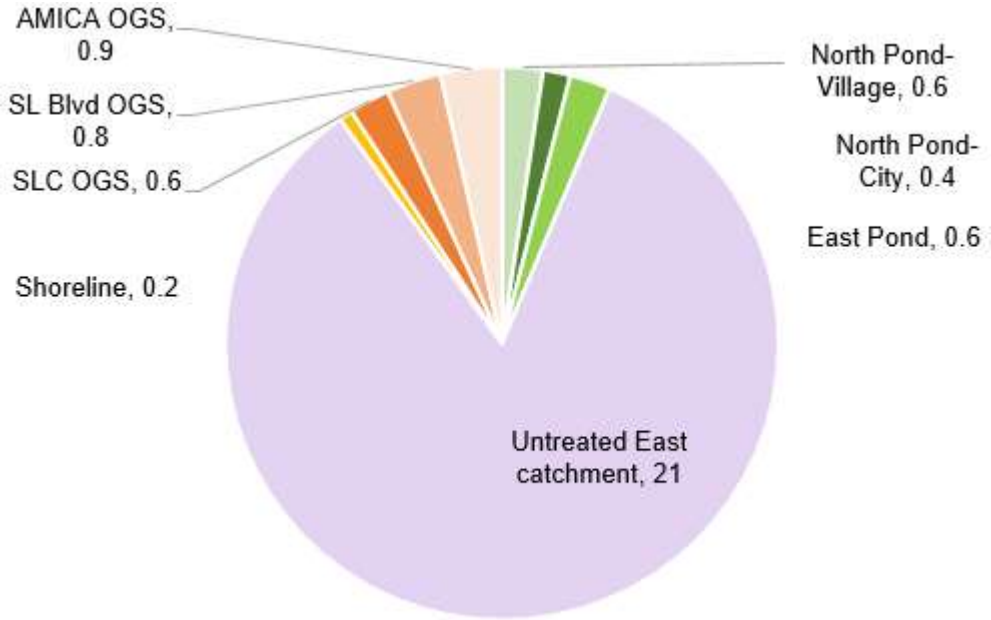
Chloride Budget

- A preliminary chloride budget was developed using available data on chloride concentration and salt usage.

Chloride Input (ton/yr, design drainage)



Chloride Input (ton/yr, blocked inlet)

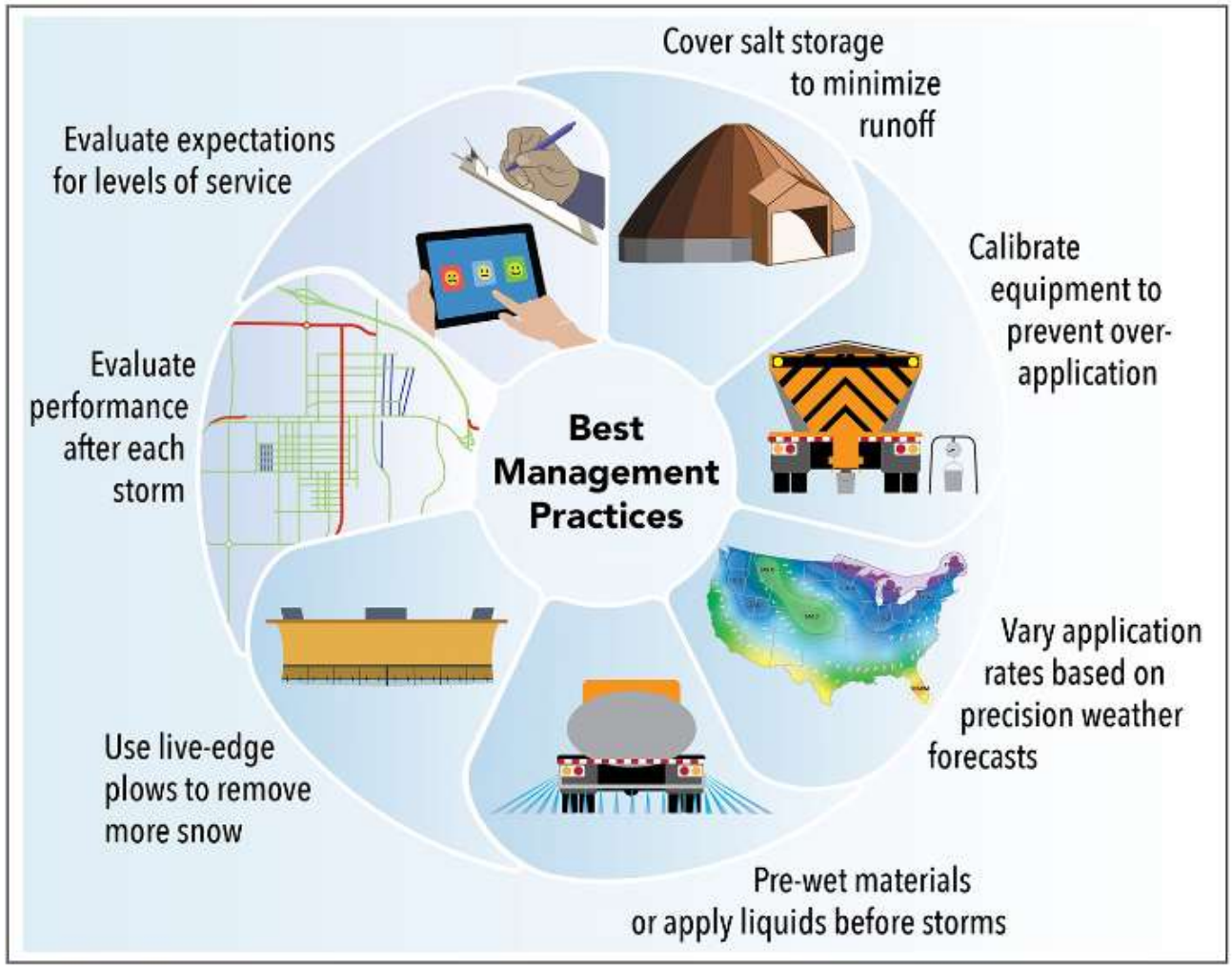


*the park pathways are not salted; shoreline contribution likely from road runoff

Summary- Water Flow and Chloride

- Highest contribution of chloride from untreated runoff (stopped in 2021) followed by Swan Lake Blvd (initial).
- More data to be collected to confirm findings re contributions, impact of cleared inlet, overall concentration in the Lake
- Other short-term measures:
  - Managing the de-icing material application rate and type (e.g., sand and salt mix or other material instead of rock salt)
  - Calibration of salting equipment and monitoring of salt application rates on different surfaces
  - Confirm contribution of each source, develop targets and educational material promoting winter maintenance BMPs
- Next level (if required):
  - Redirecting chloride-laden snowmelt/ runoff and it away from the Lake (i.e., structural modifications, requires detailed study)

Best Management Practices to Curb the Salinization of Freshwater Ecosystems



Source: https://esajournals.onlinelibrary.wiley.com/doi/epdf/10.1002/fee.2433

Review of Friends of Swan Lake Park
"Holistic Approach to Realizing Community Goals"

FOSLP Survey and Interpretation

FOSLP Survey	City's Evaluation
367 residents of the Greensborough area participated in survey completed by FOSLP in February 2021. FOSLP's evaluation states that 'Area residents clearly support a long-term plan that involves investment in sustainable solutions and restoration of the aquatic and land-based habitat'	• The Definition of Community Vision was Premature: conducted before the improvements in 2021 and those planned through the long-term water quality management plan. • Survey population not representative of the City or Ward 5 (Greensborough community, 73% retired). • Costs associated with 'restoration' (i.e. mesotrophic state) not reflected accurately in the survey (shown as $1.5 - $2M over 20 years, vs $12-20M estimated by the City). • Therefore, the definition of 'restoration' as a survey outcome is not valid. • The survey feedback suggested that 86% of respondents use Swan Lake Park primarily for walking. • The community survey identifies a low percentage of all residents having an interest in contact activities such as swimming (12%) and canoeing and kayaking (39%). The percentages are slightly higher in the 'non-retired' population. • More than half of all respondents were interested in more viewing opportunities, while only 13% looked for fishing opportunities.

Vision for Swan Lake Water Quality

FOSLP Proposal	Constraints	City's Goal Statement	City's Plan to Achieve the Goal Statement
Residents Support Environmental 'Restoration' (defined as mesotrophic state) Meets community engagement objectives for lake and park – healthy aquatic and terrestrial habitat • Supports lower-level aquatic life .. • Should reduce dependency on future chemical treatments • Environmental restoration a critical community objective	Mesotrophic Target is not Supported: - According to the City's limnologist, the best achievable outcome of aggressive management for Swan Lake is expected to be borderline meso-eutrophic with respect to phosphorus concentration and hyper-eutrophic for transparency (low due to sediment disturbance in shallow lakes). - Proposed Mesotrophic restoration is not supported	To improve the overall health of Swan Lake, which will provide opportunities for no-contact activities for the enjoyment of the community	• Water quality and shoreline improvement will support a healthier aquatic and terrestrial environment. • Due to the nature of the Lake, chemical treatment will be required in the short term (frequency and dosage adjusted at the end of each Phase).

Swan Lake Environment and Beneficial Uses

FOSLP Proposal	Constraints	Current Opportunities	Future Opportunities
Restoring the 'Original Community Role' by Supporting Contact Level Activities/ Restoration • When safe, lift current restrictions • Lake not accessible due to health risks • Fishing temporarily banned • Traditional fountain removed • Original recreational plans restricted (canoeing, kayaking, ice hockey etc.)	• Contact level activities will require conformance with E-Coli guidelines and the involvement of Public Health, which are not deemed feasible for Swan Lake.	• The Lake supports a large community of small algae-eating fish (10000 fathead minnow in 2021).	• Once the water quality improves, fish stocking and submerged plants will be introduced. • At that point, the City will revisit the fishing ban advisory (no consumption) and re-installation of the fountain.

Swan Lake Park Improvement and Uses

FOSLP Proposal	Constraints	Current Opportunities	Future Opportunities
"Natural Spaces Wildlife Places " Park • Destination to help with mental well being • Area for relaxation, exercise, bird watching • Support wildlife education (aquatic and terrestrial) • Children's playground, low impact recreation	• Swan Lake Park is classified as a Community Park. Any park use is subject to provincial gathering limits and permits. • Large portion not developable for proposed active uses. • Park environment improvements consider local conditions not equivalent to other park sites (e.g., Toogood site accommodates cold water fishery, Provincially-significant wetland, Greenbelt designation)	• Trail upgrades in 2021 provide for a safer walking experience • The Park is currently well-used for low impact recreation by all age groups. • Opportunities for wildlife observations (including bird watching) are currently abundant.	• A Park Refresh project is underway to restore the shoreline focusing on removal of invasive species. The second year of the park refresh program is on schedule to be completed in 2022.

Manipulating Flows and Lake Level

FOSLP Proposal	Constraints	Current Plan	Future Opportunities
Potential to Reduce Stormwater Flows into Markham Village Flood Control Area ; Towards a self-sustaining Swan Lake: • Raise lake level to retain local runoff within the lake • Redirect stormwater from lake to reduce road salt • Retain flood control features of current system • Needs to be validated by technical assessment	The current stormwater management system provides flood protection in the catchment area, and any change may increase flood risk upstream or downstream.	Source control has been determined as the primary means of chloride control in Phase 1.	• Structural change may be considered if other Core and Complementary measures do not achieve the set targets. • An example would be redirecting snowmelt runoff from the Lake. • During Markham Village Project 2 Area design, the role of the Lake and any change in flow patterns can be modelled.

Holistic Approach and Stewardship

FOSLP Proposal	Policy Framework and Improvement Plan	Integration and Stakeholder Engagement
Integrate Markham's Foundation Eco Policies into a Holistic "Eco Park" Strategy for Restoration of Swan Lake 1) Adopt "holistic" Eco Park approach that recognizes improved Community Engagement and Restoration of Swan Lake and Swan Lake Park … 2) Define a process for addressing the missing environmental elements 3) Implement a Stewardship Plan: centralized "holistic" standard that integrates all departmental elements – stormwater management environmental services, park management, park development backed by a long-term undertaking to maintain the standards	• Environmental improvements consider local environmental setting/sensitivities outside OP's Natural Heritage Network. • The 2021 long-term water quality-adaptive approach for setting and achieving targets for the Lake environment for the next 25 years • Improvement of the aquatic habitat • Pond maintenance • Invasive species through shoreline rehabilitation work. • Terrestrial environment: Friends of Rouge Watershed planted 1,000 native wildflowers at Swan Lake Park. • Popular passive recreational uses are supported through trail upgrades • Non-contact uses will expand with quality improvements.	• City departments work closely to maintain and improve the Lake and the Park environment according to the mandate given by the City Council. • Staff will continue to monitor the conditions and consult with the community and stakeholders to adapt the plan accordingly. 

Summary- FOSLP Proposal

Evaluation of FOSLP's Proposal	City's Approach
• Community survey by FOSLP was conducted prior to implementation of ongoing commitments. • Survey represented the Greensborough community and did not include all Ward 5 residents (73% retired). • Survey proposed unattainable water quality conditions and uses. Survey underestimated costs of implementation of 'Restoration' activities. • The survey feedback suggested that 86% of respondents use Swan Lake Park primarily for walking, which is meeting community needs now. • About 40% were interested in canoeing and kayaking, but only 12-13% were looking for fishing or swimming opportunities. • Some of the activities proposed under Vision (e.g., Artists in Park, Cultural Events, and Environmental Camps) are not consistent with the community designation for the Park – amenities / land not available for proposed active park uses.	**Current and Future Opportunities:** ✓ Passive uses of the Park ✓ Improving the health of aquatic and terrestrial habitat ✓ Lake and Park environments are being improved. ✓ A goal for water quality improvement has been defined and community/stakeholder engagement is ongoing. ✓ A long-term water quality improvement plan is approved to support environmental improvements and recreational opportunities, complemented by support of passive recreational uses. **Proposals not supported** : × Mesotrophic target is not supported based on the City's limnologist evaluation. × Manipulating flows and water level are not pursued in Phase 1of the water quality plan. × Reclassification of Swan Lake Park from Community Park to change the intended use.

Recommendations

Recommendations

1. THAT the report entitled "Swan Lake- 2021 Water Quality Status and Updates" be received;

2. AND THAT Staff continue to implement the Long-term Management Plan for Swan Lake approved by Council in December 2021;

3. AND THAT Staff report back annually on water quality results and evaluation of adapted Core and Complementary measures for consideration in Phase 2 of the strategy through the Markham Sub-Committee with the participation of the Friends of Swan Lake Park;

4. AND THAT Staff be authorized and directed to do all things necessary to give effect to this resolution.

Questions?

Report to: Markham Subcommittee Meeting Date: May 11, 2022

SUBJECT: Swan Lake- 2021 Water Quality Status and Updates
PREPARED BY: Robert Muir, Environmental Services, Ext. 2357
Zahra Parhizgari, Environnemental Services, Ext. 2867

RECOMMENDATION:

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4. AND THAT Staff be authorized and directed to do all things necessary to give effect to this resolution.

PURPOSE:

The purpose of this report is to present:

- The 2021 water quality results and evaluation of Core measures implemented in 2021;
- A high-level water flow analysis and chloride budget; and
- A review of the Friends of Swan Lake Park (FOSLP) proposals made under a 'Holistic Approach to Realizing Community Goals'.

BACKGROUND:

On November 16, 2021, Staff provided a report and presentation to the Markham Subcommittee titled Swan Lake Water Quality Management Plan, outlining the history of Swan Lake management activities up to that point and a Long-Term Management Plan for Swan Lake Water Quality for the next 25 years.

With help from our consultant, Staff developed this Plan based on a scientific evaluation of issues and opportunities for lake management and an assessment of several lake management measures designed with input from stakeholders. The stakeholder input included propositions made in FOSLP reports and presentations, "A Holistic Approach to Realizing Community Goals" (November 3, 2021) and "Towards Realizing Community Goals for Water Quality" (November 16, 2021), among others.

Link to the November 16 Subcommittee Report and Swan Lake Long-Term Management

Link to November 16 Subcommittee Meeting Minutes

The Swan Lake Long-Term Management Plan followed an adaptive management approach, through which management activities would be adjusted to maximize benefits and minimize impacts. The Plan's phased approach includes the following components:

- Phase 1: Core Measures for the first five years:
- Phase 2: Adapted Core Measures and Complementary Measures for years six to ten:
- Phase 3: Adapted Core Measures with or without Alternative Measures past year ten

On December 7 and 14, 2021, further deputations were brought by FOSLP to the General Committee and the Council, and the following resolutions were passed:

1. That the minutes and notes of the November 16, 2021 Markham Sub-Committee meeting be received for information purposes; and,
2. That the report entitled "Swan Lake Water Quality Management Plan" be received; and,
3. That Staff implement the Plan presented as Option 1 including proposed Core and new Complementary measures beginning in 2023; and,
4. That an additional $2.35M over 25 years be reflected in the 2022 Lifecycle Reserve Update; and,
5. That an additional $10K be added to the 2022 Budget for geese relocation, and fish management at Swan Lake; and,
6. That staff be given discretion to advance three low-cost programs (<$90k) into Phase 1 (initial 5 years), including:
    i) Research into chloride solutions
    ii) Planting submerged plants
    iii) Incorporation of the fish management plan and fish stocking
7. That Staff report back annually on water quality results and evaluation of adapted Core and Complementary measures for consideration in Phase 2 of the strategy through the Markham Sub Committee with the participation of the Friends of Swan Lake Park in today's presentation and other concerns, including high level lake water flow analysis; and,
8. That staff report back to the Markham Sub Committee within the next 6 months (before the end of June) to discuss suggestions in Friends of Swan Lake Park in today's presentation and other concerns that have arisen; and further,
9. That staff be directed to consider longer-term actions to achieve and maintain restoration; and further,
10. That Staff be authorized and directed to do all things necessary to give effect to this resolution.

Link to December 7, General Committee Meeting Minutes

Link December 14 to Council Meeting Minutes

The following Discussion presents 2021 Water Quality Results and High Level Water Flow Analysis to address resolution 7 above. The Discussion also evaluates suggestions by FOSLP and longer–term actions to achieve restoration, specifically the FOSLP "Holistic Approach to Realizing Community Goals", to address resolutions 8 and 9.

DISCUSSION:

2021 Water Quality Results and Evaluation of Implemented Core Measures

The Phase 1 Core Measures completed in 2021 include:

- Annual monitoring
- Enhanced geese management
- Fish management
- Chemical treatment
- Pond maintenance

Staff collected water quality data through the Swan Lake monitoring program from January to November 2021. These data provide insight into long-term trends in water quality and help determine the need for and impact of chemical treatment of Swan Lake (see Attachment A).

Contractors completed Geese management by chasing geese with border collies, oiling eggs and managing nests, and by relocation of geese in the spring. Hazing frequency was modified from previous years to focus on the migration seasons. The increased hazing frequency (starting on September 1) effectively reduced the number of geese present at different times of the day to about 50% of the geese numbers in 2020.

A fish inventory and removal campaign was completed to remove bottom-dwelling fish, which could interfere with the chemical treatment efficacy. Only three fish species were caught in the Lake through this intensive effort: Common Carp (non-native), Brown Bullhead, and Fathead Minnow. Of these, only Fathead Minnow was found in abundant numbers and this main fish species was left in Swan Lake.

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

The management activities in 2021 focused on the significant nutrient loadings identified in the Long-Term Plan (i.e., PAC treatment to reduce internal loads from the lake bottom and geese management to reduce external loads). These activities effectively improved water quality in the Lake and represent a positive step toward improving the aquatic habitat and meeting the long-term water quality goals.

Based on the measured Secchi desk transparency and nutrient concentrations in 2021, Swan Lake is classified at a low-eutrophic condition post-treatment. Monitoring in 2022 (the first complete post-treatment year) will provide more conclusive information about the efficacy of PAC treatment and other implemented Core measures.

In December 2021, at the City's request, Daniels Group cleared the northern inlet to the East Pond. This inlet was blocked for a few years, releasing untreated runoff to the Lake.

High Level Water Flow Analysis and Chloride Budget

In 2019, the City developed a PCSWMM model (which is an advanced modeling software for stormwater systems) to estimate the volume of water flowing through different catchments, in the pipes and overland to various stormwater controls and eventually to the Lake. The model has been refined since it was first developed to reflect the site conditions more accurately.

The intended use of the PCSWMM model was to develop a high-level estimate of the various catchment contributions to the total runoff into Swan Lake. The model has not been calibrated with flow monitoring data, as this information was not available for the simulation period. Thus, the runoff output from the current model represents a high-level simulated runoff estimate, which is adequate for approximating concentration inputs to the Lake. This model is not intended to analyze the impact of flow diversion on peak flows downstream or upstream of the Lake.

The model was run continuously for the period since 2009, and monthly results were used in the analysis of nutrient loads (in the Long-Term Plan). It is also being used to estimate chloride loads from different catchment areas (see Attachment B).

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

In Swan Lake, average chloride concentrations have increased over the years to values above applicable guidelines for the protection of aquatic life. In response, the City has started collecting runoff samples and salt usage data (from the City's Road department and the Swan Lake Village/AMICA management). These data are used to quantify chloride loads and determine the relative contribution of each catchment area to identify the most efficient strategy for reducing chloride loading to the Lake.

The analysis found that chloride loading from the untreated runoff from the East Pond catchment (caused by a blocked inlet) was the main contributor to the Lake concentrations. The blocked inlet was cleared in December 2021, and it is expected that chloride concentrations in the Lake will gradually decrease through the replacement of Lake water with cleaner runoff.

Based on concentrations measured in front of the outfall to the Lake, Swan Lake Blvd. may have a high chloride contribution. This load may also contribute to locally-high readings at the Dock sampling station relative to the overall Lake conditions (allowing the Lake to support a large community of minnows). These theories will need to be confirmed with more samples, as well as the monitoring of salt application rates on the boulevard.

Consistent with the recommendations of the Swan Lake Long-Term Management Plan, it is recommended to collect more data (chloride concentrations, salt usage data, fish population) and explore measures to reduce chloride load before investing in costly investigations of structural changes required to adjust the existing water flow patterns, e.g., through diversions.

Review of FOSLP Holistic Approach

On November 3, 2021, the Friends of Swan Lake Park provided a presentation to the City entitled "A Holistic Approach to Realizing Community Goals". This presentation was later expanded and presented to the Markham Subcommittee on November 16, 2021, titled "Towards Realizing Community Goals for Water Quality". The presentation includes suggested longer-term actions to achieve and maintain restoration of the park and lake, including expanded uses.

Staff responded to FOSLP regarding these presentations in a memo on March 3, 2022 (See Attachment C). As noted in the March 2022 memo, many of the suggested ideas and measures proposed in the FOSLP presentations are being advanced under the City's approved and ongoing activities, including:

- Passive uses of the Park
- Improving the health of the aquatic and terrestrial habitat
- Improving Lake and Park environments
- Definition of a goal for water quality improvement
- Community/stakeholder engagement
- A long-term water quality improvement plan to support environmental improvements and recreational opportunities

Some ideas and measures in the FOSLP proposal are not supported by staff, including:

- Mesotrophic target
- Manipulating flows and water level

The ideas in the FOSLP proposal have been put forward to achieve goals defined based on a community survey conducted by FOLSP in February 2021. However, this definition of a community vision was considered by Staff to be premature and had several limitations, as the community survey:

- did not represent all Ward 5 residents, nor all demographics;
- was conducted prior to the implementation of ongoing commitments;
- proposed unattainable water quality conditions such as a 'mesotrophic' condition that is not supported based on the City's limnologist evaluation;
- underestimated the costs of implementation of 'Restoration' activities.

With respect to activities in the Park, the survey suggested that most respondents use Swan Lake Park primarily for walking which is meeting community needs today. Some of the activities proposed (e.g., Artists in Park, Cultural Events, and Environmental Camps) will require amenities not available in the Park (e.g., parking spaces, washrooms) and are inconsistent with uses within designated Community Parks and available development space for active uses. Other ideas, such as assessing habitat and identifying actions for "other wildlife" are more appropriate within the City's designated Natural Heritage Network (excludes Swan Lake Park).

Based on this review of the FOSLP proposal, and given that suggested ideas and measures with technical merit are currently being advanced, it is recommended that Staff continue to implement the Long-term Management Plan for Swan Lake approved by Council in December 2021 and report back annually on water quality results, including the evaluation of adapted Core and Complementary measures for consideration in Phase 2 of the strategy through the Markham Sub-Committee with the participation of the Friends of Swan Lake Park.

FINANCIAL CONSIDERATIONS:

No financial impact.

HUMAN RESOURCES CONSIDERATIONS:

Not applicable.

ALIGNMENT WITH STRATEGIC PRIORITIES:

This report aligns with the areas of strategic focus as follows:

- Safe, Sustainable, & Complete Community: the proposed strategy will support the enhancement of the natural environment and built form through sustainable integrated planning, infrastructure management and services.
- Stewardship of Money & Resources: the strategy proposed will provide a reasonable cost-effective level of service.

BUSINESS UNITS CONSULTED AND AFFECTED:

Not applicable.

RECOMMENDED BY:

Eddy Wu,
Director, Environmental Services

Morgan Jones,
Commissioner, Community Services

ATTACHMENTS:

Attachment A- 2021 Water Quality Report

Attachment B- High Level Water Flow Analysis

Attachment C- Markham Review of FOSLP Holistic Approach

ATTACHMENT A- 2021 WATER QUALITY REPORT

ATTACHMENT B- HIGH LEVEL WATER FLOW ANALYSIS

ATTACHMENT C- MARKHAM REVIEW OF FOSLP HOLISTIC APPROACH

Swan Lake Water Quality Monitoring 2021 Annual Report

March 2022

Project Number: 21163

MARKHAM

Environmental Services

Prepared By:

Zahra Parhizgari, M.Sc., P.Eng.
Senior Environmental Engineer,
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Reviewed By:

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

Executive Summary

Background

Swan Lake is situated in the City of Markham at the intersection of Sixteenth Avenue and Williamson Road. Swan Lake has an approximate area of 5.5 ha and a maximum water depth of 4.5 m. 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 which was 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.

A long-term Management Plan was received by the Markham Sub Committee in November 2021 and approved by the Council in December 2021, including provisions for chemical treatment every three years.

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

This report discusses observations at the three monitored stations throughout 2021. A separate report evaluates the impact of the 2021 chemical treatment on water quality in Swan Lake.

Results

Water quality is regularly monitored at two shoreline sites; the Dock, and the Bridge. Water quality is monitored bi-weekly throughout the summer (May-September) and monthly in the spring (April) and fall (October-November). Samples and measurements are taken at 0.5 m increments for the depth of the lake. A level logger is used to record the water level in the Lake.

Additional testing completed in 2021 included:

- Pre-treatment (January and March) and post-treatment (September to November) monitoring at the deepest part of the Lake (Central station)
- Monitoring of different treatment zones during treatment (August)

The following paragraphs provide the monitoring results for the 2021 monitoring period, as well as annual summaries of available data from 2011 to 2021. The respective figures include plots of measured dissolved oxygen (DO), water clarity, phosphorus concentration, chloride concentration, geese count, and algae.

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

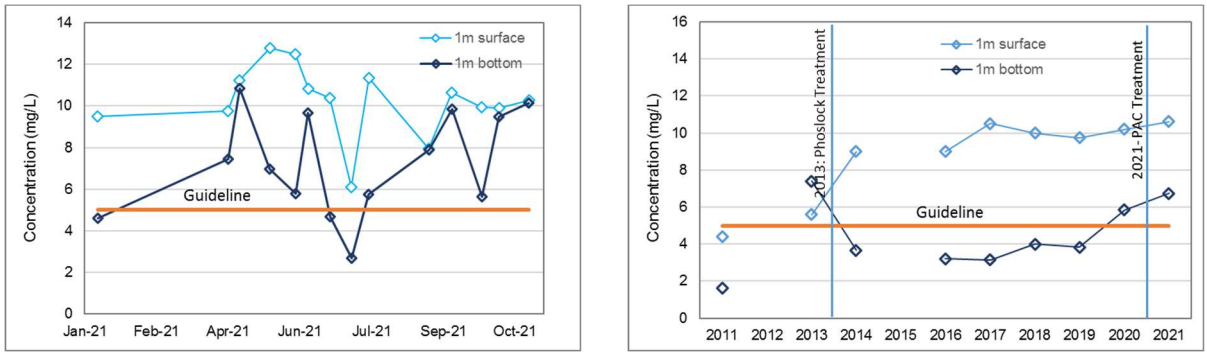
Dissolved Oxygen (DO), Temperature and pH

The minimum dissolved oxygen concentration required for the protection of warm water fish is 5 mg/L for water temperatures up to 20 °C and 4 mg/L for temperatures above 20 °C. DO concentrations for the 1m from the surface, and 1m from the bottom layers are shown below. Measured surface concentrations were above the DO guideline throughout 2021. DO concentration at 2 m increased significantly in August, but remained low at 2.5 m.

During the summer, the Lake was stratified with occasional mixing (resulting in similar surface and deep water concentrations). In the fall, the layers were mixed and similar concentrations were observed over depth.

When stratified, bottom concentrations were below the DO guideline thresholds. 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, and oxygen levels nearer to the surface remained above the minimum guideline.

Figure ES-2: 2021 Monitoring Results and 2011-2021 Annual Results- Dissolved Oxygen



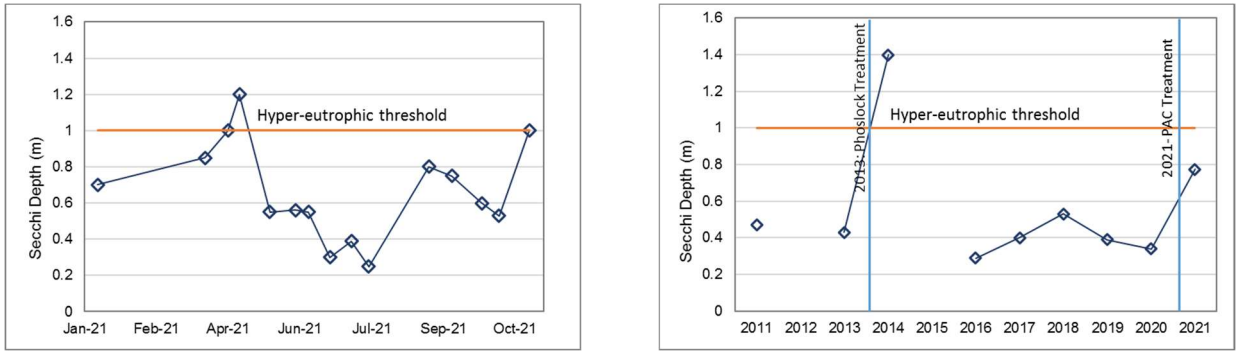
Note 1: DO concentrations are shown at 1 m from the surface and 1 m from bottom.
Note 2: Histotical data are shown for the average growing period.

pH measured at the lab ranged from 7.9 to 8.5 before the chemical treatment and 7.4 to 8.2 following the treatment.

Water Clarity (Secchi Depth)

Secchi depth represents water clarity, which declines when algae level increases. In the trophic state classification scheme, growing period average water clarity of under 1 m is the threshold for a hyper-eutrophic condition. In 2021, water clarity was under 0.5 m at the beginning of June, but increased to up to 1.2 m in August following chemical treatment..

Figure ES-3: 2021 Monitoring Results and 2011-2021 Annual Results- Secchi Depth

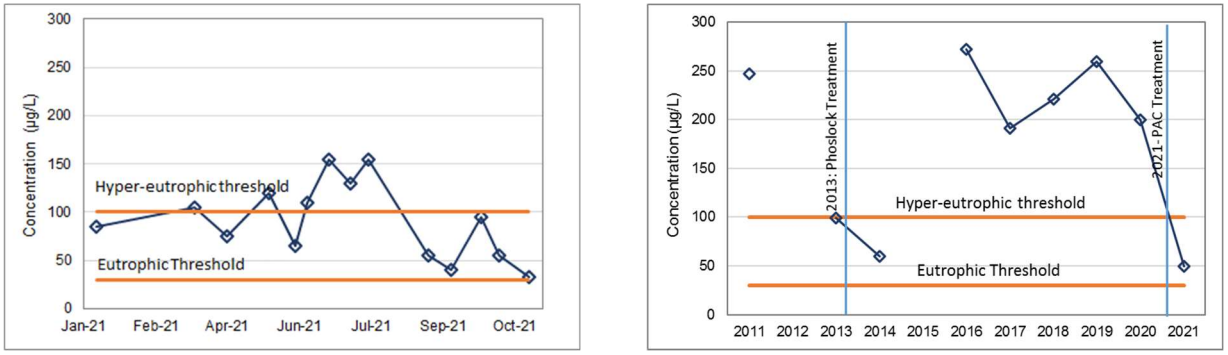


Phosphorus and Nitrogen Concentrations

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

Phosphorus concentrations above 100 µg/L represent a hyper-eutrophic condition, which entails high nutrient concentrations leading to high algae concentrations. Total phosphorus concentration in the top 1 m depth averaged at above 100 µg/L before the chemical treatment (March-July). The concentrations over the growing season (June-July) averaged about 140 µg/L (above the 100 µg/L threshold for a hyper-eutrophic condition) before dropping to about 50 µg/L after treatment.

Figure ES-1: 2021 Monitoring Results and 2011-2021 Annual Results- Total Phosphorus



Note 1: The 2021 values are averages of samples collected at 0.5 and 1.5 m from surface (1.5 m values are missing for mid-May to m0d-July).
Note 2: Annual concentrations are summaries of the growing period.
Note 3: The interim target shown is based on the water quality improvement strategy report (July 2020), and applies to the average over two consecutive years.

Total nitrogen concentrations over the growing season averaged about 2.39 mg/L before the chemical treatment to about 1.0 mg/L after treatment (below the 1.2 mg/L threshold for a hyper-eutrophic condition). In 2021, ammonia and nitrate concentrations (the forms available for uptake by biota) were generally very low, and nitrogen was mainly present as organic matter.

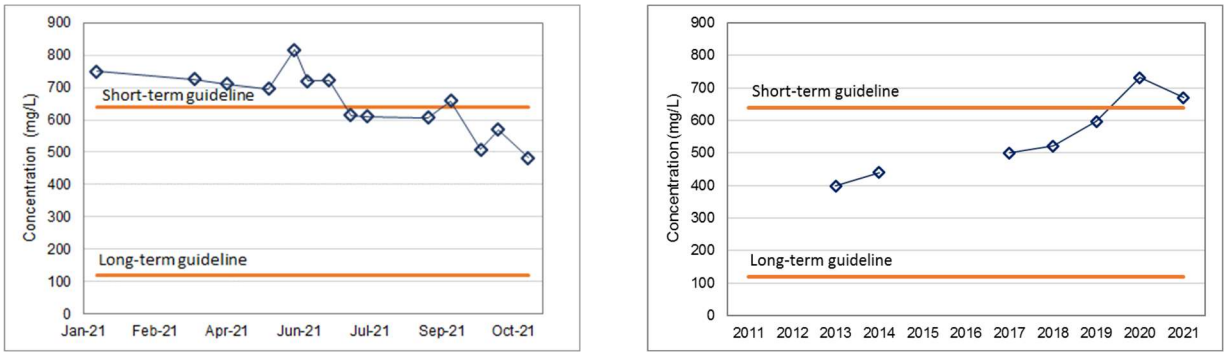
Chloride Concentration

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

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

Chloride concentrations have been increasing in Swan Lake over the past few years, and the long-term management plan for the Lake discusses practical approaches to manage this increase.

Figure ES-4: 2021 Monitoring Results and 2011-2021 Annual Results- Chloride



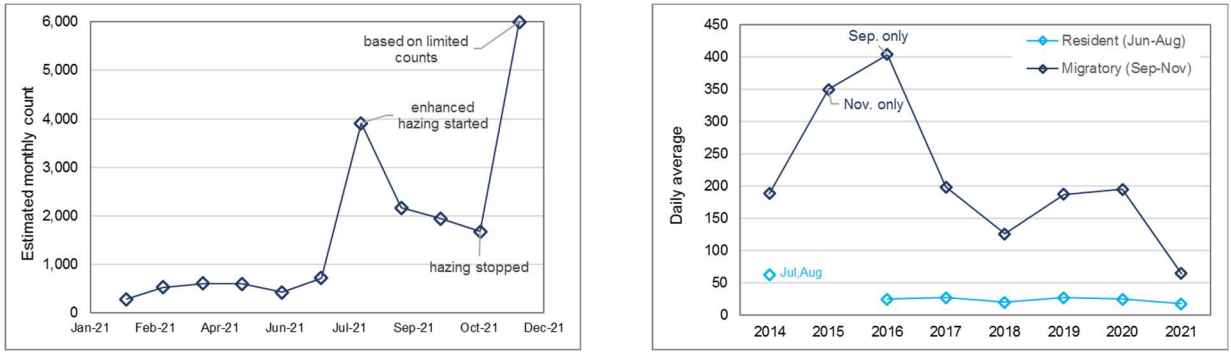
Geese Count

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

The 2021 program included an expanded hazing program starting in September, nest management and geese relocation, the installation of nine strobe lights on the Lake and adjacent stormwater ponds, and a volunteer-based geese count program.

In 2021, there was a significant decrease in the count of migratory geese as a result of increased hazing efforts. The strobe lights did not have any noticeable impact on the counts. The volunteer geese count effort resulted in the collection of a significant amount of data, which helps provide more certainty in the results, and was used to better time hazing efforts.

Figure ES-5: 2021 Monitoring Results and 2011-2021 Annual Results- Geese Count



Note 1: 2021 data are the sum of counts in each month, compensated for days with no count.
Note 2: Annual data are daily averages of counts over June-August and September to November, representing resident and migratory geese, respectively.

Algal Blooms and Cyanobacteria

In 2021, surface scums were observed along the shoreline around the Dock, as well as in the northern bay at the Bridge site.

Samples were collected before and after chemical treatment in 2021 and sent to the laboratory for phytoplankton and cyanobacteria. Test results are discussed in a report on chemical treatment evaluation.

Several algal blooms with potentially toxic cyanobacteria were observed in years before 2011; however, testing completed before 2011 and following treatment (2013-2016) did not detect any Microcystin in the water. In 2016, a bloom was tested and resulted in a Microcystin concentration of 73 µg/L. Extended blooms were observed at several sites in 2018; however, cell density was at half of WHO's threshold for significantly increased human health risk. These results suggest that in most years, toxin-producing cyanobacteria are not the dominant form of phytoplankton present in Swan Lake.

Summary and Recommendations

Based on the measured Secchi desk transparency and nutrient concentrations, Swan Lake was classified as low eutrophic in the post-treatment period in 2021.

In 2019, the City initiated a study to define a water quality management strategy for Swan Lake. The strategy was finalized in July 2020. The strategy which was 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. A long-term Management Plan was received by Markham Sub Committee in November 2021 and approved by the Council in December 2021, including provisions for chemical treatment every three years, and enhanced geese management.

The 2022 monitoring program will follow the recommendation of the long-term water quality management report and will include the annual monitoring program, as well as enhanced monitoring to determine the effectiveness of the proposed chemical application.

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

Table of Contents

Appendices

Tables

Figures

1. Introduction

Swan Lake is situated in the City of Markham at the intersection of Sixteenth Avenue and Williamson Road, as shown below in Figure 1. Swan Lake has an approximate area of 5.5 ha and a maximum water depth of 4.5 m (from the deepest point to the Lake edges). Formerly 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 which was finalized in July 2020 recommended chemical treatment starting in 2021. In August 2021, 13 tonnes of Poly Aluminum Chloride (PAC) were applied to the Lake in a controlled manner over several days.

A long-term Management Plan was received by Markham Sub Committee in November 2021 and approved by the Council in December 2021, including provisions for chemical treatment every three years.

Water quality monitoring of Swan Lake has been conducted annually since treatment in 2013 in order to track water quality and the continued effectiveness of the Phoslock. The 2021 monitoring results presented in this report are part of the ongoing monitoring program that will allow for continuous assessment of the water quality in Swan Lake and will help establish a long-term plan for the treatment of Swan Lake.

Figure 1: Swan Lake Location and Monitoring Stations

2. Water Quality

2.1 Monitoring Program

2.1.1 Locations

Water quality was monitored at two shoreline sites, the Dock, and the Bridge, and at the deepest part of the Lake, the Central station, as shown in Figure 1. The water depth at the dock is approximately 2.5-3 meters, which allows it to represent Swan Lake as a whole. 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. Field testing and sampling for laboratory analysis were completed at both sites to ensure the water conditions at Swan Lake were properly represented.

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

The horizontal sampler was damaged in mid-May and until a replacement was obtained in mid-July, surface water samples were collected using a bucket at both sites.

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

2.1.2 Duration and Frequency

In 2021, water quality was monitored bi-weekly throughout the summer (May-September) and monthly in the spring (April) and fall (October-November).

Additional testing completed in 2021 included:

- Pre-treatment (January and March) and post-treatment (September to November) monitoring at the deepest part of the Lake
- Monitoring of different treatment zones during treatment (August)

A total of 24 sampling events were completed.

2.1.3 Parameters and Methodology

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

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

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

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

- Nutrients including total and ortho phosphorus, ammonia, nitrate, Total Kjeldahl Nitrogen (TKN)
- Chloride, color, Dissolved Organic Carbon (DOC), pH
- Alkalinity, aluminum, calcium, iron, magnesium, sulphate
- Chlorophyll a

Observations of Swan Lake were noted, and photographs were taken during each monitoring/inspection site visit. Photographs provide a way to record the condition of vegetation and algae around Swan Lake. Completed inspection forms can be found in Appendix A. All photographs from the 2021 monitoring period are provided in Appendix B.

2.1.4 Targets and Thresholds

The 2019 water quality improvement study proposed a set of interim targets for Swan Lake to be used as triggers for management actions if the triggers are tripped in two consecutive years. Numerical values were defined for total phosphorus (100 µg/L) and Secchi depth (0.45 m).

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

Table 1: Eutrophic State Classification

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

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

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

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

Total and dissolve aluminum were monitored this year to determine any impact of PAC application on aluminum concentration in Lake water.

For Cyanotoxins, the Health Canada guideline for recreational activities is 20 µg/L[3].

[1] Canadian Council of Ministers of the Environment (CCME) Water Quality Guidelines for the Protection of Aquatic Life (http://ceqg-rcqe.ccme.ca/en/index.html)
[2] Ontario Provincial Water Quality Objectives or PWQO (https://www.ontario.ca/page/water-management-policies-guidelines-provincial-water-quality-objectives#section-13)
[3] Health Canada, 2012. Guidelines for Canadian Recreational Water Quality, Third Edition. Water, Air and Climate Change Bureau, Healthy Environments and Consumer Safety Branch, Ottawa, Ontario.

2.2 2021 Water Quality Results

The following sections discuss observations at the three monitored stations (Dock, Bridge, and Central) throughout 2021. A separate report evaluates the impact of the 2021 chemical treatment on water quality in Swan Lake.

2.2.1 Dissolved Oxygen and Temperature

Table 2 provides the measured DO profile over the 2021 monitoring period.

At the Dock station, surface concentrations were above 5 mg/L throughout 2021. Below 2 m depth, the DO was under 2 m/L in most of the sampling events from late May through July, indicating anoxic conditions. DO concentration at 2 m increase significantly in August, but remained low at 2.5 m. All but one measurements at the Bridge indicated a DO concentration of above 2 mg/L, with most being above or close to 4 mg/L.

Table 3 provides the measured temperature profile in 2021, indicating warm water throughout the depth in the summer months.

Profiles of temperature and dissolved oxygen (see Figure 2) indicate that Swan Lake is thermally stratified during May and July despite its shallow depth. The separation of water layers is evident during the summer months as DO decreases very drastically as water depth increases.

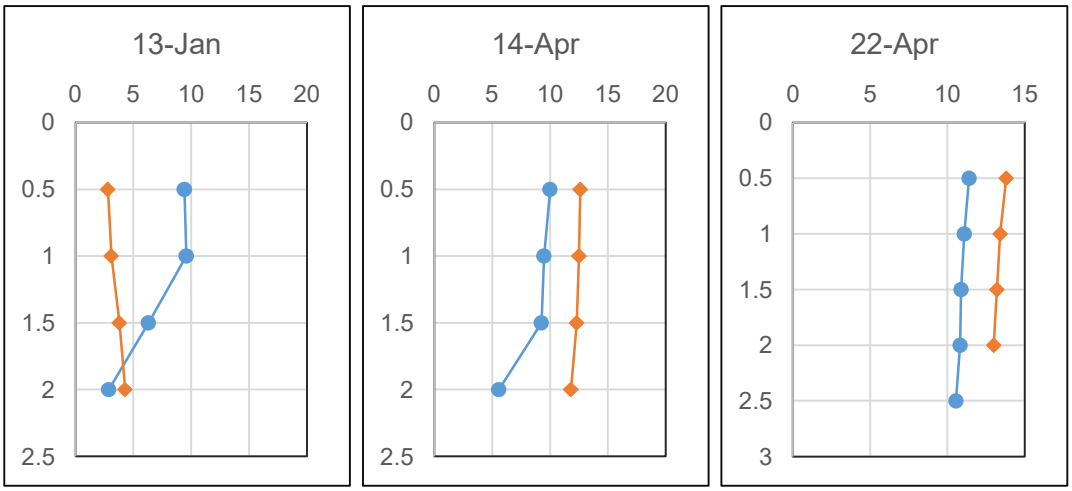
Table 2: Measured DO Profile (mg/L)

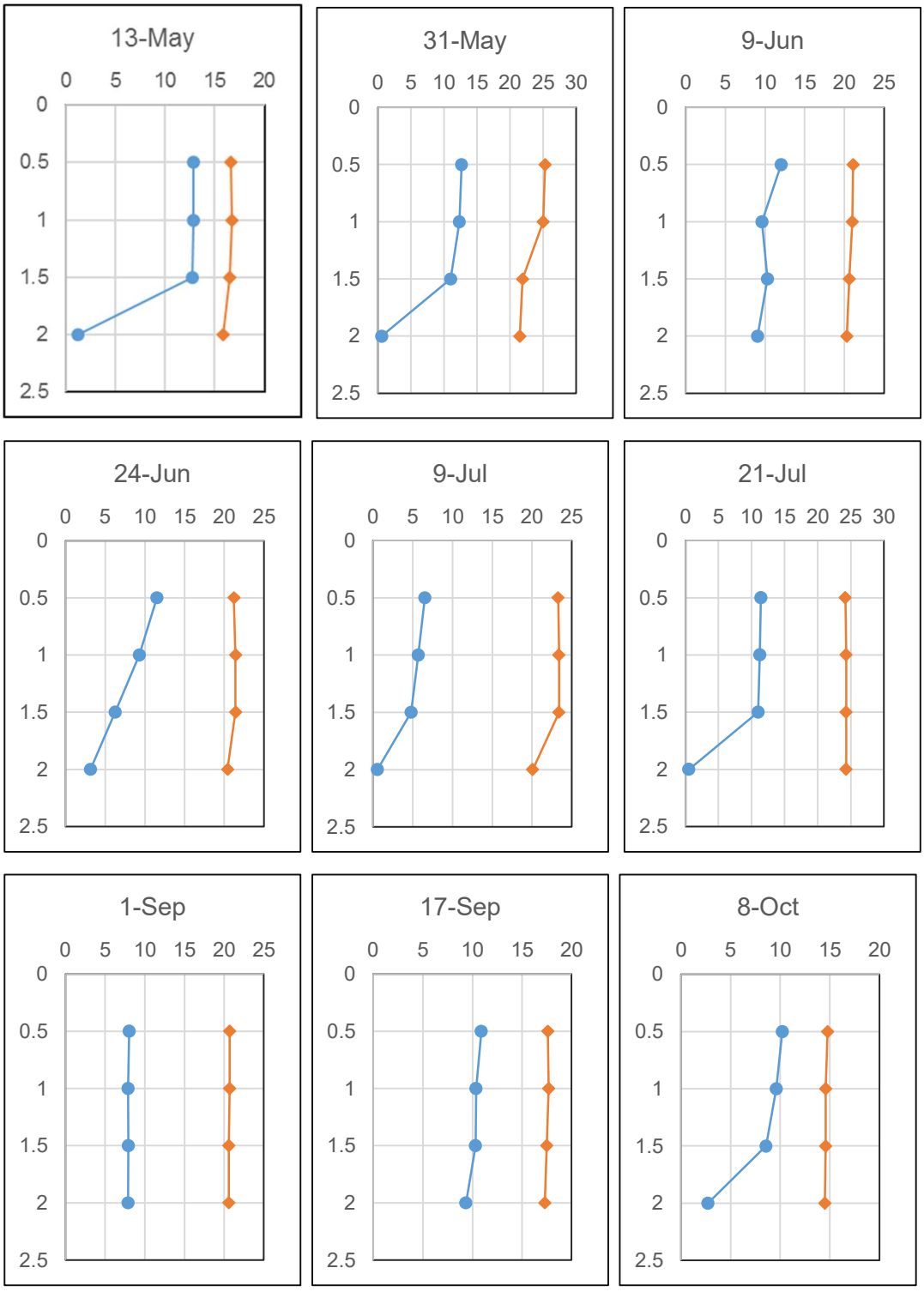
	Bridge	Dock				Central			
	Depth (m)	Depth (m)				Depth (m)			
Date	0.5	0.5	1	1.5	2	0.5	1.5	2.5	3
1/13/2021	-	9.4	9.6	6.3	2.9	-	-	-	-
3/29/2021	-	-	-	-	-	11.0	11.4	11.0	-
4/14/2021	8.5	10.0	9.5	9.3	5.6	-	-	-	-
4/22/2021	-	11.4	11.1	10.9	10.8	-	-	-	-
5/13/2021	9.8	12.8	12.8	12.7	1.3	-	-	-	-
5/31/2021	7.6	12.6	12.3	11.0	0.6	-	-	-	-
6/9/2021	1.8	12.0	9.6	10.3	9.0	-	-	-	-
6/24/2021	3.7	11.5	9.3	6.2	3.1	-	-	-	-
7/9/2021	2.3	6.5	5.7	4.8	0.6	-	-	-	-
7/21/2021	5.3	11.4	11.3	11.0	0.5	-	-	-	-
8/23/2021	-	-	-	-	-	6.3	7.3	1.9	1.0
9/1/2021	3.1	8.0	7.9	7.9	7.9	-	-	-	-
9/7/2021	-	-	-	-	-	10.4	9.2	1.3	-
9/17/2021	5.0	10.9	10.4	10.3	9.4	-	-	-	-
9/29/2021	-	-	-	-	-	7.8	8.3	7.5	-
10/8/2021	3.7	10.2	9.6	8.6	2.7	-	-	-	-
10/14/2021	-	-	-	-	-	10.8	9.2	0.1	-
10/20/2021	5.9	10.0	9.8	9.7	9.3	-	-	-	-
10/28/2021	-	-	-	-	-	10.3	9.8	4.2	-
11/10/2021	8.3	10.3	10.2	10.1	10.2	-	-	-	-

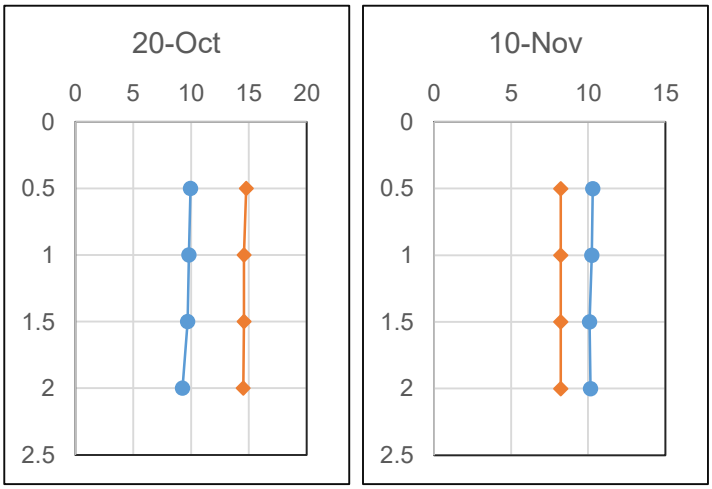
Table 3: Measured Temperature Profile (°C)

	Bridge	Dock				Central			
	Depth (m)	Depth (m)				Depth (m)			
Date	0.5	0.5	1	1.5	2	0.5	1.5	2.5	3
1/13/2021	-	2.8	3.1	3.8	4.3	-	-	-	-
3/29/2021	-	-	-	-	-	8.2	8.3	8.0	-
4/14/2021	14.0	12.6	12.5	12.3	11.8	-	-	-	-
4/22/2021	-	9.1	9.1	9.1	9.1	-	-	-	-
5/13/2021	13.2	13.8	13.4	13.2	13.0	-	-	-	-
5/31/2021	15.2	16.6	16.7	16.5	15.8	-	-	-	-
6/9/2021	24.5	25.3	25.0	21.9	21.5	-	-	-	-
6/24/2021	19.8	21.1	21.0	20.6	20.3	-	-	-	-
7/9/2021	20.0	21.2	21.4	21.4	20.4	-	-	-	-
7/21/2021	22.5	23.3	23.4	23.4	20.1	-	-	-	-
8/23/2021	-	-	-	-	-	27.7	-	22.3	23.4
9/1/2021	21.9	24.2	24.3	24.3	24.3	-	-	-	-
9/7/2021	-	-	-	-	-	22.0	21.4	21.1	-
9/17/2021	19.6	20.7	20.7	20.6	20.6	-	-	-	-
9/29/2021	-	-	-	-	-	18.3	18.2	17.2	-
10/8/2021	17.2	17.6	17.7	17.5	17.3	-	-	-	-
10/14/2021	-	-	-	-	-	19.2	18.7	17.3	-
10/20/2021	13.6	14.8	14.6	14.6	14.5	-	-	-	-
10/28/2021	-	-	-	-	-	10.8	10.8	11.2	-
11/10/2021	8.2	8.2	8.2	8.2	8.2	-	-	-	-

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

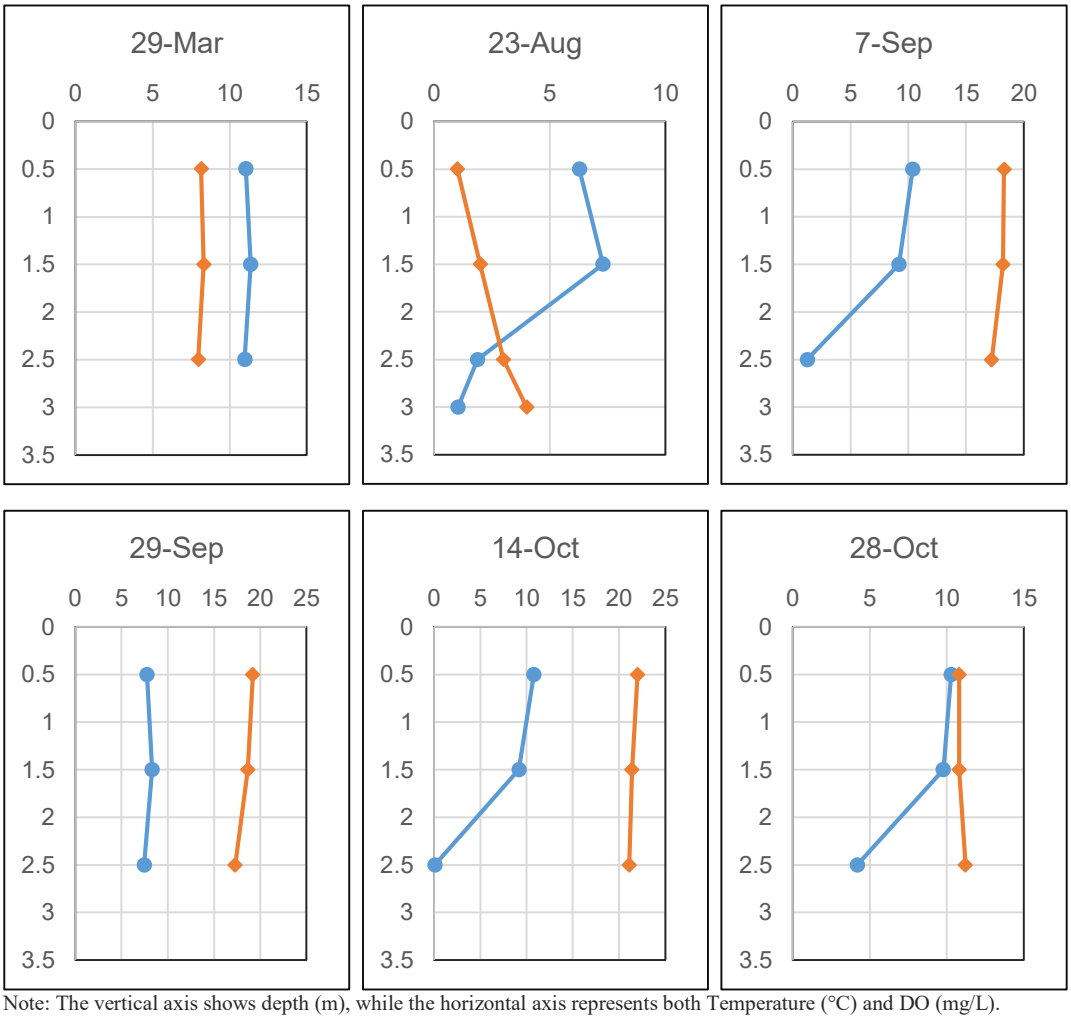



13-May
0 5 10 15 20
0 0.5 1 1.5 2 2.5
31-May
0 5 10 15 20 25 30
0 0.5 1 1.5 2 2.5
9-Jun
0 5 10 15 20 25
0 0.5 1 1.5 2 2.5
24-Jun
0 5 10 15 20 25
0 0.5 1 1.5 2 2.5
9-Jul
0 5 10 15 20 25
0 0.5 1 1.5 2 2.5
21-Jul
0 5 10 15 20 25 30
0 0.5 1 1.5 2 2.5
1-Sep
0 5 10 15 20 25
0 0.5 1 1.5 2 2.5
17-Sep
0 5 10 15 20
0 0.5 1 1.5 2 2.5
8-Oct
0 5 10 15 20
0 0.5 1 1.5 2 2.5



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

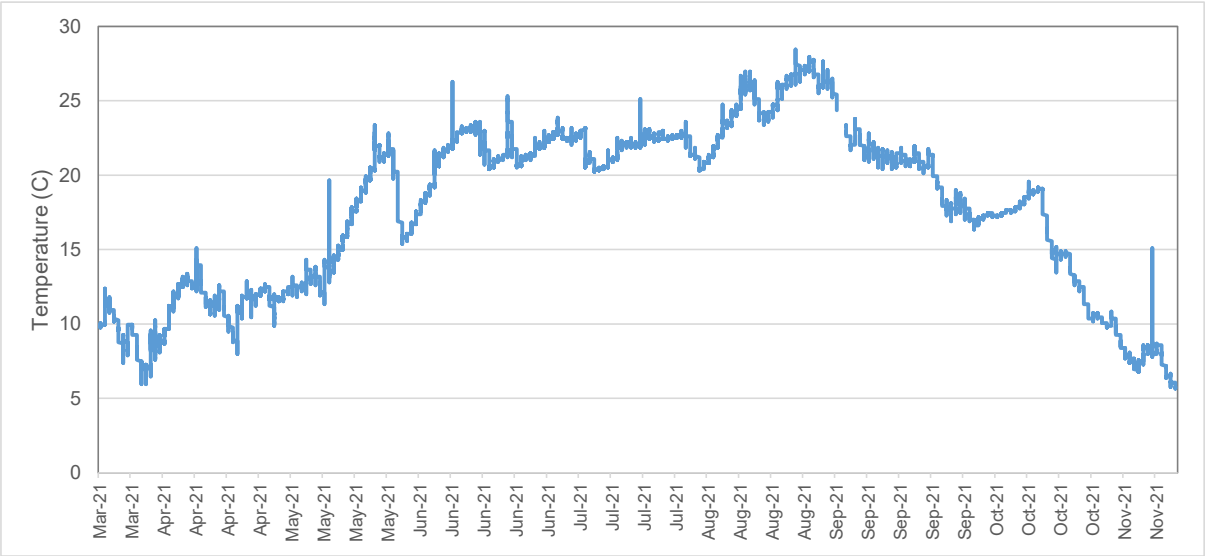
Figure 3: Temperature (orange) and DO (blue) Profile at the Cental Station



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

Water temperature was also recorded by the level/temperature logger installed at the Dock station. The probe was located at 1 m from the Lake bed. Figure 4 provides recorded temperature at 15-min intervals. Water temperature was lower in 2021 relative to 2020.

Figure 4: Temperature Recorded by the Level/Temperature Logger at the Dock Station (1m from bottom)



2.2.2 Water Transparency

Table 4 summarizes the results of the water transparency readings. Transparency at the Dock station was under 0.5 m at the beginning of June but increase to up to 1.2 m in August following chemical treatment.

Table 4: 2021 Secchi Depth Results (m)

Date	Dock	Bridge	Central
13-Jan	0.7		
29-Mar	0.85		0.5
14-Apr	1	0.62	
22-Apr	1.2		
13-May	0.55	0.54	
31-May	0.56	0.51	
9-Jun	0.55	0.41	
24-Jun	0.3	0.4	
9-Jul	0.39	0.26	
21-Jul	0.25	0.26	
23-Aug			1.2
1-Sep	0.8	0.55	
7-Sep			0.7
17-Sep	0.75	0.64	
29-Sep			0.7
8-Oct	0.6	0.4	
14-Oct			0.75
20-Oct	0.53	0.53	
28-Oct			0.8
10-Nov	1	0.52	

2.2.3 pH

On-site measurements of pH in 2019 and 2020 were very high and therefore were investigated through lab analysis for pH in 2021. pH measured at the lab ranged from 7.9 to 8.5 before the chemical treatment and 7.4 to 8.2 following the treatment.

2.2.4 Nutrients Concentrations

Samples collected during each visit were transported to Caduceon Environmental Laboratories and tested for Total Phosphorus, Phosphate, Total Kjeldahl Nitrogen, Nitrate, and Ammonia.

The results can be found in Figure 5 for the Dock site and Figure 6 for the Bridge site. The Certificate of Analysis from Caduceon Environmental Laboratories in Appendix C.

Nutrient concentrations are shown for the depths sampled.

Total phosphorus concentration in the top 1 m depth averaged at above 100 µg/L before the chemical treatment (March-July). The concentrations over the growing season (June-July) averaged about 140 µg/L (above the 100 µg/L threshold for a hyper-eutrophic condition) before dropping to about 50 µg/L after treatment.

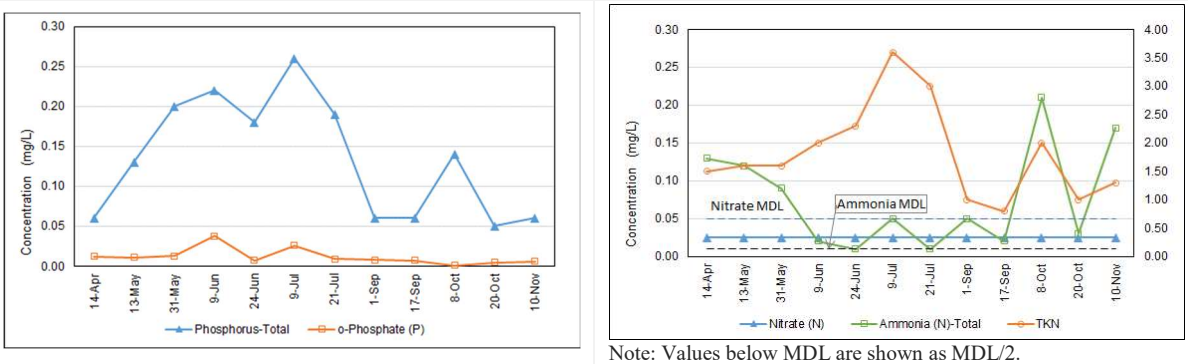
Nitrogen concentration was analyzed in terms of Total Kjeldahl Nitrogen (TKN), Ammonia (NH_3) and Nitrate (NO_3). Total nitrogen concentrations over the growing season averaged about 2.39 mg/L before the chemical treatment to about 1.0 mg/L after treatment (below the 1.2 mg/L threshold for a hyper-eutrophic condition). Before and after concentrations at the Bridge site were 2.77 mg/L and 0.96 mg/L, respectively.

Ammonia and nitrate are the forms that are directly bioavailable, with ammonia being the most usable form for algae. In 2021, Ammonia and Nitrate concentrations were generally close to or below Method Detection Limit (MDL), and nitrogen was mainly present as organic compounds (i.e., TKN less Ammonia) with the exception of spring samples.

Figure 5: Measured Nutrients Concentrations in 2021 - Dock Site

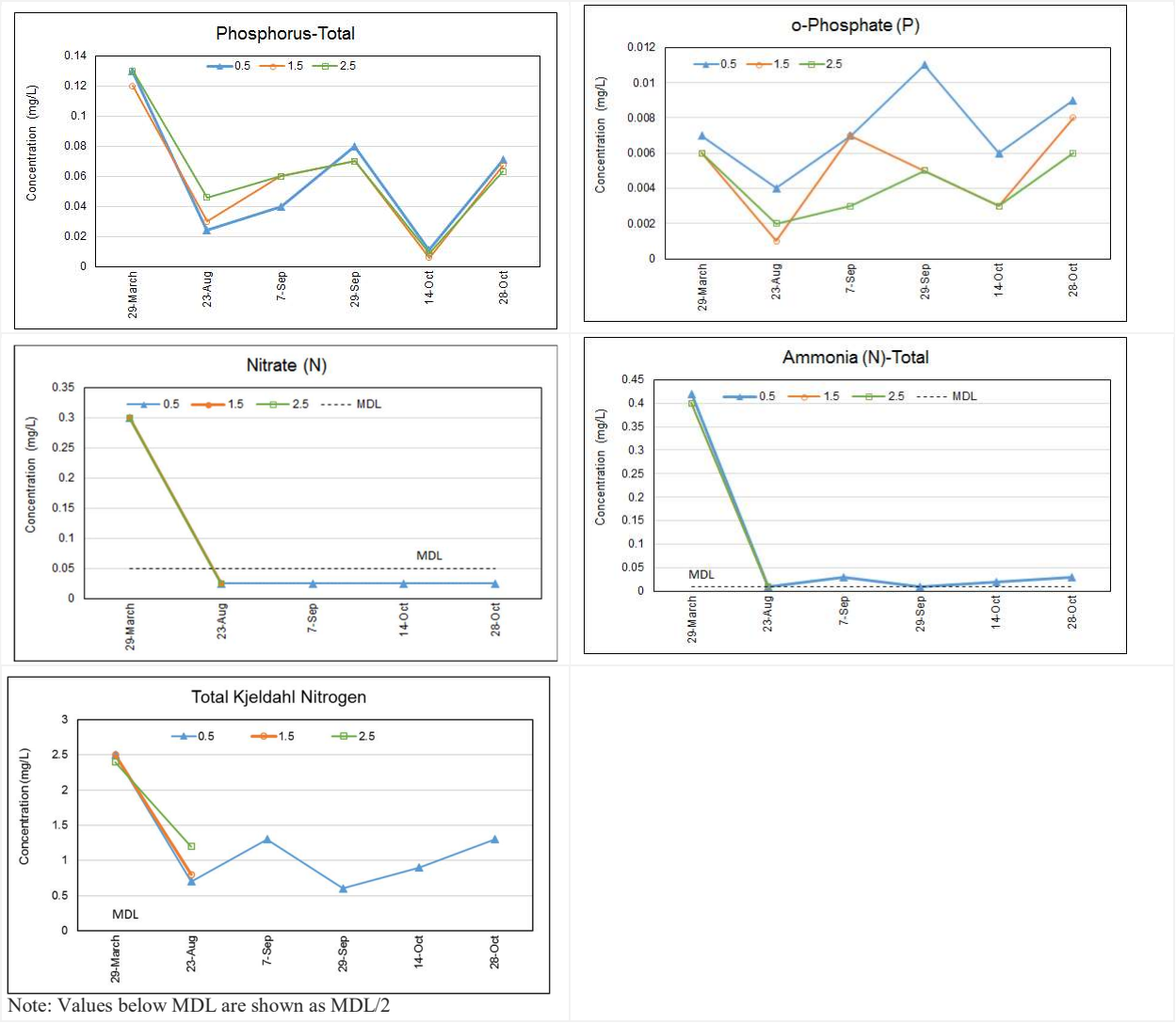
Note: Values below MDL are shown as MDL/2

Figure 6: Measured Nutrients Concentrations in 2021 - Bridge Site



Note: Values below MDL are shown as MDL/2.
TKN is shown on the secondary (right) axis.

Figure 7: Measured Nutrients Concentrations in 2021 - Central Site



Note: Values below MDL are shown as MDL/2

2.2.5 Chloride and DOC Concentrations and Color

Samples collected during each visit were also analyzed for Chloride, Dissolved Organic Carbon (DOC), and Colour. The results are summarized in Table 5.

Water quality testing results indicated that all samples taken at all sites contained high chloride levels in Swan Lake until the end of June (>640 mg/L). Samples collected in July and later on contained lower chloride concentrations with an average of 590 mg/L. Chloride levels tend to rise in the spring as runoff containing de-icing agents are discharged to the Lake. Once introduced to a waterbody, chloride does not biodegrade, readily precipitate, volatilize, or bioaccumulate. It does not adsorb readily onto mineral surfaces, and therefore when introduced, concentrations remain high in surface water.

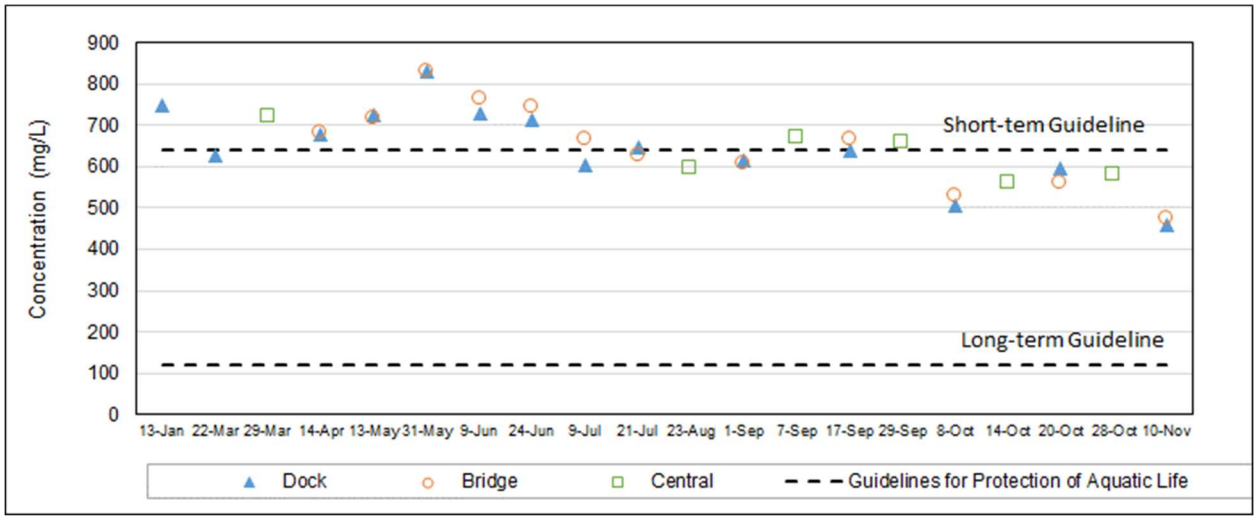
Chloride guidelines developed based on generic environmental data include a long-term guideline (120 mg/L) and a short-term guideline (640 mg/L). These guidelines may be over-protective for areas with an elevated concentration of chloride and associated adapted ecological community. For such circumstances,

it has been suggested that site-specific (higher) targets be derived considering local conditions such as water chemistry, background concentrations, and aquatic community structure.

Table 5: Measured DOC, Color and Chloride

Date	Dock			Bridge			Central		
	Cl	Colour	DOC	Cl	Colour	DOC	Cl	Colour	DOC
13-Jan	749	10	5.9	-	-	-	-	-	-
22-Mar	725	11	2.2	-	-	-	-	-	-
29-Mar	-	-	-	-	-	-	684	12	2.4
14-Apr	711	14	3.8	681	15	3.8	-	-	-
13-May	696	11	1.6	715	11	1.5	-	-	-
31-May	817	10	1.5	831	15	1.7	-	-	-
9-Jun	720	12	1.7	764	21	1.9	-	-	-
24-Jun	721	12	2.9	744	14	1.6	-	-	-
9-Jul	614	15	1.6	666	17	1.6	-	-	-
21-Jul	611	14	1.3	627	16	1.2	-	-	-
23-Aug	-	-	-	-	-	-	594	3	0.5
1-Sep	607	3	0.8	607	4	0.7	-	-	-
7-Sep	-	-	-	-	-	-	671	3	0.8
17-Sep	659	3	1.3	666	3	0.9	-	-	-
29-Sep	-	-	-	-	-	-	657	4	0.8
8-Oct	508	5	0.9	529	5	1.0	-	-	-
14-Oct	-	-	-	-	-	-	560	3	1.0
20-Oct	569	3	1.8	561	8	2.1	-	-	-
28-Oct	-	-	-	-	-	-	579	3	1.7
10-Nov	483	4	1.2	475	6	1.3	-	-	-

Figure 8: Chloride Concentrations in 2021



2.2.6 Algae Growth and Toxicity

Algae blooms, which have been a problem in Swan Lake in previous years, reoccurred during the 2021 monitoring period. During the summer, surface scum was found at both the Dock and Bridge sampling sites. The surface scum found at the Bridge site was generally worse upon visual inspection, likely due to the stagnant conditions in the bay.

Samples were collected before and after chemical treatment and sent to the laboratory for phytoplankton and cyanobacteria. Test results are discussed in the report on chemical treatment evaluation.

Signs warning the public against water contact for humans and pets remained in place throughout 2021 (see **Error! Reference source not found.**).

2.2.7 Summary of Monitoring Results in 2021

Profiles of temperature and dissolved oxygen indicated that Swan Lake was mostly thermally stratified during the summer.

DO concentrations measured in the 1 m surface water were above the DO guideline for the protection of aquatic life. When stratified, bottom concentrations were lower than the DO guideline. DO concentration at 2 m increased significantly in August, but remained low at 2.5 m.

Transparency at the Dock station was under 0.5 m at the beginning of June but increase to up to 1.2 m in August following chemical treatment.

pH measured at the lab ranged from 7.9 to 8.5 before the chemical treatment and 7.4 to 8.2 following the treatment. Total phosphorus concentration in the top 1 m depth averaged at above 100 µg/L before the chemical treatment (March-July). The concentrations over the growing season (June-July) averaged about 140 µg/L (above the 100 µg/L threshold for a hyper-eutrophic condition) before dropping to about 50 µg/L after treatment.

Total nitrogen concentrations over the growing season averaged about 2.39 mg/L before the chemical treatment to about 1.0 mg/L after treatment (below the 1.2 mg/L threshold for a hyper-eutrophic condition). Chloride concentrations were very high (close to 640 mg/L), but slightly lower than 2020.

Throughout the 2021 monitoring period, surface scum was found at both the Dock and Bridge sampling sites. Samples were collected before and after chemical treatment and sent to the laboratory for phytoplankton and cyanobacteria. Test results are discussed in the report on chemical treatment evaluation.

2.3 Water Quality Trends

Water quality monitoring of Swan Lake has been conducted annually since treatment in 2013 to track water quality and the continued effectiveness of implemented mitigation measures.

The following paragraphs and Figure 9 provide a summary of water quality trends for the period of monitoring.

Dissolved Oxygen (DO)

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

Water Clarity (Secchi Depth)

In Swan Lake, Secchi depth has typically been quite low throughout the summer, but it increases in November, reflecting the end of the growing period for phytoplankton. The average annual values shown in Figure 9 are all below 1 m, except in 2014 and 2021 following chemical treatment.

Total Phosphorus (TP)

Average growing period (May - October) TP concentrations indicate hyper-eutrophic conditions in all monitored years except for the post-treatment years, 2013 and 2014 as well as 2021.

Nitrogen Compounds

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

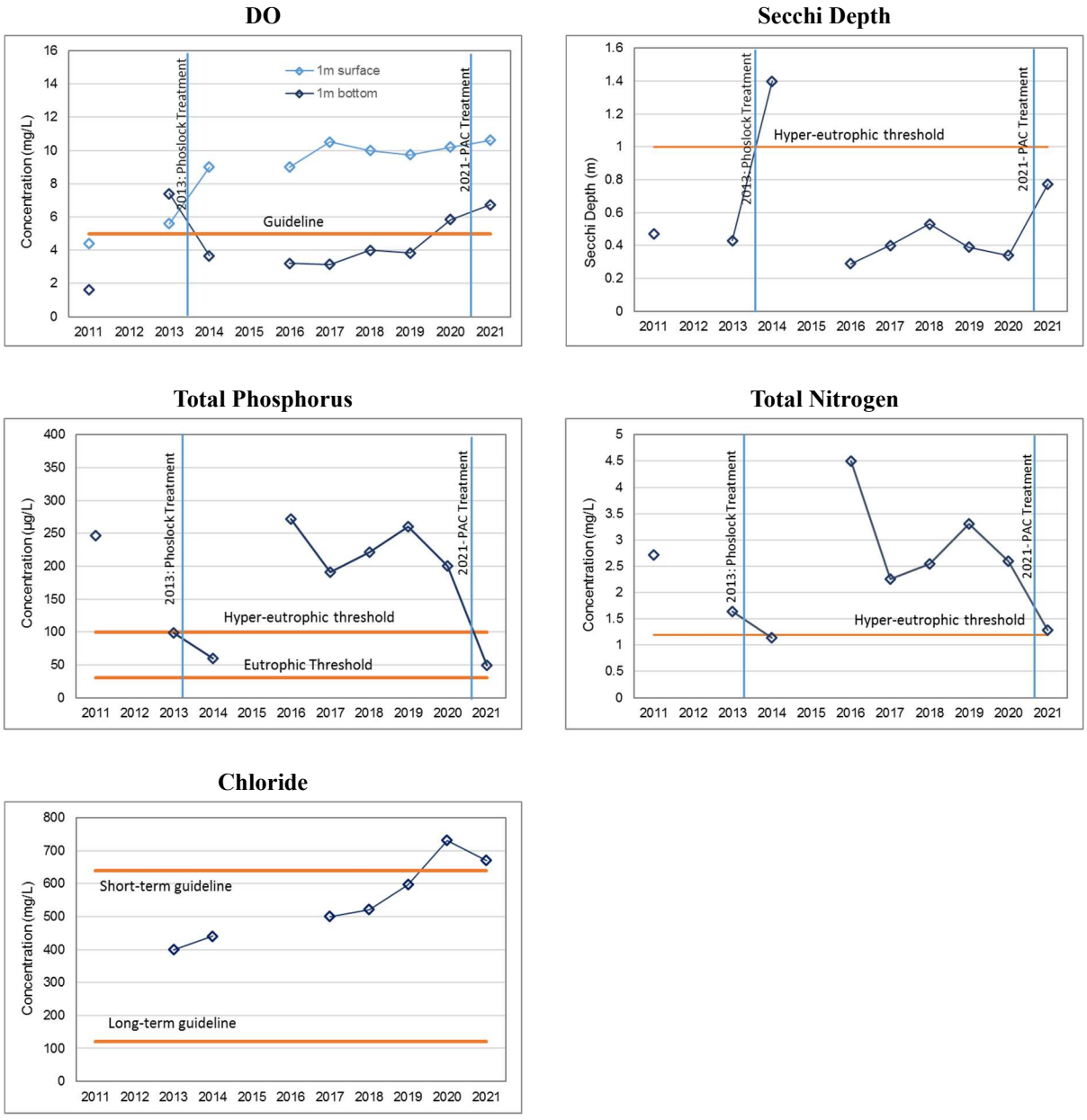
Inorganic nitrogen-compounds (NO_2, NO_3, and NH_3) have often been below detection limits, indicating relatively low levels of bioavailable nitrogen concentrations. In 2021, ammonia and nitrate concentrations were generally very low, and nitrogen was mainly present as organic matter.

Chloride

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

Chloride concentrations have been increasing in Swan Lake over the past few years with slight drop in 2021. The long-term management plan for the Lake suggests that the main mechanism for lowering chloride levels would be source control. Emerging technologies and flow redirection may be considered in future.

Figure 9: Historical Water Quality Results (Growing-Season Averages)



Algae Blooms and Cyanobacteria

Table 6 provides a summary of the observed algae blooms in the Lake over the years. It also shows any tests conducted to measure toxins (mainly in terms of microcystin concentration) in the Lake water.

Table 6: Records of Algae Blooms and Toxicity

Year/Period	Algae Blooms Observation	Toxicity Test Result
Before 2011	Several blooms of cyanobacteria were observed	Microcystin concentration under detection limit
2013-2016	No apparent cyanobacteria proliferation and blooms; no resident concern related to the Lake's water quality	Microcystin concentration under detection limit
2016	A bloom was detected at one location	Microcystin concentration of 73 µg/L in one sample tested (recreational guideline is 20 µg/L)
2017	No bloom was observed	-
2018	Extended blooms were observed at several sites	Not tested for toxicity; cell density was at half of WHO's threshold for significantly increased risk for human health
2019	Extended blooms were observed at several sites	Microcystin toxicity was measured with test strips; all samples were below 10 µg/L
2020	Blooms were observed at several sites	Microcystin toxicity was measured with test strips; all samples were below 10 µg/L
2021	Blooms were observed at several sites	(see memo on treatment performance)

3. Water Level Monitoring

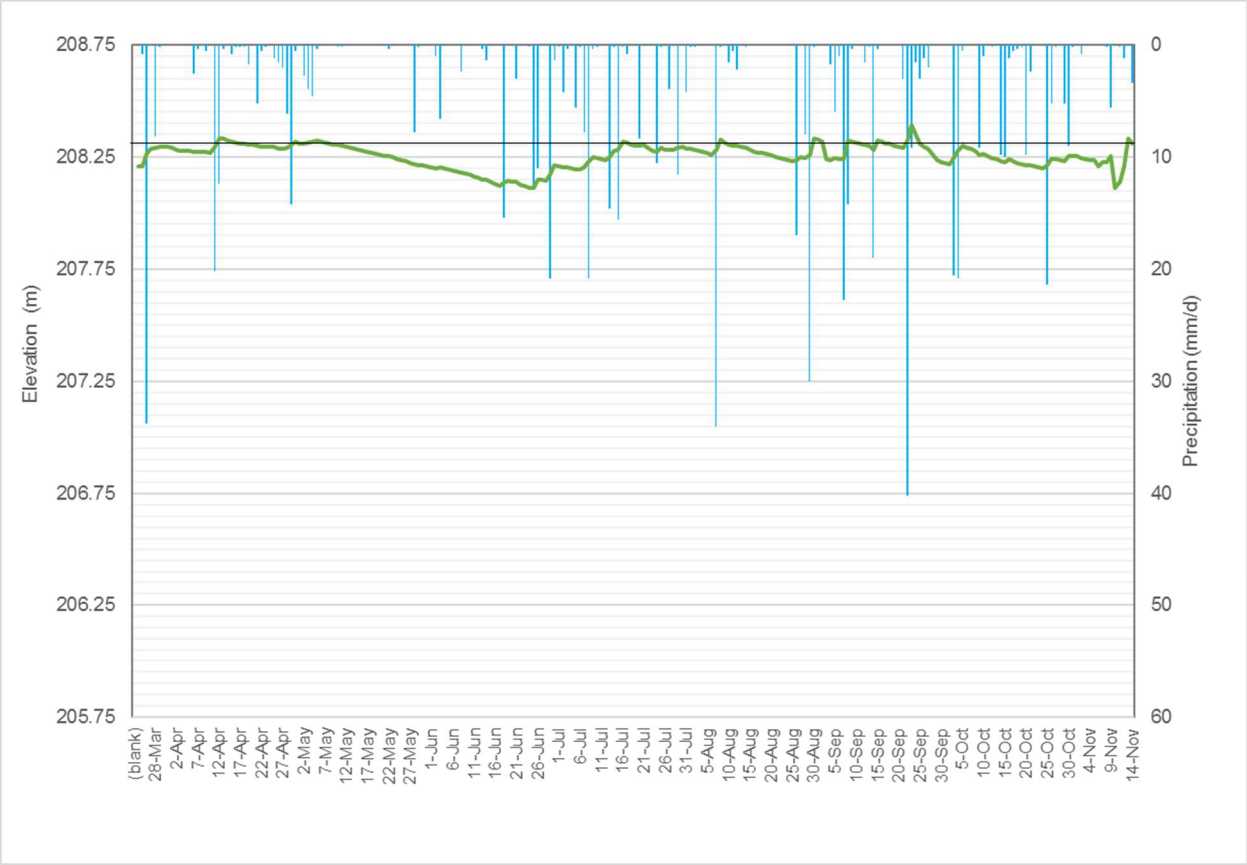
Water level and temperature were monitored using HOBOware U20 Water logger mounted at the Dock. The data logger records the pressure and temperature of the water every 15 minutes. The measured pressure is compensated using a baro-logger to calculate water depth.

The deepest site in the Lake is at 204.8 m. The sensor is located 1 m above the lakebed (at 205.75). The calculated water level changed from 208.11 m (2.36 m depth) in June to 208.39 (2.64 m depth) in September.

The maximum water level recorded in 2017, 2018 and 2020 were 208.48,208.35 and 208.25 m, respectively. The 2019 water level data were incomplete.

Rain data from the nearby rain gauge located at the Markham Museum are shown in Figure 10.

Figure 10: Lake Elevation Records and Precipitation in 2021



4. Geese Management

4.1 Geese Management Approach

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

In 2021, the geese management program was completed by two external contractors.

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

The Toronto Region Conservation Authority (TRCA) was hired to relocate resident geese from Swan Lake and to remove the nests and eggs from the area. In total, 73 Canada Geese were rounded up from Swan Lake on June 18th 2021. Four adult Canada geese and four goslings were left at Swan Lake. In addition, a total 13 nets containing 52 eggs were managed at Swan Lake during April to June.

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

4.2 Geese Count

In 2021, the geese count was completed by the consultant, City staff, and volunteers from the community.

Border Control Bird Dogs recorded the number of geese observed during each visit. Staff counted the number of geese every two to four weeks, coinciding with the water quality sampling site visits.

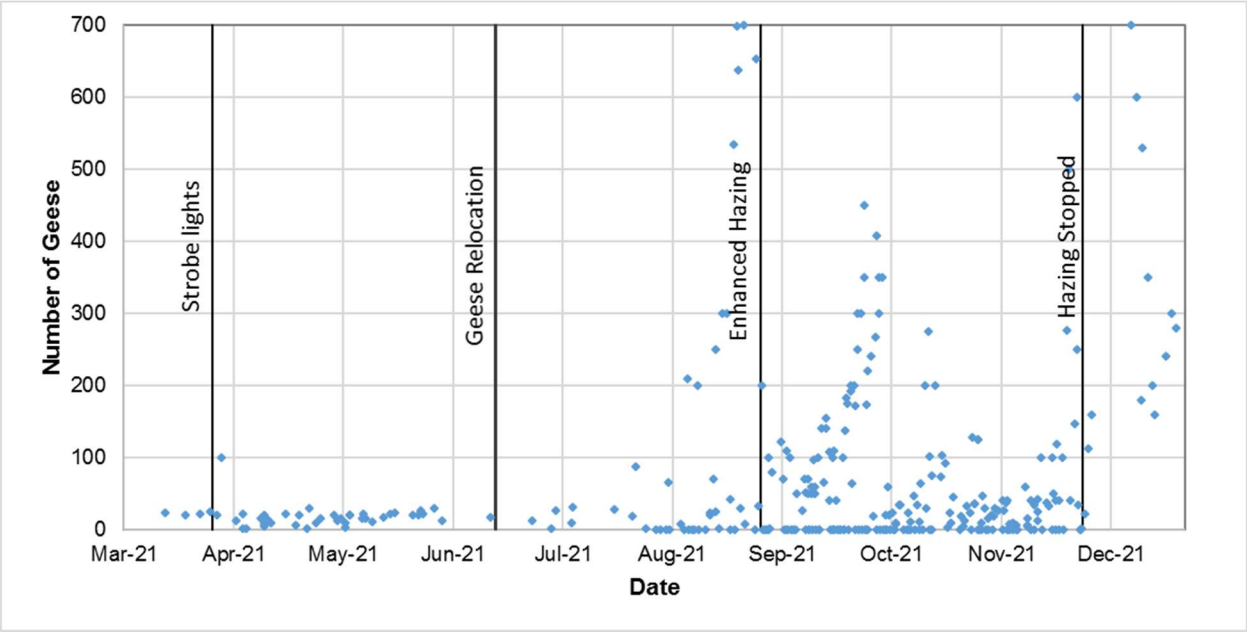
Friends of Swan Lake organized a geese count campaign and provided a spreadsheet of the counts to the City. Staff also developed a geese count App using ArcGIS Survey123, which a number of residents used to record geese count and note other wildlife observations.

4.3 Results

Figure 11 illustrates the number of geese counted at Swan Lake throughout the 2021 monitoring period.

In this figure, a significant increase in geese during the fall months is evident, which occurs when they migrate south; however, the increased hazing frequency (starting on September first) was very effective in reducing the number of geese present at different times of the day. Following the enhanced hazing, daily numbers dropped to below 500, and remained much lower than previous years. Any impact that strobe lights might have had on the geese count is not readily evident from the data.

Figure 11: 2021 Geese Count Results

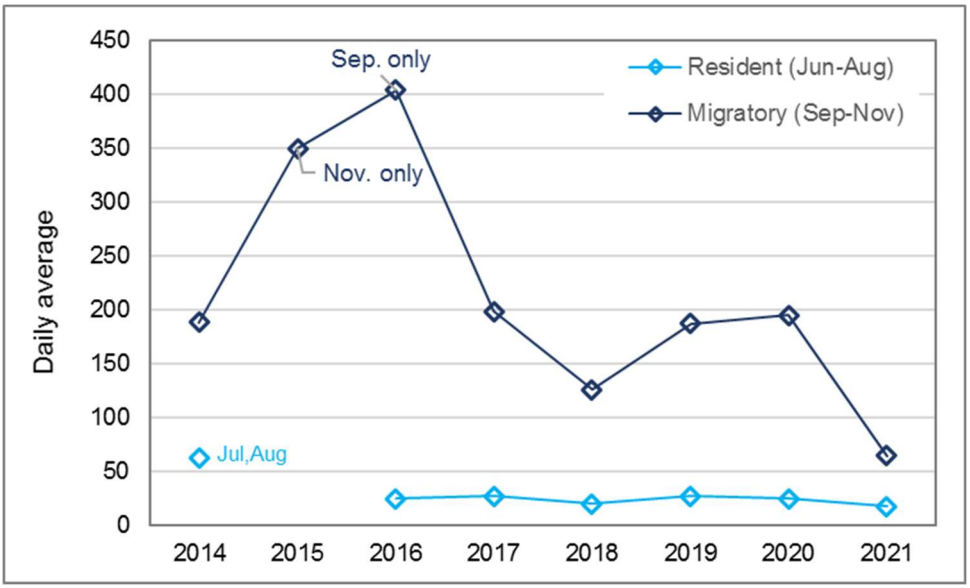


4.4 Historical Trends

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

Daily Averages of counts are shown for each year in Figure 12. Data are summarized for June to August, and September to November, representing resident and migratory geese, respectively. Despite a general increase in geese population in Southern Ontario, the numbers at Swan Lake have been controlled over the past years.

Figure 12: Historical Geese Counts



5. Summary and Conclusions

Through the Swan Lake monitoring program, data were collected from January to November 2021. The collected data provide insight into long-term trends in water quality and will also help determine the need for and impact of chemical treatment of Swan Lake.

Dissolved oxygen, temperature, and water transparency were measured at two stations through bi-weekly site visits and at the Central station pre and post-treatment. Profiles of temperature and dissolved oxygen indicated that Swan Lake was thermally stratified during the summer despite its shallow depth. The minimum dissolved oxygen concentration required for the protection of warm water fish is 5 mg/L, which was met in the surface water but not the deep water pre-treatment.

pH measured at the lab ranged from 7.9 to 8.5 before the chemical treatment and 7.4 to 8.2 following the treatment.

Transparency at the Dock station was under 0.5 m at the beginning of June, but increased to up to 1.2 m in August following chemical treatment.

Water samples were analyzed for nutrients (phosphorus and nitrogen compounds). Total phosphorus concentration in the top 1 m depth averaged at above 100 µg/L before the chemical treatment (March-July). The concentrations over the growing season (June-July) averaged about 140 µg/L (above the 100 µg/L threshold for a hyper-eutrophic condition) before dropping to about 50 µg/L after treatment.

Total nitrogen concentrations over the growing season averaged about 2.39 mg/L before the chemical treatment to about 1.0 mg/L after treatment (below the 1.2 mg/L threshold for a hyper-eutrophic condition).

Chloride concentrations were frequently high (upwards of 640 mg/L) in 2021), but slightly lower than 2020. Chloride concentration exceeded the long-term (120 mg/L) and short-term (640 mg/L) guidelines for the protection of aquatic life.

Throughout the 2021 monitoring period, surface scum was found at both the Dock and Bridge sampling sites. Samples were collected before and after chemical treatment and sent to the laboratory for phytoplankton and cyanobacteria. Test results are discussed in the report on chemical treatment evaluationA level logger was used to record the water level in the Lake. The water level at the logger location changed from 208.11 m (2.36 m depth) in June to 208.39 (2.64 m depth) in September.

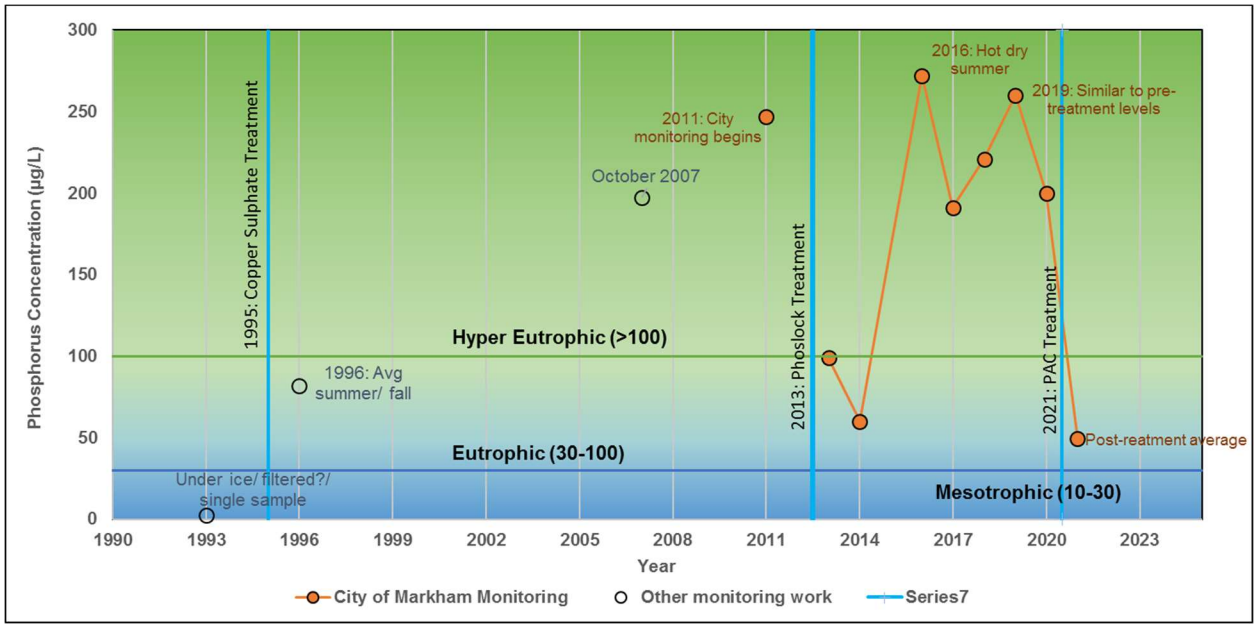
In 2021, geese management was completed by chasing terrestrial geese by border collies and egg oiling, as well as nest management and geese relocation in the spring. Program frequency was modified from previous years to focus on the migration seasons. Nine strobe lights were also installed on the Lake and the two stormwater management ponds. The increased hazing frequency (starting on September 1st) was very effective in reducing the number of geese present at different times of the day to about 50% of numbers in 2020. Any impact that strobe lights might have had on the geese count is not readily evident.

Based on the measured Secchi desk transparency and nutrient concentrations in 2021, Swan Lake is classified at a low-eutrophic condition post-treatment. Figure 13 provides a summary of phosphorus concentrations for all the years with available data.

Overall, the management activities in 2021 that focused on the significant nutrient loadings identified in the water quality management plan (i.e., PAC treatment to reduce internal loads and geese management to reduce external loads), was effective at improving water quality in the lake as shown in reduce phosphorus concentrations and improved water clarity and dissolved oxygen levels. These improvements

represent a positive step towards improving aquatic habitat in the lake and meeting the long-term water quality goals.

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



Appendix A : Swan Lake Water Quality Inspection Forms

Appendix B : Photographic Documentation

Appendix C : Certificate of Analysis

M E M O R A N D U M

To: File
Prepared by: Zahra Parhizgari, Senior Environmental Engineer,
Roshanak Maleki, Senior Environmental Engineer
Date: April 2022

**Re: Swan Lake Water Quality Management-
Water Flow and Chloride Analysis**

Introduction

This memorandum was prepared to describe the water balance model developed in support of the Long-Term Management Plan for Swan Lake, updated with additional considerations to support a water flow analysis. It also analyzes existing information on chloride concentration in the Lake, sources of chloride, and potential mitigation measures to be considered.

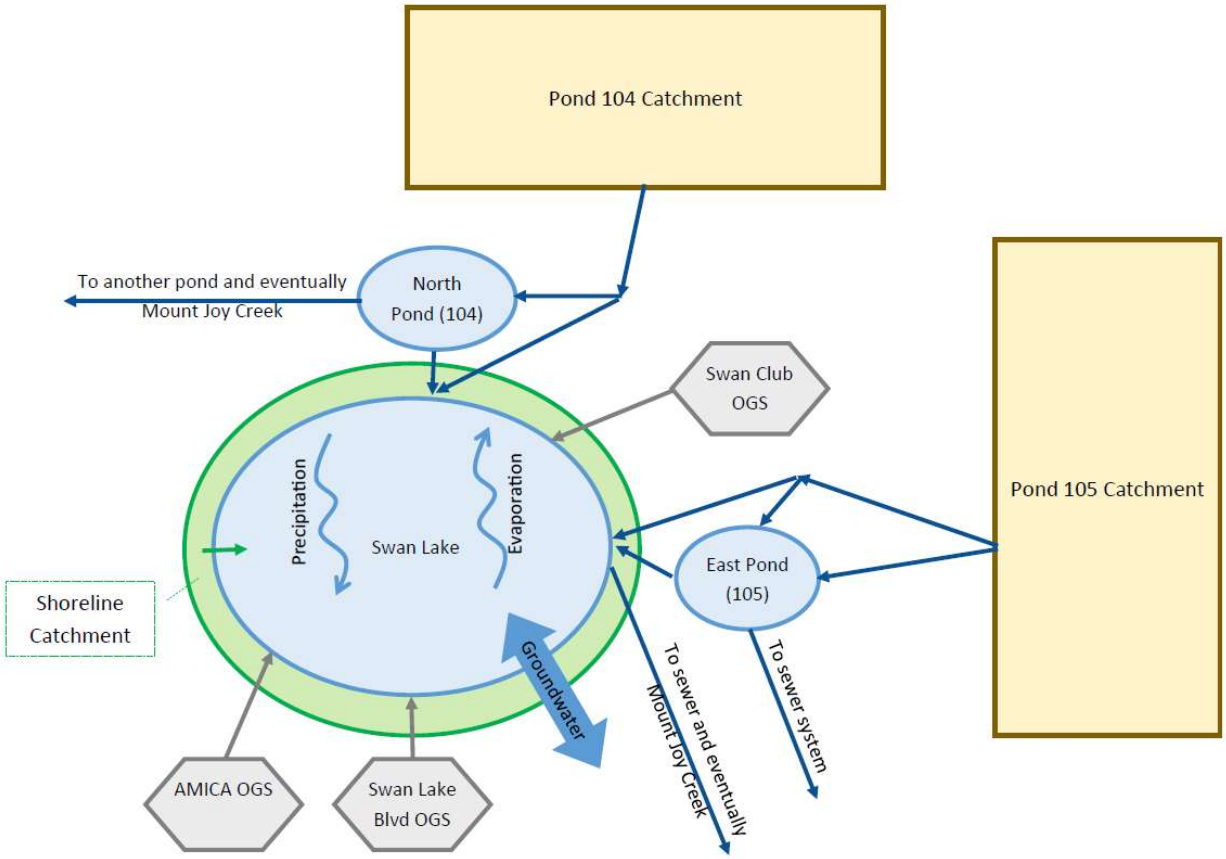
Water Flow Analysis

A conceptual model of flows in and out of Swan Lake is shown in Figure 1. Various components of this model and the data and methods used to quantify them are described below.

The majority of the runoff from the developed catchment area is treated in two stormwater management ponds, and the treated runoff is discharged to the storm sewer system. The remaining flows bypassing the ponds, overflows from the ponds, discharges from the three Oil and Grit Separators (OGS) as well as runoff from the shoreline area are discharged to the Lake.

The following sections describe the design information and modeling methodology used to estimate the runoff quantity produced in each catchment area and the fraction discharged to the Lake.

Figure 1: Swan Lake Conceptual Site Model



Drainage Plan

The Environmental Master Drainage Plan for the Swan Lake Community (Cosburn Ltd. et al., 1995) analyzed the site outlet capacities, major/minor drainage systems, and quantity and quality control requirements. The study area of this Master Plan included catchments draining to Swan Lake and areas to the west, east, and north which would drain to a storm sewer inlet on 16th Ave. and from the west drainage area to the Exhibition Creek (aka Mount Joy Creek).

Recent LiDAR data and as-built information on the existing storm sewer network were used to delineate the catchments being conveyed to the Lake and adjacent stormwater pond facilities. As per the catchment delineation performed, the drainage area to the Lake is about 37.0 ha. Of this area, two (2) stormwater management ponds serve about 81% (29.6 ha) of the Lake's catchment area. Three OGS's treat the runoff from 5% of the catchment (1.8 ha). Runoff from the remainder of the area (about 5.6 ha) is comprised of overland flow from the immediate shoreline and was considered uncontrolled in the model.

Stormwater Controls

As per the 1995 Master Plan, two wet extended detention ponds (#104- North Pond and #105-East Pond) were proposed to accommodate the proposed site layout and required grading and provide quality control. These ponds were designed to attenuate the stormwater runoff generated by a 2-hr duration, 25 mm runoff. Each pond would have a sediment forebay at each storm sewer inlet (to

concentrate larger sediment particles) and a shallow area with emergent aquatic planting at the pond outfall (to provide natural habitat and nutrient uptake). The North and East Ponds would have one and two inlets, respectively. A flow splitter immediately upstream of each pond outfall would direct the 25 mm storm runoff to the pond. Weirs within the flow splitters would direct the storm flows and the pond volume to the Lake for flood control attenuation.

The North Pond (ID #104) was constructed as an extended detention wet pond in 2001 to collect up to 25 mm storm event runoff from an area of 12.95 ha (including the pond block) conveyed to the Pond by a 1050 mm diameter concrete storm sewer. The Pond has a permanent storage volume of 1558 m^3 at an elevation of 208.3 m, and a total extended detention storage volume of 810 m^3 at an elevation of 208.8 m. It has an inlet structure, a 28 m long sediment forebay, an access road, and a maintenance road. The outlet structure includes a reversed sloped pipe to a manhole with a 100 mm diameter orifice plate, which releases controlled discharge from the North Pond to the storm sewer on Williamson Road via a 200 mm diameter storm sewer. A diversion structure is located upstream of the North Pond in a 2400 mm diameter manhole, which includes an overflow weir that conveys flow to Swan Lake at a spill elevation of 208.8 m. An emergency spillway is also located on the west side of the Pond, which discharges to Swan Lake at a spill elevation of 209.0 m.

The East Pond (ID #105) was constructed as an extended detention wet pond in 1996 to service a total drainage area of 18.49 ha (including the pond block). The East Pond has a permanent storage of 2051 m^3 at an elevation of 208.3 m and an active storage volume of 1096 m^3 at an elevation of 208.8 m with a minimum detention time of 24 hrs. The Pond outflow is controlled by a submerged perforated pipe and a precast twin catchbasin. The twin catchbasin allows for additional outflow once the active storage depth exceeds an elevation of 208.45 m. The pond release rate is controlled by a 66 mm diameter orifice plate located at the outlet. The south and north inlet structures divert flows to Swan Lake once the water surface elevation in the extended detention pond exceeds 208.7 m. An emergency spillway is also located on the west side of the Pond, which discharges to Swan Lake at a spill elevation of 209.25 m.

Both the East Pond and North Pond are currently privately owned and operated, but will ultimately be assumed by the City of Markham for long-term ownership and operation.

In addition to the two stormwater management ponds, there are three OGS units in the catchment, treating runoff from the Swan Club in Swan Lake Village and referred to as “Swan Club” thereafter (100 Lakeside Vista Way), AMICA development (6360 16th Ave.), and Swan Lake Blvd.

Lake Operation

As per the 1995 Master Plan, the water captured by Swan Lake would either be infiltrated or evaporated. A restricted outfall was also recommended for the Lake discharging to the 16th Ave. storm sewer to maintain a constant water level and positive drainage of the Lake.

Once the Swan Lake water level exceeds an elevation of 208.3 m, excess storage is released through the foundation drain collection (FDC) system. A 165 mm orifice plate located at the outlet side of the Lake headwall adjacent to the East Pond controls the outflow from Swan Lake to the FDC system. The Lake release rate was 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).

Precipitation and Evaporation

Meteorological parameters are the most frequently measured and affect several components of the water balance analysis.

Precipitation data in 5-min intervals are available from the Markham Museum meteorological station, complemented with data from the Mount Joy Community Center station. Daily minimum, average, and maximum temperature are available from the Buttonville Airport station.

Evapotranspiration (ET) rates are not measured in any station close to the study area and were therefore calculated using climate data from the nearest stations. Based on data availability and the required resolution, ET was estimated using the Priestley-Taylor model (Priestley & Taylor, 1972).

Hydrologic Modelling

The PCSWMM model was used for estimating various flows. The model traces the water flow from rainfall through different catchments in the pipes and overland to various stormwater controls and eventually to the Lake.

Both ponds were initially designed with permanent pools for water quality control and extended detention volumes for the 25-mm event. Therefore, a 25 mm storm event was simulated in the PCSWMM model to confirm that the existing SWM ponds are performing relatively close to the intended design. It should be noted that a different modelling approach was used for the purposes of this water balance analysis compared to the approach used in the original pond designs, which would lead to slight differences in results. However, the results from the PCSWMM simulation of the 25 mm storm event confirmed that both of the existing SWM ponds are functioning as designed in the model, as expected.

Surface runoff from all outfalls was modelled for the 2009 to 2021 period using the PCSWMM model. Both minor and major systems were modelled over a continuous period using a 5-min time step.

The intended use of the PCSWMM model was to develop a high-level estimate of the various catchment contributions to the total runoff into Swan Lake. By developing this high-level estimate, the relative proportion of runoff from each catchment can be assessed for:

- Total runoff controlled by existing SWM pond facilities;
- Total runoff being treated by existing OGS units; and
- Total uncontrolled runoff.

In recent years, sediment accumulation in front of the northern inlet to the East Pond blocked the flow from the upstream catchment, causing it to be directed to the Lake instead. The exact date of this blockage is not known, and therefore, an estimate was made using available water quality information (see later sections). This scenario was also modeled using PSCWMM to demonstrate the impact of pipe blockage. In the PCSWMM model, the 450 mm dia. pipe was removed, and it was assumed that all flow from the upstream catchment area is discharged to the Lake.

Groundwater Exchange

Available reports, including the 1995 Environmental Master Plan, various geotechnical reports prepared in support of development applications in the area, as well as reports on the methane gas ventilation system, 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.

Outflow

Since there is no measurement of outflow, 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.

In 2017, a water level logger was installed next to the dock on the southern shore of the Lake. The logger, which was moved to the front of the dock in 2020, has been recording the water level continuously during the ice-free periods.

The 2017-2021 data were extrapolated to the previous years by correlating water level with rainfall and evapotranspiration, and outflows were estimated accordingly for all years of modelling.

Water Balance Results

A summary of the annual water balance results for both the design conditions (unblocked inlet) and the blocked inlet is provided in Table 1and Table 2, respectively.

In these tables, the balance of all estimated components is shown as 'Balance', which could be attributed to groundwater or other uncertainties in the model assumptions.

Table 1: Average Water Balance for Design Conditions (m3/mon) for the Period of 2009-2021

Month	Direct Precipitation	Evaporation	North Pond	East Pond	Shoreline Runoff	OGSs	Outflow	Balance
Jan	2028	-388	955	681	1775	626	0	-3844
Feb	1979	-761	120	51	1267	498	0	-1366
Mar	2351	-2715	342	320	1647	627	0	-448
Apr	3881	-4605	1123	686	3046	1138	0	-1763
May	3310	-7329	584	493	2095	855	-4418	2112
Jun	4266	-8448	1393	1175	2581	997	-1616	-1875
Jul	3446	-8904	1162	1354	2254	989	-304	-1534
Aug	3513	-7059	1090	1348	2026	877	-840	-2313
Sep	3153	-4192	1175	1045	2044	839	-1677	-3124
Oct	3724	-1778	651	538	2393	966	0	-8327
Nov	2448	-723	540	284	2193	772	0	-6085
Dec	2291	-312	484	257	1948	698	0	-3297

Table 2: Average Water Balance for Blocked Inlet (m3/mon) for the Period of 2009-2021

Month	Direct Precipitation	Evaporation	North Pond	East Pond	Untreated from East Pond Catchment	Shoreline Runoff	OGSs	Outflow	Balance
Jan	2028	-386	955	0	4636	1775	626	0	-7801
Feb	1979	-752	120	0	3848	1267	498	0	-5172
Mar	2351	-2691	342	7	4340	1647	627	0	-4500
Apr	3881	-4575	1123	0	8376	3046	1138	0	-9483
May	3310	-7309	584	0	6458	2095	855	-4418	-3874
Jun	4266	-8427	1393	5	8073	2581	997	-1616	-8800
Jul	3446	-8912	1162	110	6534	2254	989	-304	-6817
Aug	3513	-7078	1090	42	6346	2026	877	-840	-7334
Sep	3153	-4233	1175	33	5883	2044	839	-1677	-7953
Oct	3724	-1805	651	0	7412	2393	966	0	-15176
Nov	2448	-734	540	5	5960	2193	772	0	-11755
Dec	2291	-313	484	0	5289	1948	698	0	-8327

Chloride Analysis

Background

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

Chloride guidelines developed for generic environmental data include a long-term guideline (120 mg/L) and a short-term guideline (640 mg/L). The long-term guideline has been developed to protect all organisms (present in Canadian aquatic systems) against negative effects during indefinite exposure. The short-term guideline aims to 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 communities. 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.

Chloride Concentration

Water quality is regularly monitored at two shoreline sites, the Dock (S1) and the Bridge (S2). The water depth at the dock is approximately 2.5-3 meters, representing deeper sections of Swan Lake, and this station has historically been used to represent the 'whole lake'. 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.

In the earlier years of monitoring, sampling was completed at the deepest point in the Lake (Main or Central station, S3). Samples were also not analyzed for chloride regularly, but conductivity was measured frequently. Conductivity has been found to be linearly related to chloride concentration in roadway runoff; however, there is higher variability in pond outlets due to the presence of other ions (MNDOT, 2017). Nonetheless, samples with both chloride and conductivity

measurements were reviewed, and a weak correlation was found between the two constituents. In the absence of any chloride data for earlier years, this correlation was used to estimate chloride concentrations in the Lake. Table 3 summarizes chloride and conductivity results available for Swan Lake.

Table 3: Dates with both Chloride and Conductivity Measurements

Date	Location	Station	Chloride (mg/L)	Conductivity (µs/cm)
7/2/2013	Main	S305	399	1189
10/28/2021	Main	S305	579	1081
1/13/2022	East Pond	EP-IN	13200	27700
1/13/2022	OGS	SLB-OGS	3160	9660
3/6/2022	East Pond	EP-IN	380	1500
3/6/2022	North Pond	NP-IN	410	1600
3/16/2022	East Pond	EP-IN	3700	12000
3/16/2022	North Pond	NP-IN	3100	10000

Monthly averages for the three Lake stations (Dock, Bridge, Central, or S1/S2/S3) averaged over all depths (when available) are provided in Table 4.

Water quality testing results indicated that all samples taken at the Dock monitoring site contained high chloride levels in Swan Lake throughout the monitoring period (>640 mg/L).

Values have generally increased year over year. Monthly values have been highest in April-July and lower in Aug-Nov. Few data points are available for Jan-Mar as the Lake is frozen during this period. A possible explanation could be that chloride concentrations in the runoff are highest during snowmelt (March-April). Lake concentrations remain high through the spring and part of the summer until the Lake water is diluted with precipitation and unsalted runoff.

Table 4: Monthly Average Concentration of Chloride (mg/L) in the Lake

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Annual Average
2011								568	529	388		492
2012			294									294
2013		199			424		436	404	348	311	220	341
2014	318			462	432	481	472	401	300	320	239	383
2017				732	638	502	429	417	409	438	398	477
2018				457	585	558	590	615	393	392	345	511
2019				581	544		585	656	575	608	570	596
2020				711	717	717	762	749	742	753	717	737
2021	749		700	784	762	733	624	968	613	515	480	679

Note: Estimated based on conductivity for 2011-2014, when few measurements of chloride are available.
Each average represents about four data points, except for 2011 and 2021 when more chloride samples were collected.

In 2022, water samples were collected from various inlets to the Lake and analyzed for chloride. These data, along with scattered data from previous years, are shown in Table 5. Based on this limited dataset, chloride concentration in the spring runoff from the pond catchments is about 1000 mg/L (average of pond inlet measurements). This concentration would not usually end up in the Lake, except through the East Pond bypass during the period that the northern inlet was blocked. At other times, the bypass would carry 'cleaner' water (after the first flush), with concentrations

around 200 mg/L. Flows from the ponds to the Lake have an average concentration of 350 mg/L (average of pond and outlet concentrations).

In 2022, samples were collected from the Swan Lake Blvd. (SLB) and AMICA OGS at the outfall to the Lake. The outfalls were not flowing during some sampling events, in which case, samples were collected from the pool of water present. There was no flow/ visible water at the outfall from the Swan Club (SLC) OGS, and therefore, no sample was collected at this location. The runoff collected from SLB OGS contained about 2000 mg/L of chloride, while AMICA OGS had a concentration of about 500 mg/L.

Samples were also collected from the shoreline runoff, which resulted in very low chloride concentrations (about 25 mg/L).

Table 5: Chloride Concentrations in Inflow and Outflow from Ponds and OGSs

	East Pond				**North Pond**				**OGSs**	
	Pond Inflow		Inflows to Lake		Pond Inflow			Inflow to Lake	Inflows to Lake	
Date	Pond Inlet	Pond	From south	Bypass	Inlet	Road	Pond	Bypass	AMICA -OGS	SLB-OGS
3/20/2012 *	577	572	-	-	673	-	56	-	-	-
3/26/2021	957	343	-	-	98.5	-	199	-	-	-
4/11/2021	-	-	673	131	79	-	-	-	-	-
1/13/2022	13200**	-	-	-	-	-	-	-	-	3160
2/15/2022	2340	-	-	-	2120	326	-	-	360	836
3/6/2022	380	410	-	-	410	-	180	-	610	1200
3/16/2022	3700	-	-	-	3100	-	-	-	470	4800
3/24/2022	1200	-	-	150	1100	-	-	-	240	1900
4/6/2022	2800	-	-	350	-	-	-	-	1100	-

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

Sources of Chloride

Salt usage data were obtained from the City's Road department and the Swan Lake Village Corporation.

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

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). Swan Lake Blvd (130 m of primary roads) received 972.4 Kg of salt, while local roads north of Swan Lake (880 m) received 2129 kg of salt. About 40 salting events were completed for primary roads and 10 for local roads.

The remaining roads and parking areas, as well as private walkways and driveways are serviced privately.

As per the Village Amenities Committee (VAC) (M. Petit personal communication, February 2, 2022), the Village Corporation employs "a qualified, reputable cleaning and maintenance service

employing Smart About Salt principles to plow/shovel and their insurance recommends the deicing methods of rock salt, applied as necessary to maintain their insurance and mitigate potential claim". The amount of rock salt applied is about 88-110 tonnes per winter season, of which 30% is applied to the 14 km of single-lane kilometers of roadways plus parking areas, and 70% is applied to unit walkways and driveways and mail locations.

Information on salt usage in the AMICA property (0.75 ha) serviced by an OGS is not available.

The amount of salt used in residential driveways north of Swan Park Road is not known.

Chloride Transport

Chloride in salting materials is readily dissolved in water and transported overland by runoff or infiltrated into soils, contaminating groundwater and surface water. A fraction of chloride in applied road salt is retained by soil and is not observed in surface runoff.

As a result, salt loading to surface water occurs primarily in winter and spring during melt conditions but continues through the summer and fall via the discharge of impacted groundwater, dry deposition of dust to the lake surface, non-point source runoff washing dry salt from land surfaces. Salt accumulated in the ponds could also be discharged into the Lake through the flushing of stormwater ponds.

Areal Load

Chloride loads can be determined from the mass of chloride in the Lake using chloride concentration and the Lake outflow data, and assuming steady-state conditions, as follows:

$L_{Cl} = [Cl] * qs * Ao$

where,

[Cl] is average chloride concentration in the Lake,
qs is the areal water load out of the Lake as Q/Ao,
Q is the mean outflow from the Lake, and
Ao is the lake surface area

As shown in Table 6, areal loads of water and chloride have increased significantly in 2018, with the annual chloride load being about twice that of previous years. This may originate from two factors, higher water load, and higher chloride concentrations. The higher water load could be due to more severe storms routed from the stormwater ponds to the Lake (the impact of blockage is not considered in this model). Higher chloride concentrations (measured in Lake) may represent when the inlet blockage occurred, resulting in higher loads. Hence, we assumed that 2018 was the year the inlet blockage occurred.

Table 6: Areal Water and Chloride Load

Year	Precipitation on Lake	Evaporation from Lake	Inflow from Pond 104	Inflow from Pond105	Shoreline Runoff	Inflow from OGSs	Outflow	Balance	Chloride in Lake (mg/L)	Lake surface (m^2)	Areal water load (m/yr)	Cl Load (t/yr)
2009	40,071	-44,215	11,384	8,168	28,748	10,490	-10,347	-38,993	378*	49940	0.99	18.6
2010	33,063	-46,919	11,966	10,768	20,967	8,373	-14,467	-23,025	378*	50018	0.75	14.2
2011	25,591	-45,891	1,036	1,116	14,066	5,875	-5,115	-67	492	47821	0.11	2.6
2012	37,419	-48,912	12,223	10,990	28,470	11,219	-9,410	-38,023	294	47757	0.99	13.9
2013	36,623	-45,556	4,634	5,225	23,897	9,363	-8,885	-21,890	341	50247	0.61	10.5
2014	36,383	-43,824	9,702	9,682	20,872	8,998	-16,467	-27,197	383	49108	0.89	16.7
2015	32,785	-47,079	12,673	10,101	21,419	8,877	-11,167	-28,918	430*	48240	0.83	17.2
2016	27,946	-48,862	1,015	1,193	14,894	6,824	-3,851	-552	430*	47076	0.09	1.9
2017	36,055	-50,139	6,207	5,214	25,090	11,112	-7,321	-26,031	477	47326	0.70	15.9
2018	44,455	-47,777	13,594	11,690	33,308	12,843	-7,246	-58,712	511	48068	1.37	33.7
2019	45,331	-46,164	17,274	11,229	39,824	13,221	-10,701	-66,757	596	48382	1.60	46.2
2020	38,016	-50,620	12,249	9,025	30,088	10,479	-4,360	-41,492	737	46940	0.98	33.8
2021	39,328	-47,851	11,088	12,621	26,864	10,811	-5,779	-42,586	679	47596	1.02	32.8

Notes:
Flow components are in m^3/yr
* Chloride concentration assumed as the average of adjacent years.

Source Contributions to Chloride Levels in the Lake

In order to identify the most efficient strategy for reducing chloride loading to the Lake, a high-level estimate was made of the contribution of different sources. Two independent methods were used for this estimate, and adjustments were made to achieve similar results between the two methods.

The first method uses available runoff concentrations and modelled flows to estimate chloride input to the Lake. Model assumptions include:

- Runoff produced from December to April contains a specified concentration of chloride. No chloride concentration was assigned to other months.
- Runoff concentrations were adjusted up to ±50% to achieve similar results to the second method.
- Runoff volumes (from Table 1 and Table 2) were divided into catchments with different salting arrangements based on catchment areas.
- The northern inlet to the East Pond has been blocked since 2018.

The second method uses salt usage data and application time, as well as assumptions related to salt retention. Model assumptions include:

- Salting operation occurred from December to April, distributed based on the number of snow events in each month (snowfall information from Toronto Buttonville station).
- Salt usage data were used to estimate the amount of salt applied in each catchment annually and the amount of chloride in runoff from the area (see Table 7).

- The fraction of runoff from each area discharged to the Lake (after passing through stormwater controls, if applicable) was estimated from the PCSWMM model. The fraction was about 10% for the North Pond catchment and 3% for the East Pond (70% when the inlet was blocked).
- Lower salt usage (up to 50%) was considered for years before 2016 to achieve similar results to the first method.

Table 7: Salt Usage Assumptions

Area	Maintained by	Road Length (m)	Walkway/ Driveway/ Parking **(ha)	Road Salt (kg/yr)	Walkway/ Parking Salt (kg/yr)	Salt used (ton/yr)	Cl Content ✶ (kg/yr)	Retention in soil (assumed)	Cl in runoff (kg/yr)
East Pond	Village	10460*	8.835	22414*	51302 *	74	44230	0.2	35384
North Pond	Village	3540*	2.99	7586*	17362 *	25	14969	0.2	11975
SLC OGS	Village	0	0.23	0	1336 *	1.3	801	0	801
North Pond	City- local road	880	0	2129	11672 ***	13.8	8280	0.2	6624
SL Blvd	City- primary road	130	0	972.4	0	1.0	583	0	583
AMICA OGS	AMICA	0	0.375	0	2178 +	2.2	1307	0	1307

Notes:
* 14 km (and associated salt usage) divided based on catchment area fractions (75% and 25%)
** Assumed 50% of the surface area
*** Assumed the same application rate as in the Village by local resident
+ Assumed the same application rate as SLC OGS
✶ 60% of rock salt is chloride

Estimated contributions are provided in Table 8and Table 9 for the two methods.

Given the many assumptions made for these estimates, the results should be used with caution. Nonetheless, both methods show a significant increase in chloride loading from the untreated runoff from the East Pond catchment. The blocked inlet causing this load was cleared in 2021, and therefore, this load will not be present in the future.

Swan Lake Blvd. may have a high chloride contribution based on measured concentrations in front of the outfall to the Lake.

Measured concentrations for AMICA outfall are not very high; however, the salt application rate should be confirmed.

No measurement was completed for the Swan Club OGS due to lack of flow.

Table 8: Chloride Contribution Estimated using Runoff Concentrations (ton/yr)

Year	Pond 104-Village	Pond 104-City	Pond105	Untreated Pond105 catchment	Shoreline	SLC OGS	SL Blvd OGS	AMICA OGS
Concentration (mg/L)	250	250	250	200 (600*)	25	600	1000	600**
2009	1.13	0.76	0.42	0.60	0.32	0.75	1.46	1.22
2010	0.26	0.18	0.07	0.10	0.17	0.40	0.79	0.65
2011	0.00	0.00	0.00	0.00	0.13	0.30	0.59	0.50
2012	0.02	0.01	0.00	0.01	0.12	0.30	0.59	0.50
2013	0.24	0.16	0.09	0.12	0.18	0.49	0.97	0.81
2014	0.03	0.02	0.03	0.04	0.12	0.33	0.65	0.54
2015	0.49	0.33	0.21	0.31	0.13	0.34	0.67	0.56
2016	0.06	0.04	0.03	0.05	0.17	0.49	0.97	0.80
2017	0.25	0.17	0.10	0.14	0.27	0.72	1.41	1.17
2018	0.24	0.16	0.00	19.14	0.29	0.70	1.37	1.15
2019	1.21	0.82	0.00	28.20	0.47	0.93	1.82	1.52
2020	1.55	1.04	0.00	28.43	0.50	0.99	1.93	1.61
2021	0.39	0.26	0.02	13.81	0.27	0.59	1.16	0.97
Average	0.45	0.30	0.08	0.15 (22.4*)	0.24	0.57	1.11	0.92

Notes:
* Concentration/ contribution of untreated runoff for the normal operation after the first flush (2009-2017) and including the first flush (2018-2021)
** Assumed the same as SLC OGS

Table 9: Chloride Contribution Estimated using Salt Usage Data (ton/yr)

Year	Pond 104-Village	Pond 104-City	Pond105	Untreated Pond105 catchment	Shoreline	SLC OGS	SL Blvd OGS	AMICA OGS
Salt Usage* (ton/yr)	24.9	13.8	73.7		0.5 ***	1.3	1.0	2.2
2009	0.56	0.62	0.25	0.61	0.15	0.39	0.57	0.64
2010	0.52	0.58	0.23	0.57	0.14	0.37	0.53	0.60
2011	0.56	0.62	0.25	0.61	0.15	0.39	0.57	0.64
2012	0.56	0.62	0.25	0.61	0.15	0.39	0.57	0.64
2013	0.54	0.60	0.24	0.58	0.14	0.38	0.55	0.61
2014	0.50	0.55	0.22	0.54	0.13	0.35	0.51	0.57
2015	0.55	0.61	0.24	0.60	0.14	0.39	0.56	0.63
2016	1.03	0.57	0.45	1.11	0.13	0.72	0.52	1.17
2017	1.05	0.58	0.46	1.14	0.14	0.74	0.54	1.20
2018	0.86	0.48	0.05	17.11	0.11	0.60	0.44	0.98
2019	1.00	0.55	0.06	19.81	0.13	0.70	0.51	1.14
2020	0.99	0.55	0.06	19.67	0.13	0.69	0.51	1.13
2021	1.09	0.60	0.07	21.62	0.14	0.76	0.56	1.24
Average	0.75	0.58	0.22	0.71 (19.6)**	0.14	0.53	0.53	0.86

Notes:
* Lower application rates before 2016
** Contribution of untreated runoff for the normal operation after the first flush (2009-2017) and including the first flush (2018-2021).
*** Not salted; however, runoff from adjacent areas contribute to slight loads from the shoreline.

Chloride Management and Mitigation Strategy

Field monitoring and data analysis were employed to estimate source contributions and chloride transport through the catchment.

Chloride loading from the untreated runoff from the East Pond catchment was found to be the main contributor to loads. The blocked inlet causing this load was cleared in 2021, and it is expected that chloride concentrations will gradually decrease now that this source is not present.

Other measures that could be considered if chloride concentration is found to affect the Lake's health may include:

- Managing the de-icing material application rate and type (e.g., sand and salt mix or other material instead of rock salt) to achieve an optimum value that addresses safety concerns as well as chloride load.
- Calibration of salting equipment and monitoring of salt application rates on different surfaces.
- Capturing chloride-laden snowmelt/ runoff and redirecting it away from the Lake.

Assumptions and Limitations

Swan Lake PCSWMM Model

As the PCSWMM model results provide a high-level estimate of these runoff contributions, it should also be noted that there are several limitations and assumptions of the PCSWMM model:

- The model has not been calibrated with flow monitoring data, as this information was not available for the simulation period. Thus, the runoff output from the current model represents a high-level simulated runoff estimate, which is adequate for approximating concentration inputs to the Lake.
- The PCSWMM model does not account for groundwater inputs, as this information was not available for the simulation period. However, from qualitative field observations, it has been observed that groundwater inputs may have some influence on water level fluctuations in Swan Lake.
- The PCSWMM model does not account for the influence of snowpack and snowmelt, as this information was not available for the simulation period. Snowpack and snowmelt can affect the timing of runoff and peak flows into the Lake during the winter months.

Water Balance Analysis

Assumptions and limitations that apply to the overall water balance analysis include:

- Balancing inflows with outflows is not feasible with existing information (due to insufficient groundwater data and limitations of the PCSWMM model).
- Water level data are available since 2017 for the ice-free period. These data were extrapolated to previous years and the under-ice period to estimate outflow. The correlation of water level with rainfall and temperature will need to be validated as more water level data are collected.
- Parts of the Swan Lake catchment have been developed in recent years; however, it was assumed that the catchment characteristics did not change pre and post-development and current conditions were used in the analysis. The impact of new stormwater controls was taken into account by attributing the catchment area of the OGS unit on 6360 16th Ave. to the unit after it was installed in 2018 (i.e., uncontrolled runoff from this catchment until 2018).

Chloride Analysis

Assumptions and limitations that apply to the chloride analysis include:

- Based on an areal load analysis, it was estimated that the northern inlet to the East Pond had been blocked since 2018.
- Missing chloride concentrations in the Lake were assumed as the average of adjacent years.
- Salt usage data for the AMICA property was assumed similar to the Swan Club.
- Salt usage date in the residential area north of Swan Lake was assumed similar to those in the Village.
- Several parameters in the equations used to estimate salt usage and chloride transport were assumed.

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Pers Comm. (2022, February 22). Email from Mark Petit to Robert Muir.

MEMORANDUM

TO: Friends of Swan Lake Park (c/o Fred Peters)

FROM: Eddy Wu, Director, Environmental Services
Alice Lam, Director, Operations

PREPARED BY Robert Muir, Manager, Stormwater
Zahra Parhizgari, Environmental Engineer
David Plant, Sr. Manager - Parks, Horticulture and Forestry

CC: Morgan Jones, Director, Community Services
Councillor Andrew Keyes

DATE: March 3, 2022

SUBJECT: Review of Friends of Swan Lake "Holistic Approach to Realizing Community Goals"

PURPOSE:

Review of the proposals made by the Friends of Swan Lake Park (FOSLP) on community goals and measures to achieve them.

BACKGROUND:

On November 3, 2021, the Friends of Swan Lake Park provided a presentation to the City entitled "A Holistic Approach to Realizing Community Goals". This presentation was later expanded and presented to the Markham Subcommittee on November 16, 2021, entitled as "Towards Realizing Community Goals for Water Quality".

Specific propositions made in these presentations related to water quality improvement have been considered in Swan Lake's long-term water quality management plan. This plan was presented to the General Committee on December 7, 2021, and was endorsed by the Council on December 14, 2021.

This memo reviews ideas and measures put forward in the November 3, 2021 presentation, specifically targeted at achieving the goals that FOSLP defined for Swan Lake and the Park through a survey conducted in February 2021 (by FOSLP). Those ideas and measures are identified as the "FOSLP Proposal".

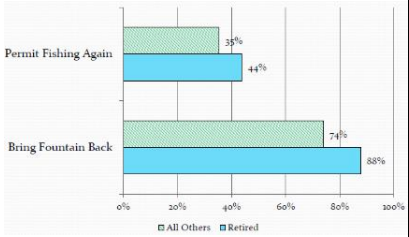
FOSLP PROPOSAL REVIEW:

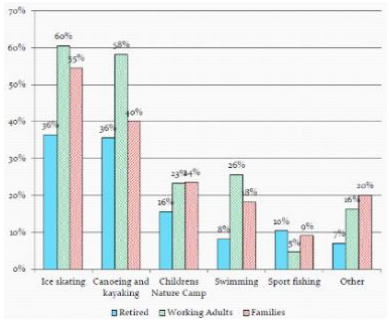
The following table provides our evaluation of the FOSLP Proposal and describes the City's current approach to advancing related topics and that aligns with previous Council resolutions (e.g., December 14, 2021) and the mandate given to staff.

FOSLP Proposal	Proposal Evaluation and Approved Approach
Slide 4- Potential to Reduce Stormwater Flows into Markham Village Flood Control Area ; Towards a self-sustaining Swan Lake: • Raise lake level to retain local runoff within the lake • Redirect stormwater from lake to reduce road salt • Retain flood control features of current system • Needs to be validated by technical assessment 	**Manipulating Flows and Water Level are not Pursued in Phase 1:** • The current stormwater management system provides flood protection in the Swan Lake catchment area, and any change may increase flood risk upstream or downstream. • Source control has been determined as the primary means of chloride control in Phase 1. • Structural change to the stormwater management system and lake operations may be considered if other Core and Complementary measures do not achieve the set targets. • When the Markham Village Project 2 Area design advances, the role of the Lake and any change in flow patterns can be modelled and confirmed.

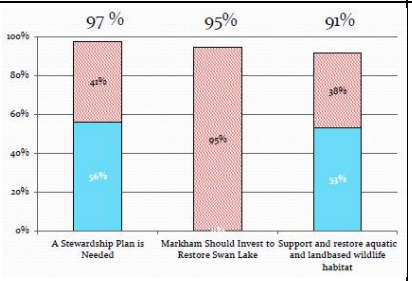
FOSLP Proposal	Proposal Evaluation and Approved Approach

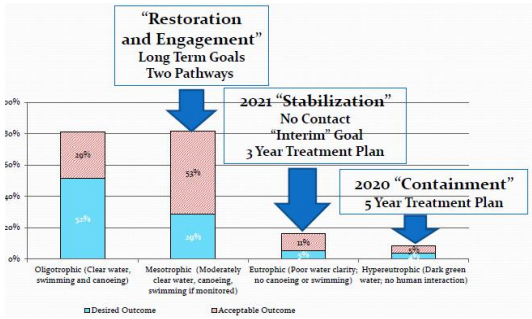
Slides 5/6/7- Need to Strengthen Community Engagement
 	
• "Natural Spaces Wildlife Places" Park
  ○ Destination to help with mental well being
  ○ Area for relaxation, exercise, bird watching
  ○ Support wildlife education (aquatic and terrestrial)
  ○ Children's playground, low impact recreation
• When safe, lift current restrictions
  ○ Lake not accessible due to health risks
  ○ Fishing temporarily banned
  ○ Traditional fountain removed
  • Original recreational plans restricted (canoeing, kayaking, ice hockey etc.)
  • Park Improvement Survey, March 2021 (367 respondents)
• Short term: making the water safe
• Reversing the cyanobacteria restrictions
 	
Restoring the Original Community Role by Supporting Contact Level Activities
	Passive uses of the Park are Supported:
	
	• The Park is currently well-used for low impact recreation by all age groups, consistent with Community Park designation.
	• Natural Spaces Wildlife Places signage is posted where applicable and does not reflect the type of park but rather marks an area
	• Opportunities for wildlife observations (including bird watching) are currently abundant and will be enhanced through proposed shoreline improvement work.
	• As water quality improves, the City will revisit the fishing ban advisory (no consumption) and re-installation of the fountain.
	
	Contact Activities are not Supported:
	
	• Contact level activities will require conformance with E-Coli guidelines and the involvement of Public Health, which are not deemed feasible for Swan Lake.
	• Some of the activities proposed (e.g., children campground) will require amenities not available in the Park (e.g., parking spaces, washrooms).
	• The community survey identifies a low percentage of the key group represented by the survey (i.e., Retired) having an interest in contact activities such as swimming.
	• Proposed activities do not align with usable space and park has limitations on developable land for active uses.





FOSLP Proposal	Proposal Evaluation and Approved Approach
Slides 8/9/10- Why Restoration Is Important?/ Residents Support Environmental Restoration 1. Meets community engagement objectives for lake and park – healthy aquatic and terrestrial habitat 2. Healthy aquatic environment healthy terrestrial environment healthy greenspace benefits all of Markham 3. Supports lower-level aquatic life that can consume algae and improved oxygen levels that reduce phosphorus drawn from the sediments • Should reduce dependency on future chemical treatments • Environmental restoration a critical community objective • Sustained through a Stewardship Plan	**Improving the Health of Aquatic and Terrestrial Habitat is Supported:** • The Lake already supports a large community of small algae-eating fish (10000 fathead minnow identified as per the inventory completed by the TRCA in 2021). • Water quality and shoreline improvement will support a healthier aquatic and terrestrial environment. • Once the water quality improves, fish stocking and submerged plants will be introduced. • Due to the nature of the Lake, chemical treatment will be required in the short term. In the proposed adaptive management approach, frequency and dosage are adjusted at the end of each Phase. **Mesotrophic Target is not Supported:** • According to the City's limnologist, the best achievable outcome of aggressive management for Swan Lake is expected to be borderline meso-eutrophic with respect to phosphorus concentration and hyper-eutrophic for transparency (low due to sediment disturbance in shallow lakes). **Eutrophic Classifications (based on DO, phosphorus, clarity)** • Oligotrophic: pristine • Mesotrophic: clear with some submerged plants • Eutrophic: somewhat unclear, lots of planktonic plant growth • Hypereutrophic: unclear, with frequent algal blooms

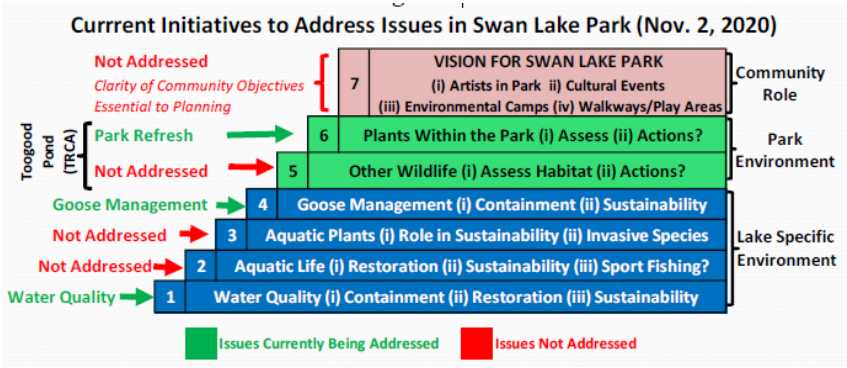




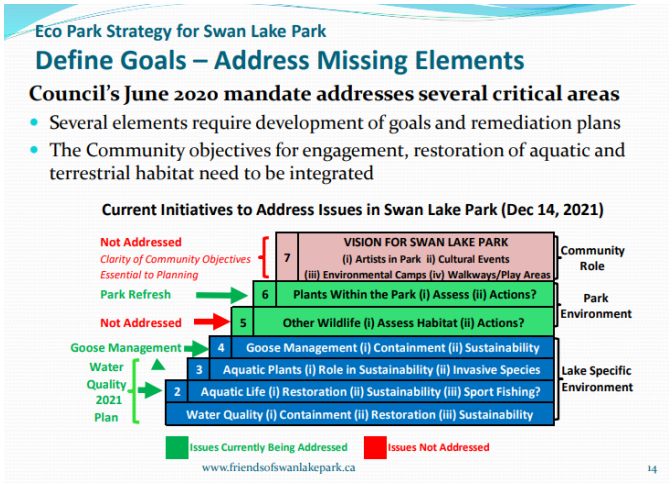
Slide 12- Define Goals – Address Missing Elements

Council's June 2020 mandate addresses several critical areas

- Several elements require development of goals and remediation plans
  - The Community objectives for engagement, restoration of aquatic and terrestrial habitat need to be integrated



Note: January 27, 2022 slides presented to Environment Advisory Committee indicate that #2 and #3 above have been addressed.



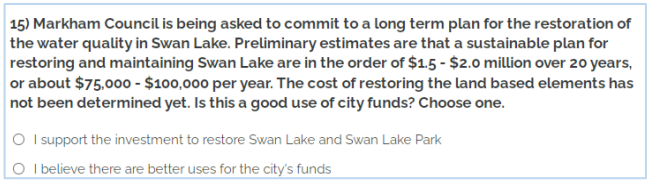
Lake and Park Environments are Being Improved:

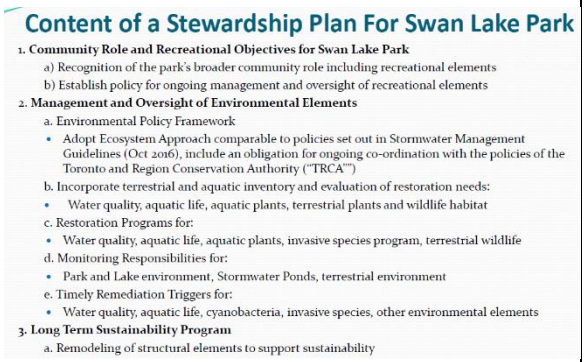
- Water quality and shoreline improvement will already support a healthier aquatic and terrestrial environment.
- Submerged plants and fish stocking will provide further advance improvement.
- As water quality improves, staff will revisit the fishing ban advisory (no consumption).
- Fish stocking recommendation will dictate 'sport fishing' potential considering suitable species.
- Park Environment improvements consider local conditions and may not be equivalent to other park sites (e.g., Toogood site accommodates cold water fishery, Provincially-significant wetland, Greenbelt designation).

The Definition of Community Vision in February 2021 was Premature:

- The FOSLP survey was conducted before the improvements implemented in 2021 and those planned through the long-term water quality management plan.
- Costs associated with 'restoration' were not reflected accurately in the survey (see Q.15 below).
- The survey provides insight from the sample population; however, the population is not representative of the City or Ward 5 (Greensborough community, 73% retired).

- Some of the activities proposed under Vision (e.g., Artists in Park, Cultural Events, and Environmental Camps) will require amenities not available in the Park (e.g., parking spaces, washrooms).



FOSLP Proposal	Proposal Evaluation and Approved Approach
Slides 15/16/17/18- Integrate Markham's Foundation Eco Policies into a Holistic "Eco Park" Strategy for Restoration of Swan Lake Recommendations: 1) Adopt "holistic" Eco Park approach that recognizes improved Community Engagement and Restoration of Swan Lake and Swan Lake Park as a critical community need. Integrate and build upon existing Markham policies 2) Define a process for addressing the missing environmental elements 3) Implement a Stewardship Plan  • Swan Lake is a regulatory orphan, does not fall under any existing regulatory framework (TRCA, other Markham Environmental guidelines) • The 1993 Environmental Management Study for Swan Lake, set out the ongoing policy framework for the City of Markham in its role as Steward of Swan Lake Park but not the management responsibilities. No longer used as a policy framework. • Need for a centralized "holistic" standard that integrates all departmental elements – stormwater management environmental services, park management, park development backed by a long-term undertaking to maintain the standards.  	**Community Goals and Role:** • The Vision defined through FOSLP's survey in Feb 2021 was premature (See the previous page). • The City's Goal is "To improve the overall health of Swan Lake, which will provide opportunities for no-contact activities for the enjoyment of the community" (water quality plan). • The community and stakeholders will be involved in the management plan updates and review of progress. • The shoreline restoration plan is being developed in consultation with the community. Note plan scope is not to add shore amenities. **Policy Framework and Improvement Plan:** • The 2021 long-term water quality plan for Swan Lake defines a management framework for the Lake. It contains an adaptive approach for setting & achieving targets for the Lake environment for next 25 years. • Provisions for the improvement of the aquatic habitat are provided. • Pond maintenance will be conducted following the assumption process. • Invasive species will be dealt with through shoreline rehabilitation work. • The terrestrial environment is being enhanced. In 2021, the City partnered with Friends of Rouge Watershed to plant over 1,000 native wildflowers at Swan Lake Park. • Popular passive recreational uses identified in FOSLP survey are supported through trail upgrades. Non-contact uses will expand with quality improvements. • Environmental improvements consider local environmental setting/ sensitivities. Per 2014 Official Plan, park is not part of Natural Heritage System (park categorized as "Other Greenway System Lands"). **Integration and Stewardship Plan:** • City departments work closely to maintain and improve the Lake and the Park environment according to the mandate given by the City Council. • Staff have developed a long-term management plan for the Lake and will continue to monitor the conditions and consult with the community and stakeholders to adapt the plan accordingly.

CLOSURE:

The FOSLP Proposal evaluation indicates that many ideas and measures are being advanced under the City's approved and ongoing activities. As summarized above:

- Passive uses of the Park are supported.
- Improving the health of aquatic and terrestrial habitat is supported.
- Lake and Park environments are being improved.
- A goal for water quality improvement has been defined and community/stakeholder engagement is ongoing.
- A long-term water quality improvement plan is approved to support environmental improvements and recreational opportunities, complemented by support of passive recreational uses.

Some ideas and measures in the FOSLP Proposal are not supported:

- Manipulating flows and water level are not pursued in Phase 1of the water quality plan.
- Mesotrophic target is not supported based on the City's limnologist evaluation.

Lastly, as indicated above, the definition of community vision in February 2021, the basis for the Holistic Approach being proposed was premature and had several limitations:

- Community survey by FOSLP was conducted prior to implementation of ongoing commitments.
- Survey proposed unattainable water quality conditions and uses.
- Survey underestimated costs of implementation of 'Restoration' activities.
- Survey represented the Greensborough community and did not include all Ward 5 residents. The feedback suggested that 73% of respondents were retired which represents Swan Lake Village and Amica well but not the entire ward.
- The survey feedback suggested that 86% of respondents (315 out of 367) use Swan Lake Park primarily for walking which is meeting community needs now.
- Some of the activities proposed under Vision (e.g., Artists in Park, Cultural Events, and Environmental Camps) will require amenities not available in the Park (e.g., parking spaces, washrooms) and are inconsistent with uses within designated Community Parks and available development space for active uses. Assessing habitat and identifying actions for "other wildlife" are more appropriate within the City's designated Natural Heritage Network (excludes Swan Lake Park).

The City has no current plans to reclassify Swan Lake Park or change the intended use. While we appreciate the feedback from FOSLP through their community survey, the results do not support a change from the current use of Swan Lake Park.