Final – Rev 2

Swan Lake Management Options

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

Prepared for:

Fred Peters
Friends of Swan Lake Park

Project No. 3645 | March 2026

NATURAL RESOURCE SOLUTIONS INC.
Aquatic, Terrestrial and Wetland Biologists

Swan Lake Management Options

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

Project Team

Phil Anderson	Sr. Aquatic Biologist, Project Advisor
Blair Baldwin	Aquatic Biologist, Project Manager
Stephen Burgin	Aquatic Biologist

Report submitted on March 9, 2026

Blair Baldwin

Project Manager

Aquatic Biologist

Table of Contents

1.0 Purpose and Objectives

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

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

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

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

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

1.1 Background and Scope

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

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

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

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

The scope of this review includes:

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

2.0 Summary of Water Quality Monitoring Program Components

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

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

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

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

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

Table 1. Swan Lake Water Quality Guidelines and Targets

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

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

2.1 Water Quality Monitoring Program Components and Recommendations

2.1.1 Water Quality Parameters

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

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

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

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

Physical Parameters

- Total Suspended Solids (TSS)
- Conductivity

Total Metals

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

Organics

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

2.1.2 Water Quality Sample Collection

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

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

2.1.3 Water Quality Sampling Locations

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

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

2.1.4 Water Quality Guidelines and Targets

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

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

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

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

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

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

Water Clarity

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

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

Total Phosphorus

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

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

Total Nitrogen

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

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

Chloride

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

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

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

Dissolved Oxygen

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

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

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

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

Cyanobacteria and Cyanotoxins

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

Chlorophyll-a

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

3.0 Water Quality Monitoring Results

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

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

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

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

Water Clarity

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

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

Total Phosphorus

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

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

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

Total Nitrogen

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

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

Chloride

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

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

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

Dissolved Oxygen

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

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

Cyanobacteria and Cyanotoxins

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

3.1 Adequacy of Water Quality Monitoring Program

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

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

3.2 Water Quality Monitoring Program Limitations

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

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

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

4.0 Water Quality Monitoring Program Enhancements

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

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

4.1 Swan Lake Management Strategy Program Considerations

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

5.0 Conclusions

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

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

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

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

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

6.0 References

Canadian Council of Ministers of the Environment. (1999). Canadian water quality guidelines for the protection of aquatic life: Dissolved oxygen (freshwater). In: Canadian environmental quality guidelines, 1999, Canadian Council of Ministers of the Environment, Winnipeg.

Canadian Council of Ministers of the Environment (CCME). (2001). Canadian water quality guidelines for the protection of aquatic life: CCME Water Quality Index 1.0, Technical Report. In: Canadian environmental quality guidelines, 1999, Canadian Council of Ministers of the Environment, Winnipeg.

Canadian Council of Ministers of the Environment. (2004). Canadian water quality guidelines for the protection of aquatic life: Phosphorus: Canadian Guidance Framework for the Management of Freshwater Systems. In: Canadian environmental quality guidelines, 2004, Canadian Council of Ministers of the Environment, Winnipeg.

Canadian Council of Ministers of the Environment. (2011). Canadian water quality guidelines for the protection of aquatic life: Chloride. In: Canadian environmental quality guidelines, 1999, Canadian Council of Ministers of the Environment, Winnipeg.

Canada Water Agency. (2025). Great Lakes water quality agreement: areas of concern. Available at: https://www.canada.ca/en/canada-water-agency/freshwater-ecosystem-initiatives/great-lakes/great-lakes-protection/canada-united-states-water-quality-agreement/areas-concern.html updated: May 29, 2025.

Environment Canada. (2011). Water Quality Status and Trends of Nutrients in Major Drainage Areas of Canada. Water Science and Technology Directorate Technical Summary.

Health Canada. (2024). Guidelines for Canadian Recreational Water Quality: Summary Document. February 2024

Markham Environmental Services. (2021). Swan Lake Long-Term Management Plan. November 2021.

Markham Environmental Services (2022). Swan Lake Water Quality Monitoring 2021 Annual Report. Project Number:21163. March 2022.

Markham Environmental Services (2023). Swan Lake Water Quality Monitoring 2022 Annual Report. Project Number:22198. March 2023.

Markham Environmental Services (2024). Swan Lake Water Quality Monitoring 2023 Annual Report. Project Number:23032. February 2024.

Markham Environmental Services (2025). Swan Lake Water Quality Monitoring 2024 Annual Report. Project Number:24254. February 2025.

Ontario Ministry of the Environment and Energy (MOEE). (1994). Water Management: Policies, Guidelines, Provincial Water Quality Objectives. Updated: August 16, 2021.

Unckless, R.L. and Makarewicz, J.C. (2007). The Impacts of nutrient loading from Canada Geese (Branta canadensis) on water quality, a mesocosm approach. Hydrobiologia 586, 393-401.