Friends of
Swan Lake Park

PATHWAY TO SUSTAINABILITY

June 1, 2020

Contents

EXECUTIVE SUMMARY

The Friends of Swan Lake Park are residents of Markham committed to saving Swan Lake and Swan Lake Park through environmental best practices that will restore safe lake water for sustainable human and wildlife activity.

Swan Lake Park in Markham is home to a rich diversity of wildlife. But this wildlife is threatened by the deteriorating water conditions in Swan Lake and the erosion of sustainable terrestrial habitat in Swan Lake Park due to the unchecked intrusion of invasive plants.

Over 27 years Swan Lake and surrounding land has evolved from an inactive, obscure gravel pit to the centre piece of a thriving community. To sustain this role, Markham must immediately put plans in place to ensure the park is environmentally safe for its citizens and wildlife.

The environmental elements in the Park are all interconnected and interdependent on each other. Once water quality gets out of balance, aquatic life and aquatic plants are directly impacted while other elements are negatively affected by the deteriorating aquatic conditions.

WATER QUALITY ISSUES IN SWAN LAKE

Water quality in Swan Lake has been regularly documented since development began in 1993.

- Excessive phosphorus was first noted in 2005. The water quality in the Lake has deteriorated annually ever since (See Appendix D).
- In 2012, in terms of water quality, Swan Lake ranked 15th out of 17 man-made lakes in Ontario.
- In spite of efforts to improve the water quality through a Phoslock treatment in 2013 and an aggressive goose management program, the water quality today is as bad as in 2012.
- Dissolved oxygen levels in the lake have deteriorated to the point that many fish have died.
- In a recent survey, 99% of respondents expressed concern about the bacteria in the lake water.
- Analysis by the city's water quality consultants, Freshwater Research, attributes 63% of the current gross phosphorus load in Swan Lake to internal sources.
- Phoslock or aluminum can efficiently reduce the existing phosphorus in the lake. Additional actions are required to minimize the buildup from external sources such as migrating geese (51% of external load) and stormwater runoff from adjacent areas (49% of external load).

MISSION

The mission of the Friends of Swan Lake Park was endorsed by over 90% in a survey of local residents. The mission is to encourage Markham, in its role as Steward of Swan Lake Park, to immediately address the poor water quality issues in Swan Lake, to establish a comprehensive Environmental Plan for the Lake and Park that addresses all environmental issues and to establish a Stewardship Policy for the Lake and Park that includes a sustainable Restoration Program and a monitoring framework that will trigger timely remedial responses in the future.

ACTION PLAN FOR SUSTAINABILITY

The following summarizes and outlines for the City of Markham, in its role as Steward of Swan Lake Park, a recommended action plan for sustainable solutions.

We estimate the cost of the programs to restore water quality over the initial three years to be approximately $285,000 - $315,000 and the annual cost to maintain water quality to be in the order of $32,000 - $36,500 thereafter (page 26). We have not estimated the cost of the restoration of the land based elements.

Specifically, we ask the City of Markham Council to direct City staff to implement our "Pathway to Sustainability Plan" by implementing the following essential steps.

Short Term Action Plan

1. **Reverse the policy that defines Swan Lake as a Stormwater Pond**
   Swan Lake was designed as a community recreational centre with a robust aquatic environment. In 2005 the City unilaterally, without any public discussion, adopted a policy to manage the lake as a stormwater pond. Under this policy the broader community roles were abandoned, water quality has deteriorated, most fish and aquatic plant life have died and the lake is now dying.

   We request that Council reinstate the original purpose and community objectives for Swan Lake and Swan Lake Park.

2. **Establish Management Goals for Water Quality**
   Immediately implement the recommendations of Freshwater Research for the establishment of management goals for water quality in the lake and the establishment of trigger mechanism's to ensure prompt remedial treatment in the future.

   The initial goal should be to restore water quality to the mid-point of the Eutrophic category - levels attained in 2014 following the initial Phoslock treatment in 2013. The ultimate long term goal should be to achieve Mesotrophic status (see page 15).

3. **Immediately Treat the Legacy Phosphorus in the Swan Lake**
   Immediately implement the recommendations of Freshwater Research to treat the buildup of excessive phosphorus with a chemical treatment of either Phoslock or aluminum.

   Following the chemical treatment, invest in aeration and water circulation equipment that will increase oxygen levels and help reduce internal phosphorus load in the lake. Starting in fall of 2020, pump out 10% of the phosphorus laden water (see page 55).

   Due to the existence of cyanobacteria in the lake, we ask that Markham post health risk warning signs at the lake, temporality ban fishing in the lake and either remove the fountain or move it further into the lake until the water quality in the lake is restored.

4. **Improve Effectiveness of the Goose Management Program**
   Engage an expert adviser to assess the comprehensiveness of the current geese mitigation program, to perhaps propose additional actions such as ways to reduce the attractiveness of the habitat and the feasibility of alternatives such as relocation and culling of the geese. Secondly, install strobe lights in the lake to disturb the migratory geese (see page 64).

5. **Engage and Adopt the Standards of the Toronto and Region Conservation Authority**
   Adopt the standards of the Toronto and Region Conservation Authority and enlist their support to undertake an environmental assessment of both the land based and aquatic elements in the Swan Lake Park, similar to a recent study undertaken for Toogood Pond (see Appendix C).

Long Term Action Plan

1. **Implement Long Term Sustainable Solutions for Water Quality**
   Implement programs that will help reduce the phosphorus sources that contribute to the annual build up in the Lake, invest in physical alterations in the Lake and restore core aquatic plants and fish that will further sustain the water quality. We estimate these actions could reduce phosphorus entering the Lake each year by 30-45% (see page 25).

   Commit to a program of a Phoslock or aluminum treatment every 3 years if the above programs are not sufficient to maintain the water quality goals.

2. **Implement Environmental Restoration Programs**
   Develop and implement a long term environmental restoration plan for all elements in Swan Lake and Swan Lake Park.

3. **Establish a Stewardship Plan**
   Establish a long term Stewardship Plan recognizing the broader community and environmental role of Swan Lake Park with management goals and responsibilities addressing all recreational and environmental elements in Swan Lake and Swan Lake Park (see page 31).

WE WANT TO GO BACK TO THE FUTURE

From This

Back to This

1) RESTORATION OF HABITAT IN SWAN LAKE PARK

Swan Lake Park in Markham is home to a rich diversity of wildlife. But this wildlife is threatened by the deteriorating water conditions in Swan Lake and the erosion of sustainable terrestrial habitat in Swan Lake Park due to the unchecked intrusion of invasive plants.

Markham manages Swan Lake Park as a "Natural Spaces, Wildlife Places" park. Natural areas such as Swan Lake Park provide shelter and food for wildlife, remove pollutants from air and water, produce oxygen through photosynthesis and provide valuable recreational and educational opportunities.

There are no streams flowing in or out of Swan Lake so Swan Lake is a unique environmental structure with its own particular set of problems.

The environmental elements in the Park are all interconnected and interdependent on each other. Once water quality gets out of balance, aquatic life and aquatic plants are directly impacted while other elements are also negatively affected by the deteriorating aquatic conditions.

Interconnected Elements within Swan Lake Park

We have identified over 80 different species of birds and mammals that inhabit the Park and 7 invasive plant species that are gaining hold. (See Appendix A and B)

Invasive Species

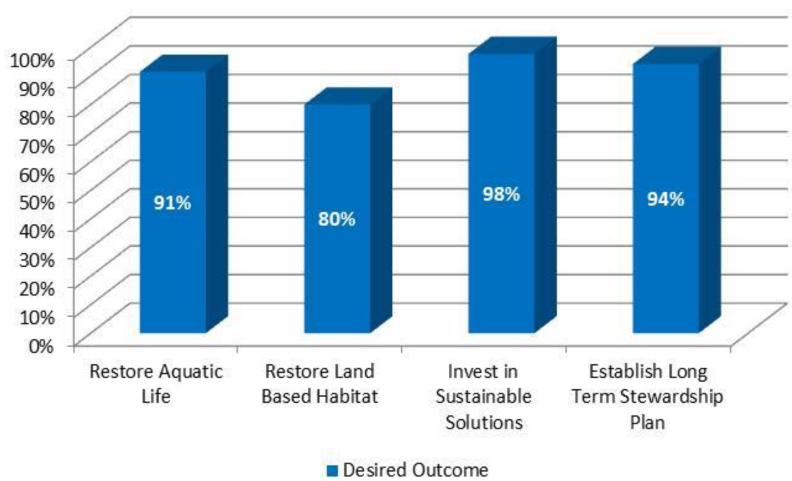
Invasive plants can have a large impact on natural areas and threaten these important services that they provide. Invasive species generally are non-native plant, animal or pest species that out compete native species for resources and dominate space.

Invasive plants impact species diversity and species richness by competing heavily for resources such as light, moisture and soil nutrients which native plants require to establish and grow. These changes in species composition may affect wildlife that have adapted to native plant communities. Ultimately, invasive plants affect the intricate linkages that make ecosystems strong and resilient.

A Concerned and Committed Community

On March 9, 2020, the Friends of Swan Lake Park hosted a public meeting titled "Back to the Future" to discuss the issues in the Park. The meeting included officials from the City of Markham and over 180 Markham residents attended. Attendees were asked to fill out a survey on their views on the desired future of Swan Lake Park.

There are cyanobacteria in Swan Lake. Cyanobacteria can be harmful to humans and deadly for small animals. 85% of respondents said they were very concerned about the possible health risks while another 14% indicated they were somewhat concerned. Only 1 respondent replied that they were not concerned about the possible health risks.



The 99 survey respondents clearly indicated support for a policy that involved investment in sustainable solutions and restoration of the aquatic and land based habitat. 98% supported the investment in long term sustainable solutions, 91% supported restoration of the aquatic life in the lake, while 80% supported restoration of the land based habitat. 94% felt that it was important to establish a long term Stewardship Plan.

Engage and Adopt the Standards of the Toronto and Region Conservation Authority

Swan Lake Park is categorized as a "local feature" within the Rouge River watershed.

The Toronto and Region Conservation Authority ("TRCA") has developed comprehensive environmental plans for the nine watersheds it oversees, including the Rouge River watershed. The comprehensiveness of the assessments and the scope of the restoration programs provide a substantive and proven environmental benchmark for assessing the needs in Swan Lake Park. There may be components of the processes that the city staff or other technical advisers may be able to undertake independently of the TRCA, however, it is important that the efforts undertaken meet or exceed the standards that are applied by the TRCA.

The TRCA followed a five step program in its assessment of the Rouge River watershed and we believe a similar program is required to address the issues in Swan Lake Park. The five steps followed by the TRCA in its Rouge River assessment were:

1. Environmental Assessment – Inventory and Study of the Existing Elements
2. Identify Areas of Concern
3. Develop a Long Term Environmental and Restoration Plan
4. Initiate an Implementation Plan
5. Monitor Progress

Recently the TRCA completed an environmental review of Toogood Pond (See Appendix C). We have requested that the City ask the TRCA to initiate a similar environmental review of Swan Lake Park, but to include the aquatic elements within Swan Lake. This effort will provide an essential baseline for the restoration work required.

From this report, we would expect the development of a Restoration Program to address the damage done by the poor water conditions in the lake and perhaps include restoration programs that will address invasive species and enhance wildlife habitats in the park.

Restoration of Swan Lake Park

The following chart summarizes some of the approaches the TRCA takes in restoring the habitat. Many of these approaches may be appropriate for Swan Lake and Swan Lake Park

2) WATER QUALITY ISSUES IN SWAN LAKE

The water quality in Swan Lake has been regularly documented since the development of the Park began in 1993. The problem of excessive phosphorus was first noted in 2005. The water quality in the Lake has deteriorated annually ever since (See Appendix D).

In 2012, in terms of water quality, Swan Lake was ranked 15 out of 17 man-made urban lakes in Ontario.[1] In spite of the City's attempt to improve the water quality through a Phoslock treatment in 2013 and an aggressive goose management program, the water quality today is as bad or worse than in 2012 plus recent analysis confirms the presence of harmful bacteria in the Lake.

Swan Lake, September 2019
Photo courtesy of Maureen Peters

Swans at the Feeding Station April 2019
Photo courtesy of Jon Van Loon

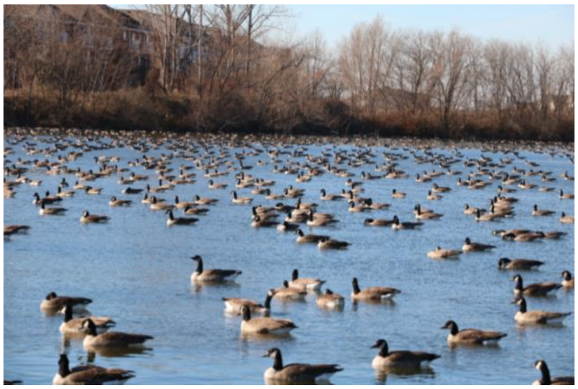
The poor water quality directly impacts the aquatic life and the quality and quantity of water based plants that are a source of oxygen for fish and food for waterfowl. The team of caregivers for the swans brought to the lake each year by the residents of Swan Lake Village believe there is not sufficient food sources in the Lake and that their effort to feed the swans three times each day is essential for the swans' survival. In a lake this large, we shouldn't have to worry about feeding swans!

There were many environmental and consultant reports written about Swan Lake and Swan Lake Park in the early 1990's, primarily in support of the development of Swan Lake Village. One report by Cosburn Patterson Wardman Limited, dated October 1994, states that "the area will be transformed from an inactive gravel pit into diverse natural habitats for aquatic and terrestrial wildlife, with passive recreational uses." At that point it notes that the pond had already been stocked with largemouth bass and is fished by local anglers and that the "former gravel pit provides quite good to excellent habitat for largemouth bass".

With the exception of the water quality and robust aquatic life, much of the original vision has materialized.

[1] Water Quality and Remediation Options for Swan Lake, Freshwater Research, August 27, 2012

The primary challenge is the excess amount of phosphorus in the Lake that stimulates excessive growth of algae and phytoplankton. Phytoplankton is what gives the water its dark green look and the algae are the slimy green substances on the surface. The excess phytoplankton and algae prevent the sunlight from reaching water based plants which is needed for their survival and absorb the free oxygen in the water that fish need to survive.



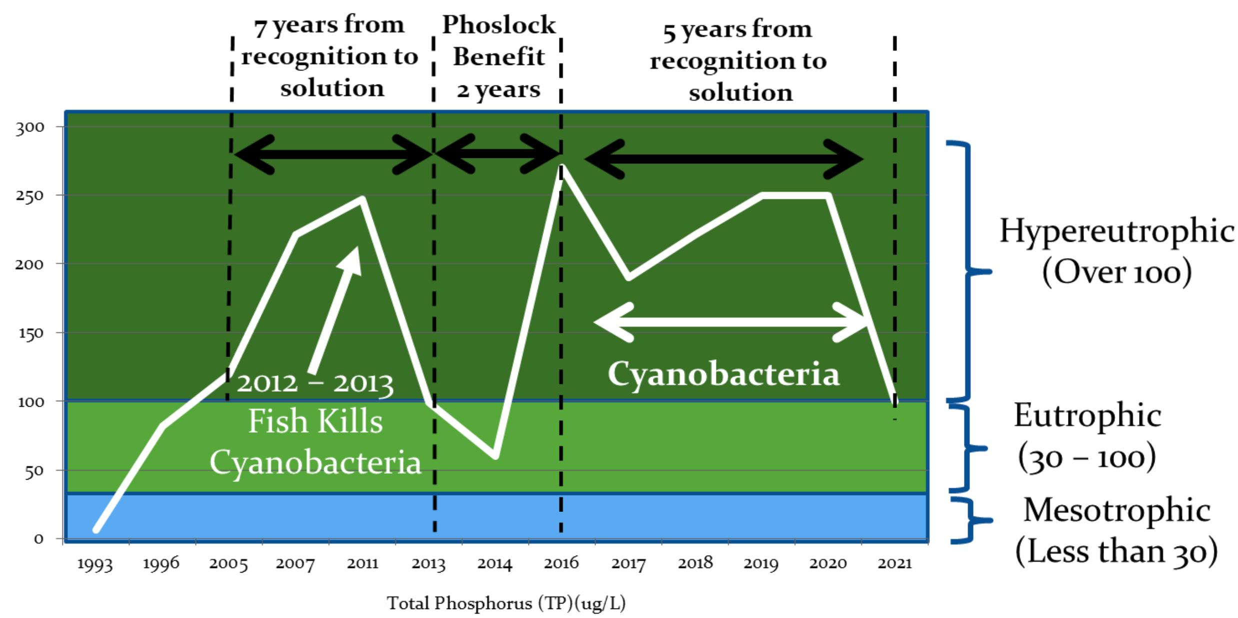
Canada Geese in Swan Lake, November 2017
Photo courtesy of Don Fowler

The excess phosphorus arises primarily from the buildup of excess annual contributions from the storm water runoff from adjacent areas and the large migrating geese population.

Recent analysis attributes 64% of the current annual phosphorus load in the lake to legacy sources within the lake, with 18% arising from recent runoff from areas that drain into the lake and 19% from migrating geese.

History of Excessive Levels of Phosphorus

There are no streams flowing in or out of Swan Lake so Swan Lake is a unique environmental structure with its own particular set of problems.



Based on water samples taken in 2005, a series of environmental studies of the Lake dated 2006 were prepared as the City assumed full responsibility for the southern area of the Lake incorporating the current viewing dock and small island (Block 9). These reports describe Swan Lake as having a "healthy warm water fish community". One report noted that the level of phosphorus in the Lake was high and would require monitoring. It recommended efforts be undertaken to identify and minimize the sources of the phosphorus, which were assumed to be related to the storm water sources.

MARKHAM'S UNILATERAL DECISION TO TREAT SWAN LAKE AS A STORMWATER POND

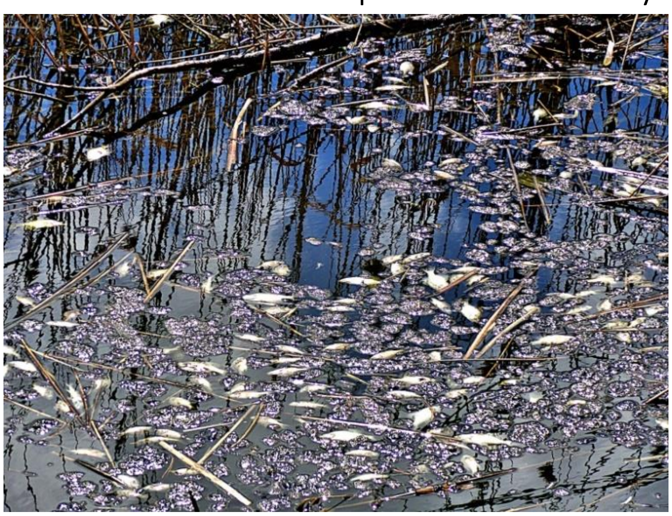
The main conclusion of the 2006 reports is that risk management measures are not needed to reduce potential health risks to humans premised upon "Swan Lake continuing to be used as a visual amenity for the community and as a storm water management facility".

These reports indicate two fundamental changes in policy from the initial 1993 Environmental Study, which was the foundation document for the community objectives for Swan Lake Park. First, that the objectives for recreational activities such as paddle sports and sport fishing had been abandoned and that the Lake was viewed and was expected to be managed as an extension of the storm water management function for the area.

To our knowledge there were no public discussions related to the redefined community role for Swan Lake. It appears to have been a unilateral decision undertaken by Markham without any public discussion on the impact.

This decision needs to be reversed and the broader community role of Swan Lake restored.

The decision was made in 2005 for Swan Lake to be managed as a stormwater pond, and in fact that is where the fundamental responsibilities rest today.



Fish Kill, Swan Lake, March 4, 2012

Since 2005 the phosphorus levels continued to rise and algae blooms were more common. As illustrated in the photo taken by Jon Van Loon, many of the fish were dying as the free oxygen was depleted by the increasing algae blooms.

No serious efforts were undertaken to curtail the growing phosphorus problems until the City was pestered by local resident Jon Van Loon in 2011 into addressing the deteriorating conditions in Swan Lake, leading to the Phoslock treatment in 2013.

A recent analysis of the sources of phosphorus in the lake concludes that currently 64% of the annual phosphorus load in the lake comes from sources within the lake, while 18% arises from runoff from the areas that drain into the lake and another 19% is attributed to waterfowl.

There are natural sources within the lake that contribute to the internal phosphorus load but the two primary internal sources are thought to be two "legacy" sources, phosphorus from the two previous dump sites in the lake and the accumulating sediment at the bottom of the lake – which arises from the inflows from external sources over the previous years. A recent test concluded that only half of the phosphorus in the sediment at the bottom of the lake is now bound by the Phoslock, therefore the other half is an available nutrient resource for the algae and phytoplankton.

Consequently the consultant’s concluded that the most effective approach for containing the phosphorus overload is to treat the “internal” load (64%) since it is currently the primary source. This is the area targeted by chemical treatments such as Phoslock or Aluminum compounds. The initial benefit of the Phoslock treatment in 2013 was estimated to have reduced the impact of the legacy phosphorus by 70%.

Programs for curtailment of the amount contributed by runoff (18%) and waterfowl (19%) are important to mitigate future build ups within the lake and to maintain a healthy aquatic environment.

Phoslock Treatment

In 2013, 8 years after the problems of phosphorus in the Lake were identified; the City decided it would treat the Lake with Phoslock. Phoslock is a clay based product that helps trap the existing phosphorus at the bottom of the Lake (see page 50).

The consultant’s report in 2012, warned that a subsequent treatment of Phoslock may be needed, but no follow up application was applied. The benefits of the initial treatment lasted for about 2 years, not the 8-10 years hoped.

It should be noted that references to the longevity of a chemical treatment typically relates to how long it will take for the water quality to deteriorate to its pre-treatment levels. Therefore if the objective is to maintain a healthy level of water quality then it must be recognized that the lifespan of a treatment is only at best half the estimate. Therefore an estimate of 6 – 10 years of benefit means that in only 3-5 years action will be required to restore healthy levels in order to minimize further environmental damage.

In 2017, the consultants stated that another treatment of Phoslock may be needed since the levels of phosphorus and cyanobacteria were approaching the levels they recommend as the “trigger” for another treatment. They were asked to investigate and report on other remediation treatment options. No doubt another treatment of some sort is essential immediately, but any such action must include a plan for long-term sustainability.

City staff has indicated they are preparing a proposal to Council that will include a recommendation for another remediation treatment (possibly Phoslock or Aluminum) in 2021 – 5 years after it was recognized that the conditions had deteriorated again.

In future, a more timely response will be needed to minimize environmental damage.

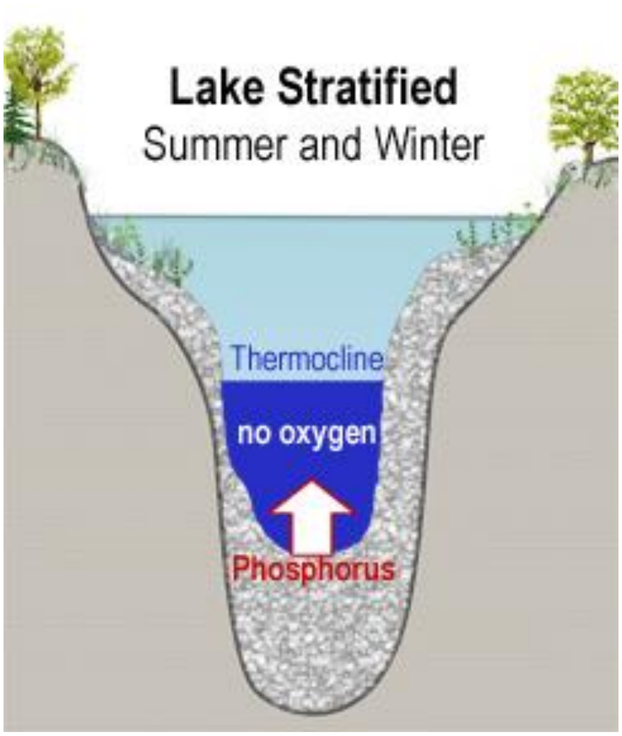
Dissolved Oxygen (Source RMB Labs, www.rmbel.com)

Dissolved Oxygen is the amount of oxygen dissolved in lake water. Living organisms breathe in oxygen that is dissolved in the water.

Dissolved oxygen is supplied to a lake from two main sources: plant and algae photosynthesis and diffusion from the atmosphere. In photosynthesis, plants use the sun's energy to convert carbon dioxide and water into oxygen and cellular material (growth).

Dissolved oxygen is used by two main processes: respiration and decomposition. Respiration is when animals breathe in oxygen and use it to produce energy, releasing carbon dioxide and water as by-products. In simpler terms, it is the act of breathing. Decomposition is when invertebrates, bacteria and fungi break down dead organic material. Most decomposition uses oxygen in the process.

Oxygen is only added to the lake near the surface because that's where the plants are and where diffusion from the atmosphere occurs. In the summer and winter in a eutrophic lake such as Swan Lake, the lake is usually separated into a top layer and a bottom layer called stratification. During stratification, the bottom of the lake becomes anoxic, void of oxygen. Anoxia occurs because respiration and decomposition takes place at the bottom of the lake and use up oxygen. The oxygen can't be replenished at the bottom of the lake because it is cut off from the top of the lake by the thermal barriers. In the spring and fall when the lake mixes again, oxygen gets replenished at the bottom of the lake.



Source: RMB Labs

If the bottom of the lake becomes anoxic, the organisms either die or move up from the bottom to where there is oxygen. For example, in late summer fish usually move closer to the surface because there is no oxygen available at the bottom of the lake. In shallow lakes in the summer and winter, the entire lake can become anoxic, causing a fish kill.

When the bottom of a lake is anoxic (usually in late summer and late winter), chemical processes at the sediment/water interface cause phosphorus to be released from the sediments. When the lake mixes again, this increased phosphorus fuels algae growth. This phenomenon is called internal loading because phosphorus is entering the lake from within the lake (from the sediment).

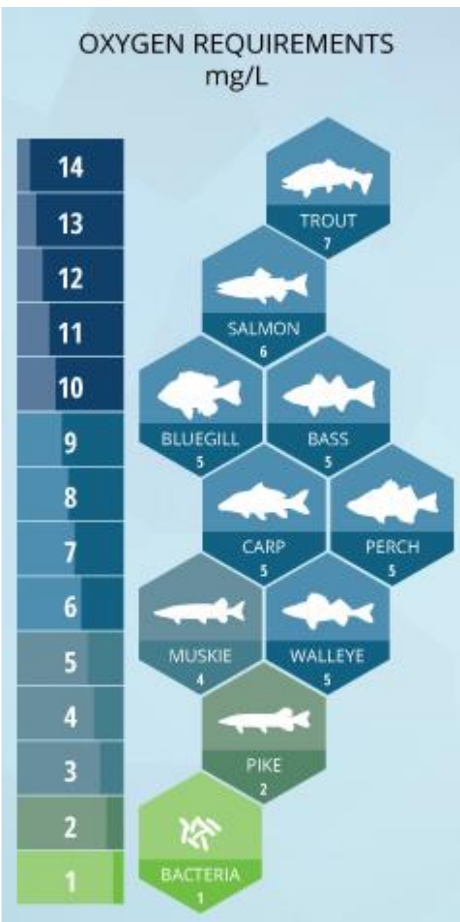
Lack of Dissolved Oxygen in Swan Lake

Freshwater Research, in its draft report dated November 2019, notes that Swan Lake thermally stratifies during the summer despite its shallow depth. This pattern of stratification and anoxia (lack of dissolved oxygen) remained similar after the Phoslock treatment. Widespread anoxia was detected during the winter months under ice in January 2014, a few months after the Phoslock treatment.

The measures of dissolved oxygen in Swan Lake, consistently fall into the poorest quality ratings of eutrophic or hypereutrophic, with recordings typically below 3 mg/L.

The report concludes that the "pattern of low dissolved oxygen in the bottom water and occasionally throughout the summer and winter water column indicated severe eutrophication and the potential of sediment phosphorus release, unless release is interrupted by a treatment" such as Phoslock.

Dissolved Oxygen and Fish in Swan Lake



Source: Fondriest Environmental Learning Centre www.fondriest.com

The original design of Swan Lake included environmental elements to support a healthy fish habitat.

Early reports cite Swan Lake as supporting pumpkinseed sunfish, fathead minnows and largemouth bass (believed to have been stocked prior to 1992 by TRCA).

Many fish died prior to the Phoslock treatment in 2013.

Levels of dissolved oxygen in Swan Lake are typically below 3 mg/L. Only the hardiest of fish can survive at such low levels. Current sightings report carp, gold fish, catfish and minnows.

A program to control phosphorus levels in Swan Lake must also restore dissolved oxygen levels in order to support a return to a balance aquatic environment in the lake.

Freshwater Research recommended that the City engage a fish specialist to advise on the type of fish that should be considered for restocking of the lake.

It suggested that the species selected should be ones that will assist in reducing algae levels in the lake, as opposed to bottom feeders such as carp and gold fish that stir up the bottom sediment and recycle the dormant phosphorus. Other species recommended prey on mosquito larvae, thereby reducing mosquitos.

Establishment of Water Quality Goals

It is important that the City commit to defining what they think success looks like. Scientists have developed a rating system for lakes that can be used to set out measurable goals.

Lake Conditions Typically Associated With Trophic States

Trophic State	Water Quality	Characteristics	Swan Lake Rating
Oligotrophic	Good/ clear	Little algae, good oxygen supply, good range of fish	1993 assessment (challenged due to algae sightings)
Mesotrophic	Fair/ Clear	Submerged aquatic plants, range of fish, periodic algae blooms	Our recommendation for a stable future goal
Eutrophic	Poor	High densities of algae, limited oxygen, suitable for hardier fish, fish kills possible	Marginally eutrophic in 2014 following Phoslock
Hypereutrophic	Very Poor	Frequent and severe algal blooms, low transparency, "dead zones"	2007, 2011, 2013, 2016 - 2019

The ultimate sustainable solution is to reach the point where Swan Lake can be categorized as a Mesotrophic Lake. The lower quality levels of Eutrophic and Hypereutrophic are not environmentally stable and damage to the aquatic and plant life would continue as would the risk of cyanobacteria.

The City of Markham's water quality consultant, Freshwater Research, has stated that it would be "nice" to keep Swan Lake in the improved Eutrophic state. Even though this goal was accomplished in 2014, they now suggest that this may be overly ambitious and recommend higher trigger points.

Initial Goals For Water Quality – Mid-Eutrophic Classification

	Eutrophic Classification Measures			Dissolved
	Total Phosphorus (µg/l)	**Secchi Depth,** (m)	**Chlorophyll** (µg/l)	**Oxygen** (mg/L)
Range	31 - 100	1 – 2	9.1 – 25	5 – 11
Remediation Trigger	100	1	25	5
Midpoint Goal	65	1.5	17	8
2014 Actual (Post Phoslock)	**60**	**1.4**	**12.6**	**<2.5**

The Phoslock treatment was successful in achieving or exceeding the mid-point Eutrophic state goals in 2014. We recommend that we strive to restore water quality to 2014 levels and establish trigger points to maintain that level.

The lesson from the initial treatment was that maintaining that success depends on either prompt follow-up treatment with Phoslock at least every 3 years or the implementation of effective programs to reduce the inflow of phosphorus from stormwater and geese plus means to improve oxygen levels.

Once the interim Eutrophic goal is stabilized, perhaps we will be able to identify approaches that may make the ultimate Mesotrophic goal feasible.

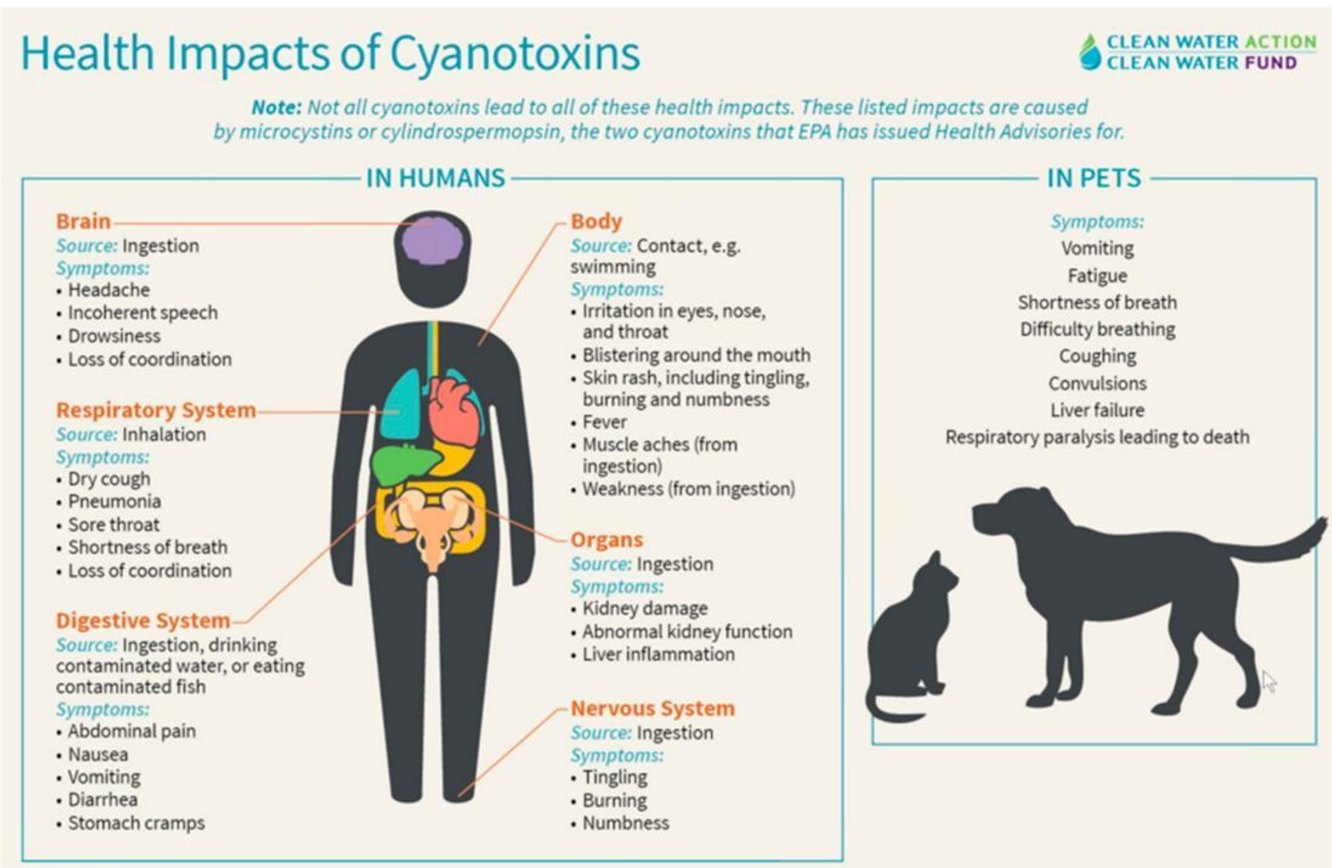
3) CYANOBACTERIA AND HEALTH RISKS

Swan Lake also contains cyanobacteria, a type of bacteria. Though not algae, cyanobacteria is often referred to as blue-green algae.

Certain forms of cyanobacteria found in Swan Lake produce toxins, or poisons, that are harmful to animals and can be harmful to humans. One form can impact individuals with respiratory issues, another can cause liver damage. The level of cyanobacteria in Swan Lake is below the guidelines for banning recreational activities but there is risk some of the bacteria may become airborne.

There was a high level of cyanobacteria identified in 2016. One of the toxins identified, microcystin, was recorded at 3.7 times the provisional federal guidelines for recreational activities. However, we are not aware that any health risk warning signs were posted at that time. Levels have moderated since 2016. (Source: memo to Markham Environmental Services Department from Freshwater Research dated Nov 29, 2018)

We believe the cyanobacteria levels within Swan Lake warrant the posting of a health risk warning at the Park and have requested that the City also post a temporary ban on fishing in the Lake until the water quality is restored***.***



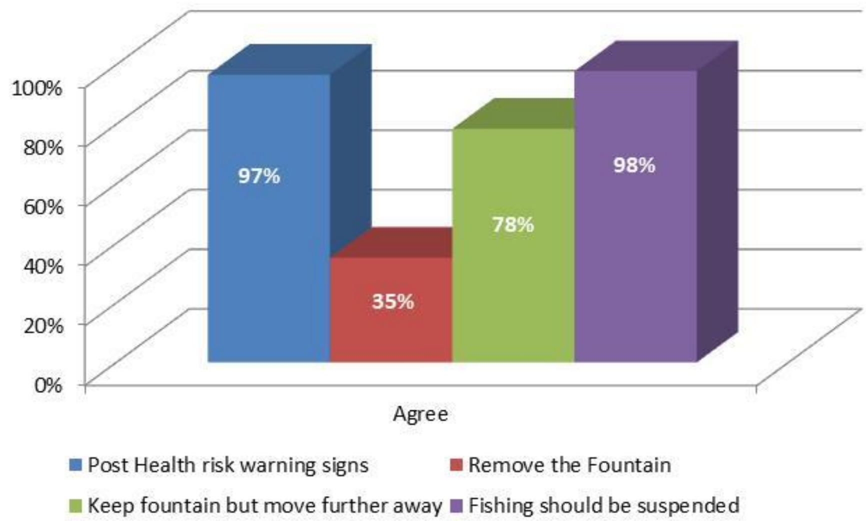
Source: www.beachipedia.com

Resident's Concerns about Cyanobacteria

Survey respondents outlined their concerns about the levels of cyanobacteria in Swan Lake.

85% of respondents said they were very concerned about the possible health risks while another 14% indicated they were somewhat concerned. Only 1 respondent replied that they were not concerned about the possible health risks.

When asked their views on what temporary measures the City should enact until the cyanobacteria risks are lowered, 97% felt posting of health risk signs was warranted and 98% said fishing should be temporarily banned.



Each summer a fountain is installed by the City at the south end of the lake close to the viewing dock. There is concern that the fountain may contribute to the risk of airborne cyanobacteria and in windy conditions water sprays on visitors on the viewing dock. 35% felt the fountain should be removed but if not removed 78% felt it should be moved further into the lake.

5) SUSTAINABILITY PLAN FOR SWAN LAKE

In 2013, the City of Markham applied a chemical treatment called Phoslock to Swan Lake that materially reduced the phosphorus levels however the benefits lasted for only two years.

Two important lessons arose from that experience: Phoslock works, but there needs to be a follow up plan for maintaining the improved water quality levels.

Long term sustainable solutions must address the three intrinsic challenges facing Swan Lake

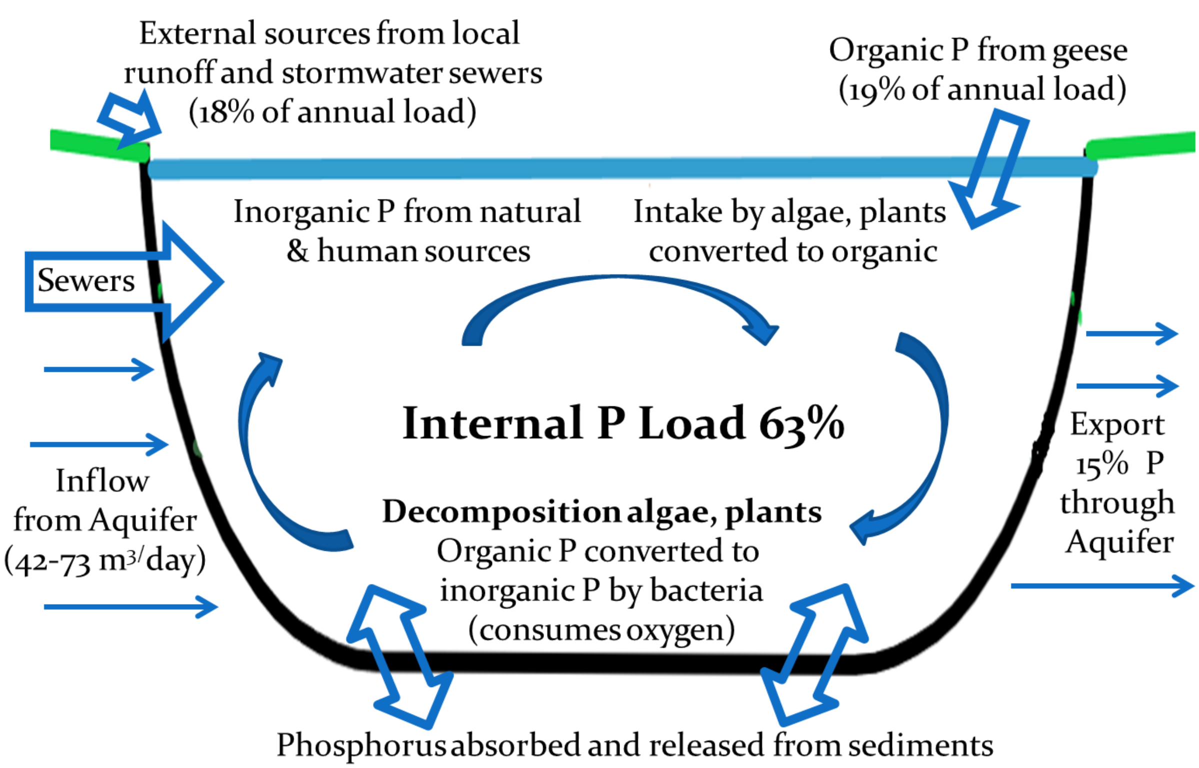
1) It is in essence a stagnant pond with no surface level inflows and outflows;
2) It must cope with direct stormwater inflows from the surrounding areas; plus,
3) It must absorb semi-annual phosphorus overloads contributed by migrating geese.

Managing the Phosphorus Sources

In their analysis of the phosphorus issues in Swan Lake, the City's advisers Freshwater Research categorized the phosphorus into a few major sources. Understanding the primary contributors helps focus the discussion on where to direct efforts towards implementing sustainable solutions.

The high level categories are external sources and internal sources. The primary external sources include drainage from the local areas and waterfowl. The primary internal sources are the accumulated excesses from previous years, plus possibly, continuing sources from the two former dumps within the lake.

The Phosphorus Cycle in Swan Lake (2017 – 2018)



External Sources

		External Load				
		Shore, Ponds, Atmosphere		Geese		Total
		kg/yr	% External	kg/yr	% External	kg/yr
Recent 2 years	2017 - 18	14.0	49%	14.6	51%	28.6
2 years After Phoslock	2013 - 14	14.7	52%	13.5	48%	28.2
10 year average	2009 - 18	13.4	45%	16.1	55%	29.5

The above table, compiled from data provided by Freshwater Research, illustrates that the external sources of phosphorus are evenly split between runoff sources from the area served by the lake and Canada Geese. Therefore efforts to reduce the input in phosphorus need to focus equally on the sources from the local drainage area and on goose management.

It should be noted that the two stormwater ponds are not considered to be material contributors – they are apparently performing as per their designs. Perhaps more runoff can be directed to the stormwater ponds, reducing the burden on the lake.

The combined sources from runoff and from geese have remained relatively constant at 28-30 kg per year over the three periods summarized in the above table.

Internal (Legacy) Sources

The primary sources of phosphorus from within the lake is referred to as "Internal Load". It is believed, but has not been quantified, that the two former dump sites within the lake are a possible regular internal source of phosphorus. There may be little that can be done to minimize these sources short of the very expensive process of excavation and removal of the contents of the former sites.

The other primary source is the cumulative build up from the annual external sources summarized above. We refer to these collectively as the "legacy sources".

		External Load				Plus Internal Load		Total Gross Load	
		Shore, Ponds, Atmosphere		Geese					
		kg/yr	% Gross	kg/yr	% Gross	kg/yr	% Gross	kg/yr	% Gross
Recent 2 years	2017 - 18	14.0	18%	14.6	19%	49.8	63%	78.4	100%
2 years After Phoslock	2013 - 14	14.7	36%	13.5	33%	12.6	31%	40.8	100%
10 year average	2009 - 18	13.4	19%	16.1	23%	41.3	58%	70.8	100%

Source: Freshwater Research

Once the current internal load is significantly reduced, techniques such as water circulators and aeration equipment can be beneficial in improving oxygen levels and reducing internal phosphorus load and minimizing the need for future chemical treatments. Further investigation is required to determine which equipment is best suited for Swan Lake, however the costs are expected to be quite low compared to the cost of additional future chemical treatments.

The above table indicates that over the past 10 years there has been on average 70.8 kg of phosphorus available in the lake each year. Of this, 58% is attributable to the legacy sources and only 42% from the annual net new contributions. In the most recent 2 years – legacy sources accounted for 63% on the total available phosphorus.

The data for the two year period after the Phoslock treatment illustrate the impact of the Phoslock on reducing the contribution from the legacy sources. The internal sources were estimated to contribute only 12.6 kg, a 70% reduction from the 10 year average of 41.3 kg.

Given the current excessive amounts of legacy phosphorus in Swan Lake, the City's consultants Freshwater Research have recommended approaches that target reducing the internal or legacy phosphorus. Additional efforts that focus on reducing the external sources will lessen the build-up of future internal volumes in the lake.

Impact of the Aquifer

Swan Lake is fed by underground water sources – aquifers. Studies have shown that the underground water around the lake flows towards the south at a rate of between 10 – 300 m^3/day, with one specific test showing a flow rate of 73 m^3/day.

		Total Gross Load		Less Export	Phosphorus Load	
		kg/yr	% Gross	kg/yr	kg/yr	% Gross
Recent 2 years	2017 - 18	78.4	100%	11.6	66.8	85%
2 years After Phoslock	2013 - 14	40.8	100%	5.9	34.9	86%
10 year average	2009 - 18	70.8	100%	10.1	60.7	86%

Source: Freshwater Research

The above table indicates that approximately 85 – 86% of the total phosphorus in the lake is retained in the lake. The remaining 15% is "exported" – it leaves the lake through the aquifer.

Total water volume in the lake is 102,000 m^3. A 15% loss would represent 15,300 m^3 and suggest a daily flow rate of 41.9 m^3 per day, a rate of flow below the measured quantities.

The water that leaves the lake through the aquifer is replaced by inflow from the aquifer - one of the primary sources of fresh water for the lake.

Perhaps there are other means of removing phosphorus each year and have these volumes also replaced by inflows of fresh water from the aquifer.

We estimate that it may be feasible to remove another 10 - 15% of phosphorus volume by pumping water from the lake in two possible ways: by using the water for irrigation or by pumping the phosphorus laden water into the stormwater systems (see page 55).

McCarron Lake – Two Prong Approach

A case study of McCarron Lake in Minnesota, cited by Lake Advocates, illustrates the importance of setting management goals that capture the different elements in a long term solution. McCarron Lake was averaging total phosphorus of 76 µg/L. The goal was to reduce the phosphorus level to 30 µg/L. The analysis assumed that a treatment of Alum would reduce the internal (legacy) load by 85%. To sustain a level of 30 µg/L, the analysis concluded that the input from external sources needed to be reduced 40%. Therefore, the best outcome required a two prong approach that addressed both the legacy sources of phosphorus and the new annual contributors to the phosphorus load on the lake.

Three Prong Approach for Swan Lake

For Swan Lake we are proposing a three prong approach towards a long term sustainable solution to the excess phosphorus issues:

1) Neutralizing the legacy sources and any ongoing excess;
2) Minimizing ongoing external contributions to the lake;
3) Identify approaches for removal of the phosphorus.

The following table compiled from information provided by Lake Advocates, illustrates the alignment of various techniques with the primary target areas: Watershed Control (external sources) and Internal Control (legacy).

		Targeted Areas		
Management Techniques	**Overall Assessment**	**Watershed P Control**	**Internal P Control**	**Algae Control**
Chemical				
Algaecides	Works			√
Phosphorus Precipitation				
- Alum	Works	√	√	√
- Calcium, iron	Probably Works	√	√	
- Phoslock (our assessment)	Works		√	√
Natural Enhancements				
Biomanipulation	May work in conjunction with other techniques			√
Physical Alterations				
Artificial Circulation	Works if designed for need		√	√
Drawdown	May work, risk of plant damage		√	
Dredging	Works		√	
Oxygenation	Works		√	
Watershed Management	Unlikely to work on its own	√		

More specific comments by Lake Advocates on the effectiveness and comparative costs of each technique are provided in Appendix E (page 49).

The Freshwater Research report outlined the pros and cons of a variety of treatments that may work to maintain the improved levels of water quality.

We do not have the expertise to advise the City on specific solutions however in addition to the summary of alternatives provided by Freshwater Research we have added some suggested approaches which have been tried elsewhere and which we believe may have the potential to contribute to a sustainable solution for Swan Lake.

We categorized the range of possible approaches into four categories: Chemical Treatments, Natural Enhancements, Physical Alterations and Goose Management. Swan Lake is also very low in dissolved oxygen essential to support a healthy aquatic environment for fish and plants, so solutions that also improve dissolved oxygen levels provide meaningful additional benefits.

Appendices E and F provide more specific details but the approaches and possible benefits are summarized in the following table.

Possible Contributors to Long Term Sustainability	**Possible Impact**	
	Phosphorus	**Oxygen**
Internal Load (Legacy Phosphorus)		
Chemical		
A) Alum	High	No
B) Phoslock	High	No
Physical Alterations		
A) Circulators	Moderate	High
B) Pumping/ recycling only	Low	Moderate
C) Fountains	Low	Low
External Sources		
Physical Alterations - all elements	Moderate	No
A) Increase overflow rate in splitters, sending more from Swan Lake Village homes into stormwater ponds	Low	No
B) Redirect north-east lands into North Stormwater Pond	Low	No
C) Redirect drainage from new Williamson Road area to sewers	Low	No
D) Redirect drainage from Amica lot and traffic circle to sewers	Low	No
Goose Management - all elements	Moderate	No
A) Habitat deterents	Low	No
B) Oiling of eggs	Low	No
C) Altering Grasses - courser varieties, planting garlic, sprays	Low	No
D) Disruption - dogs, decoys and lights etc.	Low	No
E) Relocation	Low	No

Possible Contributors to Long Term Sustainability	Possible Impact	
	Phosphorus	Oxygen
Phosphorus Removal		
Natural Enhancements		
A) Aquatic plants	Moderate	Low
B) Biomanipulation	Moderate	Low
C) Floating Islands	Low	Low
Physical Alterations		
A) Biovales (with pumping & recycling)	Moderate	Moderate
B) Pump and refresh	Moderate	Low
C) Algae Harvesting	High	Moderate

Diversity of Perspectives

We encourage City staff to investigate all options that may reduce the ongoing costs of maintaining critical water quality within the Lake, including the range of options outlined by Freshwater Research.

We encourage City staff to draw upon the diverse expertise at the Toronto and Region Conservation Authority to see if they have had success with solutions that may help Swan Lake.

The Water Environment Association of Ontario hosts an annual competition for university and college students. The students are asked to develop solutions to solve challenging environmental problems. The 2020 competition is to develop solutions for the stormwater management challenges at the Mill Pond in Richmond Hill. As a means of stimulating discussion of practical long term options, we have asked the City to enter Swan Lake Park as a project for the 2022 competition.

Recommended Five Step Action Plan for Swan Lake

We request that Markham adopt a five step action plan that will lead to a long term sustainable solution to the challenges facing Swan Lake.

Step #1: Reverse Policy Defining Swan Lake as a Stormwater Pond

Swan Lake and Swan Lake Park were designed to be an environmental and recreational highlight for the Greensborough community that included water sports and a nature preserve element. In 2005, Markham abandoned that objective without public discussion and adopted a policy of managing Swan Lake as a stormwater pond. Under the current policy Markham has allowed the environmental elements to deteriorate and has abandoned the objectives for water based activities. Swan Lake is dying as a consequence of this policy.

The irony is that since 2005, Markham has implementing a number of environmental programs including a Park Renaissance program but for some unknown reason Swan Lake and Swan Lake Park have been neglected.

In 2020, the only reference to Swan Lake on the Markham website is under stormwater management facilities where Swan Lake is cited as an example of “a stormwater management facility that is receiving ongoing monitoring to ensure healthy water quality is maintained.”

Markham’s focus on water quality in Swan Lake has been on minimizing the impact of cyanobacteria as a health risk. Whilst important, this is a minimal undertaking. No concern or consideration has been paid to the original objectives of a robust aquatic environment in the lake or in maintaining the original objectives for water based recreational amenities.

We request that Markham adopt a policy recognizing the environmental and recreational potential of Swan Lake and implement a long term Stewardship Plan that will sustain these objectives.

Step #2: Establish Management Goals

Immediately implement the recommendations of Freshwater Research, the city’s water quality consultants, for the establishment of management goals for water quality in the lake and establish trigger mechanism’s to ensure prompt remedial treatment in the future.

We believe the goal should be to maintain the lake as a mesotrophic lake (see page 15)

Step #3: Immediately Treat the Legacy Phosphorus

The draft report to the City by Freshwater Research, dated November 2019, outlined a variety of options that have been applied elsewhere. Given the high levels of phosphorus in the Lake, the report emphasized the need to address the legacy phosphorus with either Phoslock or Aluminum.

Markham needs to initiate a chemical treatment as the critical first step as soon as possible and plan for the implementation of one or more solutions to ensure a long term sustainable outcome that addresses the water quality problems in Swan Lake.

Initiate an annual pump and refresh program that will remove up to 15% of the phosphorus load from the lake each year at a very nominal cost.

Techniques such as water circulators and aeration equipment can be beneficial in improving oxygen levels and reducing internal phosphorus load and minimizing the need for future chemical treatments. Further investigation is required to determine which equipment is best suited for Swan Lake, however the costs are expected to be quite low compared to the cost of additional future chemical treatments.

Due to the existence of cyanobacteria in the Lake, we request that Markham post health risk warning signs at the lake, temporally ban fishing in the lake and either remove the fountain or move it further into the lake until the water quality in the lake is restored.

Step #4: Enhanced Goose Management Program

The geese are essentially 18 - 20% of the overall problem. The current goose management program has shown some benefits but an independent assessment is warranted to see what additional measures may help.

We recommend that Markham engage an independent expert to review the current program, review the elements of the habitat areas and advise on possible new initiatives such as relocation.

The peak volume of geese is in the October through December time frame. We recommend that the City purchase and implement the use of the Away with Geese strobe lights (see Appendix F, page 64) for 2020 to see if this will have a material impact on the number that stay on the lake.

Step #5: Implement Long Term Sustainable Solutions

Appendix E outlines some background on a variety of possible solutions that should be considered.

Rather than rely solely on periodic chemical treatments to address the buildup of legacy phosphorus, it is important to simultaneously implement changes that will reduce the volume of the annual build up. More comprehensive technical analysis is required by the experts but our guestimate of the potential impact of four major alternatives is summarized in the following table.

Guestimate of Potential Impact of Various Long Term Solutions

		Annual (kg)	Reduction Goal	Potential Impact (kg)
1)	Annual pump and refresh - 10% water volume, potentially 15% of legacy phosphorus.(Note 1)	27	10 - 15%	2.7 – 4.1
2)	Permanent redirection of stormwater flows to either existing stormwater ponds, stormwater sewers, or oil/grit separators	14	10 – 15%	1.4 – 2.1
3)	Aggressive program to minimize fall migration impact with light strobes and other geese mitigation programs	14.6	15 - 25%	2.2 – 3.6
4)	Recycling of water through a new bioswale (Note 2)	27	7.5 – 10%	2.0 – 2.7
	Potential Annual Impact			**8.3 – 12.5**
	Note 1: Current estimate assumes future legacy volumes of 12.5 kg (reduced to 25% of current levels by a chemical treatment) plus 50% of current annual external contributions. Note 2: Assumes legacy content as per Note 1 and 50% uptake of phosphorus content.			

The annual phosphorus load currently entering the lake is estimated at 28 kg per year. The above four low cost initiatives have the potential to reduce the impact by 8.3 to 12.5 kg per year or by 30% - 45%.

The reduction in phosphorus by other programs such as biomanipulation, the restoration of healthy aquatic plants and the broader benefits of aerators will build upon these base programs to further reduce the impact of excessive phosphorus on the water quality.

Cost Estimate for Sustainable Water Quality

We have attempted to prepare a cost summary of our proposed initiatives for restoring and maintaining water quality in Swan Lake. These estimates are based on very general information so we have included a contingency factor of 20%. Details on the assumptions are outlined in Appendix G.

The costs are categorized into three segments that align with the three prong approach of addressing internal sources, external sources and phosphorus removal. Additional costs are recognized for the ongoing need for technical guidance at major steps plus the need for annual monitoring of water quality.

We estimate that the initial costs for restoring the water quality levels, installation of a bioswale and redirection of stormwater runoff for the first three years would be $315,600 using Phoslock or $285,600 using an aluminum compound. The ongoing costs for maintenance, two additional chemical treatments and replacement of strobe lights would average $32,229 - $36,514 per year over the next 7 years.

Estimated Cost	Initial 3 Year Total	Percent of Total
Water Quality Guidance/Monitoring	$30,000	10%
Phoslock Treatment	$100,000	32%
Removal of Phosphorus	$26,000	8%
Reduce External Load		
- Redirect Stormwater Inflows	$80,000	25%
- Goose Management	$27,000	9%
Plus Contigency Provision (20%)	$52,600	17%
Total Estimated Cost With Phoslock	**$315,600**	**100%**
Total Estimated Cost With Aluminum	**$285,600**	
Annual Cost With Phoslock thereafter	**$36,514**	
Annual Cost With Aluminum thereafter	**$32,229**	

6) NEED FOR A STEWARDSHIP PLAN FOR SWAN LAKE PARK

Lack of Regulatory Oversight

Swan Lake is a regulatory orphan.

Swan Lake is not connected to a tributary of the Rouge River so it does not fall under the regulatory umbrella of the Toronto and Region Conservation Authority.

Nor is Swan Lake a Stormwater Pond. So it does not fall under the auspices of Markham's Stormwater Management Policy which states that its work should be based upon an "ecosystem approach that must consider the need of not only protecting, but whenever possible enhancing the natural environment."

The following objectives are to be considered under Markham's ecosystem approach:

i. Consider the protection of sensitive natural resources and propose appropriate restoration and naturalization measures for areas where these resources have been previously impacted;
ii. Provide peak flow control, and water quality protection, habitat enhancement, water balance and erosion control;
iii. Avoid negative impacts on wetlands, Areas of Natural and Scientific Interests (ANSI), Environmentally Sensitive Areas (ESA);
iv. Maintain groundwater recharge through infiltration practices in areas confirmed as significant recharge areas or supporting key hydrologic and natural features;
v. Protect, Rehabilitate and Enhance ecological linkages which secure wildlife movement and the biodiversity of plants and animals, such as valley buffers;
vi. Promote visual and passive recreational use of natural features and corridors;
vii. Restore eroded stream banks and vegetation to natural conditions;
viii. Protect and Enhance Fish and other aquatic habitats; and
ix. Ensure public input opportunities are provided at multiple points in the process

We were told that the governing document for Swan Lake and Swan Lake Park is the 1993 Environmental Management Study provided by the developers that built the Park in conjunction with the development of Swan Lake Village.

The Environmental Management Study sets out the primary objectives in terms of the development of the Park and the related storm water ponds. The report does not contain reference to ongoing management responsibilities nor does it set out any management goals for the maintenance of the environmental elements. The Swan Lake Rehabilitation Plan (1994) sets out more specifically some of the features to be developed.

Markham has other programs that one might expect would have had an impact on the issues facing Swan Lake and Swan Lake Park, for example:

> **Parks Renaissance Strategy:**
> "a framework for the re-imagination of reinvestment in Markham's existing parks and open spaces"
>
> **Wildlife Management Guidelines** which state in part that they:
> "… will endeavour to identify and protect natural heritage systems and wildlife habitats to conserve biodiversity for future generations"

Yet it is not apparent that Swan Lake and Swan Lake Park have been impacted by any of these policies.

Today's Amenities Compared to the Original Vision

The following table summarizes our assessment of the status today of the original recreational features and environmental elements set out in the 1993 Environmental Management Study.

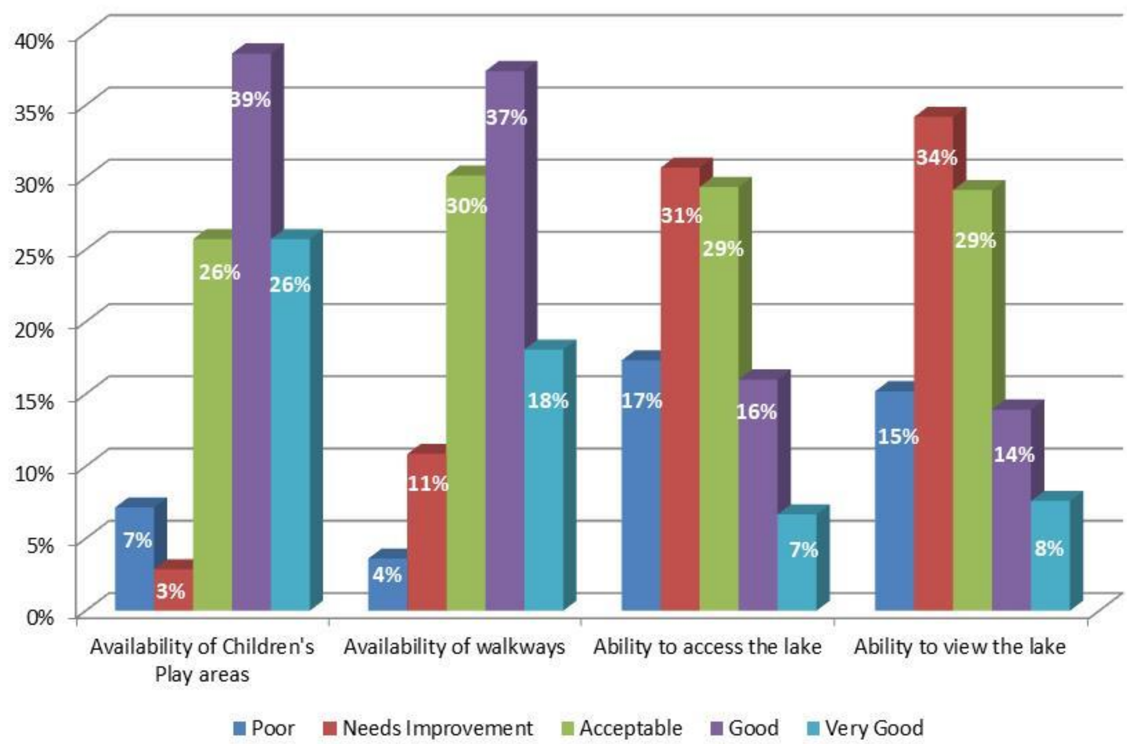
Swan Lake Park: Vision vs. Reality	
Today	**Original Plan: 1993 Environmental Management Study**
	Recreational Plan: A Passive Use Park
Available	a) Nature interpretation/education centre
Available	b) Walkway/cycle system
Available	c) Picnicing
NA	d) Hockey ice skating
NA	e) Fishing
NA	f) Paddle sports
Available	g) Free play area
Available	h) Sunning/volleyball beach use
	A diverse natural habitat for aquatic and terrestrial wildlife
NA	a) Water quality to support large mouth bass, sunfish
NA	b) Water quality adequate to support aquatic plants
NA	c) Shoreline management to support aquatic life
NA	d) Best management practices to maintain water quality
Requires Attention	e) Environment for terrestrial wildlife
NA - Not Available	

Resident's Perspective on Markham's Role as Steward of Swan Lake Park

Availability of Recreational Amenities

Survey respondents provided positive responses on a range of recreational amenities in Swan Lake Park. 65% rated the availability of children's play areas as either good or very good while another 26% rated it as acceptable. Similarly, 55% rated the availability of walkways as good or very good and another 30% rated the availability of walkways as acceptable.

29% rated the accessibility to the lake as acceptable while 48% felt accessibility was either poor or in need of improvement. Similarly, 29% felt the ability to view the lake as acceptable while 49% rated the viewing ability as either poor or in need of improvement.

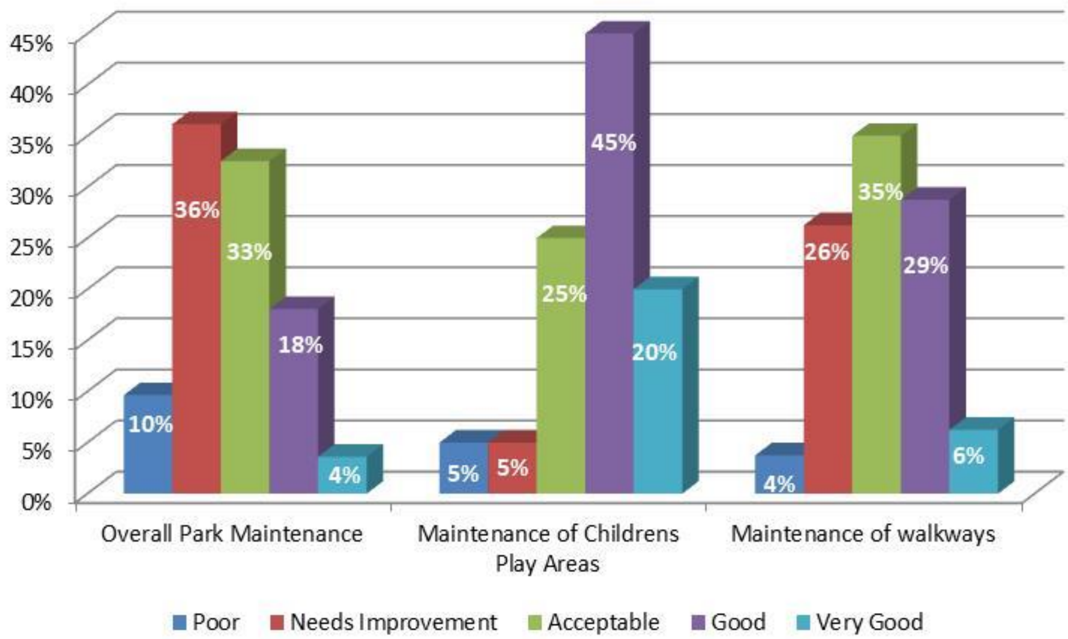


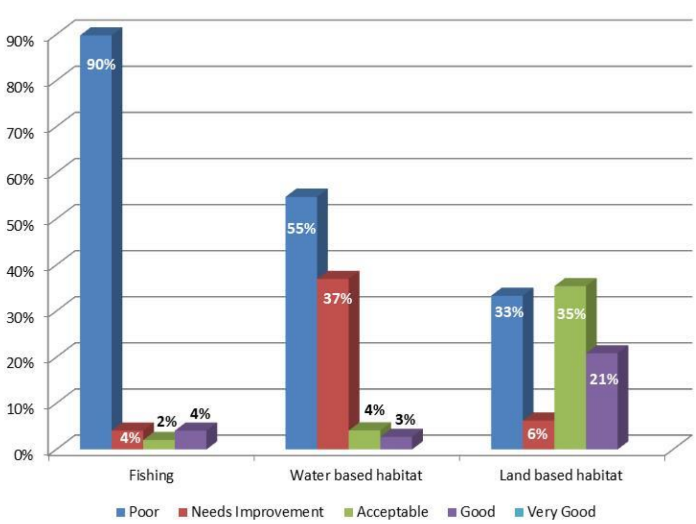
Rental Canoes in Professors Lake, Brampton

The original vison for Swan Lake included canoeing and kayaking, ice skating and fishing as recreational activities on the lake. This has not materialized. 45% of survey respondents said they would like to see canoeing and kayaking on the lake while 54% would like to see ice skating. There was less support for sport fishing – 31% supported a return of sport fishing while 69% were opposed to sport fishing on the lake.

Maintenance of Recreational Amenities
Survey respondents provided a positive assessment of the City's maintenance of the children's play areas – 65% rating the maintenance as good or very good and another 25% assessed the maintenance as acceptable. 70% rated the maintenance of the walkways as acceptable or better; however 26% felt there was need for improvement.

10% rated the overall park maintenance as poor while another 36% reported that there was a need for improvement. 33% found the level of maintenance acceptable while only 22% rated the overall park maintenance as good or very good.





Maintenance of Environmental Elements
The assessment of the environmental elements was much lower than the rating for the recreational elements in the park.

90% rated the maintenance of fishing in the park as poor. 92% rated the maintenance of water based habitat as poor or in need of improvement.

39% rated the land based elements as being poor or in need of improvement whereas 56% rated the care of land based elements as acceptable or good.

7) FRAMEWORK FOR A STEWARDSHIP POLICY FOR SWAN LAKE PARK

We propose that a new governing document titled "Stewardship Policy for Swan Lake Park" be developed that would set out the ongoing policy framework for the City of Markham in its role as Steward of Swan Lake Park. It would include:

1. Community Role and Recreational Objectives for Swan Lake Park

a. Recognition of the Park's broader community role as a venue for cultural activities

b. Redefine the recreational role of the Park. In addition to play areas, walking and cycling paths, the original 1993 plan included:
- Ice skating
- Canoeing and kayaking
- Sport fishing

c. Establish a policy for ongoing management and oversight of the recreational elements, particular any elements unique to the park (such as safe access points for kayaking and fishing)

2. Management and Oversight of Environmental Elements

a. Environmental Policy Framework
- Adopt an Ecosystem Approach with policies comparable to those set out in Stormwater Management Guidelines – Oct 2016
- As per the Stormwater Guidelines, include an obligation for ongoing co-ordination with the policies of the Toronto and Region Conservation Authority ("TRCA"")

b. Incorporate the TRCA Inventory and Evaluation proposed for 2020 on:
- Water quality, aquatic life, aquatic plants
- Terrestrial plants and wildlife habitat

c. Restoration Programs for:
- Water quality, aquatic life, aquatic plants
- Invasive species program

d. Monitoring Responsibilities for:
- Park and Lake environment
- Stormwater Ponds

e. Timely Remediation Triggers for:
- Water quality, aquatic life, cyanobacteria
- Invasive species
- Other environmental elements

3. Long Term Sustainability Program

a. Remodeling of structural elements to support sustainability

Appendices

A) Wildlife in Swan Lake Park

B) Invasive Species in Swan Lake Park

C) TRCA Report on Toogood Pond (Table of Contents)

D) Swan Lake Water Quality in 2017 (Summary)

E) Phosphorus Management Options

F) Goose Management Programs

G) Cost Estimates

Appendix A: Wildlife in Swan Lake Park

Swan Lake Park in Markham is home to a rich diversity of wildlife. But this wildlife is threatened by the deteriorating water conditions in Swan Lake and the erosion of sustainable terrestrial habitat in Swan Lake Park due to the unchecked intrusion of invasive plants.


HELP SAVE SWAN LAKE PARK'S BIODIVERSE ENVIRONMENT

In a report dated April 18, 2018, City of Markham's Wildlife Services, notes that Markham's interactions with wildlife are guided by the following principles:

1. Wildlife has intrinsic, ecological, economic, social and cultural value.
2. Markham residents desire healthy and sustainable wildlife populations.
3. The City will endeavour to identify and protect natural heritage systems and wildlife habitats to conserve biodiversity for future generations.
4. The City recognizes the importance of planning and managing natural heritage resources at a landscape/watershed scale in order to provide for wildlife connectivity, a diversity of habitat types and sizes, and to consider water-related functions.

Friends of Swan Lake Park, a group of local citizens committed to saving Swan Lake and Swan Lake Park, is asking the City to address the deteriorating conditions in Swan Lake and Swan lake Park immediately. They can start by engaging the Toronto and Region Conservation Authority ("TRCA") to undertake a biological assessment of the aquatic and terrestrial habitats in Swan Lake and Swan lake Park. This important foundation work will set the stage for development of a meaningful protection and restoration program for the Swan Lake and Swan Lake Park.

The following summary of terrestrial wildlife in Swan Lake Park was compiled by Don Fowler based on photographs and sightings of Don and Cindy Fowler, members of the Friends of Swan Lake Park.

	Common Name	TRCA Code	Scientific Name	Photographed
BIRDS				
1	American Crow	AMCR	Corvus brachyrhynchos	2014-2019
2	American goldfinch	AMGO	Carduelis tristis	2007-20019
3	American Redstart	AMRE	Setophaga ruticilla	2018-05-16
4	American robin	AMRO	Turdus migratorius	2007-2019
5	Baltimore oriole	BAOR	Icterus galbula	2017-05-23
6	Barn Swallow	BARS	Hirundo rustica	
7	Belted Kingfisher	BEKI	Ceryle alcyon	2017-2019
8	Blackburnian Warbler	BLBW	Setophaga fusca	2019
9	Black-capped Chickadee	BCCH	Parus atricapillus	2007-2019
10	Black-crowned Night Heron			2012-2019
11	Blackpoll Warbler	BLPW	Setophaga striata	2019
12	Black-Throated Blue Warbler	BTBW	Setophaga caerulescens	2017
13	Blue Jay	BLJA	Cyanocitta cristata	2013-2019
14	blue-grey gnatcatcher	BGGN	Polioptila caerulea	
15	Brown-headed Cowbird	BHCO	Molothrus ater	2017
16	Bufflehead duck	BUFF	Bucephala albeola	2016-2019
17	Canada goose	CANG	Branta canadensis	2007-2019
18	Canada Warbler	CAWA	Cardellina canadensis	2017
19	Caspian Tern	CATE	Hydroprogne caspia	2012-2019
20	Cedar Waxwing	CEDW	Bombycilla cedrorum	2012-2019
21	Chestnut-sided Warbler	CSWA	Setophaga pensylvanica	2019
22	Chipping Sparrow	CHSP	Spizella passerina	
23	Common Grackle	COGR	Quiscalus quiscula	2007-2019
24	Common Loon	COLO	Gavia immer	2012-2019 - spring
25	Common Merganser	COME	Mergus merganser	2016-2019
26	Common Yellowthroat	COYE	Geothlypis trichas	
27	Double-crested Cormorant	DCCO	Phalacrocorax auritus	2016-2019
28	Downy woodpecker	DOWO	Picoides pubescens	2015-2019
29	Eastern Kingbird	EAKI	Tyrannus tyrannus	2017-2019
30	Eastern Phoebe			2016-06-29
31	Eastern Wood-Pewee	EAWP	Contopus virens	2019
32	European Starling	EUST	Sturnus vulgaris	2007-2019
33	Forster's Tern	FOTE	Sterna forsteri	2019 first
34	Golden-crowned Kinglet			
35	Gray Catbird		Dumetella carolinensis	2017
36	Great Blue Heron			2012-2019
37	Great Egret	GREG	Ardea Alba	2012-2019 some years
38	Grey Catbird	GRCA	Dumetella carolinensis	
39	Hairy woodpecker	HAWO	Picoides villosus	
40	Herring Gull	HERG	Larus argentatus	2019

	Common Name	TRCA Code	Scientific Name	Photographed
BIRDS				
41	Hooded Merganser	HOME	Lophodytes cucullatus	2016-2019
42	Horned Grebe	HOGR	Podiceps auritus	2018
43	House finch	HOFI	Carpodacus mexicanus	2012-2019
44	House sparrow	HOSP	Passer domesticus	2007-2019
45	House Wren	HOWR	Troglodytes aedon	
46	indigo bunting	INBU	Passerina cyanea	
47	Killdeer	KILL	Charadrius vociferus	2012-2019 some years
48	Magnolia Warbler	MAWA	Setophaga magnolia	2019
49	Mallard	MALL	Anas platyrhynchos	2007-2019
50	Mourning dove	MODO	Zenaida macroura	2007-2019
51	Northern cardinal	NOCA	Cardinalis cardinalis	2007-2019
52	Osprey	OSPR	Pandion haliaetus	2012-2019
53	Palm Warbler	PAWA	Setophaga palmarum	2017-2019
54	Philadelphia Vireo	PHVI	Vireo philadelphicus	2019
55	Pied-billed Grebe	PBGR	Podilymbus podiceps	2012-2019 some years
56	Red-breasted nuthatch	RBNU	Sitta canadensis	2018
57	Red-eyed vireo	REVI	Vireo olivaceus	2019
58	Redhead duck	REDH	Aythya americana	
59	Red-tailed Hawk	RTHA	Buteo jamaicensis	
60	Red-winged Blackbird	RWBL	Agelaius phoeniceus	2007-2019
61	Ring-billed Gull	RBGU	Larus delawarenis	2007-2019
62	Ring-necked Ducks			2019
63	Rose-breasted Grosbeak	RBGR	Pheucticus ludovicianus	?
64	Ruby-crowned Kinglet			2017-2019
65	Ruby-throated hummingbird	RTHU	Archilochus colubris	?
66	Scarlet Tanager	SCTA	Piranga olivacea	2017-2019
67	Snow Goose	SNGO	Chen caerulescens	2016-2019 - fall
68	Song Sparrow	SOSP	Melospiza melodia	2012-2019
69	Sora	SORA	Porzana carolina	??
70	Spotted Sandpiper	SPSA	Actitis macularius	20012-2019 some years
71	Swamp Sparrow	SWSP	Melospiza georgiana	
72	Tree swallow	TRES	Tachycineta bicolor	2007-2019
73	Trumpeter Swan	TRUS	Cygnus buccinator	2012-2019 - spring
74	Turkey Vulture			2007-2019
75	Virginia Rail	VIRA	Rallus limicola	
76	Warbling vireo	WAVI	Vireo gilvus	
77	White Crowned Sparrow	WCSP	Zonotrichia leucophrys	2019-05-18
78	White-breasted nuthatch	WBNU	Sitta carolinensis	
79	Yellow Warbler	YWAR	Setophaga petechia	2019
80	Yellow-rumped Warbler	YRWA	Setophaga coronata	2017-2019

	Common Name	TRCA Code	Scientific Name	Photographed
Mammals				
1	Beaver			
2	Black Squirrel			2019
3	Coyote			
4	Eastern Chipmunk		Tamius striatus	2007-2019
5	Eastern Cottontail Rabbit			2007-2019
6	Grey Squirrel			2019
7	Mink			
8	Muskrat			
9	Racoon		Procyon lotor	2007-2019
10	Red Fox			2014-2019
11	Red Squirrel			2019
12	Skunk (very young)			2019
Turtles				
1	Eastern Midland Painted Turtle			2007-2019
2	Large unidentified turtle			2019
3	Red-eared Slider			2012-2019
4	Snapping Turtle			2007-2019

	Common Name	TRCA Code	Scientific Name	Photographed
INSECTS				
1	Bald Faced Hornet			2017-2019
2	Black Blowfly			2018
3	Black Saddlebags Dragonfly			2019
4	Black-tipped Darner Dragonfly		Aeshna Tuberculifera	2017
5	Bumble Bee			2007-2019
6	Cabbage White Butterfly			2018
7	Canada Darner Dragonfly			2019
8	Carolina Grasshopper		Dissosteira Carolina	2019
9	Carpenter Bee			2014-2019
10	Common Whitetail Dragonfly			2017-2019
11	Eastern Amber Dragonfly			2019
12	Eastern Black Swallowtail Butterfly			2019
13	Familiar Bluet Damselfly			2018-2019
14	German Yellow Jacket Wasp		Vespula Germanica	2017
15	Great Black Wasp			2019
16	Green Blowfly			2018-2019
17	Honey Bee			2016-2019
18	Japanese Beetle			2017-2019
19	Large White Butterfly			2019
20	Monarch Butterfly			2007-2019
21	Mustard White Butterfly			2016-2018
22	Narrow-headed Marsh Fly		Helophilus fasciatus	2017
23	Orange Sulfur Butterfly			2018
24	Painted Lady Butterfly			2017-2019
25	Pecks Skipper Butterfly			2017-2019
26	Question Mark Butterfly			2018-2019
27	Red Admiral Butterfly			2017-2019
28	Red-legged Grasshopper			2019
29	Slender Spreadwing Damselfly			2019
30	Viceroy Butterfly			2017-2019
31	Western Conifer Seed bug		Leptoglossus Occidentalis	2019
32	Widow Skimmer Dragonfly			2019
33	Yellow-legged Mud-dauber		Sceliphron Caementarium	2019
34	Western Tiger Swallowtail Butterfly			2018 - SL Village

Appendix B: Invasive Species in Swan Lake Park

SWAN LAKE PARK AND INVASIVE SPECIES

Natural areas such as Swan Lake Park provide shelter and food for wildlife, remove pollutants from air and water, produce oxygen through photosynthesis and provide valuable recreational and educational opportunities. Invasive species can threaten these important services.

Invasive species generally are non-native plant, animal or pest species that out compete native species for resources and dominate space. Invasive plants impact species diversity and species richness by competing heavily for resources such as light, moisture and soil nutrients that native plants require to establish and grow, ultimately, affecting the intricate linkages that make ecosystems strong and resilient.

Invasive plants that invade recreational areas often reduce the area’s attractive and enjoyable qualities. Invasive plants may reduce native plant biodiversity, affecting the number of songbirds in the area. Walking through dense vegetation can prove difficult. Seeds and other plant parts can hitch rides on hiking boots, clothing, and pets resulting in new infestations, potentially over great distances.

The following invasive species have been reported in Swan Lake Park by local residents.

The invasive plant and fish species are listed as invasive under either the Ontario Invading Species Awareness Program (”OISAP”) or by the Toronto and Region Conservation Authority (“TRCA”). Information on invasive insects is from the Ministry of Agriculture.

Invasive Plants	Listing	Impacts
• **Black Locust** (Robinea psuedoacacia)	OISAP	The branches of young black locust trees have five centimeter spines that grow all along the branches and can tear the skin and damage eyes of people and animals that wander too close. Being a legume, black locusts have nitrogen-fixing nodules which increase the nitrogen content in soils, altering the growing conditions for other species. Black locust leaves, stems, bark and seeds contain gastrointestinal neurotoxins. These can be fatal to humans and some animals (horses in particular).
• **Common Reed Grass** (Phragmites australis).	OISAP & TRCA	Invasive Phragmites is an aggressive plant that spreads quickly and out-competes native species for water and nutrients. It releases toxins from its roots into the soil to hinder the growth of and kill surrounding plants.

• **Dog Strangling vine** (Cynanchum rossicum)	OISAP & TRCA	The name "Dog-strangling Vine" refers to two invasive plants that are look-alike members of the milkweed family – black swallowwort and pale swallowwort. The vine forms dense stands that crowd out native plants. Leaves and roots may be toxic to livestock. The vine threatens the monarch butterfly, a species at risk in Ontario. The butterflies lay their eggs on the plant, but the larvae are unable to complete their life cycle and do not survive.
• **Giant Hogweed** (Heracleum mantegazzianum)	OISAP	Giant hogweed is a member of the carrot family and it's resemblance to Queen Anne's lace caused it to become a garden ornamental. It has a phototoxic sap, that when exposed to light can cause severe burns if on the skin and possibly cause blindness.
• **Manitoba Maple** (Acer negundo)	OISAP	Also known as the Box-elder, this is our only native maple that has divided leaves. These maples only grow to about 20 m but they grow quite quickly. A protoxin present in the seeds has been identified as a major risk factor for, and possibly the cause of, a disease in horses. Ingesting *Acer negundo* seeds, or other parts of the plant, may therefore be toxic to humans, in large doses. *Acer negundo* is a severe allergen. Its pollination occurs from winter to spring, depending on latitude and elevation.
• **Oriental Bittersweet** (Celastrus orbiculatus)	TRCA	Oriental bittersweet grows by twining around shrubs and trees. It can easily overrun native vegetation, forming nearly pure stands. It can strangle shrubs and small trees and weaken or even kill mature trees by girdling the trunk and smothering the crown.
• **Tartarian Honeysuckle** (Lonicera tartarica)	OISAP	Rapidly invade areas, out-competing native plant species by forming dense patches. Affect light and nutrient availability to neighboring plants. Produce toxic chemicals that prevent other plants from growing in that area. Fruit does not offer migrating birds the nutrients needed for long flights compared to native plant species. The flowers attract pollinators causing native species to reduce the amount of seeds they produce.

Invasive Fish		
• **Goldfish** (Carassius auratus)	OISAP	Goldfish are quite tolerant of poor water quality, including water with low levels of dissolved oxygen and may threaten some native species in degraded ecosystems. Goldfish eat snails, small insects and young fish, making this species a competitor with and predator of native fish. They stir up mud and other matter when they feed, which increases the cloudiness of the water and affects the growth of aquatic plants.
Invasive Insects		
• **Japanese Beetles** (Popillia japonica)		Adult beetles skeletonize foliage. While adults do not damage turf, they do feed on foliage and fruit of about 300 species of plants. Larval feeding on the fibrous roots of grasses makes this stage a destructive pest for turf. Injured turf initially wilts and yellows during August and September. Eventually, dead patches of turf can be observed.
• **Yellow-headed Spruce Sawfly** (Pikonema alaskensis (Rohwer))		Larvae emerge in early spring and begin feeding on the succulent needles. Larvae initially feed on the new needles, leaving only short brown stubs. Once the new growth is devoured, the larvae move back on the branch and feed on the older needles. By July, infested trees appear ragged and yellowish-brown especially near the tops. Heavily-infested trees may be completely stripped of foliage. Three to four consecutive years of moderate to heavy attacks can kill the tree.

Appendix C: TRCA Report on Toogood Pond (Table of Contents)

Toogood Pond

Terrestrial Biological Inventory and Assessment

February, 2013

Toronto and Region Conservation for The Living City

Toronto and Region Conservation for The Living City

Toogood Pond
February, 2013

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Appendix D: Swan Lake Water Quality in 2017 (Executive Summary)

SWAN LAKE WATER QUALITY IN 2017

Prepared by **Gertrud Nürnberg, Ph.D.**

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Prepared for **The City of Markham, Ontario**

Date Mar 26, 2018

Respectfully submitted: 26 March, 2018

Dr. Gertrud Nürnberg

Acknowledgement

Rob Grech, Environmental Engineer and Rob Muir, Manager, Asset Management Department of the City of Markham, provided steady support and their enthusiasm is gratefully acknowledged. He also supervised an ambitious monitoring program conducted by students J. Johnson and T. Chenthat, which included an enhanced water sampling program at two shore line stations and supplemental goose counts. This effort produced a separate report, here cited as *City of Markham 2017*.

Staff of *Cole Engineering Group Ltd*. sampled water twice at the deep open water site. *Border Control Bird Dogs* provided waterfowl counting and control.

Title photo: Apr 10, 2017 (Photo, Gertrud Nürnberg)

Executive Summary

Swan Lake in the City of Markham used to be a highly eutrophic (hyper-eutrophic) lake with cyanobacterial blooms ("bluegreen blooms"). These blooms often contained species that can produce toxins with health effects on pets, livestock or humans. A detailed monitoring study in 2011-2012 and historic data (1993-2008) revealed that most of the water quality problems originated primarily from internal P sources, such as the bottom sediments. After the determination of available treatment methods a chemical treatment with Phoslock was conducted in the spring of 2013. Several post-treatment monitoring studies evaluated the effects and efficiency of the treatment in several reports and published peer-reviewed papers.

To assess these potential health effects, Swan Lake water quality has been monitored almost annually since 2011 when there was severe degradation of water quality (hyper-eutrophy, see 2011 in *Summary Table*). Hypertrophy indicates severely nutrient-enriched conditions with visual degradation. Since then, water quality has fluctuated with the first two years (2013, 2014) after Phoslock application indicating significant improvement in water quality variables, while 2016 deteriorated below 2011 (2016 in *Summary Table 1*) and included severe cyanobacteria toxicity at the eastern shore.

Because of the deteriorated conditions closer to shore, 2017 monitoring added two shore line sites (Site 1&2), besides two visits to the previously monitored open water site (Site 3) accessible by boat only. Simplified accessibility made it possible to enhance monitoring frequency and extend the monitoring period so that more information could be assembled for a similar amount of resources. In addition a continuous lake level and temperature recorder were deployed at the shoreline Site 1 (main dock).

Summary Table. Trophic state of Swan Lake based on growing season averages

	Swan Lake					Eutrophic	Hyper-eutrophic
	2011	2013	2014	2016	**2017**		
Secchi Disk Transparency (m)	0.47	0.43	1.4	0.29	**0.40**	1 – 2.1	< 1
Total phosphorus (TP, mg/L)	0.247	0.099	0.060	0.27	**0.19**	0.031 – 0.100	> 0.100
Total nitrogen (mg/L)	2.7	1.6	1.1	4.5	**2.3**	0.651 – 1.200	> 1.200
Chlorophyll *a* (µg/L)	32	52	12.6	111	**61**	9.1 – 25	> 25
Anoxia in polymictic lakes	severe	severe	some	severe	**severe**	occasional during summer stratification	
Modeled anoxia (AA, d/summer)**	90	70	59	92	**84**	40 – 60	> 60

2017 water quality characteristics of the three monitoring sites were quite similar and we conclude that Site 1 (main dock) water is representative of the nutrient and trophic state of Swan Lake and can be used for the comparison with previous lake data.

Similarity between Site 1 and Site 3 (open water) extended to thermal stratification and hypoxia and other trophic state variables. Only variables most affected by shoreline influences, like those indicating organic acids from shoreline vegetation, and those related to watershed anthropogenic activities such as de-icing of paved surfaces, were higher at the shore sites because of shore line runoff.

2017 water quality (2017 in *Summary Table 1*) was worse than in the immediate post-treatment years (2013, 2014), but much better than in 2016, and there were no sightings of cyanobacteria surface blooms. Possible reasons are climate-related conditions that yielded higher lake levels, lower temperature and less sun light, leading to less favorable conditions for the proliferation of cyanobacteria and sediment P release, and there were also less water fowl compared to 2016.

Several possible sources were investigated as contributors to the 2017's average total phosphorus concentration. Waterfowl contributed about 40% of the total load which is much lower than in 2016, indicating that the goose management efforts are working. Other possible nutrient sources include elevated groundwater and runoff from historic dumpsites and other shoreline features because of unusual high precipitation in March - August 2017, and the re-occurrence of sediment P release enhanced by observed bottom dwelling fish including goldfish and carp even after the Phoslock treatment.

We recommend further management of the migrating population of Canada Geese and/or envision further chemical treatment to combat the P release from settling feces in the future. Future monitoring is recommended to facilitate the incorporation of a triggering mechanism for such treatment, as the public expectation of Swan Lake water quality may not otherwise be met.

Detailed recommendations include:

- Continued water quality monitoring in 2018 by city of Markham staff at the 2 shore sites.
- Continued water fowl management with more extensive management of migrating geese.
- Investigation of historic dump sites and bottom dwelling fish as a potential nutrient source.
- The establishment of a management protocol for Swan Lake by the City of Markham, because a chemical treatment may become necessary in the future.

To accomplish this last step, we investigated potential triggers that would invoke another Phoslock treatment. Because the most direct concern is one for public safety, we propose the bloom of a potentially toxic strain of cyanobacteria as immediate trigger. Further, we propose the establishment of an interim water quality goal for Swan Lake with exceedances triggering a treatment. Based on past monitoring data, we suggest a combination of TP and Secchi growing period averages of 0.15 mg/L TP and 0.45 m transparency.

In summary, we recommend the following potential triggers for a Phoslock treatment:

1. The surface bloom of a potentially or proven toxic strain of cyanobacteria, confirmed by a licenced or provincial (MOECC) lab.
2. Water quality not compliant with the interim goal of growing period average 0.15 mg/L total phosphorus concentration and 0.45 m Secchi disk transparency.

Similar variables are used in many such thresholds and guidelines by other jurisdictions.

Because these triggers were tripped in 2016 and other indications, we suggest that a treatment in the near future would be beneficial. Costs of a similar Phoslock application as in 2013 are about \$100,000 for the treatment itself (*approximate costs according to Phoslock Water Solutions Ltd, March 2018*) and \$37,000 for post-treatment monitoring and evaluation (*based on 2017 costs*) to a total of \$163,300, including 20% for contingencies.

Appendix E: Phosphorus Management Options

This appendix outlines the major management techniques available to address excessive phosphorus levels in fresh water lakes summarized into three categories:

A) Chemical Treatments
- i) Phoslock
- ii) Aluminum
- iii) Calcium and Iron

B) Natural Enhancements
- i) Biomanipulation
- ii) Filtration and consumption by bulrushes, aquatic plants

C) Physical Alterations
- i) Reduction in drainage areas
- ii) Flow Augmentation and Filtration
- iii) Aeration and oxygenation

The following table compiled from information provided by Lake Advocates, illustrates the alignment of various techniques with the primary areas targeted for phosphorus management: Watershed Control (external sources) and Internal Control (legacy).

		Targeted Areas		
Management Techniques	**Overall Assessment**	**Watershed P Control**	**Internal P Control**	**Algae Control**
Chemical				
Algaecides	Works			√
Phosphorus Precipitation				
- Alum	Works	√	√	√
- Calcium, iron	Probably Works	√	√	
- Phoslock (our assessment)	Works		√	√
Natural Enhancements				
Biomanipulation	May work in conjunction with other techniques			√
Physical Alterations				
Artificial Circulation	Works if designed for need		√	√
Drawdown	May work, risk of plant damage		√	
Dredging	Works		√	
Oxygenation	Works		√	
Watershed Management	Unlikely to work on its own	√		
Source: Lake Management Best Practices: Managing Algae Problems; Osgood, Gibbons; Lake Advocates Publishers, 2017				

Lake Advocates (www.lakeadvocates.org) is a U.S. based non-profit organization that advocates and facilitates scientifically-based lake protection, management and restoration through applied research and policy development.

The following table, compiled from information provided by Lakes Advocates, summarizes the overall effectiveness of a select number of management techniques available for lake resource management.

	Assessment					
Management	**Overall**	**Applicability**	**Reliability**	**Duration**	**Application**	**Cost**
Chemical						
Algaecides	Works	High	High	Short	Frequent	Medium-Low
Phosphorus Precipitation						
A) Alum	Works	High	High	Variable	Variable	Medium-Low
B) Calcium, Iron	Probably Works	High	High	Variable	Variable	Medium-Low
C) Phoslock (our assessment)	Works	High	High	Variable	Variable	High
Natural Enhancements						
Biomanipulation						
- Long Term	May Work (Beware)	Medium	High	Medium	Occasional	Low - High
- Short Term	Not Recommended	Low	Low	Medium	Seasonal	Medium-Low
Physical Alterations						
Artificial Circulation						
A) Designed for need	Works	High	High	Short	Continuous	High-Medium
B) Not tailored to need	Not Recommended	Low	Low	N/A	N/A	N/A
Drawdown	May Work (Beware)	Medium	Medium	Medium	Periodically	Low - High
Dredging	Probably Works	High	Medium	Years	Rare	High
Oxygenation	Works	High	High	Short	Continuous	High-Medium
Watershed Management	Unlikely to work on its own.	Medium	Little success demonstrated	N/A	N/A	High

It is worth noting that most techniques are focused on addressing internal load within a lake. Efforts focused on reducing the external sources receive a poor rating as a sole solution to addressing phosphorus issues but are seen to have a complimentary role.

Lake Advocates were aware of Phoslock but did not believe there was enough documented experience to provide a rating of its effectiveness. We include our assessment.

Lake Advocates appears to have a bias towards use of Alum, due to its long history and documented successes. Artificial circulation, biomanipulation and oxygenation are considered effective techniques if the solution is tailored for the specific situation in a lake.

A) Chemical Treatments

There appears to be one long term solution at hand – treatment by Phoslock or Aluminum. While chemical treatments may work, they are a costly solution since each treatment would apparently cost over $100,000.

A chemical treatment that addresses the legacy phosphorus in Swan Lake is the essential first step to bring the water quality within manageable levels and may indeed be the long term backstop solution. The need to resort to a chemical treatment can be greatly reduced by implementing other solutions such as biomanipulation, circulation and oxygenation that also help manage internal load and others that minimize the impact from external sources. Success in minimizing both internal and external sources may reduce the necessary frequency of future chemical treatments.

i) PHOSLOCK (Source – Phoslock website)

Phoslock is a modified clay product which removes soluble phosphorus from all kinds of water bodies. Phoslock is made from naturally occurring products. The manufacturing process involves combining naturally occurring clay (bentonite) with a lanthanum. Lanthanum is absorbed into sites in the bentonite and is the active element to remove phosphorus.

When Phoslock is applied to a water body, the phosphorus present in the water column is attracted to the lanthanum to produce lanthanum phosphate. Lanthanum phosphate is very insoluble and therefore phosphorus remains locked up within the bentonite. After a couple of hours, the Phoslock will settle on the sediment and so long as it has active sites it will continue to react with any phosphorus either released from the sediment or present in the water.

Phoslock has been the subject of extensive ecotoxicity and other testing in a number of countries including Australia, USA, China, Germany, the Netherlands and New Zealand.

In order to remove as much phosphorus as possible, the best time to apply Phoslock is when most phosphorus in the water column and sediment pore water is in a form which can be removed by Phoslock (i.e. ortho-phosphate or FRP). For the temperate and continental climates (most of Europe), this occurs in general over the autumn and winter periods, during which time algae die off and organic phosphorus is released and subsequently mineralised to FRP. Therefore the best time to apply in these climates is from early autumn to early spring.

How often does Phoslock need to be applied?

Treatment with Phoslock provides a "reset" of the ecological clock of the water body. That is, it returns the water body to the phosphorus level which is likely to have existed many years prior to the events which have given rise to the increased levels.

Management strategies limit additional nutrients finding their way into the water body. However, it is rarely possible to prevent nutrients from building up as there are various sources of new nutrients including runoff and waste from birds and animals. Phoslock may remain active and capture phosphorus from natural sources for many years. If there are unmanaged phosphorus inputs, Phoslock treatment may be required at much more regular intervals.

ii) Aluminum Based Products (Source: Lake Advocates[2])

Aluminum sulfate, or alum, has been used for phosphorus control in lakes and ponds since the 1960's. Alum is a widely available commodity that is safe, effective and relatively inexpensive. It is used as an additive in food processing and in drinking and waste water treatment.

Aluminum is the critical element in alum (aluminum sulfate) for binding with or inactivating phosphorus. Aluminum-phosphate is the ultimate product following alum additions and it is stable, nontoxic and unreactive, meaning that phosphorus becomes locked in a form that is not available in the water and usable by algae.

HAB Aquatic Solutions, one of the U.S. sponsors of Lake Advocates, specializes in improving surface water quality through the use of aluminum-based products (e.g., alum and sodium aluminate) and cites the following successes on its website (http://habaquatics.com/):

Lake Leba, Nebraska

Lake Leba is a sandpit lake located in eastern Nebraska. An Alum treatment resulted in a 97% reduction in internal phosphorus loading and a 74% reduction in phosphorus in the water column over the three year experiment.

Le May Lake, MN

Le May Lake is a 32 acre lake located in central Minnesota in the town of Eagan. Prior to the Alum application, total phosphorus in the late summer/early fall averaged near 120 ppb, but was reduced by over 80% to 23 ppb after the application.

Observation of a small number of case studies cited on various websites on the use of Alum, suggests that it takes about 4 years for the phosphorus levels to return to pre-treatment levels.

Therefore, if the objective is to maintain a healthy environmental balance this suggests that a treatment may be required every 2-3 years to avoid a return to high phosphorous levels.

iii) Calcium and Iron (Source Freshwater Research)

Due to the specific water quality issues in Swan Lake, Freshwater Research has advised that these treatments would not be effective and may possibly make matters worse.

[2] Lake Management Best Practices, Alum for phosphorus control in lakes and ponds, Osgood, Gibbons, Brattebo, Lake Advocates Publisher, 2017

Natural Enhancements

Restored and enhanced natural elements could play an important role in maintaining a stable aquatic environment. There are a number of approaches that can be considered.

i) Biomanipulation

Freshwater Research suggested investigation into "biomanipulation", a method that involves restocking with game fish and planting of native water plants to spur support for zooplankton that feeds on the algae.

Freshwater Research suggested that the City engage a fish specialist to advise on the type of fish that should be considered for restocking of the lake. The species selected should be ones that will assist in reducing algae levels in the lake, as opposed to bottom feeders such as carp and gold fish that stir up the bottom sediment and recycle the dormant elements. Other species recommended prey on mosquito larvae, thereby reducing mosquitos.

Perhaps there is the potential to leverage Swan Lake's needs into a broader solution for the numerous stormwater ponds throughout the region.

Ontario sponsors a fish hatchery program. Perhaps Swan Lake could be overstocked with fish that address its immediate needs and at the same time provide a source of fish for stocking stormwater ponds, helping to address broader problems such as mosquito control.

ii) Filtration and Consumption by Bulrushes and other Aquatic Plants

Swan Lake is challenged by an excess amount of phosphorus and to a lesser extent nitrogen. These nutrients are absorbed by bulrushes and other aquatic plants. Several creative approaches have been developed to leverage the use of these plants as sponges to absorb the phosphorus and nitrogen.

Bioswales: North Channel and Turtle Inlet

Bioswales are ditch-like areas that contain plants that can help control and absorb nutrients. They are commonly used for stormwater management control but they have the added benefit of absorbing nutrients from the water flow.

There is a dry channel along the north end of Swan Lake that could be converted to a Bioswale. The channel, approximately 50 metres (150 feet) long, is designed as an emergency spillway that would be used should the north stormwater pond overflow; however, it has rarely been used. The channel is typically dry, though during wet periods it will have water from the runoff from the surrounding areas.

Our proposal is to plant the channel with nutrient absorbing plants, such as bulrushes, or installing floating islands outlined in the following section. This channel would then be serviced by water pumped from the Lake (not from the north stormwater pond).

Freshwater Research noted that the deeper areas of the Lake hold dense nutrient rich waters. Pumping this nutrient rich water from the deeper areas through the bioswale could reduce the amount of phosphorus in the water returned to the lake.

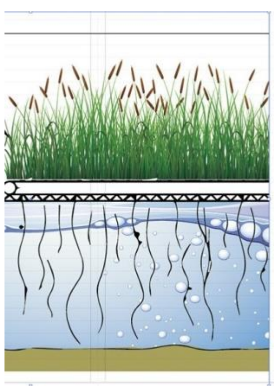
The creation of circulation in the lake should be of benefit in general and the water returned to the Lake through the bioswale could be oxygen enriched through the process.

Energy for the proposed pumps would either be derived by repurposing the existing windmill at the north pond to support a water pump and/or the installation of solar panel driven pumps.

Similarly, Turtle Inlet, the small inlet of water near the foot bridge on the north-west portion of the lake could be converted to a bioswale.

Floating Islands and Harvesting

CURRY INDUSTRIES



Curry Industries has developed floating platforms that are planted with bulrushes (Cattails).

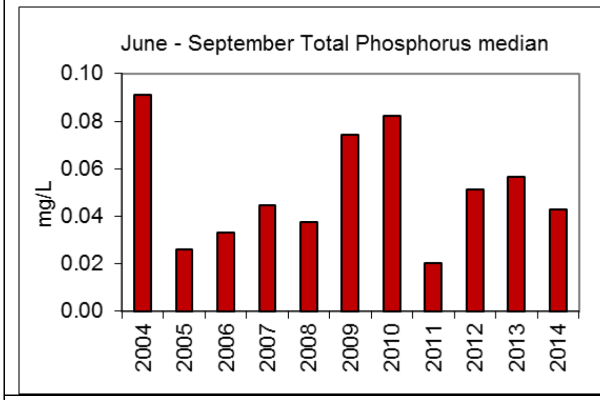
The roots extend into the water and absorb nutrients (phosphorus) from the water. The plants are then harvested in late summer. The roots remain intact on the platform and are left to regrow the next spring, repeating the process.

Curry Industries has initiated discussions with an environmental research specialist at the Centre for Advancement of Water and Waste Water Technologies at Fleming College, in Lindsay, about doing a research study on the effectiveness of using their platforms in Swan Lake. Discussions are at a very preliminary stage but there is the potential for a pilot project to assess the effectiveness as a solution for Swan Lake.

Perhaps an annual harvest of the phragmites and bulrushes surrounding the Lake shoreline would contribute to increased absorption by the existing shoreline plants.

BIOMATRIX

Biomatrix provides floating islands, known as Floating Treatment Wetlands, which are designed to encourage plant growth above and below the waterline. The technology of the Biomatrix floating island was designed to mimic how natural wetlands purify water. A Dynamic Biofilter Media can be added to hang below the island. This feature multiplies the island's efficiency for water purification by creating rich habitat in the root systems for billions of beneficial bacteria.



A case study on the Biomatrix website, cites the success of the floating islands on Hicklin Lake, in Washington State. What's interesting is that the local residents encouraged the adoption of the floating islands as an alternative to a third alum treatment.

The initial results showed improvement but not as significant as that provided by the alum treatment.

Important dates: April 2005, first alum, May 2011 second alum, July 2013 floating islands

The use of floating islands may be beneficial in an area like Turtle Inlet (the small bay near the north foot bridge) or in the northern channel in lieu of a traditional bioswale.

B) Physical Alterations

Chemical treatments such as Phoslock or aluminum compounds can improve the water quality levels, however unless efforts are made to reduce the impact of the forces that create the phosphorus imbalance, it is only a matter of time before another treatment is required.

The category of physical alterations includes techniques such as:

i) Reduction in Drainage Area
   - Rerouting existing drainage sources
   - Decreasing flows from drainage areas

ii) Flow augmentation
   - Pump and Refresh (Drawdown)
   - Recycling and Filtration (Algae Harvesting)

iii) Aeration and Oxygenation

i) Reduction in Drainage Area

Most recent measures estimate that the areas that drain into the lake add 14 kg of phosphorus to the lake each year – or 49% of the new sources of phosphorus that enter the lake each year.

The two stormwater ponds are designed as "settling" ponds to contain impurities that flow from the drainage area they were designed to support. Reports show that they are performing as designed and are not major contributors to the phosphorus issues in Swan Lake. If required to support more water flow, the capacity of the ponds could be increased by dredging or deepening.

The total drainage area served by the stormwater ponds and the lake is about 38 hectares (94 acres). Normally the flow from about 75% of this area enters directly into the stormwater ponds. However, in the event of a heavy rainfall or spring melt, flows in excess of 25 mm per 2 hour period from this area will not go into the stormwater ponds but rather be directed into the lake thus bringing contaminants into the lake.

The amount of run-off flowing into the lake could be reduced in two fundamental ways:

1) Send more water directly into the two stormwater ponds by increasing the capacity of the "splitters" that redirect the excess runoff from the stormwater ponds so that flows over 25 mm still flow into the ponds.
2) Redirect as much as possible of the run-off from the remaining 25% to either the stormwater ponds, to existing stormwater sewers or into oil/grit separators. An oil/grit separator acts like a mini stormwater pond. One is already in use for managing the stormwater flowing from the Amica site and into the lake. Three areas could be considered:
   a. The traffic circle on Swan Lake Boulevard could be redirected to the 16th Avenue storm sewer system or through an oil/grit separator before going into the lake;
   b. The open space on the northeast of the Park near the windmill could be redirected into the north stormwater pond;
   c. The new parkland along Williamson Road flows into the sewer system along Williamson Road. The older playground area flows directly into the lake but could be redirected to either the sewers or the existing drainage trenches could be turned into a bioswale planted with phosphorus filtering plants before draining into the lake.

   These sources contribute 14 kg of phosphorus into the lake each year. A reduction of 10 – 15% from these sources would reduce the contribution by 1.4 – 2.1 kg per year.

ii) Water Flow Augmentation and Filtration

All forms of aquatic life rely upon free oxygen elements in lake water for their survival. Swan Lake is deprived of the natural benefit of free oxygen that is added through the natural flow of water through rapids and waterfalls. Lack of free oxygen is believed to be the primary factor in the fish kills within Swan Lake.

Flow augmentation techniques can contribute to improved levels of dissolved oxygen.

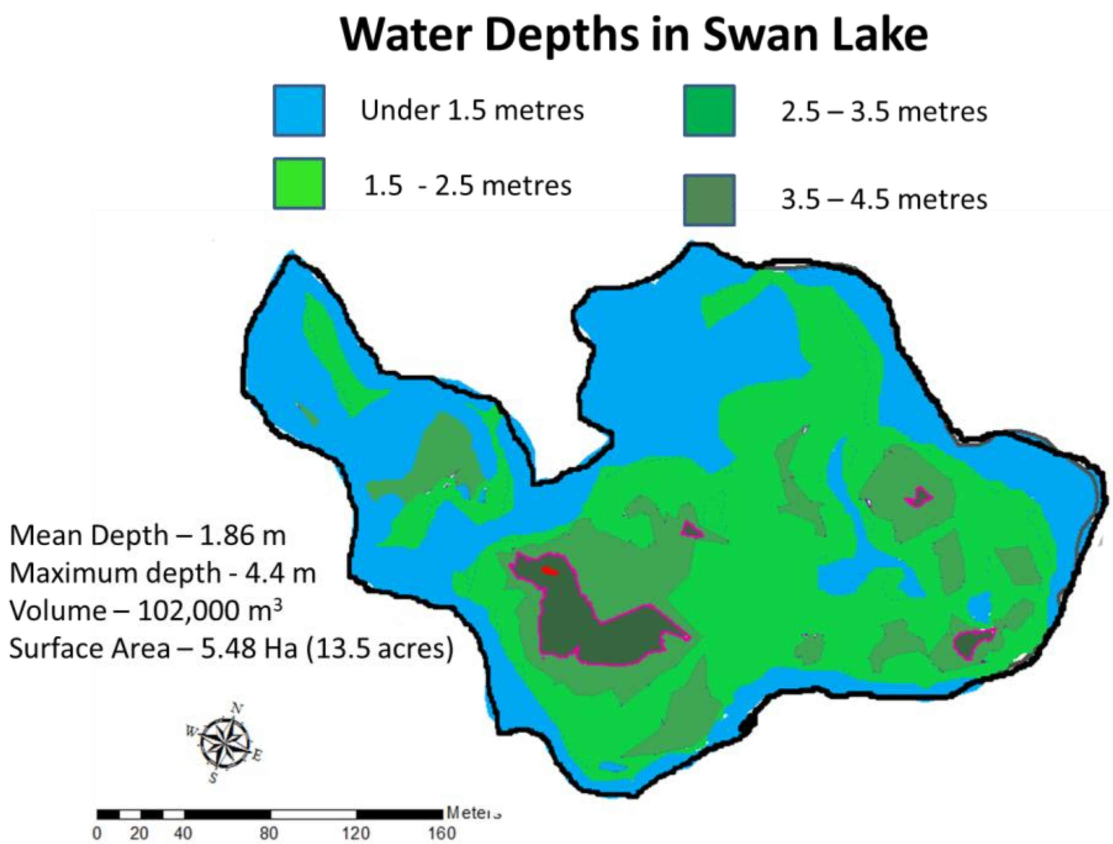
Pump and Refresh (Drawdown)

Swan Lake has two natural sources for fresh water – precipitation and underground sources from the local aquifer. The aquifer is the source that filled the original quarry.

We cannot influence precipitation but it is possible to draw periodically from the aquifer.

Studies have shown that the groundwater around the lake flows towards the south at a rate of between 10 – 300 m^3/day, with one specific test showing a flow rate of 73 m^3/day. Estimates of the loss of phosphorus from the lake suggest an average annual flow rate of 42 m^3/day.

Freshwater Research noted that the deeper areas of the lake hold dense phosphorus laden waters. Periodically pumping out some of this phosphorus laden water from the lake would reduce the amount of phosphorus content in the lake water. Fresh water would then gradually enter the lake from the aquifer, improving the fresh water mix within the Lake.



Water could be removed in two possible ways:

1) Withdrawn in the summer months for irrigation. Phosphorus rich water from the lake could be used to refill city of Markham water trucks, used to irrigate the new park area along Williamson Road or used by neighbouring Swan Lake Village for lawn irrigation.
2) Alternatively or in addition, water could be pumped into the 16th Avenue stormwater system through existing connections. The stormwater sewer system is designed to absorb and treat the phosphorus elements arising from stormwater sources.

If we assume that the water drawn from the deeper areas has 50% more phosphorus content than the lake water in general then a 1% volume of water from the deeper areas may represent 1.5% of the phosphorus content. Similarly a 10% withdrawal could remove 15% of phosphorus content.

Assuming an average flow rate of 73 m^3/day, the following table illustrates that the aquifer could replace up to 10% of the phosphorus laden lake water in 140 days or about 4.6 months. At 42 m^3/day. It would take approximately 243 days or 8 months to replenish the lake.

Percent Removed	Volume of Water Removed (m^3)	Potential Percent of Phosphorus Removed	Days Required to Refresh at 73 m^3/day	Days Required to Refresh at 42 m^3/day
1%	1,020	1.5%	14 days	24 days
5%	5,100	7.5%	70 days	121 days
10%	10,200	15%	140 days	243 days

Average precipitation data for the Greensborough area show low precipitation rates for the months from November through March and consequently this period would represent a period of low volume demands on Markham's stormwater sewer system and therefore a period during which the stormwater sewer system would have the capacity to handle these small volumes of water.

Consideration would have to be given as to whether the lower lake volumes during the winter months could be detrimental to the welfare of the aquatic life in the lake.

The pump and refresh option is a relatively low cost option – the infrastructure is in place, all that is required is the temporary deployment of water pumps.

Recycling and Filtration of Lake Water

As noted above, pumping of water from the Lake through the bioswale will provide a basic level of circulation in the Lake. The volume of the circulation will be dependent on the capacity of the pumps deployed.

A small ½ HP pump with an ability to pump 10 gallons per minute could move 54.5 cubic metres of water per day. A pump of this capacity, driven either by solar sources or by repurposing the existing windmill on the north pond, would have the ability from April through November (245 days) to recycle 13,350 m^3 of water or 13% of the water volume within Swan Lake.

If we assume that the water drawn from the deeper areas has 50% more phosphorus content, a drawdown of 13% water volume may represent approximately a 20% drawdown of the phosphorus content. If we assume a 50% uptake of the phosphorus by the bioswale this could represent removal of 10% of the phosphorus content in the lake.

Movement of water within the lake will be beneficial in mixing nutrients however the water returned to the lake could be enhanced in two ways: first, by having the water flow over water falls or over rough stones, the water will pick up oxygen from the air, thus returning to the lake with enhanced levels of oxygen. Furthermore there are techniques available to filter out some of the algae within the water itself – thereby reducing the algae and phosphorus content within the water returned to the lake.

Algae Harvesting

Algae harvesting is an established process that has numerous uses, including production of food ingredients such as omega fatty acids or natural food colorants and dyes, food and bioplastics.

The following information from the University of Alberta illustrates one technique for removing algae from water. This method usually begins with flocculation; adding chemicals to clump the suspended algae particles into bigger clusters. Various chemicals can be used for flocculation. The type of flocculent used will depend on the type of algae.

Flocculation is followed by collecting the clumped algae. This can be done by one of three methods:

1. Filtration - using filters to capture and remove the clumped algae.
2. Flotation - sending air bubbles to bring the algae clumps to the surface.
3. Gravity sedimentation - using time and gravity to bring the algae clumps to the bottom.

Many variations of each process exist, which involve the addition of chemicals, pressurized apparatus or combined processes.

Flocculation Process

Source: Energy Education, University of Alberta

The algae recovered from Swan Lake could be mixed by Markham into compost and used as fertilize within the Park system or by local farmers as food stock for animals.

By passing algae laden water from Swan Lake through a similar filtering system, a significant amount of algae could be removed, returning purer, aerated water back to the lake.

Removal of the algae would have an immediate effect on the clarity of the water plus it would represent permanent removal of phosphorus that would otherwise be returned to the lake as the algae died and decayed.

iii) Aeration and Oxygenation - Water Circulators

Water circulators stir the water, increase oxygen levels and have the potential to improve water quality through aeration and circulation and support biodiversity.

These approaches are aimed at addressing the legacy (internal) sources of phosphorus and can have a material impact on addressing dissolved oxygen issues. Lake Advocates cautions that it is important to tailor the use of this type of equipment to the specific situations in the lake.

The manufacturers cite the following benefits:

- Prevents and controls cyanobacteria (blue-green algae) blooms.
- Improves dissolved oxygen (DO) and pH levels throughout the circulation zone.
- Reduces invasive aquatic weeds and filamentous algae.

Little River Pond Circulators	**Solar Bee® Lake Circulators**
In essence, it is a floating windmill with a propeller below the water surface. The circulator has successfully reversed the signs of eutrophication/remediation of surface waters (lakes, ponds, dugouts, etc.) for more than 26 years. 	Designed to solve a variety of water quality problems in lakes and reservoirs. Active lake circulation can prevent and control harmful cyanobacteria (a.k.a. blue-green algae) blooms in the top water above the thermocline or they can be deployed to treat the bottom water below the thermocline. 

Appendix F: Goose Management Programs

It is estimated that geese add almost 15 kg of phosphorus to the lake each year – or 51% of the new sources of phosphorus that enter the lake each year.

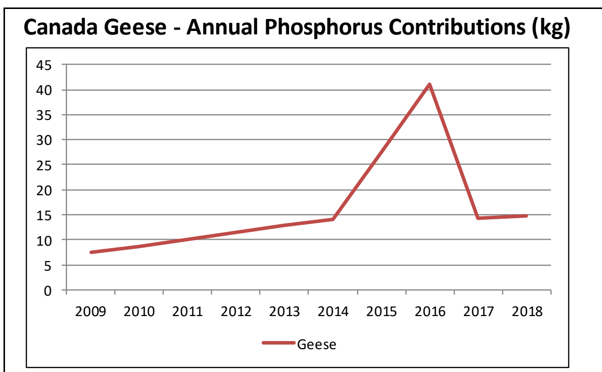
The high volume of migrating geese on the lake in the spring and fall are viewed as the primary source of phosphorus contributed by waterfowl. However the swans and the growing population of cormorants are also contributors. If we assume that the cormorants stay on the lake for about 90 days until the water gets too murky to see the fish and that we have on average 4 mute swans on the lake for 7 months their combined contribution of phosphorus totals 4 kg, about 26% of the amount attributable to the geese.

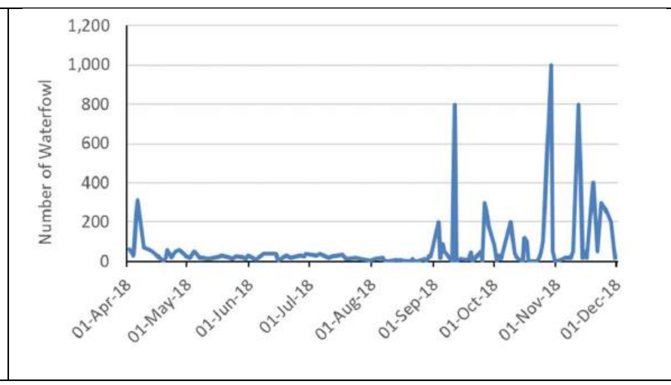
Type of Bird	Daily Phosphorus Contribution (1)	# Days on the Water	# Birds	Estimated Seasonal Impact
Mute Swan	0.57	210 days	4	0.48 kg
Cormorant	2.6	90 days	15	3.50 kg
Mallard Duck	n/a			
Total				3.98 kg

Source: Freshwater Management Report, Nov 2019

This summary suggests that the cormorants may be a growing problem. If we are successful in improving the clarity of the water and the aquatic life the cormorant population may increase and stay longer, become a more significant contributor to the problems in the lake.

The City has hired a firm to reduce the impact of geese on the lake. There have been a number of approaches applied with some limited success. The following chart illustrates the reduction due to the various programs.





Source: Freshwater Research, November 2019

One program involves oiling the eggs to minimize the number of new born each year. It is believed that female geese will return to the lake where they were born to nest. So this program should help reduce the number on the lake during the summer months each year plus reduce future volumes returning to the lake. The other programs such as use of dogs are designed to discourage the migrating geese from staying on the lake. Bird counts peak in the fall (see above). The nightly volume of migrating geese on the lake in the fall of 2018 is still quite high but is approximately 1/3 lower than the peak in 2016.

One expert commented that the number of visiting geese on the lake is lower in the spring because they do not linger - they are anxious to move on to their nesting areas. In the fall, the volumes will be larger because they are returning with their new offspring and if there is food in the area, travelling south is less urgent so they may be comfortable staying a while.

The number of geese that spend the summer on the lake seems to have diminished but perhaps Markham should engage a specialist to advise on what other things can be done to the habitat to make it even less attractive.

The following information from the Canada Wildlife Services outlines some of the options available.

A Protected Species (Source: Canadian Wildlife Service)

Canada Geese are protected under the *Migratory Birds Convention Act, 1994* (MBCA). This Act arose from an international treaty – the *Migratory Birds Convention* – between Canada and the United States, signed in 1916. The MBCA provides for the protection and conservation of migratory birds, and prohibits people from harming birds, except under specified conditions.

Several species, including Canada geese, are considered game birds and may be hunted. The Act gives the federal government the responsibility to establish hunting seasons, and Canada Geese are greatly appreciated by migratory game bird hunters across the country. More than 500,000 Canada Geese are taken in Canada each year by hunters.

In southern Ontario, Canada Geese will pair up and start the nesting process in late March. Incubation lasts about 28 days. The adults must grow new wing feathers each year – a process called moulting – usually in late May or early June. During this time the adults cannot fly and while they are with their young, they will remain on or near the safety of bodies of water where there is easy access to nearby food sources. It is during this period that they can be captured and relocated.

A handbook published by the Canadian Wildlife Services outlines a variety of habitat modification approaches that are used to manage geese populations such as:

- Reduce attractiveness of feeding and nesting habitats
- Scare away pre-molting geese
- Erect barriers that restrict access when they have their young.
- Reduce the attractiveness of area grasses – type of grass, let grass grow longer, apply goose repellant
- Scarring or hazing techniques (that do not require permits) include:
  - Propane cannons

  - Strobe lights
  - Recordings of geese in distress
  - Balloons and kites shaped like birds of prey
  - Scarecrows – eagle, swan, coyote, human scarecrows carrying shot guns
  - Motion activated sprinklers
- Scaring techniques that require a permit include use of raptors such as falcons, eagles etc. and use of firearms to simulate hunting.

The handbook notes that geese may quickly learn that non-lethal methods do not pose a threat to them. For non-lethal devices to be effective, they must be strategically placed in areas of high goose use and be moved and changed frequently.

Relocation and Removal

A permit is required to relocate geese. They are rounded up during the molting phase. They may return to area after they regain their flight feathers.

Lethal Management

The handbook cites three forms of lethal management techniques permitted:

- Egg sterilization or destruction
  - Female geese will tend to return to the area where they were born.
  - Canada geese have long lives (20+ years) so this program needs to be repeated for a number of years to encourage nesting birds to relocate to more successful nesting areas.
- Hunting, authorized under a federal migratory bird permit
- Lethal removal of geese
  - Permits for lethal kills will be considered if it can be demonstrated that all other reasonable management options have been attempted and the problem persists.

In addition to reducing the attractiveness of public lands to geese and employing deterrent techniques, municipal governments can also reduce conflicts by allowing hunting wherever possible, preventing well-meaning citizens from feeding wild waterfowl, and considering geese when making future landscape planning decisions.

Commercial Options

A mini industry has evolved around services and tools designed to keep the Canada Geese away. The following table summarizes some of the more effective techniques.

Goose Control Methods: Comparison Table

(Source: Michael Potter www.stoppestinfo.com)

Method	Type	Advantage	Disadvantage	Effectiveness
Reducing food availability	habitat modification	geese lose the habit of visiting the site; long-term solution	effective only in a combination with other methods	9
Altering the landscape	habitat modification	geese feel unsafe and uncomfortable, lose the habit of visiting the site; especially deters geese with goslings; long-term solution	labor-consuming; reduces accessibility to the pond for humans as well; tall grass is a favorable environment for many pest insects.	10
Fencing	exclusion	very effective if constructed properly; not expensive; electric shock is an additional deterrent; keeps geese away without harming them	geese may fly over the fence; labor-consuming; except for fences made from wood, is not in harmony with the surrounding landscape; electric fences are energy-consuming	10
Noise-making devices (pyrotechnics, distress calls etc)	Frightening	popular because geese are easy to frighten; make geese believe that the site is unsafe	not recommended for densely populated areas as noises will disturb people; special federal permit is required to frighten nesting geese; hazardous to humans if not handled properly; short-term solution; geese habituate to scare tactics	8
Visual goose deterrents (scare tapes, balloons, swan decoys)	Frightening	can be placed in any urban or suburban area without disturbing its residents; popular because geese are easy to frighten; there is a wide choice of visual deterrents; visual deterrents can be handmade	geese have to see the deterrents frequently, in different positions and places as they easily get used to them; short-term solution	9
sprays (methyl anthranilate, anthraquinone)	repellent	effective when applied to the sites of large congregations of geese; does not harm the geese; there are two compounds suggested by scientists: methyl anthranilate and anthraquinone; do not have dangerous residue; not washed off with rains	mowing reduces the repellent effect; expensive, especially for large areas; short-term solution; should be re-applied every five days	10

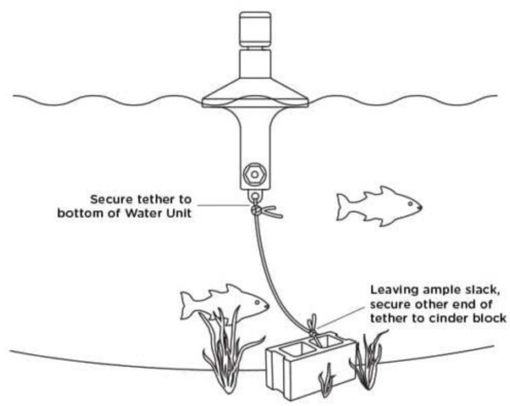
Use of Decoys

There are a range of decoys available that can have some affect but apparently may require being moved about frequently to remain effective.

Some samples include swans, coyote and foxes.

Strobe Light – Manufactured by Away With Geese

Since the largest volume of migratory geese use the lake in the fall, one tool that may be worth trying – a flashing light that disturbs their sleep and makes them seek a more peaceful setting.



The Away With Geese website describes the product as follows:

The Water Unit is recommended for use in ponds, lakes, retention areas and any waterway where unwanted geese are a problem. This floating unit features an amber 360-degree solar-powered LED light that flashes every two seconds, from dusk to dawn, year-round.

The light is mounted on a base comprised of ¼ inch thick ABS black plastic that is configured completely in a one-piece design. 5 pounds of added ballast keeps the unit weighted and a built-in eyebolt is used to keep it localized when tethered to a cinder block. With a recommended 10 feet of slack in the line, the unit is able to float in a small circular area, when moved by wind or current. This movement adds an additional level of deterrence for the geese. A cinder block and a tether rope are required for installation, but are not included.

The Water Unit's light is scarcely noticeable to humans but is very disruptive to the sleep of the geese: it is directly at their eye level, and is annoying to their incredibly sensitive eyesight. Geese choose to sleep in locations that feel safe to them, in which they are free of threats from predators while they rest. The safety in the water is why they choose lakes, ponds and other waterways for sleep and/or rest at night. The light causes them to no longer feel secure at night in the water. Because geese prefer to sleep and eat in the same area, they will no longer find the adjacent grassy area attractive during the day either, and will leave to find another habitat, usually after just a few restless nights. To humans, this light is very dim: in 15 years, no one has ever complained about it bothering them.

The LED light component has been specifically designed to be trouble-free and effective. The LED light is integrated with the solar-powered battery, and specially sealed to withstand any weather conditions. The solar panels that span the top of the light only need 15 minutes of sunlight per week to operate and a fully charged battery (6-8 hours of sunlight) will operate the light for 6 nights. The light is guaranteed for its estimated life of two years, though the average lifespan of a light is 4-5 years.

The Water Unit has a 100-yard effective radius and is incredibly effective at deterring geese as it flashed light while also moving with the water. It is maintenance free, satisfaction guaranteed, and comes with a two-year parts warranty.

The manufacturer recommends the following placement of 7 units for the Swan Lake and 1 for each stormwater pond. The total delivered cost of 9 units would be Cdn$6,200.

The supplier states that the lights will not impact the swans on the lake since swans sleep with their heads tucked back. It the units prove effective and if they are to be deployed for the following season it may then be necessary to deploy some visually protective area for the swans.

Appendix G: Cost Estimates for Sustainable Water Quality

We have attempted to prepare a cost summary of our proposed initiatives. These estimates are based on general information therefore we have added a 20% contingency to the total costs.

The costs are categorized into three segments that align with the three prong approach of addressing internal sources, external sources and phosphorus removal. Additional costs are recognized for the ongoing need for technical guidance at major steps plus the need for annual monitoring of water quality.

Phoslock/Aluminum ($75,000 - $100,000 over 3 years)
In its 2017 report to the city, Freshwater Research estimated that the cost for an application of Phoslock was $100,000 for the initial treatment. In addition they estimated costs for consulting oversight and monitoring which we have included in our guidance/monitoring estimate plus they recommended a 20% contingency factor, which we have adopted for all of our estimates. We have seen information that implies that an aluminum treatment may cost only 50% of a Phoslock treatment however for our purposes we have assumed a cost of 75% of a Phoslock treatment or $75,000 for the initial treatment.

We have recommended the implementation of a number of actions however we also assume that in addition to these actions there will be a perpetual need for a chemical treatment to sustain the lake at our recommend mesotrophic level. Our financial estimate assumes a full treatment of either Phoslock or aluminum in 2021 with a reduced follow up treatment at 50% of the cost two years later in 2023 that will remove the additional buildup in phosphorus. Once the benefits of the other initiatives take effect, we assume additional chemical treatments will be required every five years thereafter at the lower 50% cost.

Removal of Phosphorus ($26,000 over 3 years)
We have included costs for two programs for removal of phosphorus.

We believe an annual pump and refresh program may be the lowest cost and most effective option for removing phosphorus and refreshing water in the lake. We have included an initial cost of $5,000 for laying of piping or hoses in the lake. We assume there is no need for permanent pumps since we assume there are already in inventory and are likely needed for only 10 days each year. We have provided an estimate of $2,000 per year for the costs of setting up and removing the pumps each year. If the city is able to use the water to refill its irrigation trucks then these costs may be reduced or eliminated.

We estimate a onetime cost of $20,000 to setup a bioswale in the northern channel. This cost includes planting, the cost of laying a hose from the lake to the channel and conversion of the windmill to a water pumping system to bring water in from the lake. We have assumed no ongoing annual costs.

Redirection of Stormwater Flows ($80,000 onetime costs)

We have estimated onetime costs for redirecting some of the current stormwater flows that go directly into the lake at $80,000. Of this, $40,000 is applied to redirecting two existing areas in the park: 1) redirecting the parkland near the windmill into the north stormwater pond and 2) redirecting the drainage from the children's' playground area into the northern channel bioswale and by planting phosphorus absorbent plants in the existing drainage trenches.

The stormwater from the traffic circle on Swan Lake Boulevard drains directly into the lake. We recommend that these flows either be directed into the sewers on 16th Avenue or if that is not feasible then to install an oil/grit separator that the stormwater flows into before going into the lake. A similar setup has been installed to serve the Amica complex. We have estimated $40,000 for this one time cost.

Goose Management ($27,000 over 3 years)

We have assumed an ongoing annual cost of $3,000 for a program of oiling eggs and use of dogs etc. We have also assumed an initial $6,000 cost to acquire strobe lights for the lake and full replacement after 5 years. We have assumed an additional guidance cost of $2,000 by an independent expert in 2020 with a follow up 5 years later. Also included is a onetime cost of $10,000 for redesign of habitat settings.

Additional options that may reduce the need for future chemical treatments

We have identified two additional treatments, use of circulators and use of floating islands, which address the buildup of internal phosphorus load within a lake. Technical assessment of these options will be required. If they are viewed as effective, then the cost of implementation should be offset by a reduction in the cost estimates provided in our estimates for future chemical treatments, such as Phoslock or aluminum.

	Estimate of Costs of Proposed Program					
	Initial Cost	Cost to Repeat/ Replace	Annual Costs	Initial 3 Year Total	Years 4 - 10	Years 1 - 10
Water Quality Guidance/Monitoring	$20,000	$20,000	$5,000	$30,000	$65,000	$95,000
Internal (Legacy) Load						
Chemical Treatment						
- Phoslock	$100,000	$50,000		$100,000	$100,000	$200,000
- Aluminum	$75,000	$37,500		$75,000	$75,000	$150,000
Removal of Phosphorus						
a) Pump and Refresh	$5,000		$2,000	$6,000	$14,000	$20,000
b) Bioswale	$20,000		$0	$20,000	$0	$20,000
Sub Total	$25,000	$0	$2,000	$26,000	$14,000	$40,000
Reduce External Load - Redirect Stormwater Inflows						
a) Redirect 2 parkland areas to stormwater ponds	$40,000			$40,000	$0	$40,000
b) Redirect traffic circle into oil/grit separator	$40,000			$40,000	$0	$40,000
Sub Total	$80,000	$0	$0	$80,000	$0	$80,000
Reduce External Load - Goose Management						
a) Guidance/ Annual Management	$2,000	$2,000	$3,000	$11,000	$23,000	$34,000
b) Strobe Lights	$6,000	$6,000		$6,000	$6,000	$12,000
c) Habitat redesign	$10,000	$5,000		$10,000	$5,000	$15,000
Sub Total	$18,000	$13,000	$3,000	$27,000	$34,000	$61,000
Estimated Cost With Phoslock				$263,000	$213,000	$476,000
Contingency	20%			$52,600	$42,600	$95,200
Total Phoslock Cost with Contingency				$315,600	$255,600	$571,200
Estimated Cost With Aluminum				$238,000	$188,000	$426,000
Contingency	20%			$47,600	$37,600	$85,200
Total Aluminum Cost with Contingency				$285,600	$225,600	$511,200
Annual Estimated Cost With Phoslock				$105,200	$36,514	$57,120
Annual Estimated Cost With Aluminum				$95,200	$32,229	$51,120