Swan Lake Water Quality Monitoring 2020 Annual Report

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MARKHAM

Environmental Services

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Executive Summary

Background

Swan Lake is situated in the City of Markham at the intersection of Sixteenth Avenue and Williamson Road. Swan Lake has an approximate area of 5.5 ha and a maximum water depth of 4.5 m. A gravel pit in the 1960s and 1970s, Swan Lake is currently a community feature with multiple trails and urban development surrounding it.

Several issues were discovered with Swan Lake in 2010, including high phosphorus levels and significant algal blooms during the summer months, which led to low oxygen levels and degraded fish habitats. A Phoslock treatment was administered in 2013 to reduce the phosphorus levels and algal blooms in Swan Lake. In 2019, the City of Markham conducted a study to define a water quality management strategy for Swan Lake. The strategy was finalized in July 2020.

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

Results

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

The following paragraphs provide the monitoring results for the 2020 monitoring period, as well as annual summaries of available data from 2011 to 2020. The respective figures include plots of measured dissolved oxygen (DO), water clarity, phosphorus concentration, chloride concentration, geese count, and algae.

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

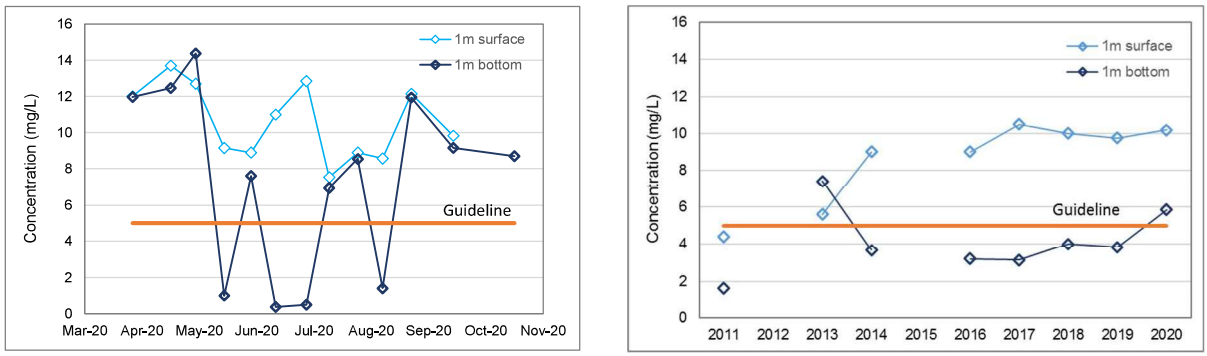
Dissolved Oxygen (DO), Temperature and pH

The minimum dissolved oxygen concentration required for the protection of warm water fish is 5 mg/L for water temperatures up to 20 °C and 4 mg/L for temperatures above 20 °C. DO concentrations for the 1m from the surface, and 1m from the bottom layers are shown below. Measured surface concentrations were above the DO guideline throughout 2020.

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

When stratified, bottom concentrations were below the DO guideline thresholds. Lower concentrations could have lethal or sub-lethal (physiological and behavioral) effects on fish. However, some fish can acclimate to lower oxygen levels and survive concentrations between 1 and 3 mg/L, and oxygen levels nearer to the surface remained above the minimum guideline.

Figure ES-2: 2020 Monitoring Results and 2011-2020 Annual Results- Dissolved Oxygen



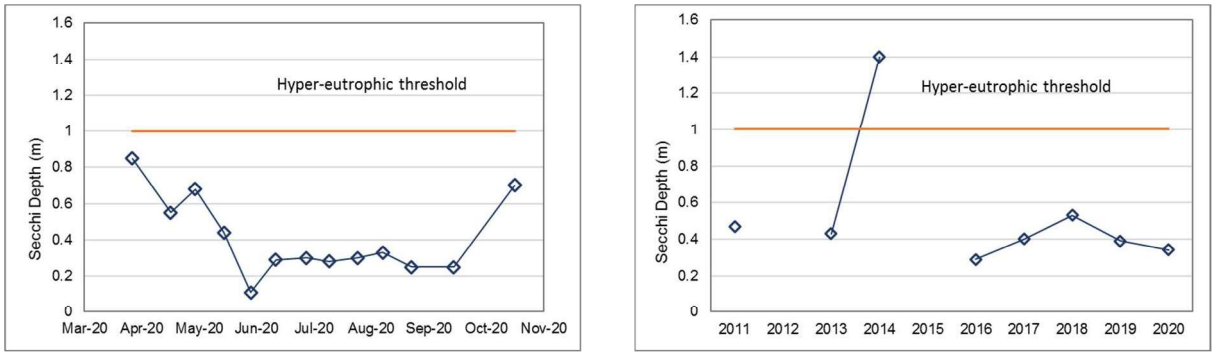
Note 1: DO concentrations are shown at 1 m from the surface and 1 m from bottom.
Note 2: Histotical data are shown for the average growing period.

Measured pH values ranged from 9.6 to 11.6 with overall averages of 10.4 at the Bridge and 11.0 at the Dock station. These results are very high and will be investigated through lab analysis for pH in 2021.

Water Clarity (Secchi Depth)

Secchi depth represents water clarity, which declines when algae level increases. In the trophic state classification scheme, growing period average water clarity of under 1 m is the threshold for a hyper-eutrophic condition. In 2020, water clarity was lower than 1 m, indicative of a hyper-eutrophic condition.

Figure ES-3: 2020 Monitoring Results and 2011-2020 Annual Results- Secchi Depth



Phosphorus and Nitrogen Concentrations

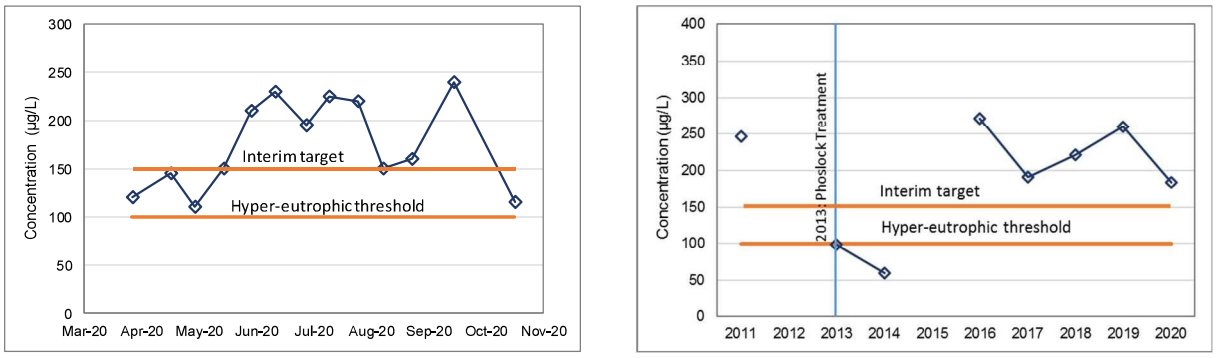
Phosphorus concentration is the most important indicator of trophic state in Swan Lake. It is an indication of how prone the Lake is to algae growth.

Phosphorus concentrations above 100 µg/L represent a hyper-eutrophic condition, which entails high nutrient concentrations leading to high algae concentrations. The relative drop in September of 2020 will be reviewed through the Chemical Treatment planning study, as the results are contrary to past trends, and there is no obvious explanation for the drop in concentrations.

Phosphorus concentrations in 2020 were lower than in 2019 despite lower precipitation in 2020. A possible cause may be the impact of the removal of the fountain from the south island. The fountain may have contributed to the mixing of deep water with higher concentrations than in the surface water.

The Annual average concentration is further skewed since depth samples were not collected in mid-May and mid-July of 2020 due to equipment damage, and therefore the average may be biased towards lower surface concentrations.

Figure ES-1: 2020 Monitoring Results and 2011-2020 Annual Results- Total Phosphorus



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

Total nitrogen concentrations over the growing season averaged about 2.8 mg/L, which is above the 1.2 mg/L threshold for a hyper-eutrophic condition. In 2020, ammonia and nitrate concentrations (the forms available for uptake by biota) were generally very low, and nitrogen was mainly present as organic matter.

Chloride Concentration

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

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

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

Figure ES-4: 2020 Monitoring Results and 2011-2020 Annual Results- Chloride

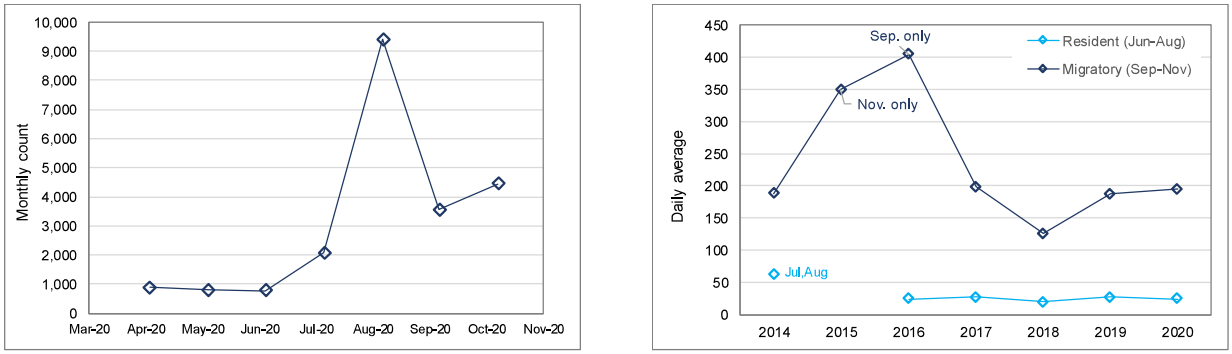
Geese Count

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

The 2020 program included an expanded hazing program starting in September, the installation of nine strobe lights on the Lake and adjacent stormwater ponds in October, and a volunteer-based geese count program.

In 2020, there was a significant decrease in the count of migratory geese as a result of increased hazing efforts. The strobe lights did not have any noticeable impact on the counts. The volunteer geese count effort resulted in the collection of a significant amount of data, which helps provide more certainty in the results, and was used to better time hazing efforts.

Figure ES-5: 2020 Monitoring Results and 2011-2020 Annual Results- Geese Count



Note 1: 2020 data are the sum of counts in each month, compensated for days with no count.
Note 2: Annual data are daily averages of counts over June-August and September to November, representing resident and migratory geese, respectively.

Algal Blooms and Cyanobacteria

In 2020, surface scums were observed along the shoreline around the Dock, as well as in the northern bay at the Bridge site. However, similar to 2019, Abraxis testing in 2020 indicated that microcystin concentrations were consistently below 10 µg/L (recreational guideline is 20 µg/L).

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

Summary and Recommendations

Based on the measured Secchi desk transparency and nutrient concentrations, Swan Lake was classified as hyper-eutrophic in 2020.

In 2019, the City initiated a study to define a water quality management strategy for Swan Lake. The strategy was finalized in July 2020. Based on this strategy, internal loading of phosphorus was determined to contribute the most to the overall nutrient loading, leading to poor water quality. Phosphorus released from the bottom sediments has high biological availability, and its release during elevated water temperature increases its effect on the Lake water quality during summer and fall. For these reasons, the management of internal load was determined to be promising for immediate results. The preferred treatment to abate the internal phosphorus loading was identified as a Phoslock application program, with the first application to be completed in the spring of 2021.

Geese dropping was identified as the second most important contributor to nutrient loading. Enhanced geese management activities were initiated in September 2020 and will continue with additional components (geese relocation and habitat modification) in 2021.

In 2020, signs were erected as a precaution at multiple locations around Swan Lake to warn the public against water contact for humans and pets.

The 2021 monitoring program will follow the recommendation of the water quality management report and will include the annual monitoring program, as well as enhanced monitoring to determine the effectiveness of the proposed chemical application.

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Figures

1. Introduction

Swan Lake is situated in the City of Markham at the intersection of Sixteenth Avenue and Williamson Road, as shown below in Figure 1. Swan Lake has an approximate area of 5.5 ha and a maximum water depth of 4.5 m (from the deepest point to the Lake edges). Formerly a gravel pit in the 1960s and 1970s, Swan Lake is currently a community feature with multiple trails and urban development surrounding it.

Several issues were discovered with Swan Lake in 2010, including high phosphorus levels and significant algal blooms during the summer months, which led to low oxygen levels and degraded fish habitats. A Phoslock treatment was administered in 2013 to reduce the phosphorus levels and algal blooms in Swan Lake. In 2019, the City of Markham conducted a study to define a water quality management strategy for Swan Lake.

Water quality monitoring of Swan Lake has been conducted annually since treatment in 2013 in order to track water quality and the continued effectiveness of the Phoslock. The 2020 monitoring results presented in this report are part of the ongoing monitoring program that will allow for continuous assessment of the water quality in Swan Lake and will help establish a long-term plan for the treatment of Swan Lake.

Figure 1: Swan Lake Location and Monitoring Stations

2. Water Quality

2.1 Monitoring Program

2.1.1 Locations

Water quality was monitored at two shoreline sites, the Dock, and the Bridge, as shown in Figure 1. The water depth at the dock is approximately 2.5-3 meters, which allows it to represent Swan Lake as a whole. The water depth at the bridge is about 0.5 meters deep, and it is used to represent the conditions of the shallow bays around Swan Lake. Field testing and sampling for laboratory analysis were completed at both sites to ensure the water conditions at Swan Lake were properly represented.

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

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

Water level dropped to around 2 m in mid-September, and samples were not collected from the 2.5 m depth at the Dock station.

2.1.2 Duration and Frequency

In 2020, water quality was monitored bi-weekly throughout the summer (May-September) and monthly in the spring (April) and fall (October-November). A total of 13 sampling event was completed.

2.1.3 Parameters and Methodology

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

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

An Oakton EcoTestr™ pH 2+ Pocket pH Meter was used for onsite measurement of pH.

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

Water samples for laboratory testing were taken using a horizontal water sampler at different depths.

Observations of Swan Lake were noted, and photographs were taken during each monitoring/inspection site visit. Photographs provide a way to record the condition of vegetation and algae around Swan Lake. Completed inspection forms can be found in Appendix A. All photographs from the 2020 monitoring period are provided in Appendix B.

2.1.4 Targets and Thresholds

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

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

Table 1: Eutrophic State Classification

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

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

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

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

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

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

2.2 2020 Water Quality Results

2.2.1 Dissolved Oxygen and Temperature

Table 2 provides the measured DO profile over the 2020 monitoring period. At the Dock station, surface concentrations were above 5 mg/L throughout 2020. Below 2 m depth, the DO was under 2 m/L in most of the sampling events from late May through July, indicating anoxic conditions. All measurements at the Bridge indicated a DO concentration of above 2 mg/L, with most being above or close to 4 mg/L.

Table 3 provides the measured temperature profile in 2020, indicating warm water throughout the depth in the summer months.

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

In 2020, anoxia was not as widespread as previous years (which could explain lower TP concentrations in water due to lower internal loadings).

Water temperature was also recorded by the level/temperature logger installed at the Dock station. The probe was located at 1 m from the Lake bed. Figure 3 provides recorded temperature at15-min intervals. Average temperature at each depth was similar to 2019 records.

Table 2: Measured DO Profile (mg/L)

	Bridge	**Dock**				
	Depth (m)	Depth (m)				
Date	0.25-0.5	0.5	1	1.5	2	2.5
4/24/2020	10.1	12.0	12.0	12.0	12.0	12.0
5/14/2020	8.6	13.7	13.7	13.3	12.2	11.9
5/27/2020	9.8	12.0	13.4	15.5	15.3	12.3
6/11/2020	2.0	9.2	9.1	8.4	1.0	-
6/25/2020	2.3	9.4	8.4	7.9	7.6	-
7/8/2020	2.2	13.8	8.2	0.5	0.4	-
7/24/2020	6.2	12.9	12.8	2.5	0.5	-
8/5/2020	4.8	7.7	7.4	7.1	6.9	-
8/20/2020	6.6	9.1	8.7	8.6	8.6	-
9/2/2020	3.9	9.5	7.7	5.6	1.4	-
9/17/2020	6.4	12.1	12.2	12.1	11.9	-
10/9/2020	6.8	10.1	9.6	9.5	9.2	-
11/10/2020	5.4	10.2	9.0	9.3	8.7	-

Note: DO below 2 mg/L is shown in red.

Table 3: Measured Temperature Profile (°C)

Date	Bridge	Dock				
	Depth (m)	Depth (m)				
	0.25-0.5	0.5	1	1.5	2	2.5
4/24/2020	8.0	8.0	7.9	7.9	7.7	7.7
5/14/2020	12.0	11.1	10.6	10.2	9.4	9.1
5/27/2020	26.7	26.0	25.0	20.0	15.4	14.0
6/11/2020	22.8	23.5	23.5	23.5	19.9	-
6/25/2020 *	20.0	20.8	20.8	20.7	20.6	-
7/8/2020	26.3	27.0	26.2	24.4	21.2	-
7/24/2020	23.7	24.2	24.2	24.0	23.1	-
8/5/2020	22.1	22.1	22.2	22.4	22.4	-
8/20/2020	20.8	21.7	21.8	21.8	21.8	-
9/2/2020	22.4	22.6	22.6	22.4	21.8	-
9/17/2020	17.2	17.9	17.9	17.9	17.9	-
10/9/2020	12.7	12.7	12.7	12.8	12.8	-
11/10/2020	10.0	10.2	9.8	9.2	9.1	-

* Likely a turnover/mixing event, given the high DOs on the same day.

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

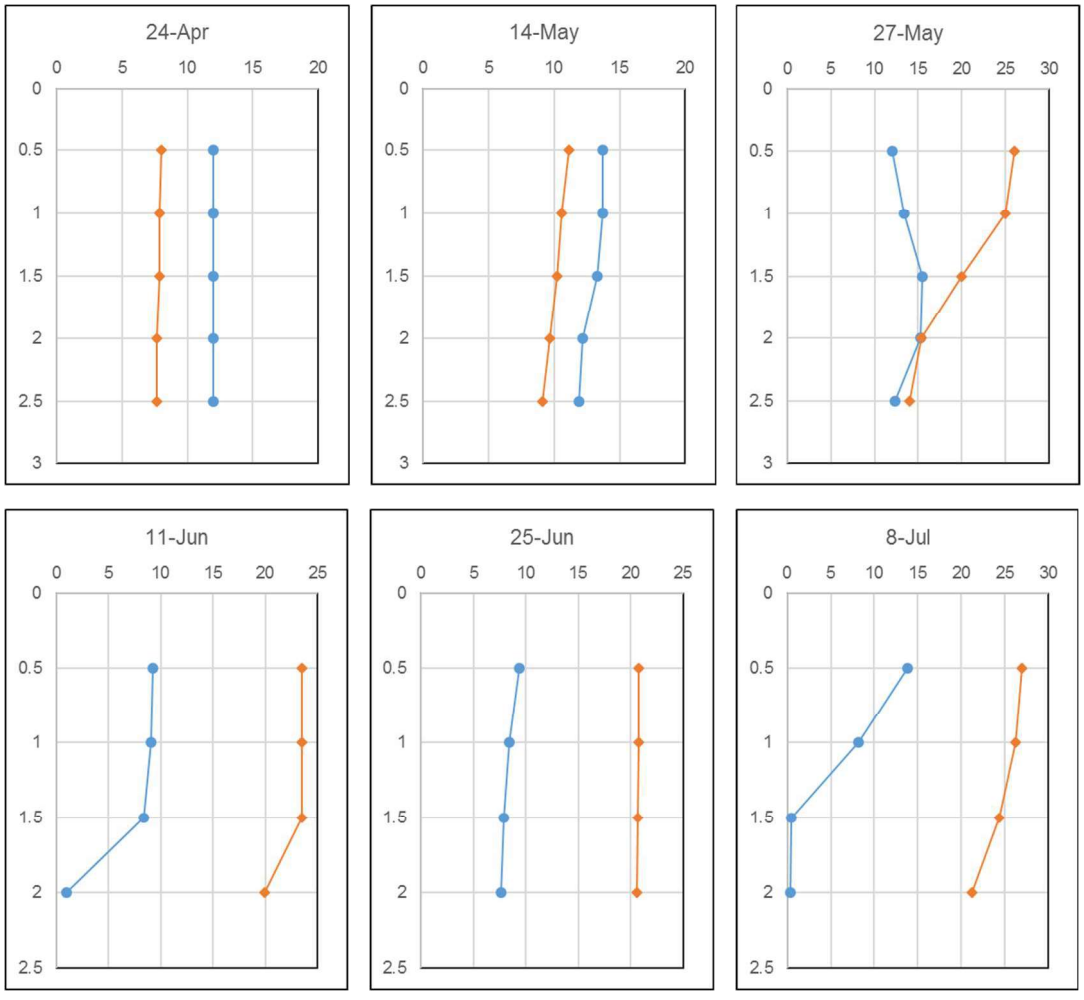
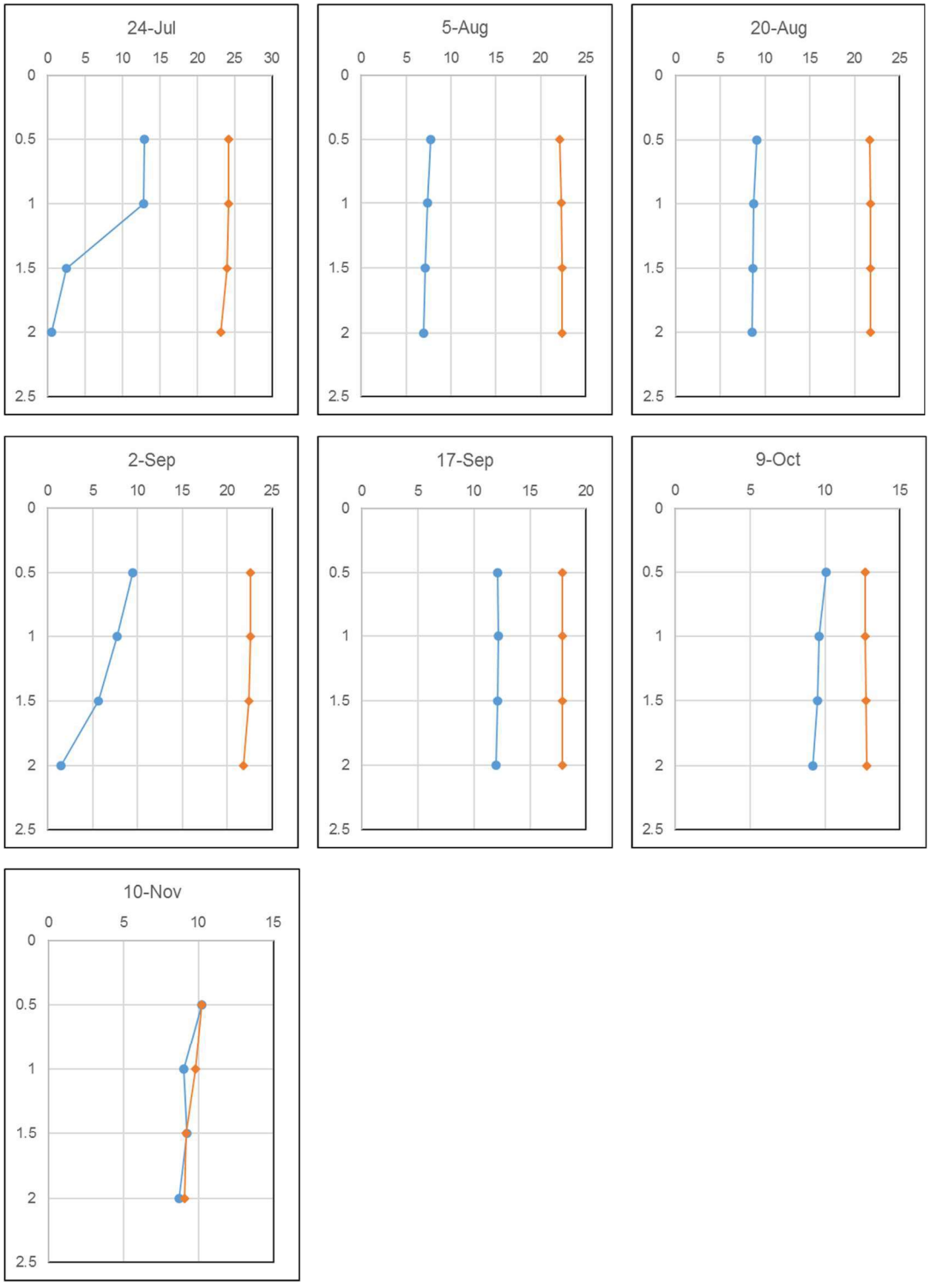
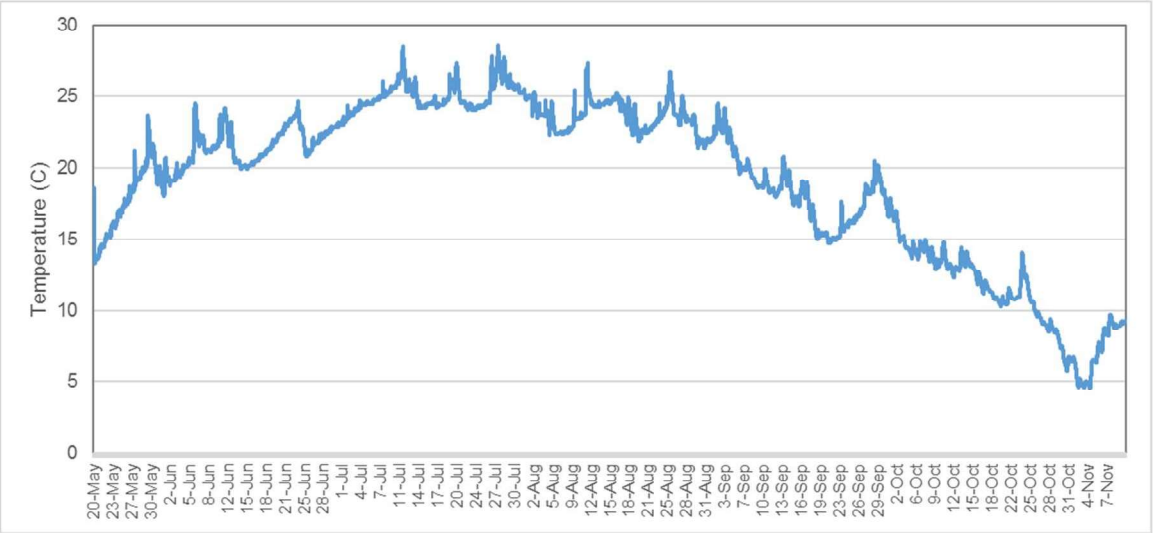


Figure 2: Temperature (orange) and DO (blue) Profile at the Dock Station, Cont'd



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

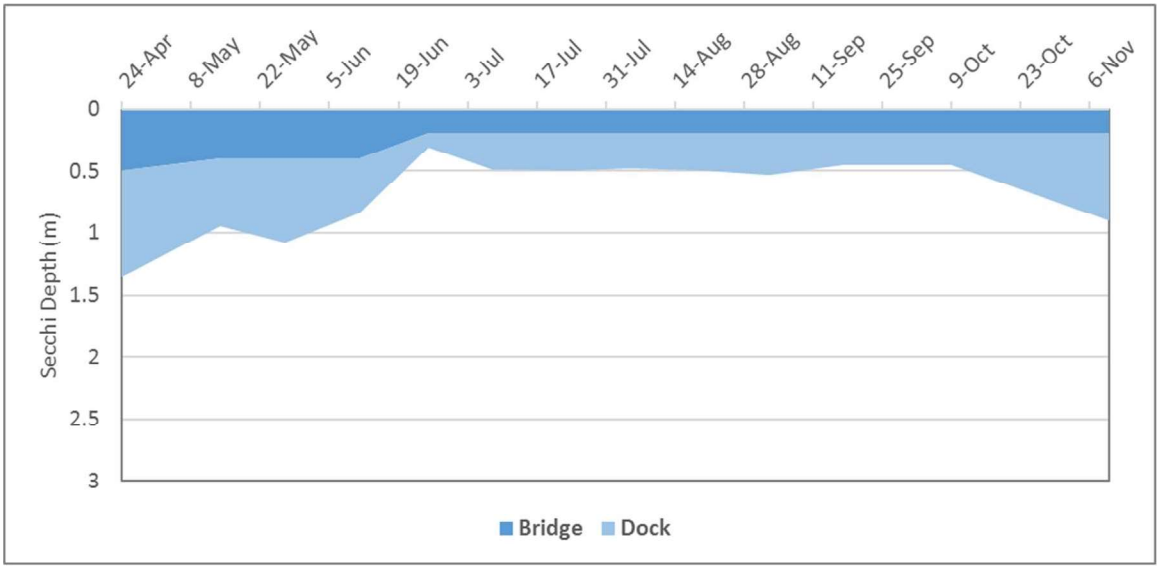
Figure 3: Temperature Recorded by the Level/Temperature Logger at the Dock Station (1m from bottom)



2.2.2 Water Transparency

Figure 4 summarizes the results of the water transparency readings. Transparency at the Dock station was under 0.5 m at the beginning of June and remained so until November.

Figure 4: 2020 Secchi Depth Results



2.2.3 pH

Measured pH values ranged from 9.6 to 11.6 with overall averages of 10.4 at the Bridge and 11.0 at the Dock station. These results are very high and will be investigated through lab analysis for pH in 2021.

2.2.4 Nutrients Concentrations

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

The results can be found in Figure 5 for the Dock site and Table 4 for the Bridge site. The Certificate of Analysis from Caduceon Environmental Laboratories in Appendix C.

Nutrient concentrations are shown for the depths sampled. Between mid-May and mid-July, only surface samples were collected due to equipment damage. The water level dropped to around 2m in mid-September, and samples were not collected from the 2.5 m depth at the Dock station.

Total phosphorus concentration ranged from 100 µg/L in early spring to about 250 µg/L in summer (in the top 1 m depth). Total phosphorus concentrations over the growing season averaged about 200 µg/L, which is above the 100 µg/L threshold for a hyper-eutrophic condition.

The drop in phosphorus concentration in September is unlikely to be a sampling error, as multiple samples in the period showed lower phosphorus concentrations. This will be further reviewed through the Chemical Treatment planning study.

Phosphorus concentrations in 2020 were lower than in 2019 despite lower precipitation in 2020. A possible cause may be the impact of the removal of the fountain from the south island. The fountain may have contributed to the mixing of deep water with higher concentrations with surface water.

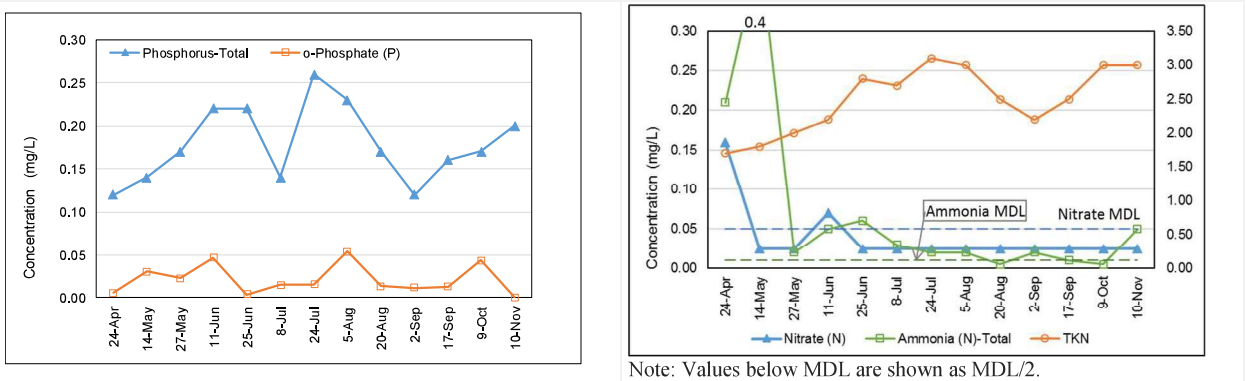
Nitrogen concentration was analyzed in terms of Total Kjeldahl Nitrogen (TKN), Ammonia (NH_3) and Nitrate (NO_3). Total nitrogen concentrations over the growing season averaged about 2.7 mg/L, which is above the 1.2 mg/L threshold for a hyper-eutrophic condition.

Ammonia and nitrate are the forms that are directly bioavailable, with ammonia being the most usable form for algae. In 2020, Ammonia and Nitrate concentrations were generally close to or below Method Detection Limit (MDL), and nitrogen was mainly present as organic compounds (i.e., TKN less Ammonia). Exceptions included two samples collected in April and May.

Figure 5: Measured Nutrients Concentrations in 2020 - Dock Site

Note: Values below MDL are shown as MDL/2

Table 4: Measured Nutrients Concentrations in 2020 - Bridge Site



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

2.2.5 Chloride and DOC Concentrations and Color

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

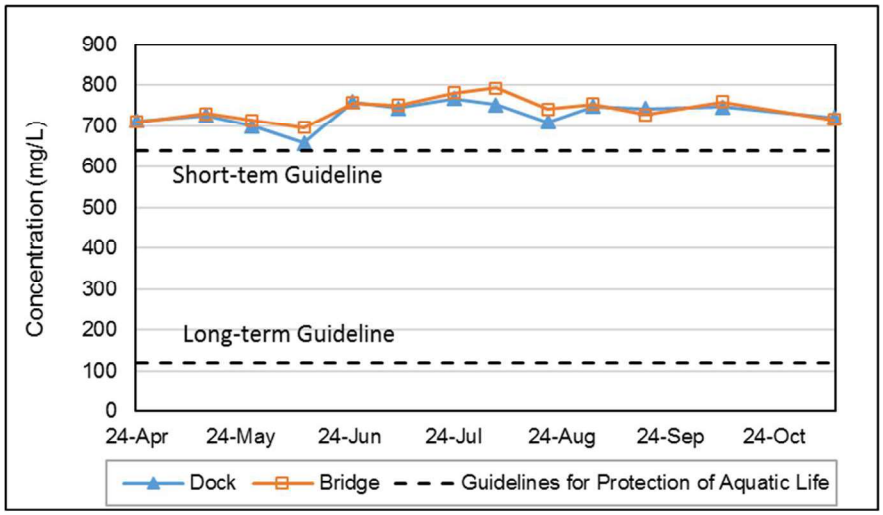
Water quality testing results indicated that all samples taken at the Dock monitoring site contained high chloride levels in Swan Lake throughout the monitoring period (>640 mg/L). Chloride levels tend to rise in the spring as runoff containing de-icing agents are discharged to the Lake. Once introduced to a waterbody, chloride does not biodegrade, readily precipitate, volatilize, or bioaccumulate. It does not adsorb readily onto mineral surfaces, and therefore when introduced, concentrations remain high in surface water.

Chloride guidelines developed based on generic environmental data include a long-term guideline (120 mg/L) and a short-term guideline (640 mg/L). These guidelines may be over-protective for areas with an elevated concentration of chloride and associated adapted ecological community. For such circumstances, it has been suggested that site-specific (higher) targets be derived considering local conditions such as water chemistry, background concentrations, and aquatic community structure.

Table 5: Measured DOC, Color and Chloride

Date	Dock			Bridge		
	Cl (mg/L)	Colour	DOC (mg/L)	Cl(mg/L)	Colour	DOC (mg/L)
24-Apr	712	11	2	709	11	2
14-May	726	11	2.3	730	10	2.3
27-May	699	10	2.2	713	13	2.2
11-Jun	659	13	1.6	695	18	2
25-Jun	758	10	1.6	756	13	1.3
8-Jul	743	48	2.4	750	13	2.3
24-Jul	766	12	2.3	780	17	2.5
5-Aug	752	13	2.8	793	14	2.5
20-Aug	709	11	3.1	740	11	2.6
2-Sep	747	14	2.6	753	14	2.8
17-Sep	742	13	3.1	727	14	3
9-Oct	746	14	2.2	759	15	2.7
10-Nov	720	11	1.2	714	13	1.5

Figure 6: Chloride Concentrations in 2020



2.2.6 Algae Growth and Toxicity

Algae blooms, which have been a problem in Swan Lake in previous years, reoccurred during the 2020 monitoring period. During the summer, surface scum was found at both the Dock and Bridge sampling sites. The surface scum found at the Bridge site was generally worse upon visual inspection, likely due to the stagnant conditions in the bay.

The observed aerial extent of algae growth was more limited than the one observed in 2019.

In 2020, Abraxis Microcystins Strip Test for Recreational Water was used to measure microcystin toxicity in the Lake water. This test is a rapid immune-chromatographic test designed for use in the qualitative screening of Microcystins and Nodularins in recreational water.

Samples were collected throughout the summer and tested with the strips. The results showed all samples contained Microcystins concentrations below the recreational guideline of 10 ppm.

Nonetheless, in 2020, signs were erected at multiple locations around Swan Lake to warn the public against water contact for humans and pets (see Appendix D).

2.2.7 Summary of Monitoring Results in 2020

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

DO concentrations measured in the 1 m surface water were above the DO guideline for the protection of aquatic life. When stratified, bottom concentrations were lower than the DO guideline.

Transparency at the Dock station was under 0.5 m at the beginning of June and remained as such until November.

Measured pH values ranged from 9.6 to 11.6, with overall averages of 10.4 at the Bridge and 11.0 at the Dock station.

Total phosphorus concentration ranged from 100 µg/L in early spring to about 250 µg/L in summer (in the top 1 m depth).

Total nitrogen concentrations over the growing season averaged about 2.8 mg/L, which is above the 1.2 mg/L threshold for a hyper-eutrophic condition.

Chloride concentrations were very high (upwards of 700 mg/L.

Throughout the 2020 monitoring period, surface scum was found at both the Dock and Bridge sampling sites. Samples were collected throughout the summer and tested for Microcystin toxicity with the test strips. The results showed all samples contained concentrations below 10 ppm.

2.3 Water Quality Trends

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

The following paragraphs and Figure 7 provide a summary of water quality trends for the period of monitoring.

Dissolved Oxygen (DO)

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

Water Clarity (Secchi Depth)

In Swan Lake, Secchi depth has typically been quite low throughout the summer, but it increases in November, reflecting the end of the growing period for phytoplankton. The average annual values shown in Figure 7 are all below 1 m, except in 2014.

Total Phosphorus (TP)

Average growing period (May - October) TP concentrations indicate hyper-eutrophic conditions in all monitored years except for the two post-treatment years, 2013 and 2014. Phosphorus concentrations in 2020 were lower than in 2019 despite lower precipitation in 2020. A possible cause may be the impact of the removal of the fountain from the south island. The fountain may have contributed to the mixing of deep water with higher concentrations with surface water.

Nitrogen Compounds

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

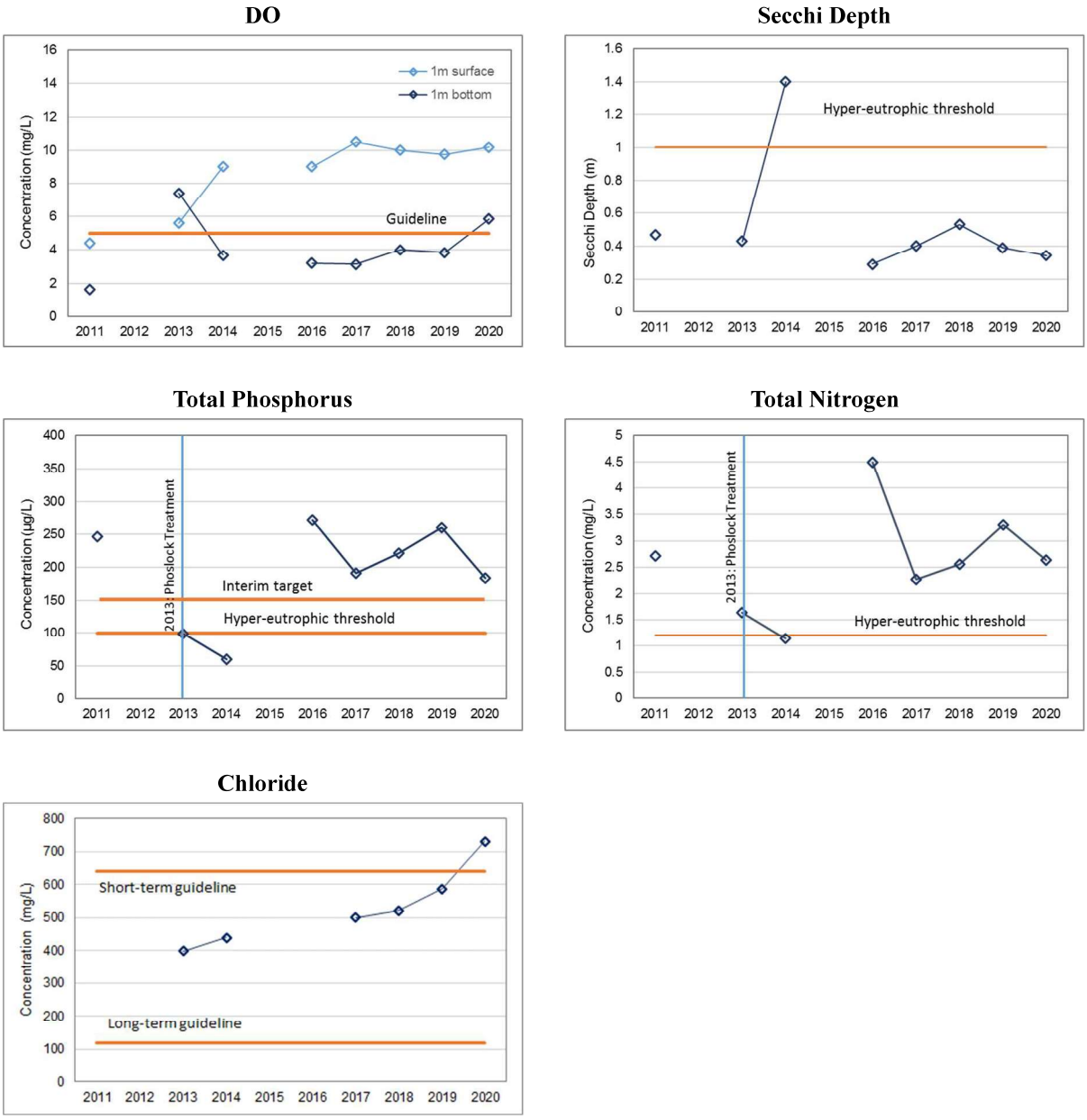
Inorganic nitrogen-compounds (NO_2, NO_3, and NH_3) have often been below detection limits, indicating relatively low levels of bioavailable nitrogen concentrations. In 2020, ammonia and nitrate concentrations were generally very low, and nitrogen was mainly present as organic matter.

Chloride

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

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

Figure 7: Historical Water Quality Results (Growing-Season Averages)



Algae Blooms and Cyanobacteria

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

Table 6: Records of Algae Blooms and Toxicity

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

3. Water Level Monitoring

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

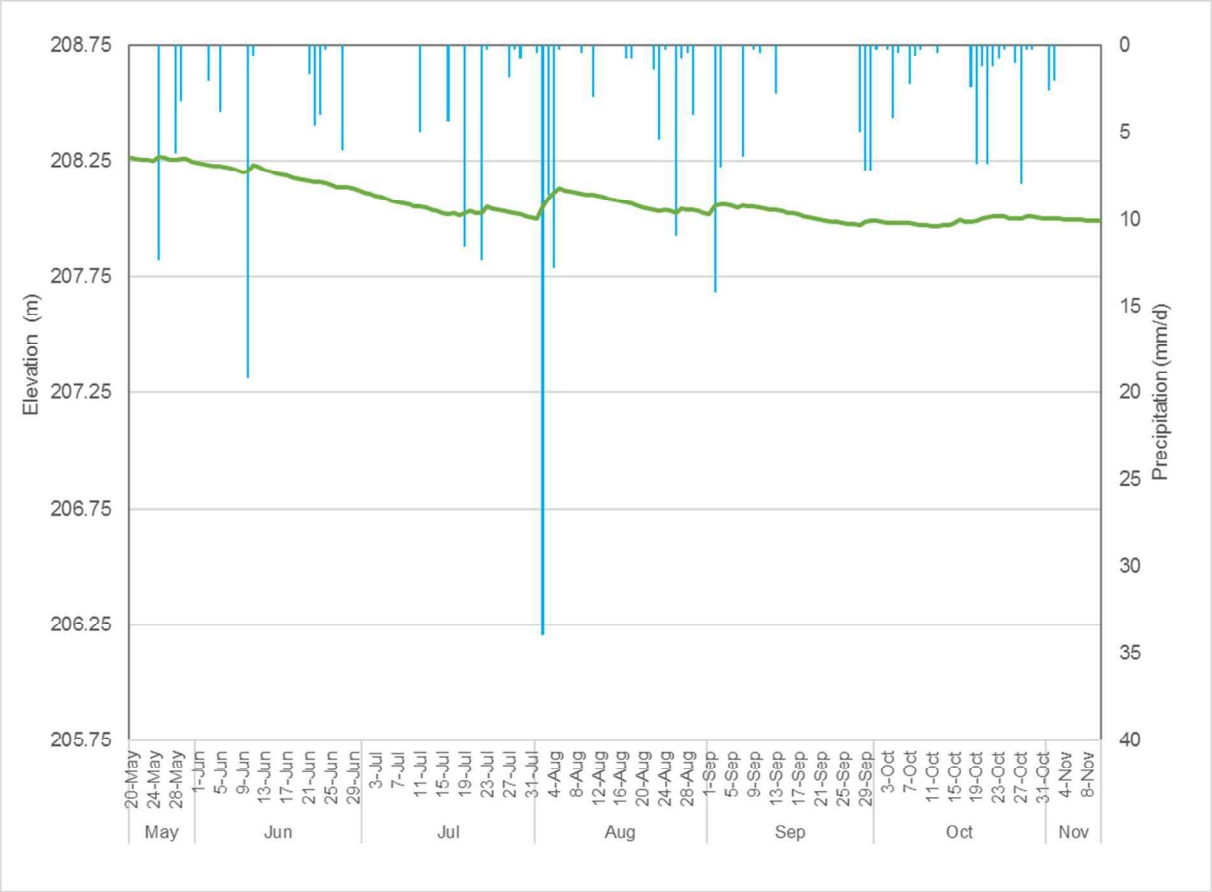
The logger location was moved in May 2020 from the southwest corner of the Dock to the Dock's north side to represent open water conditions better. The sensor is located 1 m above the lakebed (at 205.75). Appendix E provides a schematic of the current installation of the logger.

The calculated water level changed from 208.25 m (2.52 m depth) in May to 207.97 (2.22 m depth) in November. The deepest site in the Lake is at 204.8 m.

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

Rain data from the nearby rain gauge located at the Markham Museum are shown in Figure 8.

Figure 8: Lake Elevation Records and Precipitation in 2020



4. Geese Management

4.1 Geese Management Approach

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

Geese management in 2020 started like in previous years. Border Control Bird Dogs, an external consultant, was hired to chase terrestrial geese by border collies, and perform egg oiling. The frequent geese chasing would encourage the geese to relocate to a quieter place and reduce the number of resident geese at Swan Lake.

In an effort to reduce the number of geese further, a thorough investigation of other geese management methods was completed. It was concluded that increasing the hazing frequency will be the most efficient method in the short term, and an enhanced hazing program was completed from late September to the end of November.

At the request of a resident group, Friends of Swan Lake, and upon Council approval, nine strobe lights were also purchased and installed on the Lake and the two adjacent stormwater management ponds. Strobe lights work by using a solar-powered LED light that flashes every two seconds and is intended to disrupt the geese's sleep patterns and discourage them from staying on the Lake.

4.2 Geese Count

In 2020, the geese count was completed by the consultant, City staff, and volunteers from the community.

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

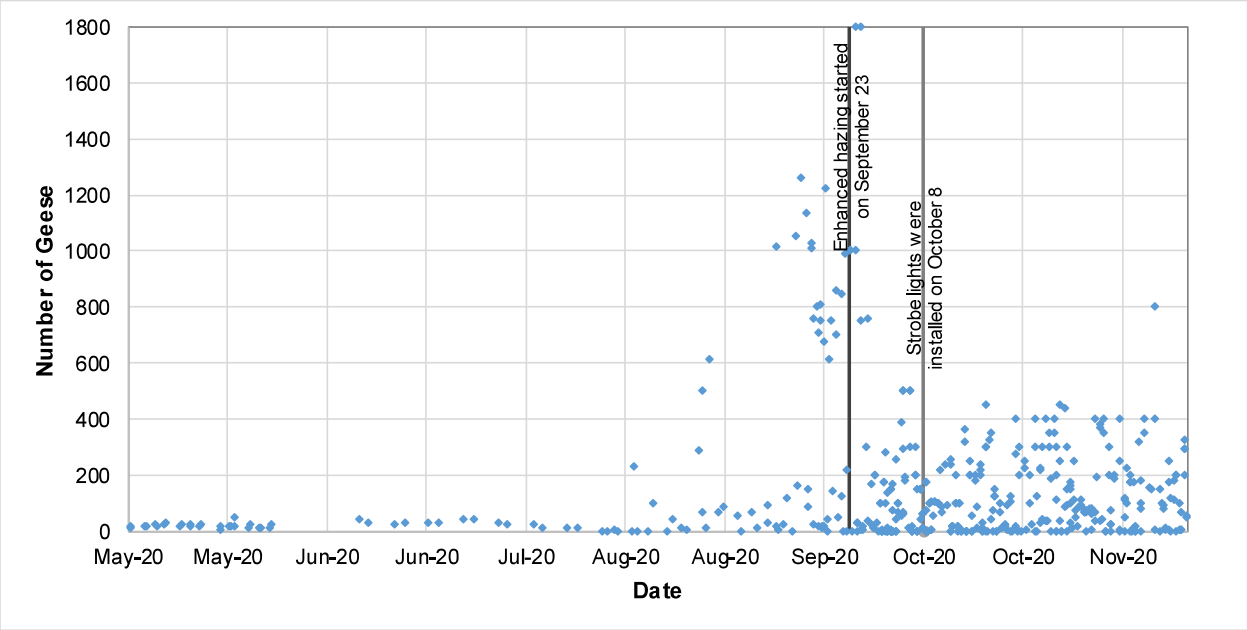
Friends of Swan Lake organized a geese count campaign and provided a spreadsheet of the counts to the City. Staff also developed a geese count App using ArcGIS Survey123, which several residents used to record geese count and note other wildlife observations.

4.3 Results

Figure 9 illustrates the number of geese counted at Swan Lake throughout the 2020 monitoring period.

In this figure, a significant increase in geese during the fall months is evident, which occurs when they migrate south; however, the increased hazing frequency (starting on September 23) was very effective in reducing the number of geese present at different times of the day. Any impact that strobe lights might have had on the geese count is not readily evident from the data.

Figure 9: 2020 Geese Count Results

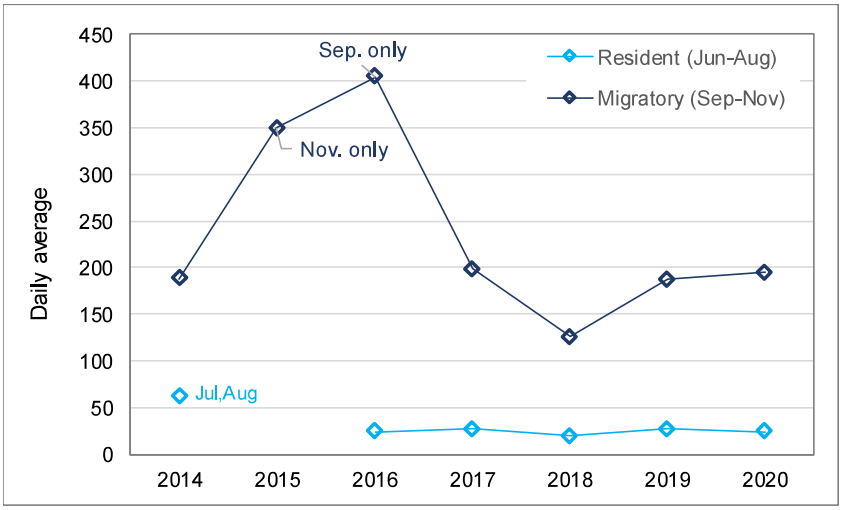


4.4 Historical Trends

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

Daily Averages of counts are shown for each year in Figure 10. Data are summarized for June to August, and September to November, representing resident and migratory geese, respectively. Despite a general increase in geese population in Southern Ontario, the numbers at Swan Lake have been controlled over the past years.

Figure 10: Historical Geese Counts



5. Summary and Conclusions

Through the Swan Lake monitoring program, data were collected from April to November 2020. The collected data provide insight into long-term trends in water quality and will also help determine if and when further treatment of Swan Lake is required.

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

Measured pH had overall averages of 10.4 at the Bridge and 11.0 at the Dock station. These results are very high and will be investigated through lab analysis for pH in 2021.

Transparency at the Dock station was under 0.5 m at the beginning of June and remained so until November. Water clarity of under 1 m represents a hyper-eutrophic condition.

Water samples were analyzed for nutrients (phosphorus and nitrogen compounds). Total phosphorus concentration ranged from 100 µg/L in early spring to about 250 µg/L in summer, with an average of growing-season of about 200 µg/L (in the top 1 m depth). A Phosphorus concentration average above 100 µg/L represent a hyper-eutrophic condition.

Total nitrogen concentrations over the growing season averaged about 2.8 mg/L, which is above the 1.2 mg/L threshold for a hyper-eutrophic condition.

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

Samples were collected throughout the summer and tested for Microcystin toxicity with Abraxis test strips. The results showed all samples contained concentrations below the recreational guideline of 10 ppm.

A level logger was used to record the water level in the Lake. The water level at the logger location changed from 208.25 m (2.52 m depth) in May to 207.97 (2.22 m depth) in November.

In 2020, geese management was completed by chasing terrestrial geese by border collies and egg oiling. In an effort to reduce the number of geese further, a thorough investigation of other geese management methods was completed, and increasing the hazing frequency was completed as the most efficient method in the short term. At the request of a resident group, Friends of Swan Lake, and upon Council approval, nine strobe lights were also purchased and installed on the Lake and the two stormwater management ponds. The increased hazing frequency (starting on September 23) was very effective in reducing the number of geese present at different times of the day. Any impact that strobe lights might have had on the geese count is not readily evident.

Based on the measured Secchi desk transparency and nutrient concentrations, Swan Lake was classified as hyper-eutrophic in 2020. Figure 11 provides a summary of phosphorus concentrations for all the years with available data. Based on these values, the Lake has been hyper-eutrophic since 2016.

Figure 11: Trophic State Classification for Swan Lake based on Phosphorus Concentration