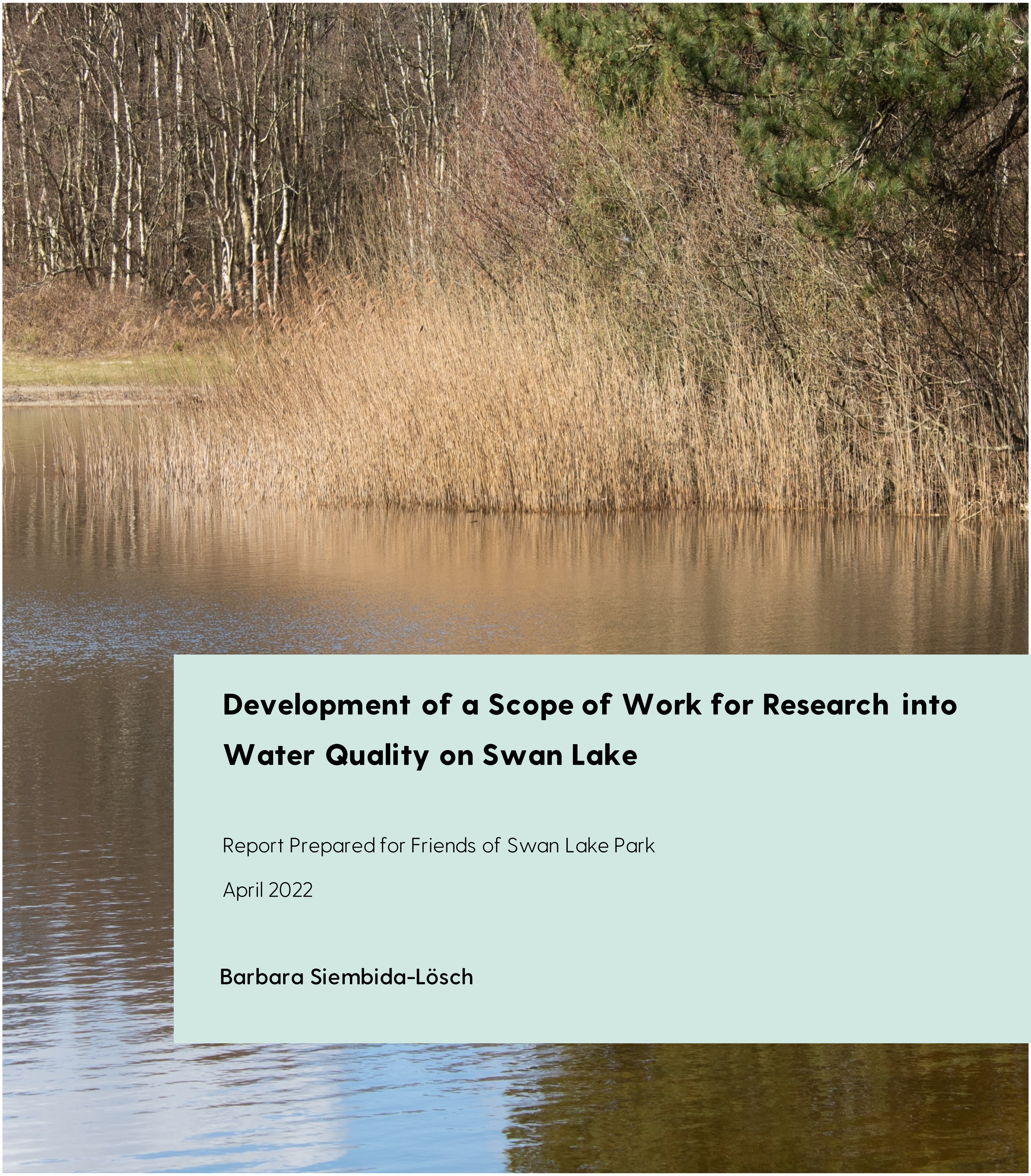

Development of a Scope of Work for Research into Water Quality on Swan Lake

Report Prepared for Friends of Swan Lake Park

April 2022

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centre for advancement of water and wastewater technologies

FLEMING

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1.0 Introduction

1.1 Background

Swan Lake, a man-made lake located in Markham, Ontario, has long suffered the effects of eutrophication, an over enrichment of minerals and nutrients. A surplus of external nutrient inputs has resulted in the continued accumulation of nutrients stored within the lake from year to year. The overall nutrient load, accompanied with warm weather conditions, has allowed for continued oxygen depletion (anoxia) and prolonged cyanobacteria blooms throughout Swan Lake, perpetuating the eutrophication issue even further.

Currently, phosphorus levels in Swan Lake are managed in two ways: using Phoslock®, a patented phosphorus locking technology, and/or using Polyaluminium Chloride (PAC), an inorganic coagulant. While these chemicals address the phosphorus concerns, they do not necessarily address the anoxia issues within Swan Lake. Anoxic conditions remain a concern for the health of Swan Lake and in the long-term care and sustainability of the flora and fauna in the area.

1.2 Purpose

The Friends of Swan Lake Park (FSLP) is a not-for-profit organization located in Markham, Ontario. Working with the City of Markham, the FSLP have spent several years providing input and feedback into important environmental concerns related to the quality and treatment of Swan Lake and its surrounding environment. Of particular interest is addressing oxygen levels within Swan Lake through possible treatment options. The focus of this report is to address this challenge, and to detail a scope of work outlining the use of calcium peroxide as a treatment option to improve oxygen levels within Swan Lake.

2.0 Research on Use of Oxygen Release Compounds

2.1 Calcium/Magnesium Peroxide

The biological mineralization of organic matter in lake sediments consumes large quantities of oxygen. This consumption can lead to more serious issues, including anoxic conditions. A lack of oxygen in the lake environment can result in the release of excess nitrogen and phosphorus from sediment into the overlying water. These excess nutrients, in turn, allow for excessive plant and algae growth, inevitably leading to deterioration of water quality (Lu et al., 2017; Li et al., 2020). Therefore, the improvement of dissolved oxygen (DO) levels is significant in the restoration and sustainability of surface water bodies.

The common approaches to controlling eutrophic water include:

1) physical methods (e.g., environmental water diversion/hydraulic control, artificial aeration, sediment dredging);

2) chemical methods (e.g., flocculation/precipitation, chemical alga-killing, adding Fe/Al salt or Phoslock®); and

3) biological methods (e.g., ecological floating islands, constructed wetlands).

Although these approaches can occasionally alleviate eutrophication, they are often characterized by high costs and low efficiency. In addition, some (e.g. biological methods) are susceptible to environmental factors while others (e.g. aluminium salts) can be toxic to aquatic organisms (Wang et al., 2019).

An alternative technique for the oxygenation of the water column and sediments is chemical oxidation. This technique can be performed using oxygen release compounds (ORCs) such as calcium peroxide (CaO_2) and/or magnesium peroxide (MgO_2). This alternative method avoids the limitation of mechanical aeration in the affected area and inefficient oxygen diffusion (Lu et al., 2017; Xu et al., 2018; Wang et al., 2019, Li et al., 2020). CaO_2 is an oxygen release compound, comprising a high-energy peroxide covalent bond, which can easily liberate oxygen when it is in contact with hydrous media (Song et al., 2020).

Various studies have proven that the addition of CaO_2 to surface water and sediments, slowly releases oxygen in water, leading to an increase in the DO levels, suppression of anaerobic conditions, control of water blooming, and aerobic biodegradation of accumulated organic contaminants in the sediments (Lu et al., 2017).

In a study by Huang et al. (2017) the addition of 20 g CaO_2 to 37.5 L water containing municipal river sediments increased the DO (1 mg/L) of surface water for eight weeks (Huang et al., 2017). Nykänen et al. (2012) observed more prominent effects of increasing the DO levels of sediments for 14 weeks in laboratory tests (75 g CaO_2/m^2 sediment surface) and 40 weeks in field tests (50 g CaO_2/m^2

sediment surface) when using granulated CaO_2. In addition to the increased DO levels of sediments, Nykänen's study also showed accelerated aerobic microbial activity following CaO_2 amendment. The organic matter contents in the pond sediment decreased from 18% to 4% while the control test showed no changes.

Other studies have shown that adding CaO_2 into sediment could restrain phosphorus release from sediment for over 10 weeks, controlling water blooming (Huang et al., 2011). In the aerobic conditions, phosphorus concentrated in the sediment creates insoluble metal-phosphate complexes and can't be released to the water column. Cho and Lee (2002) investigated the effect of CaO_2 on the growth and proliferation of a water-blooming cyanobacterium and observed that the phosphate concentration quickly decreased when CaO_2 was added. Most of the soluble phosphate was removed within 1 hour, and an accumulation of precipitated residue was observed as a result of the reaction with CaO_2. Therefore, it could be concluded that the addition of CaO_2 promotes phosphorus transfer into the sediment from the total water system (Lu et al., 2017).

In practical applications, it is crucial to modify CaO_2, permitting the slow, continuous release of oxygen. Application of CaO_2 in compressed forms such as granules, briquettes, or as composites with other materials for surface water and sediments restoration can meet that requirement. These coarser CaO_2 products sink more easily to the sediment, where oxygen is required. Mixing of water is avoided to prevent the movement of nutrients to the surface and the growth of algae and aquatic plants (Lu et al., 2017).

In addition, using other materials to embed CaO_2 powder to achieve more controllable release rates have been studied. The composite of CaO_2 and stearic acid was found to have a longer oxygen-releasing period, a milder effect on pH, and reduced 79.6% total phosphorus (TP) in 35 days compared to CaO_2 powder during experiments with urban river sediments (Li et al., 2014). Zhou et al. (2019) mixed calcium peroxide material with water purification sludge and cement, suggesting that modified calcium material can release oxygen continuously and slowly, effectively reducing the dissolved inorganic phosphorus concentration of the overlying water and pore water.

The aforementioned research demonstrates that use of CaO_2 may have promising treatment effects on the increase of DO and should be considered for use in Swan Lake. The following scope of work outlines how to introduce and assess its treatment capability.

3.0 Proposed Scope of Work

The following scope is all encompassing, meaning it contains the full suite of recommended parameters and analytes to be tested for maximum results. This scope is a draft and open to feedback and input from stakeholders and researchers working on Swan Lake. In an attempt to keep costs low, two treatment totes have been included, however it may be beneficial to include a third treatment tote to evaluate a range of CaO_2 concentrations and their effect (high vs low).

3.1 Laboratory Scale Testing

Sample collection and characterization

Sediment samples from Swan Lake would be collected with a columnar sampler from the top 40 cm layer. Overlying water would be collected in plastic buckets at the same time, at a depth of approximately 3.5 - 4 m (depending on sampling site). Sampling would occur during summer months (July – August) when anoxia conditions are the most severe within the lake. The collected samples would then be transported to the CAWT laboratory immediately after sampling. To maintain sample integrity all samples would be kept cool during transportation, avoiding light exposure and disturbance.

Temperature, pH, conductivity, dissolved oxygen (DO), and oxidation reduction potential (ORP) in the overlying water would be analyzed immediately following sample collection and while on site. Prior to commencing experiments, sediment and water samples would first need to be characterized. The following parameters are recommended, and would be analyzed in the CAWT's ISO 17025:2017 accredited laboratory:

- <u>Sediment:</u> ammonia, nitrate, nitrite, total Kjeldahl nitrogen (TKN-N), total phosphorus (TP), total solids (TS), volatile solids (VS), total organic carbon (TOC), moisture, total and dissolved iron (Fe), Aluminum (Al), Magnesium (Mg), and Calcium (Ca), dissolved Chloride (Cl), ORP, pH, alkalinity, adenosine triphosphate (ATP), DO
- <u>Overlying water:</u> ammonia, nitrate, nitrite, TKN-N, TP, soluble reactive phosphorus (SRP, also called orthophosphate), total suspended solids (TSS), TOC, total and dissolved iron (Fe), Aluminum (Al), Magnesium (Mg), and Calcium (Ca), dissolved Chloride (Cl), ORP, pH, alkalinity, DO, colour, turbidity, and conductivity

Experimental set-up

Following the collection and characterization of sediment and overlying water samples, experiments would be carried out under the following operating conditions:

- <u>Equipment</u>: 2 totes (1 treatment tote and 1 control)

- Sampling location and timelines: sediment and overlying water samples would be collected from Swan Lake during summer (July-August)
- Sample volume: 1000 L of lake sediment and 1000 L of the sediment overlying water
- Oxidant: granulated CaO_2
- Doses: suggest either 100 g CaO_2/m^2 or 1000 g CaO_2/m^2 (estimated amount of CaO_2 is 1.5 kg)
- Sample analysis of the overlying water: ammonia, nitrate, nitrite, total Kjeldahl nitrogen (TKN-N), total phosphorus (TP), SRP, total suspended solids (TSS), TOC, total and dissolved Fe, Al, Mg, Ca, dissolved Cl, ORP, pH, alkalinity, DO, turbidity, temperature and conductivity
- Sample analysis of the sediment: TKN-N, TP, total solids (TS), volatile solids (VS), total organic carbon (TOC), Fe, Al, Mg, Ca, Cl, ORP, pH, adenosine triphosphate (ATP), DO, temperature

The analytical methods to be used are outlined in Table 1 (over).

Table 1. A summary of the analytical methods used at the CAWT for the analysis of the sediment and overlying water parameters.

Analyte	Test Method	Accredited*	Reference Method	Unit	CAWT Reporting Limit
pH	M531	Yes	SM 4500-H+B	n/a	n/a
conductivity	M531	Yes	SM 2510B,	μs/cm	4
turbidity	M562	Yes	SM 2130B,	NTU	0.2
alkalinity	M531	Yes	SM 2320 B	mg/L	5.0
ORP	M555	No	SM 2850	mV	n/a
DO	M554	No	SM 4500-O H	mg/L	n/a
Ammonia	M546	Yes	In-house	mg/L	0.020
Nitrate	M532	Yes	EPA 353.2	mg/L	0.020
Nitrite	M532	Yes	EPA 353.2	mg/L	0.006
TKN	M533	Yes	EPA 351.2	mg/L	0.29
TP	M534	Yes	SM 4500-P E	mg/L	0.01
SRP	M534	Yes	SM 4500-P-E	mg/L	0.003
TS	M561	No	EPA 180.1	mg/L	3
TVS	M561	No	EPA 180.1	mg/L	3
TSS	M545	Yes	SM 2540D	mg/L	3
ATP	M575	No	LUMINULTRA MICROBIAL; MONITORING (QGA-25/QGA-100)	pg ATP/mL	n/a
TOC	M547	Yes	SM 5310 B	m/L	1.0
Cations/anions	M549	Yes	ASTM D6919-09, SM 4110 B	mg/L	

* *ISO/IEC 17025:2017*

Test plan

The following experiments would be carried out to identify the effect the addition of calcium peroxide will have on DO and phosphorus levels in sediment and overlying water.

<u>Step 1:</u> Two reactors (totes) named A and B would be operated as follows: Reactor A would act as a blank (control) test and would be filled with sediment and water collected from Swan Lake without any oxidizing agent. Reactor B would be filled with the Swan Lake sediment and overlying water and a granular grade of calcium peroxide (CaO_2) spread evenly over the sediment surface (concentration to be determined).

<u>Step 2</u>: All reactors would be sealed and kept in an environmental chamber in the dark at 20°C for 4-6 weeks.

<u>Step 3:</u> Sediment samples would be collected from the reactors twice a week using a sample corer. The overlying water samples would twice a week be collected half way between the sediment and water surface. Samples would be analyzed for parameters outlined in *Experimental set-up*.

Statistical analysis and data interpretation

The experimental data would be statistically analyzed, calculated, and plotted using Excel software. The average value, standard deviation, and variance of the data would be analyzed. The mean would be tested using t-test methods with a significance level of $p < 0.05$.

3.2 Bench-Scale Testing - Bioavailable Phosphorus Assay (Optional)

Phosphorus bioavailability in lake sediment is an important factor to consider with regards to Swan Lake's potentially worsening trophic status. Internal phosphorus release from sediment could become a predominant long-term source of phosphorus to the water once the external phosphorus load is controlled. The total and/or dissolved phosphorus concentration may not be adequate to assess the phosphorus release risk associated with its presence in natural waters. Before an environmentally-sound and long-term phosphorus management strategy for Swan Lake can be developed, it is important to understand what forms of phosphorus occur in sediments, the dynamics of cycling between forms of differing bioavailability (i.e., available for uptake by plants and aquatic biota), and the processes controlling sediment phosphorus removal. Sediment samples collected from various locations along the lake would be subjected to varying anoxic conditions, changes in pH, and perhaps temperature, to identify the factors that influence the release of phosphorus, which is either particulate-bound or dissolved in the overlying water.

Using this information, we can assess how to best manage phosphorus to minimize environmental impacts.

Therefore, it is important to investigate the potential release of bioavailable phosphorus from the lake's sediment. This can be done in a bench-scale study (anaerobic chamber/glove box) by simulating anoxic conditions in the collected sediment samples. The study would determine and assess the environmental factors influencing phosphorus mobilization from sediments (e.g. pH, temperature, redox). Additionally, while analyzing the sediment composition the levels of bioavailable phosphorus fractions that are released from sediments under various environmental conditions could be determined. The CAWT has an algal bioassay in place to determine and monitor the bioavailable fractions of phosphorus in water and sediments. It would be of great value to monitor this parameter over several seasons to evaluate changes.

The CAWT has the capability to perform this testing should there be interest in pursuing this work in future.

4.0 Proposed Timeline and Budget

Anticipated Start Date: June 13, 2022

Anticipated End Date: September 16, 2022

Duration: 14 weeks

Phase	Project Start-up	Sample characterization	Calcium Peroxide Experiments	Decommission & Summary	Total
Duration (weeks)	2	2	6	4	14
Anticipated Start Date	13-Jun-22	27-Jun-22	11-Jul-22	22-Aug-22	13-Jun-22
Anticipated End Date	24-Jun-22	08-Jul-22	19-Aug-22	16-Sep-22	16-Sep-22
Salary & Benefits					
Project Management & Coordination	$ 415	$ 83	$ 332	$ 415	$ 1,245
Research Scientist	$ 663	$ 332	$ 1,326	$ 1,326	$ 3,647
Lab Analysis & Quality Assurance		$ 732	$ 9,407		$ 10,139
Operations & Field	$ 787	$ 525	$ 2,098	$ 263	$ 3,673
Student	$ 255	$ 255	$ 1,020	$ 255	$ 1,785
SUBTOTAL Salaries & Benefits	**$ 2,120**	**$ 1,927**	**$ 14,183**	**$ 2,259**	**$ 20,489**
Non Capital					
Lab Consumables & supplies		$ 237	$ 3,983		$ 4,220
Operational Supplies		$ 15	$ 660		$ 675
Travel & Shipping		$ 1,130	$ 3,323		$ 4,453
SUBTOTAL Non Capital	**$ -**	**$ 1,382**	**$ 7,966**	**$ -**	**$ 9,348**
Overhead, Admin & Contingency					
Overhead (20%)	$ 424	$ 662	$ 4,430	$ 452	$ 5,968
Contingency (5%)	$ 106	$ 166	$ 1,108	$ 113	$ 1,493
SUBTOTAL Non Capital	**$ 530**	**$ 828**	**$ 5,538**	**$ 565**	**$ 7,461**
Total Budget	**$ 2,650**	**$ 4,137**	**$ 27,687**	**$ 2,824**	**$ 37,298**

**Budget is an estimate based on maximum number of parameters analyzed; it can be reduced and optimized at request.*

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About the CAWT

Fleming College's Centre for Advancement of Water and Wastewater Technologies (formerly the Centre for Alternative Wastewater Treatment) is a research centre located at the college's Lindsay, Ontario, Canada campus. When its doors opened in 2004, the CAWT was primarily focused on researching treatment wetland systems and phytoremediation technologies for cold climates.

No longer focusing on just alternative technologies, in the last decade the CAWT has gained an international reputation for engaging in innovative water and wastewater applied research and offering technology development services to the private sector, governments, non-governmental agencies, and to universities.

Designed for customizable operations and project implementation, the CAWT is a unique centre with advanced infrastructure and on-site facilities.

The CAWT is ISO/IEC 17025 certified by the Canadian Association for Laboratory Accreditation (CALA), participates in the CALA Proficiency Testing Program, and has passed the VerifiGlobal Peer Assessment (ISO/IEC 17020:2012 Conformity Assessment in the scope of ISO 14034:2016 Environmental Management – ETV).

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