Experimental Plan for Aeration System Field Testing at Swan Lake

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1.0 - Experimental Goal

Swan lake is a former rock quarry located in the Greensborough community of Markham, ON. While restoration over the past years has led to increased wildlife in and around the lake, hypoxic (low oxygen) water conditions prevent it from sustainably supporting an aquatic ecosystem. The primary goal of this experiment is to determine if the wind-powered aeration system previously developed by the Water and Energy Research Lab is a viable option for addressing the persistent hypoxic conditions within Swan lake and contributing to long-term restoration plan for the site. The specific objectives of the study are to measure the impact of the aeration system on dissolved oxygen levels within the lake, determine the consistency of the system's operation based on local wind conditions, and evaluate the long-term robustness of the system in this setting.

2.0 - Site description

Swan Lake is located in a residential community and is surrounded by a park with partial sheltering from trees along the north shore (Figure 1). Its overall dimensions are 375m by 250m with a depth of up to 4.5m [1]. This is an artificial lake created from a former gravel quarry with no natural inflows or outflows, resulting in stagnant water conditions.

Figure 1: Swan Lake overview

The water quality of the lake is heavily eutrophic with high turbidity and dense algae/aquatic vegetation. Previous water chemistry studies have reported dissolved oxygen (DO) concentrations under 3mg/L [2], making it uninhabitable for fish and most other aquatic species.

3.0 - Introduction to aeration system

The Water and Energy Research Lab at the University of Toronto has previously developed a wind-powered aeration system for passively aerating in-ground reservoirs. The current system consists of a vertical-axis wind turbine coupled to a sub-surface impeller (Figure 2). The impeller, mounted within a draft tube, generates vertical circulation of water throughout the reservoir when driven by the turbine, leading to increased concentration and distribution of dissolved oxygen throughout the water body. The turbine is positioned ~1.5m above the water surface and is mounted on a floating baseboard 2m^2 in area. The base of the draft tube extends approximately 1m below the surface.

The system was primarily designed for supporting aquaculture operations, although it is potentially suitable for other applications involving aeration of outdoor ponds and reservoirs. In the summer of 2022, a prototype of the wind-powered aeration system was tested in a small aquaculture tailing pond where it raised dissolved oxygen levels by 18% compared to a control area and reduced the stratification of dissolved oxygen between the upper and lower pond depths.

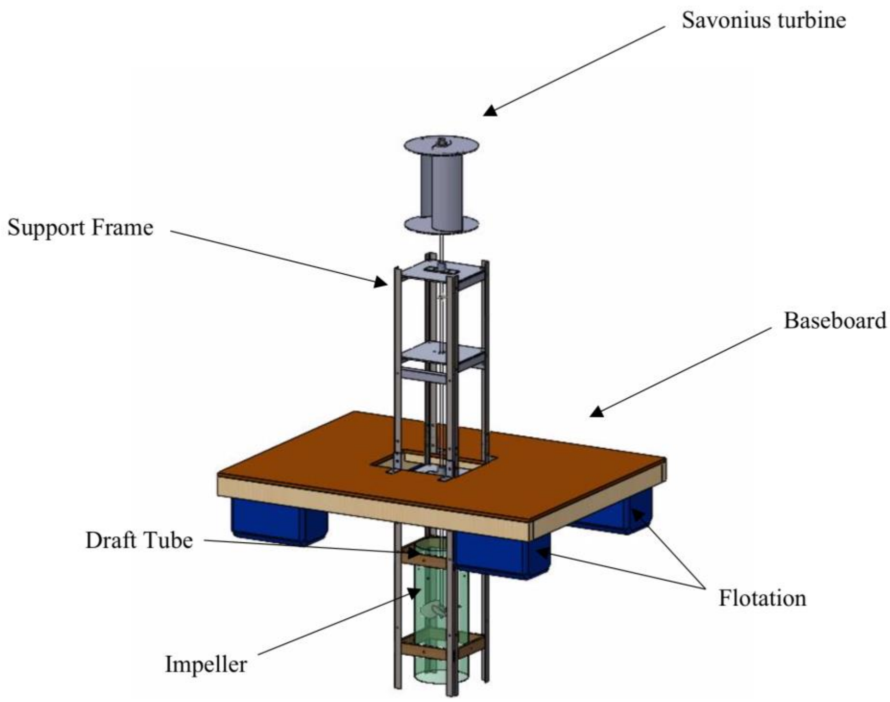

Figure 2: Overview of wind-powered aeration system components

4.0 Proposed Experiment Plan

4.1 Partition of test and control areas

Swan Lake is relatively large and in practice may require a modular installation of the aeration system order to generate the desired impact. To more readily measure the impact of a single device within this setting, it is proposed to partition off a smaller area of the lake for the test. The partition will utilize three dividers walls to section off two 30x30m areas of the north-east corner of the lake. One section will be used as the test area in which the system will be installed, and the other will serve as a control.

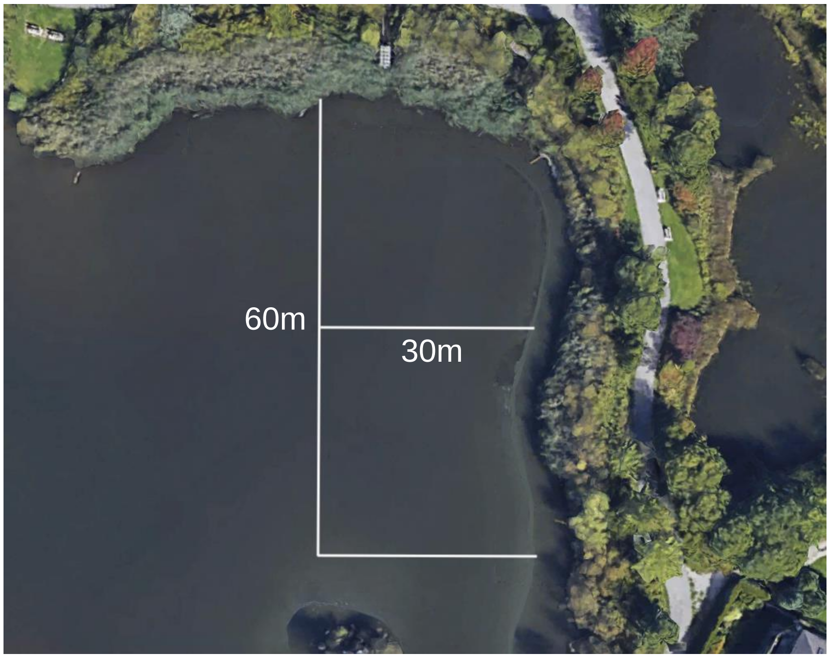

Figure 3: Proposed layout of partitioned test areas

Figure 4: Similar divider configuration from previous field experiment

The divider is constructed from heavy-duty plastic drop sheet to limit transfer of water and oxygen from the test and control areas to the surrounding lake. The divider will be supported at the surface by a float line and secured using ground stakes at the edge of the lake. The lower edge of the liner will be weighted using sandbags to sink into the sediment at the bottom of the reservoir.

4.2 Description of sensors

For monitoring the environmental conditions of the lake, surroundings, and the mechanical performance of the turbine throughout the duration of the experiment, sensors will be assembled and positioned as listed in Table 1.

Table 1: Sensor list for field experiment

Sensors	Metric	Number and position
DO sensor	Dissolved O_2 (mg/L)	3 - At reservoir surface 3 - At reservoir bottom (in each partitioned area)
Water temperature	Temperature (°C)	12 - Built into DO sensors
Anemometer	Wind Speed (m/s)	1 – Within test area (at height of turbine)
Pyranometer	Solar Irradiance (W/m^2)	1 - Adjacent to lake
Ambient Temperature	Temperature (°C)	1 - Adjacent to lake
Hall effect sensor	Shaft Speed (RPM)	1 – Mounted on turbine shaft

The rotational speed of the turbine will be monitored with a magnet mounted on the turbine shaft, which once per rotation will trigger a hall effect sensor. A microcontroller will be used to collect shaft speed data and save it to an SD card. This sensor box will be installed on the floating baseboard of the aeration system and will be powered by a 12V battery regularly charged with a 20W solar panel.

A separate weather station will be positioned at the side of the lake for monitoring ambient temperature, solar irradiance, and wind speed. The anemometer and pyranometer will be mounted on a pole in the lake, while ambient temperature will be monitored from the shore. All environmental sensors will log data to an SD card and will be powered by a solar panel as with the shaft speed sensor. Although not provisioned in this current plan, there may also be plans for periodic water sampling to evaluate the impacts of the circulation on other water quality parameters, such as nitrates, phosphates, and TDS.

4.3 Test Procedure

Following installation of the divider sheets, 6 dissolved oxygen sensors will be installed in the test and control areas as shown in Figure 5. At each point indicated two DO sensors are to be installed: one 20cm below the surface, and another 20cm from the bottom of the lake so that the distribution of oxygen across the water column can be measured. The DO sensors will be left for 3-weeks prior to installation of the aeration system to establish baseline dissolved oxygen concentration values.

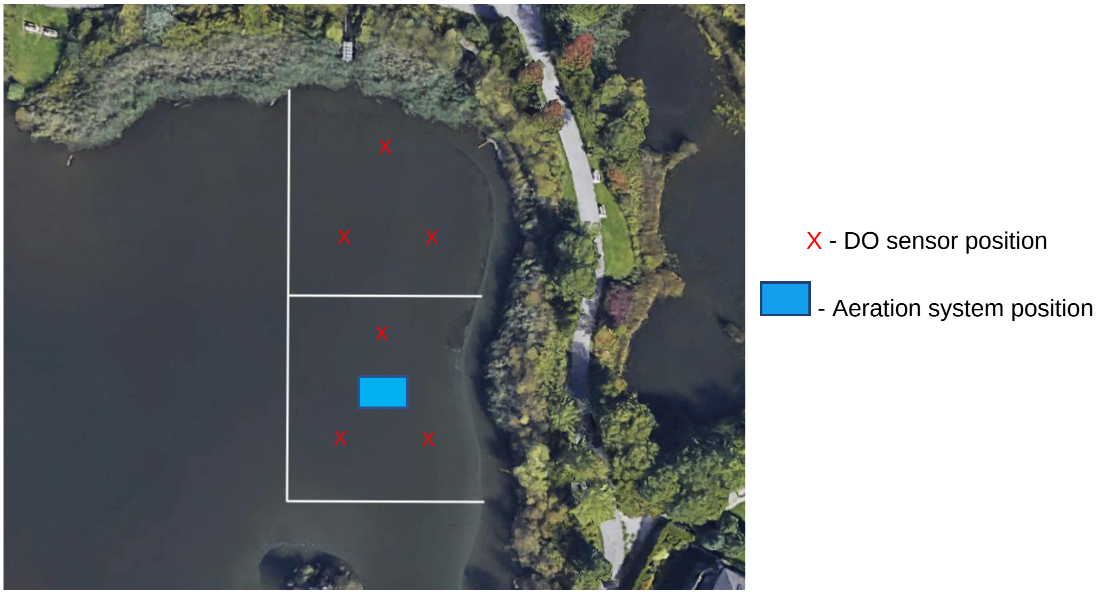

Figure 5: Position of aeration system and DO sensors

After 3-weeks, the aeration system is to be installed and anchored at the indicated location in Figure 5 and will remain in place for 1 month to evaluate its long-term effect on water conditions in the lake. After the 1 month, the aeration system will be changed to the other partitioned area to minimize any bias which may occur due to environmental conditions. At regular intervals over test period, the system will be inspected for any damage or fouling which may have occurred and the data from each sensor box will be collected. The DO sensors are also to be regularly inspected and cleaned to ensure measurement accuracy. The aeration system, dividers, and sensors will be removed from the lake following completion of the experiment.

Works Cited

[1] R. Muir and Z. Parhizgari, "Swan Lake: Long Term Management Plan," Markham, 2021.
[2] Friends of Swan Lake Park, "Pathway to Sustainability," Markham, 2020.