HONEOYE LAKE AERATION SYSTEM ENGINEERING PLANNING – FINAL REPORT

ONTARIO COUNTY, NY

JUNE 2022

PREPARED FOR:

ONTARIO COUNTY PLANNING DEPARTMENT
& HONEOYE LAKE WATERSHED TASK FORCE
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NYS Contract No. T00925GG: Ontario County Honeoye Lake Aeration Destratification System Feasibility Study (modified 3/8/2022)

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ACKNOWLEDGMENTS

Funding for this project was provided from the Environmental Protection Fund as administered by the New York State Department of Environmental Conservation.

Additional funding support was provided by the Honeoye Lake Watershed Task Force and Ontario County Water Resources Council.

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Staff of New York State Department of Environmental Conservation Region 8 and Division of Water provided helpful consultation during this project.

NYS Contract No. T00925GG, Ontario County Honeoye Lake Destratification System Feasibility Study was modified (3/8/2022) to include feasibility analysis and engineering design for a hypolimnetic aeration system based on the consultant team's recommended approach for Honeoye Lake.

EXECUTIVE SUMMARY

The overall objective of the Honeoye Lake Aeration System Engineering Planning Project was to identify and provide planning level details of an aeration system best suited to meet Honeoye Lake's harmful algae blooms (HABs) management needs.

Multiple studies identify the primary driver of the lake's mid-summer algae and cyanobacteria blooms to be the lake's internal phosphorus load, defined as the phosphorus released from lake sediments and recycled into the water column when the lake's deeper waters become anoxic or depleted of dissolved oxygen (DO). Honeoye Lake has been documented to annually experience anoxic conditions shortly following the onset of summer thermal stratification.

As surface water warms, it becomes less dense, leading to measurable differences in water density from the top to the bottom of the water column. When the difference in water temperature and water density becomes pronounced, the water column can no longer freely vertically mix, leading to distinct temperature strata. The maintenance of dissolved oxygen levels in a lake is largely the result of the constant mixing and exposure of the water column to the overlying atmosphere. When a lake becomes thermally stratified, the deeper waters of the lake can no longer freely circulate to the surface. Because bacterial decomposition and respiration occurring within the lake's sediments consume oxygen, the deeper waters of a lake quickly become anoxic and devoid of oxygen, once thermally stratified.

As long as oxygen is present, the phosphorus stored in lake sediments is bound to iron and not available for assimilation by algae and cyanobacteria. However, anoxic conditions alter the sediment's chemical properties, breaking the phosphorus-iron bond. The result is the rapid release of phosphorus stored in the sediments into the overlying water. The amount of phosphorus released from the sediments is a function of the amount of lake bottom overlaid by oxygen depleted water and the amount of time anoxic conditions persist. Under anoxic conditions, deep water total phosphorus (TP) concentrations can quickly increase to 3-5 times that needed to stimulate and sustain a HAB.

For medium depth lakes, such as Honeoye, the intensity to which the water column thermally stratifies is often weak, resulting in the lake alternating between a stratified and non-stratified state. Such lakes are referred to as being thermally polymictic. Studies have repeatedly documented Honeoye Lake to be a polymictic waterbody. The phosphorus rich water that accumulates at the bottom of the lake when the water column is thermally stratified can be up-welled to the surface when the water column destratifies (due to strong north or south winds) and may stimulate a summer HAB.

If oxic (measurable dissolved oxygen) conditions are maintained at the bottom of the lake, phosphorus remains bound to iron, preventing internal loading, thus decreasing the potential for a HAB, even upon lake mixing.

Aeration is a common lake restoration technique used to control internal phosphorus loading by maintaining oxygen in the bottom of the lake. There are essentially two general aeration approaches used to control internal phosphorus loading. One approach uses compressed air to circulate the water column, thus maintaining oxic conditions at the bottom of the lake. Aeration systems that fully mix the water column are referred to as destratification systems, whereas those that only partially mix the water column, thereby maintaining the lake in a somewhat thermally stratified state, are referred to as hypolimnetic aeration systems. In either case, the compressed air plays a small role in the reoxygenation of the water, which is accomplished by exposing deep, DO-poor water to the atmosphere (destratification) or mixing it with surface, DO-rich water (hypolimnetic aeration). The alternative approach is to mix or inject pure oxygen into deep, anoxic waters of the lake. Such reoxygenation systems do not alter the lake's thermal properties, which means the lake remains stratified.

A comprehensive analysis was conducted to identify the best aeration approach for Honeoye Lake. Past studies have recommended a destratification aeration system as suitable for polymictic lakes such as Honeoye. Further analysis of Honeoye Lake data for this project indicates an oxygenation system is the most appropriate, cost-effective, long-term aeration approach for Honeoye Lake. Specifically, the system recommended for Honeoye Lake is a super-saturation, side stream (SSS) oxygenation system. The SSS system draws water from the deepest part of the lake to a pump house on shore, mixes it with oxygen generated on-site using pressure swing adsorption (PSA) oxygen generation equipment, and then returns the oxygen-rich water to the bottom of the lake. Oxygen-rich water diffuses across a thermal density gradient to blanket bottom sediments and control phosphorus release. The primary advantage of the SSS system approach is its ability to consistently maintain target DO concentrations > 4 mg/L at the bottom of the lake without disrupting the lake's natural thermal profile. Additionally, the SSS system uses far less energy (resulting in lower operational costs) with significantly less equipment installed on the lake bottom compared to a destratification system. By avoiding continuous mixing during the treatment period, the SSS system has the added benefit of maintaining habitat conditions (temperature and DO concentrations) suitable for a cool-water fishery.

Details of a custom SSS system are provided in the report including preliminary specifications of the necessary equipment; cost estimates; a siting analysis for the location of the SSS system pump/compressor building; short- and long-term maintenance requirements; minimum field data needed to measure system performance and an optional modeling approach to estimate reductions in phosphorus loading; and a general overview of the permitting process to install the system in Honeoye Lake.

The total estimated cost of the SSS system is $1.2 million in capital and installation costs with an additional $35,000 to $50,000 in annual operating costs. Grant funding through the New York State Department of Environmental Conservation Water Quality Improvement Program has been available in recent years to fund up to $1,000,000 of eligible costs for aeration systems meeting certain prerequisites, such as an approved engineering design. This report concludes with a few questions Honeoye Lake stakeholders may find helpful in deliberating the next steps for pursuing an aeration strategy to control HABs in Honeoye Lake.

SECTION 1: INTRODUCTION

1.1 UNDERSTANDING THE PHOSPHORUS DYNAMICS OF HONEOYE LAKE AND HARMFUL ALGAE BLOOMS

Honeoye Lake, located in Ontario County New York and bordered by the towns of Canadice and Richmond, is the second smallest of the Finger Lakes. The lake has a surface area of 1,805 acres and respective mean and maximum depths of 16 feet (4.9 meters) and 31 feet (9.1 meters). Data collected since the early 2000s document the lake is sometimes subject to intense, mid-summer algae blooms, including cyanobacteria harmful algae blooms (HABs). The occurrence of these blooms has been linked through various studies dating back to the early 2000s to elevated concentrations of bio-available phosphorus. For most of New York's lakes, phosphorus is the limiting nutrient, meaning increases in the amount of bioavailable phosphorus triggers increases in phytoplankton productivity. An increase in phytoplankton productivity becomes problematic by negatively impacting a lake's ecology and recreational uses when it progresses to the level of an algae bloom, especially one dominated by cyanobacteria.

Bioavailable phosphorus originates from both external (the phosphorus entering a lake via stormwater runoff, fertilizers, animal waste, septic systems, and atmospheric deposition) and internal (the phosphorus recycled during the decomposition of organic material and released from the lake's sediment) sources. For Honeoye Lake, a number of studies have documented the major source of phosphorus responsible for the lake's mid-summer algae blooms is that which is internally recycled during periods when the lake is weakly thermally stratified and portions of the lake bottom become overlain by anoxic (dissolved oxygen depleted) water (Princeton Hydro 2007, 2014 and 2020; NYSDEC 2018 and 2019). As such, the Honeoye Lake management and restoration plans contained in these same reports emphasize the importance of decreasing and controlling the lake's internally recycled phosphorus load and identify internal phosphorus load reduction as the primary means to decrease the frequency and intensity of the lake's mid-summer HABs.

The objective of this project is to develop an aeration system design customized for Honeoye Lake based on lake science and engineering principles. Operation of the aeration system shall prevent deep-water anoxia, control/decrease internal phosphorus loading, and decrease the occurrence, intensity and duration of mid- to late-summer cyanobacteria HABs.

1.2 THERMAL STRATIFICATION

Thermal stratification[1] is a normal process that can potentially affect any lake, but especially lakes deeper than six (6) feet. The physical properties of water are such that water reaches its greatest density at 4°C. As water warms above 4°C, its density progressively decreases. During the summer, due to the sun's heating of a lake's surface, the shallower waters (referred to as the epilimnion) become warmer and less dense than the deeper waters (referred to as the hypolimnion). As little as a 1°C temperature difference measured over as little as 1 meter can result in a density difference great enough to inhibit the vertical mixing of the water column. When this occurs, the lake is considered to be thermally stratified. Referred to as the thermocline, the depth at which the greatest relative difference in density is measured is the depth at which vertical mixing is most strongly inhibited. The intermediate depth zone of the lake within which the thermocline becomes established is referred to as the metalimnion.

Once the thermocline is established and the vertical mixing of the water column is inhibited, the deeper hypolimnetic waters of the lake become isolated from the shallower, epilimnetic surface waters. Under such

[1] Readers not familiar with some of the limnological terms used in this report should refer to the Glossary of Key Terms provided at the end of the report.

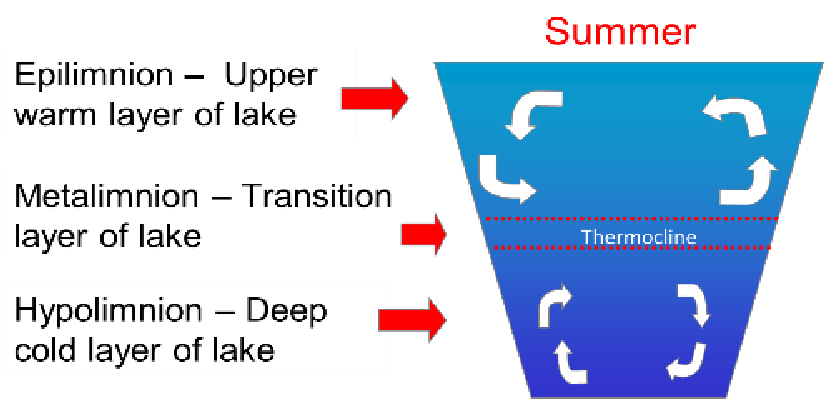
conditions the lake can no longer freely mix from bottom to surface and the lake is characterized as being thermally stratified.

The depth at which the thermocline develops is dictated by several factors including:

- Time of year and light intensity
- Water color and clarity
- Lake depth
- Wind and wave action
- Flushing rate (hydraulic retention)
- Lake fetch (the uninterrupted distance that wind blows across a lake's surface)
- Magnitude and strength of the lake's seiche (an internal wave most commonly produced along the thermocline by the wind)
- Other factors that affect light penetration and water column stability.

Figure 1 is a schematic of a thermally stratified lake, showing the warm epilimnion, the transitional metalimnion and the colder hypolimnion. The illustration shows the thermocline impeding the vertical mixing of the denser hypolimnetic water and warmer epilimnetic water.

Figure 1 – Thermal Stratification



1.3 EFFECTS OF THERMAL STRATIFICATION ON DISSOLVED OXYGEN

The solubility of gases in water, including dissolved oxygen (DO), decreases as water temperature increases and water density decreases. The maintenance of dissolved oxygen levels in lake water is largely a function of the continued, repeated exposure of water to the atmosphere. Although some re-oxygenation may occur as a result of the photosynthetic activity of benthic algae, phytoplankton, and aquatic plants, turbulence and mixing associated with stream discharge, or the turbulence created by wind, wave and physical disturbance of the water's surface, the majority of re-oxygenation occurs due to the exposure of lake water to the atmosphere and the basic dissolution of atmospheric oxygen into the exposed water. Once a lake becomes thermally stratified, the waters below the thermocline are no longer able to freely mix to the surface (Figure 1), and over time the thermally segregated deep hypolimnetic water becomes depleted of oxygen (anoxic). Some hypolimnetic oxygen consumption is due to community respiration (dissolved oxygen used by fish and other aerobic organisms). However, the majority of hypolimnetic oxygen consumption is the result of the bacterial decomposition of the organic material that settles and accumulates at the bottom of the lake, referred to as sediment oxygen demand (SOD). The rate at which deep water, hypolimnetic dissolved oxygen is depleted during a thermally stratified state is variable from lake to lake, being affected by a number of factors including:

- The volume of the hypolimnion
- The amount and concentration of DO in the hypolimnion at the time of stratification
- The organic composition of the sediments which influences decomposition and SOD
- Water temperature
- Other biotic and abiotic factors

As noted above, when density differences between the epilimnion and the hypolimnion are great enough the lake will become thermally stratified. Once thermally stratified, vertical mixing of the water column is prevented, and the deep hypolimnetic water is now inhibited from exposure to the atmosphere. The amount of dissolved oxygen in the hypolimnion is steadily depleted due to the bacterial decomposition of the lake's organic sediments. If stratification persists for a long enough period, all of the dissolved oxygen in the hypolimnion becomes exhausted, resulting in the lake's hypolimnion becoming devoid of oxygen (anoxic). For large, deep lakes, mid-summer thermal stratification can result in a large percentage of the lake's total volume becoming anoxic. This not only results in a substantial portion of the lake being unable to support the organisms dependent on oxygen (fish, zooplankton, etc.), but it also alters the chemistry of the lake's sediments resulting in the liberation of large amounts of phosphorus from the sediments. Under such conditions, the lake's hypolimnion quickly attains high concentration of phosphorus, including forms of phosphorus immediately bioavailable for phytoplankton assimilation.

1.4 EFFECTS OF THERMAL STRATIFICATION ON INTERNAL PHOSPHORUS RECYCLING

Under oxic conditions (presence of oxygen) most of the phosphorus present in lake sediments is covalently bound to ferric iron (Fe^{3+}), forming ferric phosphate and ferric hydroxyl phosphate complexes. These complexes effectively "lock" a substantial portion of potentially biologically available phosphorus in the sediment. However, the ferric hydroxyl phosphate complexes are redox sensitive, and the covalent bond is relatively weak. When water overlying the sediments becomes anoxic the ferric iron gains an electron, becoming soluble ferrous iron (Fe^{2+}). When this occurs, the complexed phosphate is released from the sediment into the water column. The released dissolved inorganic phosphorus then becomes potentially available for algal assimilation under any of the following circumstances:

- The anoxic boundary extends into the photic zone of the epilimnion where phytoplankton (including cyanobacteria) are actively photosynthesizing,
- The lake destratifies or mixes to some extent resulting in the transport / upwelling of the phosphorus rich water into the photic zone of the epilimnion, and/or
- Certain species of cyanobacteria may sink down into the unlit but phosphorus rich waters of the lake, assimilate the available phosphorus, and then, because they possess gas vacuoles, buoy back into the photic zone of the epilimnion to photosynthesize and biologically utilize the assimilated phosphorus.

1.5 HONEOYE LAKE PHOSPHORUS LOAD AND PHOSPHORUS SOURCES

In 2014, Honeoye Lake's relative sources of phosphorus were modeled, and the estimated contributions are presented in Table 1 (Princeton Hydro 2014).

Table 1 – Honeoye Lake Annual Phosphorus Load	
External Load Source	**kg P / year**
Stormwater Runoff and Tributary Loading	2,566.7
Septic Loading	168.2
Geese	324.0
Direct Precipitation and Fallout on Lake Surface	20.0
Total External Load	**3,078.9**
Internal Load Source	**kg P / year**
Anoxic Sediment Loading	2,161.3
Oxic Sediment Loading	340.0
Plant Decomposition Load	111.0
Zebra Mussel Decomposition Load	116.0
Total Internal Load	**2,728.3**
Total Annual Load	**5,807.2 kg P / year**

The 2014 modeling of the lake's internal total phosphorus load computed the contribution from anoxic sediments to be 2,161.3 kg/year[2], approximately 37% of the lake's annual total phosphorus load. More recent modeling studies computed a much higher internal phosphorus load for Honeoye Lake. Specifically, Princeton Hydro (2020) and NYSDEC (2018 and 2019) arrived at internal phosphorus loads of greater than 7,000 kg/yr., approximately 90% of the lake's total annual phosphorus loads. These higher calculations of internal load were based on an average anoxic period of 150 days as compared to the 45-day period used in Princeton Hydro's 2007 and 2014 modeling analyses. The longer the duration of thermal stratification and anoxia, the greater the amount of internal phosphorus loading. Regardless of the duration of thermal stratification and/or anoxia, the important matter is that mid-summer internal phosphorus loading has been repeatedly documented as a driver of the lake's mid-summer harmful algal blooms. As such, management of this internal load is critical to the improvement and protection of the lake's water quality. In addition, several Best Management Practices have been implemented over time to control external sources of phosphorus from the watershed. While watershed stabilization to control external loading will be an ongoing effort, the major source of phosphorus not yet mitigated is the internal load from deep sediments following periods of anoxia.

Although the phosphorus originating from decaying plants and zebra mussels can also be assimilated by phytoplankton and cyanobacteria, most becomes available at the end of the growing season, thus phosphorus contributed by decaying plants, zebra mussels and other autochthonous sources (decaying fish, algae, aquatic plants, zebra mussels and other organisms) is not a driver of mid-summer blooms.

In comparison to stormwater and other external sources of phosphorus which can occur throughout the year, the majority of the lake's anoxic sediment load is concentrated during mid to late summer, at the peak of the cyanobacteria growing season. Additionally, much of the phosphorus resulting from stormwater loading is in a particulate form, which is not immediately available for uptake by algae and cyanobacteria. Conversely, most of the regenerated phosphorus released from bottom sediments is in a bioavailable form, and easily utilized by cyanobacteria. Granted, the external phosphorus load originating from stormwater runoff and tributary inflow is significant and over time should be reduced. Many watershed erosion and sediment control projects have been implemented in recent years, including the extensive Honeoye Lake Inlet Restoration Project, as noted on the Honeoye Lake Watershed Task Force (HLWTF) website at www.honeoyelakewatershed.org/projects. External phosphorus sources are watershed-based and disparate, making them more difficult to manage than the lake's internal load. As discussed in Princeton Hydro's 2014 report, a significant decrease in the lake's stormwater and

[2] As will be discussed in Section 4, the 2007 and 2014 computed internal P load is based on 45 days of hypolimnetic anoxia. A larger internal P load is to be expected should the lake remain stratified and anoxia persists for a longer period of time (Princeton Hydro 2020, NYSDEC 2018 and NYSDEC 2019).

stream based external load will require installation of multiple stormwater best management practices (BMPs) and extensive stabilization of eroded stream banks. Additionally, due to seasonal rainfall and runoff patterns, most of the stormwater and tributary external loading occurs in the spring at the onset of the growing season, making these sources of phosphorus less likely to stimulate a mid-summer HAB. For controlling HABs, emphasis has been placed by the NYSDEC and HLWTF on the reduction and long-term management of the lake's internal total phosphorus load from anoxic sediments.

1.6 HONEOYE LAKE INTERNAL PHOSPHORUS LOADING DYNAMICS

Northeastern lake surfaces naturally warm up from the sun's intensifying energy from spring into the summer. For some lakes, this leads to thermal layering based on related density differences, which causes the lake to become thermally stratified. As previously established by Princeton Hydro (2007 and 2020), NYSDEC (2019) and the HLWTF's 15+ years database, Honeoye Lake is subject to thermal stratification and hypolimnetic anoxia during the summer. This invariably leads to the internal recycling of sediment-bound phosphorus into the water column. While Honeoye Lake remains stratified, the phosphorus rich water present at the bottom of the lake generally remains in the hypolimnion, unavailable for uptake and assimilation in the epilimnion by phytoplankton and cyanobacteria. However, when the lake thermally destratifies, the phosphorus rich hypolimnetic water is quickly circulated into the epilimnion. The rapid influx of the additional phosphorus, most of which is bioavailable, has been shown to trigger a major algae bloom or HAB. Even if the lake remains well stratified, some of the phosphorus rich water may be upwelled into the metalimnion and/or epilimnion due to turbulence at the thermocline. This "pulsing" of hypolimnetic water into the metalimnion and/or epilimnion is referred to as metalimnetic erosion and can stimulate algae and cyanobacteria bloom formation even without the complete destratification of the lake. In Honeoye Lake, this occurs because of the lake's significant seiche (deep internal wave) and fetch (allowing disturbance from predominant south-north wind and waves moving across the surface along the long axis of the lake).

Honeoye Lake is characterized as a polymictic waterbody, a term used to define weakly thermally stratified waterbodies. Polymictic lakes stratify and destratify multiple times over the course of the spring and summer. This increases the potential for the lake's internal phosphorus load to be a significant responsible driver of algae blooms, including HABs, as the internally regenerated phosphorus load becomes intermittently available throughout summer. This has been documented through both field sampling and water quality, trophic state modeling. In fact, numerous studies have shown abrupt availability of the lake's internal phosphorus load due to a weather related mixing event is the major source of the phosphorus responsible for stimulating large summer HABs that impair the lake's water quality and recreational use. These studies (Princeton Hydro 2007, NYSDEC 2018 and NYSDEC 2019) have uniformly concluded the management and reduction of the lake's internal phosphorus load is the most important means by which to prevent HABs, protect the lake's water quality, and enhance its overall ecology.

To summarize, during periods of thermal stratification, hypolimnetic dissolved oxygen concentrations decrease due to community respiration and the sediment-related oxygen demands (SOD). Anoxia results when the combined dissolved oxygen demands attributable to community respiration and SOD exceeds the amount of dissolved oxygen present in the hypolimnion. Even though Honeoye Lake only weakly stratifies and even though it is polymictic, the lake's hypolimnion can quickly become anoxic. During periods of anoxia the lake's sediment chemistry is altered and a large amount of sediment-bound phosphorus is quickly released into the hypolimnion. Most of this internally regenerated phosphorus is in a form easily assimilated by phytoplankton and cyanobacteria. Either as a result of full water column destratification or metalimnetic erosion, the phosphorus present in Honeoye Lake's hypolimnetic water is mixed into the metalimnion and epilimnion. This influx of bioavailable phosphorus into the metalimnion and epilimnion has been documented as a primary driver of the lake's mid-summer harmful algae blooms.

1.7 AERATION: A RECOMMENDED STRATEGY

The water quality data collected over approximately the past fifteen years by the HLWTF, NYSDEC, Finger Lakes Community College, and Cornell University document during the summer months Honeoye Lake is subject to periods of thermal stratification, followed shortly by deep water anoxia and internal phosphorus recycling. Controlling and reducing a lake's internal phosphorus load can often be accomplished through the installation and operation of a properly designed aeration system. The use of aeration has thus been a major recommendation contained in Honeoye Lake's various restoration plans, including the Honeoye Lake Harmful Algal Bloom (HAB) Action Plan (NYSDEC 2018), the Honeoye TMDL Report (NYSDEC 2019), and the Feasibility Assessment of Harmful Algal Bloom Management Options for Honeoye Lake and Conesus Lake, New York (Princeton Hydro 2020).

SECTION 2: PROPOSED HONEOYE LAKE AERATION SYSTEM

The following section discusses various aeration systems and recommends a strategy and system design suitable for Honeoye Lake.

2.1 WHY AERATE HONEOYE LAKE?

Due to the thermal properties of water, lakes attaining a maximum depth of greater than 6 to 8 feet can be subject to seasonal thermal stratification. During periods of thermal stratification, the vertical mixing of the water column is impeded. This leads to the depletion of dissolved oxygen (anoxia) in the deeper waters (hypolimnion) of the lake. Once the hypolimnion becomes anoxic, the lake's sediment chemistry is quickly altered triggering the rapid release of sediment bound phosphorus into the water column.

It has been established over the past 20 years through the field data compiled by the HLWTF, Finger Lake Community College, and Cornell University, as well as the modeled data contained in numerous studies, that Honeoye Lake at times experiences thermal stratification. Although the ensuing thermal stratification is weak and inconsistent (polymictic), the duration of thermal stratification can be long enough to result in deep water (hypolimnetic) anoxia and internal phosphorus loading. The lake's internal phosphorus load has been identified as a major cause of Honeoye Lake's mid-summer algae blooms and HABs (Princeton Hydro 2007, 2014, 2020; NYSDEC 2018 and 2019). Each of these reports conclude that controlling and reducing the lake's internal phosphorus load is the most important means by which to reduce the occurrence of mid-summer harmful algae blooms (HABs). Each of these studies also recommends aeration as a principal means of controlling and reducing the lake's internal phosphorus load. Nationwide, aeration is the one of the most implemented and widely employed lake restoration strategies to address deep water anoxia and control the internal phosphorus loading caused by thermal stratification (Alhamarna and Tandyrak 2021).

There are two primary aeration strategies for internal phosphorus control: 1) prevent the development of thermal stratification and keep the water column vertically mixed and well oxygenated and 2) allow the water column to thermally stratify but maintain adequate dissolved oxygen concentrations in the hypolimnion. There are four main types of aeration systems, each of which are discussed in more detail in Section 2.2 of this report:

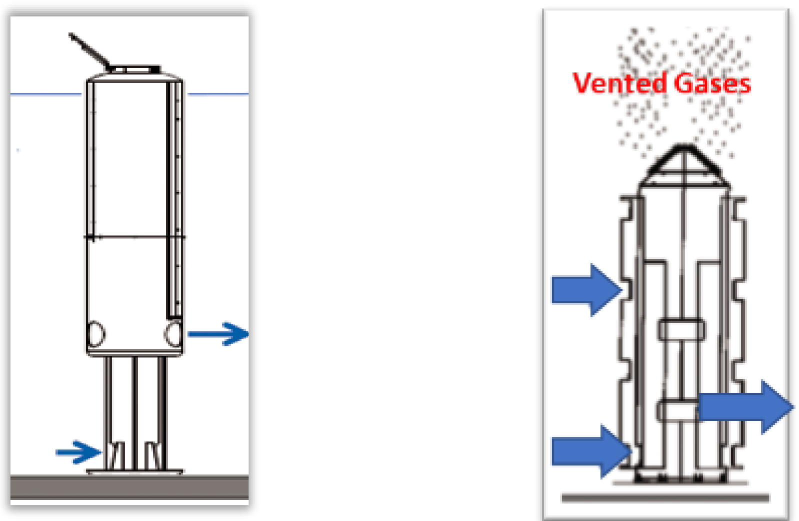
- Partial Air-Lift (Hypolimnetic and LayerAir™ systems),
- Mechanical Axial Pumping,
- Direct Gas Sparging (Full Air-Lift/Destratification and Oxygen Injection), and
- Super Saturation Oxygenation

In the northeast United States and New York state, the majority of aeration systems used to manage lake water quality are either some type of Direct Gas Sparging (Full Air-Lift/Destratification) system or Partial Air-Lift (Hypolimnetic) system. Both full air-lift/destratification and partial air-lift/hypolimnetic aeration systems use compressed air to mix the water column. However, the compressed air is not the primary source of oxygen by which the oxygen depleted (anoxic) water is reoxygenated. Rather, the reoxygenation and subsequent maintenance of dissolved oxygen concentrations within the hypolimnion (Partial Air-Lift) or throughout the entire water column (Full Air-Lift/Destratification) is accomplished by using the compressed air in basically one of two ways:

- Aid the mixing of oxygen depleted water with oxygen saturated (or near saturated water), or
- Continuously circulate the water column thereby re-exposing lake water to the atmosphere so oxygen can diffuse into the water.

When thermal stratification needs to be maintained (typically for deep lakes with a cold-water fishery), Partial Air-Lift Hypolimnetic or Layer-Aeration™ systems are utilized. With hypolimnetic systems, the deep oxygen depleted hypolimnetic water is drawn into the unit from the bottom of the lake and forced to the lake surface within an internal cylinder, where it passively mixes with oxygen rich epilimnetic water. The reoxygenated water is then returned via a second cylinder back to the hypolimnion and released at or near the bottom of the lake (Figure 2). Layer-Aeration™ works in a similar manner, but rather than only mix hypolimnetic water with epilimnetic water, hypolimnetic water may be mixed with oxygen rich water drawn from an intermediate depth and the reoxygenated water returned close to the lake bottom (Figure 2).

Figure 2 - Schematic Illustrations of Partial-Lift Hypolimnetic Aeration and Layer-Air Aeration™ Systems[3]



Hypolimnetic Aerator

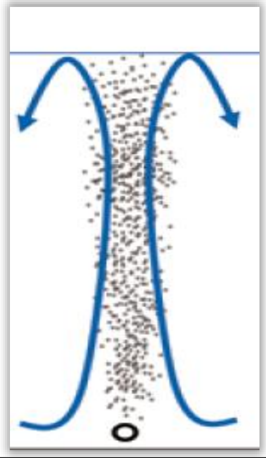
Layer-Air Aerator

With either hypolimnetic or Layer-Aeration™ it may be necessary to release accumulated hypolimnetic gases (e.g., hydrogen sulfide) either at the surface or into the water column (Figure 2). While the amount of water column mixing using either conventional hypolimnetic aeration or Layer-Aeration™ is enough to increase hypolimnetic oxygen concentrations, it not enough to significantly warm the circulated deep cold water or cause the lake to thermally destratify. For the most part, hypolimnetic and Layer-Aeration™ systems are used to manage large, deep, dimictic lakes[4].

Destratification aeration systems are most commonly used to manage shallow lakes lacking a cold-water fishery. For such lakes the maintenance of thermal stratification is not a management goal. Destratification aerators keep the water column fully mixed by using a number of compressed air diffusers strategically placed along the lake bottom. As illustrated in Figure 3, the diffusers generate a fine bubble plume that creates a convection current capable of keeping the water column in a fully vertically mixed, thermally uniform state. By constantly vertically circulating the entire water column, lake water is continuously exposed to the atmosphere. A properly designed destratification system can effectively prevent thermal stratification, maintain near isothermal (uniform temperature) conditions throughout the water column, and prevent deep-water anoxia. Destratification systems (Figure 3) are especially well suited to manage the thermal and dissolved oxygen properties of polymictic lakes[5].

[3] Figures 2 and 3 from Moore, et al., 2012
[4] Lakes that stratify and destratify to a fully mixed state twice per year, generally in the spring after ice out and once again in fall, with the fall mixing event the more ecologically significant of the two.
[5] Lakes that become only weakly thermally stratified, experiencing multiple episodes of stratification and destratification from the spring into the fall.

Figure 3 -Schematic Illustration of a Destratification System



Destratification Aerator

Given that Honeoye Lake is a polymictic waterbody, a destratification aeration system would be considered the most appropriate approach to preventing deep water anoxia and controlling the lake's internal phosphorus load. As such, destratification aeration has been recommended in numerous studies as an appropriate aeration approach for Honeoye Lake (Princeton Hydro 2007, 2014, and 2020). While effective, the amount of water column re-oxygenation accomplished using destratification is highly dependent upon the amount and efficacy of surface re-aeration, with that being a function of water temperature and the rate at which the water column is vertically mixed. The amount, efficacy and frequency of water column mixing is affected by the size of compressed air bubbles, the rise velocity of the water entrained within the compressed air bubble plume, the amount of oxygen transfer that occurs within the bubble plume, total mixing volume and temperature/gas dissolution properties (Cook et al., 2005). For larger, intermediate depth lakes such as Honeoye Lake, an effective system requires the use of large air compressors and numerous fine-bubble diffusers distributed throughout the deeper reaches of the lake. Although the use of a destratification system is appropriate, there may be a better, more efficient, and effective aeration option for Honeoye Lake.

2.2 AERATION OPTIONS CONSIDERED FOR HONEYOE LAKE

Within this section of the report each aeration option evaluated for implementation at Honeoye Lake is presented and discussed.

Partial Air-lift systems – These systems use high pressure, compressed air and a "tube within a tube" column to move deep water to the surface, mix oxygen poor water with oxygen rich water and then return the reoxygenated water to the bottom of the lake (Figure 2). The lake's thermal stratification is preserved with these systems. As previously noted, while some reoxygenation results from the introduction of the compressed air, overall, this is responsible for only a minor amount of the water's reoxygenation. The majority of reoxygenation results from mixing oxygen poor water with oxygen rich water and basic dissolution processes, whereby oxygen is transferred from the oxygen rich to the oxygen poor water.

The oxygen transfer efficiency of Partial Air-Lift systems typically ranges between 20 and 25 percent. As a result, to effectively keep the hypolimnion of large lakes sufficiently mixed and constantly reoxygenated, these systems require the operation of one or more air compressors generating 20 horsepower (HP) or greater. To be effective, operation of these systems must begin before the lake starts to thermally stratify and be continued until the lake would naturally destratify. Therefore, in most cases, Partial Air-Lift systems must be operated from late-April/early-May through late-September/early-October.

Because the aeration goal of hypolimnetic aeration is often to simply prevent anoxia, these systems may increase and maintain deep water dissolved oxygen concentrations to only 1-2 mg/L. While this is enough to prevent the release of phosphorus and heavy metals from hypolimnetic sediments, it is not enough to support a fishery or provide enough dissolved oxygen for other aerobic organisms. To do so often requires the use of even larger compressors and the installation of multiple Partial Air-Lift units. Figure 4[6] contains pictures of a Hypolimnetic and Layer Air™ Partial Air-Lift aeration systems.

Figure 4 - Examples of Partial Air-Lift Aeration Systems

Hypolimnetic Aerator

Layer-Air Aerator

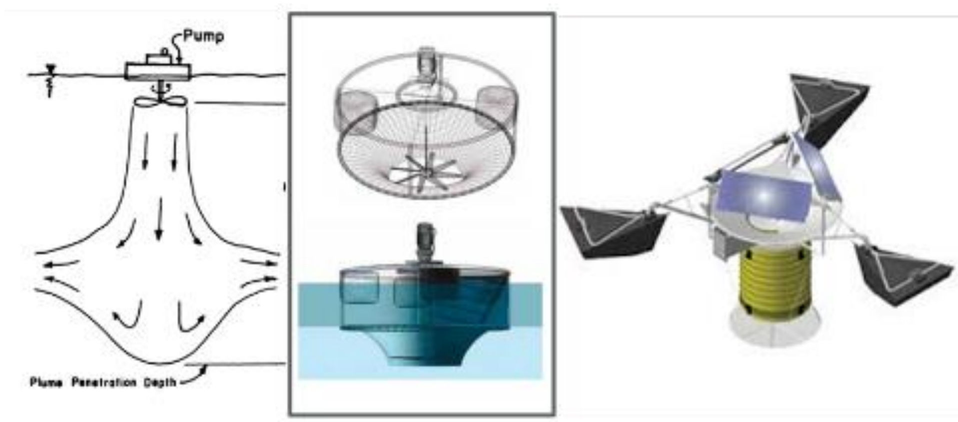
Mechanical axial systems – These systems use high-flow pumps to move deep water to the surface of the lake using a tube-like structure. Circulation of the hypolimnion is accomplished using compressed air in a manner similar to that achieved by hypolimnetic aerators. Once again, the re-oxygenation of hypolimnetic oxygen poor water is accomplished by exposing the water to the atmosphere or mixing it with oxygen rich water. There are two general categories of mechanical axial pump systems: "top-down" or "bottom-up," referring to the direction water is moved through the tube. Figure 5 provides examples of mechanical axial pump systems (ResMix™ developed by WEARS, Australia, and SolarBee™ developed by Medora Corporation Dickinson, ND).

Mechanical axial pump mixers require a large floating platform securely anchored on the lake bottom. The upwell tube is secured to the floating platform. The platform also supports the electric motor, gearbox, driveshaft, and impeller used to pump water from the bottom to the surface of the lake. Power is delivered to the pumps via water-proof cables extending to each unit from a land-based power supply. The Solar Bee units are solar powered. For these units, the floating platform supports the large solar panels used to power the circulating pumps. To repeatedly pump and circulate enough water to effectively maintain adequate dissolved oxygen levels in the hypolimnion, large lakes will require the installation of several mechanical axial pump mixers. This is due to the fluid dynamics of pumping and circulating large volumes of water, which requires more energy than moving water using compressed air.

[6] Photos sources General Environmental Services (Hypolimnetic photo) and Ecosystem Consulting Services (LayerAir photo)

The ResMix™ units have a minimum working depth of approximately ten (10) feet. They operate by moving water in a downward direction. The SolarBee™ units create a bottom-up circulation pattern. They rely on a large impeller, approximately three feet in diameter that rotates slowly (< 100 rpm). Water is drawn up from an expandable shroud that is lowered to the targeted aeration depth. The pumped water is released and distributed over a circular deflector plate at the surface to promote a 360-degree outward flow pattern.

Figure 5 - Examples of Axial Pump Systems: Down Flow Mixers ResMix™ 1000 and Bottom Up SolarBee™.



ResMix™ 1000 | SolarBee™

Direct gas sparging (diffuser) systems use a weighted air supply line to carry either compressed air or pure oxygen to an engineered structure, located on or near the bottom of the lake. The compressed air or pure oxygen is released as very fine bubbles directly into the overlying water column.

Compressed air, gas sparging systems are generally used to destratify and fully mix the water column. They are commonly referred to as Full Air-Lift or Destratification systems. When used in large lakes, these systems require one or more large air compressors (>20 HP) to create the amount of water mixing needed to fully mix the water column. The compressed air is typically released via several diffusers placed along the bottom of the lake, with each diffuser fed by an individual air line. When properly designed, Full Air-Lift or Destratification systems are very effective at disrupting a lake's thermal structure, thus preventing thermal stratification and maintaining near isothermal conditions throughout the water column. However, because of bubble size, bubble rise velocity, and minimal oxygen transfer within the fine bubble plume, re-oxygenation of the water column is heavily dependent upon surface re-aeration (Cook et al., 2005). Nonetheless, destratification systems can successfully prevent deep water anoxia and in doing so, control and decrease internal phosphorus loading. As a result of their effectiveness, these systems have been successfully utilized in lakes of various sizes and depths and used to manage internal phosphorus loading for both dimictic and polymictic waterbodies. However, these systems are not always effective at significantly elevating and maintaining high (>4 mg/L) dissolved oxygen concentrations at the sediment-water interface. While gas sparging destratification systems prevent the bottom waters from becoming anoxic, the resulting DO concentrations as measured at the sediment-water interface may remain low at 1 and 2 mg/L. While this is satisfactory with respect to controlling internal phosphorus loading, it does not greatly benefit the use of deep-water habitat by fish nor is it especially effective in addressing legacy SOD.

Similar to the Partial Air-Lift hypolimnetic systems, operation of a destratification system needs to begin prior to the onset of thermal stratification and be continued until the lake would naturally become isothermal in the fall, in order to be effective. The system should be operated from late-April/early-May through mid-September/early-October. If the system is turned on after the onset of stratification and the development of deep-water anoxia or hypoxia, a significant amount of phosphorus could be upwelled into the epilimnion by the aeration system. This upwelled phosphorus could stimulate an algae bloom or HAB.

As compared to compressed air gas sparging systems, pure oxygen systems operate under much lower pressures and by design do not disrupt a lake's thermal profile. As such, with pure oxygen sparging systems, referred to as Oxygen Injection (OI), it is possible to increase and sustain elevated oxygen levels in the bottom waters while preserving thermal stratification. Such systems are thus suited for use in lakes supporting a cold-water fishery and lakes where thermal stratification must be preserved.

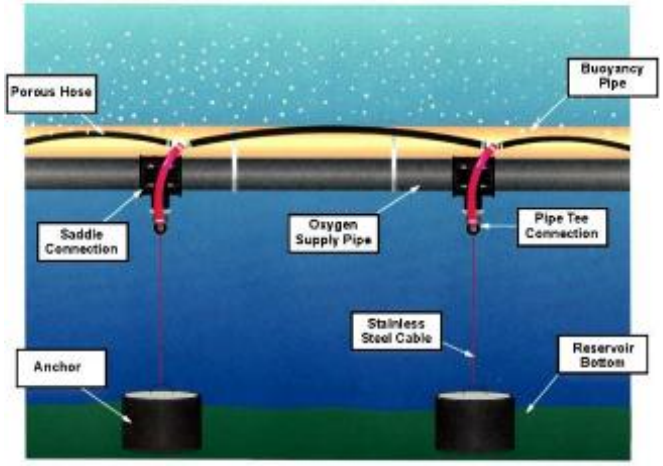
In terms of reoxygenation potential, pure oxygen sparging systems are highly efficient with almost all the bubbles becoming completely dissolved before reaching the surface. Therefore, these systems are not only an effective means of controlling internal phosphorus loading but are also an effective means of retaining a well-oxygenated hypolimnion capable of supporting both a cold-water and warm-water fishery throughout the summer.

Even for large lakes and lakes with a large hypolimnion, the relative compressor power requirements of OI systems are overall much lower as compared to Destratification systems. Ideally, to maximize efficiency, OI systems can be operated from late-April/early-May through mid-September/early-October. However, because these systems are not designed to disrupt thermal stratification, start-up of OI systems technically could be delayed until a lake is thermally stratified and only after the hypolimnion has become hypoxic or anoxic. Because the lake remains stratified, even if some phosphorus loading had occurred, the high concentration phosphorus water would not be circulated to the surface of the lake upon system start-up.

Figure 6 - Example of Direct Gas Sparging Point Diffuser Typically Used in a Destratification Application[7]

[7] Illustration courtesy of Vertex Air Solutions

Figure 7 - Example of Direct Gas Sparging Line-Diffuser Typically Used in an OI System[8]

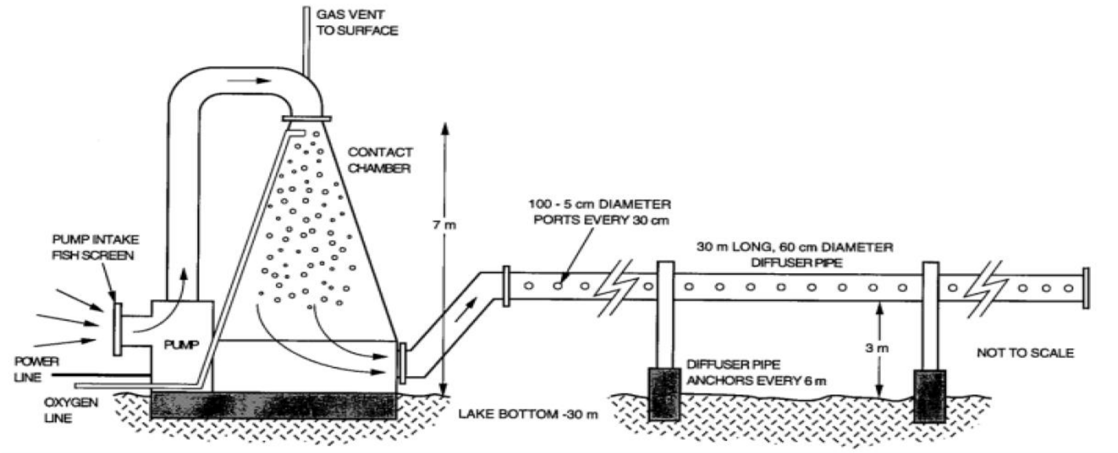


Super Saturation Oxygenation - The objective of Super Saturation Oxygenation (SSO) systems is to promote and maintain oxic conditions in the deepest part of a lake, right over the sediments, without altering the lake's thermal profile. SSO systems can thus be considered a type of hypolimnetic aeration. However, unlike conventional hypolimnetic systems, SSO systems do not rely on the mixing of oxygen poor and oxygen rich water to achieve reoxygenation of the hypolimnion. Rather, reoxygenation using SSO results from the actual injection of oxygen into the oxygen depleted water. This is done by pumping water from the lake's hypolimnion into a mixing container, injecting pure oxygen into the container, and then discharging the oxygen-enriched water under low pressure back into the water column. Water is withdrawn and returned to the lake using intake and distribution headers, anchored to, but suspended slightly above the lake bottom. This is similar to the gas sparging line-diffusers used in OI systems (Figure 7). SSO systems can achieve oxygen transfer efficiencies greater than 90%. By introducing a prescribed amount of oxygen into the oxygen/water mixing container, a specified dissolved oxygen concentration can be targeted and maintained in the lake's hypolimnion. Due to the low velocity at which water is removed and returned to the lake, thermal stratification is preserved. Additionally, because the intake or discharge header are suspended off the lake bottom and water withdrawal and discharge velocities are low, the turbulence is minimal, which in turn prevents localized sediment resuspension.

The most common example of an SSO system involves the use of a Speece Cone (Figure 8). The Speece Cone is a large mixing container that can be placed on the bottom of a lake or in a pump-house on the shoreline of the lake. The former requires running power from the land to the Speece Cone using an underwater power cable. The on-land option does not require running power from land to lake but does typically require much longer water intake and discharge lines. Depending on the location of the pump house, these lines could run a considerable length along the bottom of the lake to and from the Speece Cone. Typically, the Speece Cone approach is used for large, deep (> 50 feet) lakes and reservoirs.

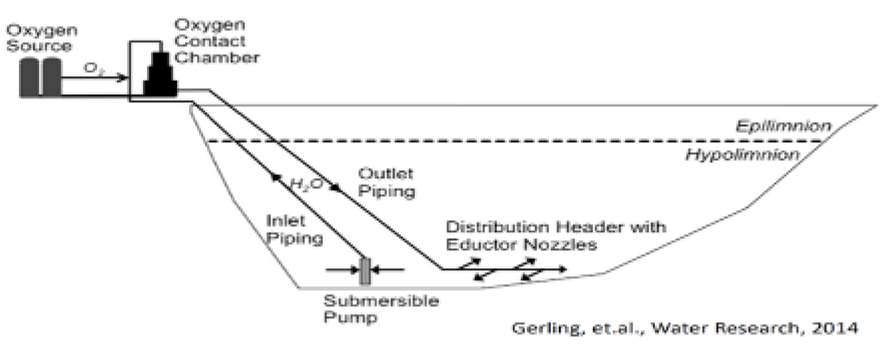
[8] Illustration courtesy of Mobley Engineering

Figure 8 – Speece Cone Illustration



An alternative, and somewhat more newly evolved SSO application referred to as Side-Stream Super Saturation (SSS) uses smaller mixing containers (oxygen contact chamber) located in an on-land pump house (Figure 9). Although this requires longer intake and discharge water lines, and perhaps larger water pumps, this design avoids the need to run power into the lake. SSS systems are most effective in shallower applications, such as lakes and reservoirs attaining a maximum depth of less than 35 feet. With SSS systems, enough oxygen can be mixed with the hypolimnetic water to not only satisfy the lake's biological oxygen demand, but to also meet and exceed the lake's sediment oxygen demand (SOD). Doing so depresses the sediment oxic/anoxic boundary below the sediment-water interface and deeper into the underlying sediments. This enables targeted management of a lake's legacy SOD (Gerling et al. 2014) and over time, as residual organic matter is oxidized, a decrease in the lake's SOD. Overall, Speece Cone SSO and SSS systems are not only an effective means of controlling and reducing a lake's internal phosphorus load, but are an effective means of maintaining a well-oxygenated hypolimnion capable of supporting both deep cold-water and/or warm-water fishery throughout the summer.

Figure 9 - Schematic of the Side-Stream Super Saturation System



Pure Oxygen Supply Options for OI and SSS Systems - The oxygen supply for SSO, SSS, or OI systems can be met in two different ways, either by using oxygen delivered and stored on site in large storage tanks or by producing oxygen on-site. It should be noted both on-site oxygen storage and on-site oxygen generation are regularly used at hospitals and commercial facilities.

For systems using on-site storage, liquid oxygen (LOx) is transported to the site by large tank trucks and stored in large tanks. The stored oxygen is then metered into the lake via the OI, SSO, or SSS system at a predetermined rate. While the initial capital costs of on-site storage systems are typically lower than on-site generation systems, the large on-site storage tanks pose several problems. This may include local zoning or code restrictions, aesthetic impacts, public safety concerns, and the routine access of the site by large tank trucks.

The on-site oxygen generation option requires a suite of equipment located in a pump house on shore. It has a greater initial capital cost due to the compressor equipment used to create the air supply and the pressure swing adsorption (PSA) oxygen generation equipment. The PSA unit is a molecular sieve that strips nitrogen from the compressed air to produce "pure oxygen."

For Honeoye Lake, on-site generation would be the more feasible of the two options based on a number of factors including the required footprint of the land-based elements of the system, code restrictions related to the storage tanks, public acceptance issues associated with large on-site LOx tanks and truck traffic associated with periodic refilling of LOx tanks and, perhaps most significant, the long-term operational goals relative to the maintenance of deep water oxic conditions and internal phosphorus load reductions. Even with the additional capital outlay for the mechanical components needed for on-site oxygen generation (large air compressor, air dryer and filters, PSA unit(s), mixing chambers, storage reservoir, and controls) on-site oxygen generation is the recommended option for Honeoye Lake.

Table 2 provides a summary of the aeration options considered for Honeoye Lake and the respective advantages and disadvantages of each option.

Table 2 Summary of Aeration Options for Honeoye Lake

Technology	Pros	Cons	Applicability for Honeoye Lake
Full Air-Lift Aerators	• Zone focused aeration, emphasis placed on the deeper water. • Maintains lake's natural thermal profile. • Can control/prevent circulation of phosphorus rich water into metalimnion and epilimnion.	• Limited oxygen addition capacity 20-25% OTE. • Floating structures on lake surface. • No mixing (turbulent diffusivity) to drive cyanobacteria into non-photic zone of lake. • Multiple units required to be effective. • Often marginally effective at reducing internal phosphorus load.	**Not Applicable -** • Lake is not dimictic. • Possible structures floating on lake surface creating boat navigational issues. • High energy demands to power large compressors. • May not adequately decrease lake's internal phosphorus load.
Mechanical Axial Pump Systems	• Often achieves surface to bottom Δ temperature < 2.0 C° • No metalimnetic oxygen minimum. • Simple operation involving the pumping of water.	• Large structures floating on lake surface creating boat navigational issues. • Limited oxygen addition capacity (oxygen addition mostly function of surficial oxygen transfer) • Not scalable…requires the use of multiple units • Lower efficiency and higher costs due to energy required to pump large volumes of water • Mixing (turbulent diffusivity) below threshold to promote diatoms and green algae over blue-green algae • Minimum depth restrictions	**Not Applicable -** • Marginally effective in reducing internal nutrient loading. • Large structures floating on lake surface. • High energy demands. • May not adequately control lake's internal phosphorus load. • May need to annually remove equipment from lake to avoid ice damage.

Technology	Pros	Cons	Applicability for Honeoye Lake
Direct Gas Sparging Oxygen Injection (OI) System	• OTE (> 80% full reservoir) • Capable of oxidizing legacy SOD • Ease of operation • Minimal operational oversight • Can be gravity fed reducing electricity costs • Highly effective in reducing internal nutrient loading	• Major infrastructure including possible large on-site LOx storage tanks • Minimal mixing to prevent metalimnetic oxygen minimum • Marginal mixing to promote desired phytoplankton shift	**Not Applicable -** • Lake too shallow to meet depth required for system to be cost-effective.
Direct Gas Sparging Air (Destrat) System	• Can achieve surface to bottom Δ temperature < 0.5 C° • No metalimnetic oxygen minimum • Simple operation • Mixing (turbulent diffusivity) can drive cyanobacteria deeper into lake • No equipment floating on lake surface	• Limited oxygen addition capacity (oxygen addition regulated by surficial oxygen transfer). • Natural thermal properties of lake altered. • Cannot create or maintain mid-summer cool water fish habitat. • Large amount of equipment on lake bottom (air lines, diffusers, distribution manifolds) increasing potential for snagging and damage. • Added routine inspection, maintenance and servicing costs for underwater elements of the system • High electrical costs to operate needed large compressors	**Applicable –** • Capable of preventing thermal stratification and hypolimnetic anoxia • Capable of controlling and decreasing lake's internal phosphorus load • May achieve only marginal increases in oxygen levels within the sediments and therefore provide marginal reductions in SOD.
Side-Stream Supersaturation (SSS)	• 90% Oxygen Transfer Efficiency (OTE) • Direct oxygen input over sediments, capable of oxidizing legacy SOD • Does not alter lake's "natural" thermal profile • No equipment mounted or floating on lake surface	• Greater amount of operational oversight • More equipment to maintain • Insufficient mixing to prevent metalimnetic oxygen depletion • Insufficient mixing to drive cyanobacteria from surface to bottom of lake • Maintenance of intake and discharge headers	**Applicable –** • Can reduce and control internal phosphorus load • Does not artificially destratify lake • Can maintain high deep water (>4 mg/L) DO, create mid-summer cool water fish habitat • High DO concentrations directly at sediment – water interface could overtime decrease legacy SOD

2.3 RECOMMENDED AERATION APPROACH FOR HONEOYE LAKE

As previously noted, based on the data, information and findings contained in numerous Honeoye Lake reports, but in particular Princeton Hydro's 2020 "Feasibility Assessment of Harmful Algae Bloom Management Options for Honeoye Lake and Conesus Lake, New York", destratification aeration has been recommended for Honeoye Lake. The projected aeration system discussed in the 2020 Princeton Hydro report consisted of two (2) 40-50 HP compressors delivering compressed air to 20-28 individual diffusers distributed throughout the central, deep basin of the lake. The destratification system would be operated from May through September, thus preventing the lake from ever becoming thermally stratified. In doing so, the lake's bottom waters would be prevented from becoming anoxic. In turn, this prevents the internal recycling of phosphorus from the sediments, thus significantly decreasing the lake's internal phosphorus load and the development of mid-summer HABs. The total capital cost of the system plus its installation was estimated by Princeton Hydro to be in the range of $1.7-$1.8 million dollars. With respect to the system's projected operational costs, Princeton Hydro noted "because of the uncertainty of where the [destratification system] compressor building can be sited, detailed annual operational costs were not computed," but were estimated to be at least $50,000/year. The annual cost for the routine maintenance and servicing of the system was projected to be in the range of $15,000/year, based on data compiled by Princeton Hydro for similar systems operating regionally throughout New York, New Jersey, and Pennsylvania.

Nationwide over the past decade, oxygenation has become the most common aeration method used to address hypolimnetic anoxia and internal phosphorus loading, with side-stream supersaturation (SSO and SSS) and direct oxygen gas injection (OI), the two techniques used to introduce "pure" oxygen into the water. In comparison to OI and SSO systems, SSS is best suited for shallow, polymictic lakes (such as Honeoye Lake) because SSS systems achieve better oxygen transfer efficiencies (OTE). Additionally, the annual operating costs of OI and SSS systems are typically lower than conventional full-lift, destratification aeration systems due to the use of significantly smaller compressors, potentially shorter period of operation, and higher OTE and reoxygenation capabilities.

Both SSS and OI systems can be tailored to meet site-specific deep-water and sediment oxygen demands and can be designed to preserve thermal stratification. SSS and OI systems can be operationally optimized to provide sufficient oxygen capacity, thereby meeting community respiration needs as well as generate enough oxygen to meet legacy SOD. The ability for SSS as compared to OI systems to better address legacy SOD from years of organic detritus buildup ultimately increases their longer-term effectiveness of meeting water quality management goals, especially in terms of preventing anoxia and reducing internal phosphorus loading. Decreased SOD demands translate to decreased total oxygen demand, which ultimately results in lower, long-term operating cost. Thus, over time SSS operational costs should become progressively less than OI operating costs.

Based on further analysis of Honeoye Lake's thermal properties, its hypolimnetic oxygen demands, and the relative efficiency and effectiveness of the various aeration techniques used to control internal phosphorus loading and meet the lake's overall aeration needs and goals, it was determined that a side-stream super saturation (SSS) system is the best approach for Honeoye Lake. Thus, rather than aerate and mix the lake's water column using a destratification system, SSS is being recommended as the approach used to meet Honeoye Lake's oxygen demands, decrease mid-summer internal phosphorus loading, and decrease the frequency, intensity and duration of mid-summer cyanobacteria blooms.

2.4 DATA USED TO SIZE THE HONEOYE LAKE SSS SYSTEM

As is the case for many northeast temperate lakes deeper than 5 meters/16 feet, Honeoye Lake experiences seasonal thermal stratification that in turn leads to oxygen depletion in the lake's deeper hypolimnion (7-9 meters/ 23-29.5 feet). Thermal stratification of northeastern dimictic lakes typically begins as early as mid-May and persists through mid-September to as late as mid-October. However, Honeoye Lake is polymictic, destratifying multiple times during this period. Its pattern of stratification is much different than a dimictic lake. Additionally, the year-to-year timing, intensity, and duration of thermal stratification and disruption varies based on local climatic conditions, the occurrence of severe storm and wind events, and other factors that affect the thermal regime of Honeoye Lake. For Honeoye Lake, thermal stratification usually begins to develop around late-June and persists until mid- to late August. Additional periods of stratification ranging from a few days to several weeks have been observed throughout September. However, by October, the water column shows no evidence of thermal stratification and is uniformly mixed from surface to bottom. As documented by the HLWTF's database, when the lake is not stratified, dissolved oxygen (DO) concentrations are usually near saturation from surface to bottom regardless of the time of year. However, during periods of thermal stratification, DO concentrations typically drop to < 1mg/L in waters deeper than 7 meters (23 feet).

Data developed by Cornell University (Hairston et al. 2017 and 2018) show Honeoye Lake's patterns of thermal stratification and water column mixing to be highly influenced by south to north winds that create an internal seiche (longitudinal, internal waves). The seiche essentially depresses the depth of the thermocline and induces water column mixing, at times even without fully disrupting thermal stratification. The influence of wind events and the lake's seiche is evident when examining intra- and inter-annual month-to-month water temperature and DO profiles. An evaluation of wind data and thermal structure revealed that during periods of higher sustained winds, the thermocline boundary migrates deeper in the water column. Invariably this causes deeper hypolimnetic water to upwell into the epilimnion, resulting in an associated upwelling of hypolimnetic, phosphorus rich water (Hairston et al. 2017 and 2018). These weather-related mixing events and associated internal recycling of phosphorus released from the sediments during periods of anoxia in turn stimulate phytoplankton growth and often lead to severe cyanobacteria harmful algal blooms (Hairston et al. 2018). This is dynamically equivalent to the effects of metalimnetic erosion described in Section 1. The seiche does not thermally disrupt the thermocline. However, it does create enough turbulence at the thermocline to entrain phosphorus rich deep water that is then circulated to the surface where enough light is present to support photosynthesis subsequently leading to an algae bloom.

The pattern, intensity, and duration of stratification also affects the relative concentrations of DO measured in the lake's epilimnion and hypolimnion. During periods of extended stratification, hypolimnetic DO concentrations drop to anoxic levels (< 1 mg/L). Conversely, even during periods of stratification, epilimnetic DO concentrations tend to remain near saturation, with supersaturated conditions often experienced in the uppermost reaches of the lake. In the open water (pelagic) areas of the lake, the observed supersaturated DO concentrations in the epilimnion are typically the result of storm, wave and wind induced turbulence or photosynthetic related oxygen production resulting from a major algae bloom or cyanobacteria HAB. During periods of water column turnover, epilimnetic DO concentrations may temporarily drop below 6 mg/L as the anoxic water from the hypolimnion rises and is mixed with the lake's epilimnetic water.

A series of images were created of the lake's relative thermal resistance to mixing (RTRM) using 2017 – 2020 lake temperature data (Figures 10-13)[9]. RTRM is based on the density differences of water with change in temperature. At temperatures greater than 4^{o}C (39.2^{o}F), the density of water progressively decreases with an increase in temperature. Changes in density affect water column mixing, with thermal differences of as little as 2-3^{o}C (4-5^{o}F) resulting in enough RTRM to impede mixing. Taking into consideration that oxygen diffusion is restricted at high RTRM values, a threshold of approximately 20 RTRM was assigned to identify the range in the hypolimnion at which oxygen mixing is predicted. The average hypolimnion boundary was estimated to be 7.75 m (25 feet) deep. Although thermocline boundaries were typically observed at 7 m (23 feet) deep, the hypolimnion was consistently observed to be deeper. In Figures 10-13, green was assigned to RTRM values < 20 when observed from the top down, coinciding with the epilimnion. Pink was assigned to values > 20, which represents the region with the greatest RTRM and greatest impediment to mixing. This can be equated to the thermocline, the density boundary that impedes full lake mixing and segregates the hypolimnion from the epilimnion. Blue was assigned to values < 20 from the bottom up to identify the hypolimnion.

[9] Although the most recent complete data years were used in this analysis (2017-2020) and the preparation of Figures 10-15, the full complement of available lake thermal and DO data (1996-2020), as provided by HLWTF was reviewed as part of our assessment of the lake's dissolved oxygen needs.

Figure 10 - 2017 (May 11 – August 24) [Average hypolimnion boundary depth: 8.0 m]

Date	11-May	17-May	22-May	24-May	30-May	31-May	5-Jun	7-Jun	12-Jun	14-Jun	19-Jun	21-Jun	26-Jun	28-Jun	3-Jul	4-Jul
0.0	3.5	3.7	2.0	2.2	2.3	4.8	2.4	0.0	0.0	0.0	-2.9	0.0	-2.9	0.0	5.9	3.0
0.5	1.7	1.8	0.0	0.0	0.0	2.4	0.0	0.5	2.8	-2.9	-3.0	0.0	-2.9	2.8	5.9	0.0
1.0	4.3	0.9	0.0	1.1	0.0	0.0	1.2	2.1	2.8	0.0	0.0	1.5	0.0	0.0	2.9	0.0
1.5	4.2	0.9	0.0	1.1	0.0	0.0	1.2	2.1	2.8	0.0	0.0	1.5	0.0	0.0	2.9	0.0
2.0	4.9	3.6	2.0	2.2	0.0	2.4	2.4	0.0	5.5	2.9	3.0	0.0	0.0	2.8	2.9	0.0
3.0	1.6	1.8	0.0	10.6	4.6	2.3	2.4	0.0	2.7	2.9	0.0	2.9	0.0	2.8	2.9	2.9
4.0	3.2	3.5	0.0	8.2	2.3	4.6	0.0	0.0	16.1	5.7	17.5	0.0	0.0	2.8	14.3	0.0
5.0	1.6	3.5	0.0	4.0	2.2	2.3	13.9	0.0	38.2	94.7	80.8	63.2	0.0	0.0	22.2	17.4
6.0	3.1	3.4	0.0	5.9	0.0	0.0	17.8	2.3	19.2	14.2	24.4	51.9	63.2	63.1	47.1	57.5
7 (23)	0.8	4.2	0.0	1.9	12.1	21.2	5.4	10.3	9.3	8.0	8.2	6.9	31.6	19.4	17.2	25.4
7.5 (25)	0.8	4.1	0.0	1.9	11.7	20.0	5.3	10.0	9.1	7.9	8.1	6.8	29.6	18.6	16.6	24.1
8 (26)	4.5	1.6	2.0	1.9	8.3	2.0	8.3	21.3	4.5	2.2	4.5	2.2	2.3	2.3	4.6	9.3
8.5	1.5	0.0	0.0	1.9	2.0	2.0	2.0	2.1	6.6	2.2	0.0	0.0	2.3	2.2	4.6	2.3
9.0																

Date	5-Jul	7-Jul	10-Jul	12-Jul	17-Jul	19-Jul	24-Jul	26-Jul	31-Jul	2-Aug	7-Aug	9-Aug	14-Aug	15-Aug	17-Aug	21-Aug	23-Aug	28-Aug
0.0	3.1	-3.1	-3.0	-3.2	0.0	0.0	-3.2	3.1	3.1	0.0	-5.9	3.0	-3.0	3.0	0.0	-3.0	0.0	0.0
0.5	6.2	0.0	0.0	-3.2	0.0	6.5	0.0	0.0	3.1	9.7	0.0	8.9	0.0	0.0	0.0	0.0	-3.0	-2.8
1.0	3.1	0.0	0.0	1.6	4.7	4.9	1.6	0.0	1.5	8.0	1.5	0.0	0.0	3.0	1.5	-1.5	0.0	0.0
1.5	3.1	0.0	0.0	1.6	4.7	4.8	1.6	0.0	1.5	7.9	1.5	0.0	0.0	3.0	1.5	-1.5	0.0	0.0
2.0	9.1	3.1	0.0	28.0	3.1	3.2	3.2	3.0	0.0	9.4	3.0	2.9	3.0	3.0	0.0	0.0	0.0	0.0
3.0	3.0	6.1	0.0	12.1	9.3	3.2	0.0	3.0	6.1	33.7	3.0	0.0	0.0	0.0	0.0	0.0	3.0	0.0
4.0	14.9	47.0	0.0	9.0	36.3	61.6	3.2	0.0	9.0	6.0	0.0	0.0	3.0	0.0	0.0	6.1	-3.0	0.0
5.0	48.4	19.6	0.0	14.7	14.6	34.7	6.3	6.0	6.0	8.9	5.9	2.9	3.0	0.0	0.0	6.0	9.0	0.0
6.0	52.4	39.9	3.0	69.0	36.5	24.9	83.2	54.8	26.3	28.8	17.3	2.9	8.8	34.7	3.0	23.7	11.8	2.8
7 (23)	12.3	8.9	61.4	12.9	22.8	19.9	28.8	20.4	32.2	18.1	12.7	14.4	11.6	2.8	19.2	11.6	7.3	5.7
7.5 (25)	12.0	8.8	55.7	12.6	21.9	19.2	27.4	19.7	30.5	17.5	12.5	14.1	11.4	2.8	18.6	11.4	7.2	5.6
8 (26)	4.7	14.6	4.9	7.4	10.0	10.0	10.1	7.7	7.7	18.3	8.2	13.7	8.4	5.6	5.6	8.4	14.2	2.8
8.5	2.3	9.5	2.4	9.7	12.2	7.3	5.0	5.1	5.1	7.6	18.6	16.1	5.5	11.0	5.6	8.3	8.4	0.0
9.0																		

Figure 11 - 2018 (May 16 – August 25) [Average hypolimnion boundary depth: 7.5 m]

Date	16-May	22-May	28-May	29-May	4-Jun	5-Jun	11-Jun	12-Jun	15-Jun	18-Jun	19-Jun	20-Jun	21-Jun	25-Jun	26-Jun	2-Jul	5-Jul	9-Jul
0.0	2.4	2.3	2.7	5.0	-0.5	-2.6	0.5	0.0	0.0	2.1	0.0	0.0	-2.9	0.0	-2.8	1.0	0.0	0.3
0.5	39.4	0.0	2.6	5.0	0.0	0.0	4.7	0.0	0.0	0.6	0.0	3.0	0.0	1.1	0.0	8.2	3.4	7.8
1.0	1.1	0.0	0.0	2.9	0.3	-2.6	2.3	0.0	0.0	1.8	-1.4	0.0	0.0	2.5	0.0	6.8	6.8	3.9
1.5	1.1	0.0	5.2	2.8	0.0	0.0	0.8	0.0	0.0	1.8	-1.4	3.0	0.0	1.4	0.0	5.8	3.4	2.9
2.0	15.0	0.0	0.0	8.1	0.5	0.0	2.3	0.0	10.9	20.3	0.0	6.0	0.0	0.8	0.0	27.1	16.8	2.9
3.0	4.2	0.0	7.8	46.4	-2.4	0.0	14.2	2.7	2.7	10.8	2.9	3.0	2.9	0.8	0.0	68.5	88.8	22.3
4.0	18.0	0.0	5.1	36.6	2.9	0.0	9.7	0.0	0.0	29.7	0.0	3.0	14.5	0.3	2.8	7.9	26.6	37.2
5.0	5.8	2.3	70.4	47.4	0.0	0.0	2.9	2.7	0.0	25.2	2.9	37.3	33.5	0.0	0.0	8.6	20.0	46.5
6.0	42.8	2.3	12.6	14.2	0.5	0.0	5.1	0.0	2.7	1.0	28.2	35.3	10.8	2.8	0.0	5.5	8.4	11.7
7 (23)	6.0	13.4	6.1	1.8	82.5	65.3	14.9	38.2	0.0	21.0	19.0	7.8	8.0	48.7	2.8	13.2	5.5	8.1
7.5 (25)	5.7	13.0	13.8	1.8	20.9	17.5	26.3	2.4	28.6	6.3	28.6	5.2	13.0	6.1	48.3	5.8	5.5	3.2
8 (26)	1.4	37.8	3.8	0.2	6.4	6.3	12.8	2.4	29.4	-1.0	5.0	5.1	7.6	6.5	5.1	6.6	8.1	7.4
8.5	1.4	10.9	5.6	0.2	0.8	4.2	15.3	9.6	11.7	32.2	14.8	12.6	22.2	7.6	-12.9	11.4	5.4	3.4
9.0																		

Date	11-Jul	15-Jul	16-Jul	17-Jul	20-Jul	23-Jul	24-Jul	27-Jul	29-Jul	30-Jul	31-Jul	6-Aug	7-Aug	13-Aug	14-Aug	15-Aug	20-Aug	22-Aug	25-Aug
0.0	-6.4	17.2	15.9	0.0	0.0	3.7	-6.2	0.0	-3.2	0.0	-3.1	-1.6	0.0	-0.3	-3.2	3.2	-0.3	0.0	-3.0
0.5	0.0	20.3	5.7	0.0	3.3	4.0	0.0	0.0	3.2	0.0	0.0	2.0	-3.2	1.9	0.0	0.0	0.0	0.0	0.0
1.0	-3.2	6.7	0.7	3.4	0.0	3.4	-3.1	0.0	12.7	6.3	6.3	3.2	0.0	1.0	-3.2	3.2	0.0	0.0	0.0
1.5	0.0	9.9	6.0	0.0	0.0	0.6	3.1	3.1	6.3	0.0	3.1	10.9	0.0	0.3	0.0	3.2	0.0	0.0	0.0
2.0	3.2	6.6	3.0	3.4	3.3	0.9	0.0	0.0	3.1	3.1	0.0	8.9	0.0	0.0	0.0	0.0	0.9	0.0	0.0
3.0	0.0	3.3	7.9	39.4	3.3	1.8	0.0	0.0	0.0	0.0	3.1	1.9	9.7	0.6	0.0	0.0	0.0	0.0	0.0
4.0	9.6	35.2	56.6	19.1	3.2	-0.3	3.1	3.1	3.1	3.1	0.0	8.5	34.7	0.3	0.0	0.0	0.9	0.0	0.0
5.0	37.5	63.3	76.3	18.7	6.5	1.8	0.0	0.0	3.1	3.1	0.0	23.5	9.2	28.3	25.1	12.5	0.3	0.0	0.0
6.0	69.9	19.9	20.7	62.1	3.2	0.3	0.0	0.0	6.2	12.4	0.0	21.0	9.1	31.8	9.2	12.3	0.3	0.0	0.0
7 (23)	5.5	5.6	1.3	-2.8	49.8	0.0	3.1	9.3	3.1	6.1	0.0	3.8	6.0	3.0	6.1	6.1	0.6	0.0	0.0
7.5 (25)	2.7	5.5	2.1	16.8	46.8	39.0	0.0	15.2	27.1	12.1	3.1	22.0	6.0	1.2	3.0	9.0	4.5	0.0	5.9
8 (26)	2.7	5.5	0.5	11.0	16.8	9.5	0.0	6.0	11.2	6.0	39.0	0.3	3.0	5.0	6.0	8.9	13.2	3.0	3.0
8.5	5.4	2.7	1.3	2.7	16.3	0.6	0.0	5.9	3.5	5.9	11.6	5.4	14.7	2.6	8.9	3.0	13.8	0.0	-3.0
9.0																			

Figure 12 - 2019 (May 24 – August 29) [Average hypolimnion boundary depth: 7.4 m]

Date	24-May	31-May	3-Jun	10-Jun	17-Jun	19-Jun	22-Jun	24-Jun	1-Jul	8-Jul	9-Jul	15-Jul	18-Jul
0.0	0.0	2.4	0.0	0.0	13.1	5.5	-2.7	0.0	0.0	0.0	3.4	-3.2	13.4
0.5	0.0	0.0	-2.3	0.0	15.3	5.4	2.7	0.3	6.1	0.0	23.4	0.0	13.2
1.0	0.0	0.0	0.0	0.0	7.5	8.0	0.0	0.3	6.0	0.0	13.1	0.0	3.3
1.5	2.1	0.0	0.0	0.0	2.5	2.7	2.7	0.3	3.0	0.0	6.5	3.2	3.3
2.0	0.0	0.0	0.0	0.2	4.9	0.0	2.7	5.2	3.0	3.2	12.9	0.0	3.2
3.0	0.0	9.6	0.0	0.2	2.4	25.8	23.7	26.9	0.0	3.2	3.2	0.0	9.7
4.0	2.0	23.0	0.0	0.5	0.0	19.7	12.7	9.4	0.0	52.1	78.8	3.2	6.4
5.0	2.0	13.1	0.0	2.5	2.4	2.4	7.5	26.3	106.7	55.2	39.1	101.1	67.2
6.0	6.0	2.1	0.0	3.2	0.0	2.4	7.4	5.9	5.0	46.0	21.3	52.9	74.6
7 (23)	3.9	6.3	0.0	0.2	2.4	2.4	2.4	6.6	2.5	9.9	10.3	7.5	17.8
7.5 (25)	1.9	8.3	0.0	0.2	2.4	2.4	2.4	0.7	0.0	2.4	15.1	9.8	12.4
8 (26)	0.0	0.0	32.9	0.0	-2.4	2.4	4.8	0.2	0.0	2.4	7.4	2.4	4.9
8.5	0.0	0.0	6.2	0.2	0.0	2.3	4.7	1.4	4.9	0.0	2.4	0.0	2.4
9.0													

Date	23-Jul	26-Jul	29-Jul	1-Aug	5-Aug	7-Aug	9-Aug	11-Aug	12-Aug	14-Aug	19-Aug	21-Aug	23-Aug	26-Aug	27-Aug	29-Aug
0.0	0.0	0.0	0.6	-3.4	-3.2	-6.4	-3.1	0.0	-6.0	0.0	0.0	0.0	-3.1	0.0	-2.9	-2.9
0.5	3.3	9.8	1.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.3	-3.1	0.0	0.0	2.9
1.0	0.0	6.5	0.6	13.4	-3.2	0.0	0.0	0.0	0.0	3.1	0.0	0.0	0.0	0.0	0.0	0.0
1.5	0.0	0.0	2.5	6.6	0.0	0.0	0.0	0.0	0.0	3.1	0.0	3.1	3.1	3.0	0.0	0.0
2.0	0.0	3.2	4.1	6.6	0.0	3.2	0.0	6.1	-3.0	3.1	0.0	3.1	6.2	0.0	0.0	0.0
3.0	3.3	0.0	1.3	0.0	3.2	0.0	0.0	0.0	0.0	3.0	9.2	3.1	3.1	0.0	0.0	0.0
4.0	12.9	3.2	3.8	3.3	0.0	3.2	3.1	0.0	0.0	3.0	3.1	6.2	0.0	0.0	0.0	2.9
5.0	67.8	79.2	119.5	38.4	0.0	28.2	3.1	3.1	0.0	0.0	6.1	15.3	0.0	0.0	0.0	0.0
6.0	64.6	68.4	27.4	112.9	141.5	56.4	88.5	52.9	6.1	6.0	23.8	18.0	59.0	0.0	0.0	2.9
7 (23)	36.1	10.2	18.7	20.9	28.5	27.9	21.8	66.9	32.5	57.6	17.3	23.3	14.0	2.9	0.0	2.9
7.5 (25)	9.9	12.5	6.7	10.1	5.0	29.3	23.5	7.5	78.6	29.6	16.9	47.0	11.0	14.5	0.0	0.0
8 (26)	4.9	4.9	-2.9	12.4	2.5	17.8	15.1	2.5	0.0	25.6	53.1	23.4	16.1	44.5	0.0	2.9
8.5	2.4	2.4	3.1	0.0	2.5	7.5	4.9	0.0	2.5	9.9	2.5	7.6	18.2	18.5	0.0	2.9
9.0																

Figure 13 - 2020 (May 16 – August 27) [Average hypolimnion boundary depth: 8.25 m]

Date	16-May	21-May	25-May	1-Jun	5-Jun	8-Jun	11-Jun	15-Jun	18-Jun	22-Jun	26-Jun	29-Jun	2-Jul	6-Jul
0.0	3.1	2.0	2.2	0.0	25.0	0.0	0.0	0.0	18.8	9.3	-3.0	-3.1	3.2	-3.3
0.5	4.6	0.0	6.7	0.0	8.1	0.0	0.0	0.0	9.2	3.1	3.0	0.0	9.6	0.0
1.0	4.5	2.0	2.2	0.0	10.6	0.0	0.0	0.0	12.1	3.1	3.0	3.1	12.6	0.0
1.5	5.7	15.3	6.5	0.0	5.2	0.0	0.0	5.5	17.8	3.1	3.0	0.0	6.2	3.3
2.0	5.5	16.1	4.3	0.0	15.4	2.7	0.0	5.5	5.9	3.0	0.0	3.1	3.1	0.0
3.0	4.0	5.1	4.2	0.0	14.9	0.0	0.0	5.4	22.9	55.5	3.0	3.1	3.1	0.0
4.0	1.3	1.7	8.3	0.0	14.5	2.6	2.9	2.7	22.1	16.6	35.0	15.2	3.1	6.5
5.0	3.8	4.9	4.0	0.0	11.7	2.6	62.7	2.7	18.7	21.5	5.7	29.5	6.1	89.1
6.0	2.4	3.2	2.0	16.4	6.9	96.5	22.7	53.3	15.6	25.7	60.1	42.0	107.0	39.4
7.0	5.8	0.0	7.9	82.5	40.7	14.2	9.8	34.5	57.6	51.9	20.3	18.6	17.8	16.2
7.5	1.1	0.0	16.9	1.7	21.2	7.8	0.0	13.0	13.2	8.8	24.3	20.5	5.0	28.5
8.0	1.1	1.6	44.9	1.7	12.6	9.4	72.4	10.4	6.4	18.9	2.4	12.4	7.3	5.0
8.5	-1.1	24.5	2.7	1.7	3.5	1.8	2.0	4.1	0.0	0.0	22.8	26.2	7.2	0.0
9.0														

Date	9-Jul	13-Jul	17-Jul	20-Jul	24-Jul	27-Jul	30-Jul	3-Aug	6-Aug	10-Aug	13-Aug	17-Aug	19-Aug	20-Aug	24-Aug	27-Aug
0.0	6.8	-3.3	-3.2	0.0	0.0	-3.3	-3.3	0.0	0.0	0.0	-3.3	-3.2	-3.2	-6.3	0.0	-3.1
0.5	6.8	0.0	0.0	-3.3	0.0	0.0	3.3	-3.3	3.2	0.0	10.0	0.0	0.0	0.0	6.4	0.0
1.0	3.4	-3.3	0.0	0.0	-3.3	-3.4	3.3	0.0	6.4	3.3	3.3	0.0	3.2	0.0	3.2	0.0
1.5	0.0	0.0	0.0	0.0	3.3	0.0	0.0	0.0	0.0	6.5	6.6	3.2	0.0	0.0	0.0	0.0
2.0	3.4	0.0	0.0	0.0	6.7	0.0	3.3	0.0	3.2	3.2	3.3	0.0	0.0	3.1	9.5	0.0
3.0	6.7	0.0	0.0	6.6	6.6	0.0	0.0	0.0	0.0	3.2	0.0	0.0	0.0	0.0	3.1	0.0
4.0	3.3	0.0	3.2	16.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.2	0.0	0.0	0.0
5.0	91.8	0.0	0.0	9.6	9.8	3.4	3.3	0.0	0.0	3.2	6.5	0.0	0.0	0.0	18.6	0.0
6.0	52.0	109.2	87.4	0.0	28.9	0.0	48.4	0.0	0.0	15.9	35.1	0.0	3.2	0.0	3.1	0.0
7.0	5.5	34.1	16.8	15.7	40.1	61.7	27.8	0.0	3.2	6.3	3.1	0.0	0.0	0.0	3.0	0.0
7.5	24.3	34.9	8.2	39.5	49.4	57.5	23.9	32.1	31.0	3.1	9.3	9.6	9.5	0.0	0.0	0.0
8.0	10.5	5.2	2.7	45.9	19.3	36.9	23.1	45.9	44.3	15.4	6.1	22.0	9.4	0.0	3.0	0.0
8.5	2.6	5.1	56.8	27.1	10.8	10.9	25.1	3.0	90.3	21.1	9.1	3.1	18.4	12.4	3.0	0.0
9.0																

As per the above, the lake's average hypolimnetic boundary corresponds to a depth of 7.75 m (25 feet). This was determined by multiplying the hypolimnetic boundary by the number of days between data, summing and then dividing the sum by the total number of days. All four years of DO data were overlaid on the same date range (Figure 14) to show the annual trends of 1) DO depletion in late spring, 2) the development of anoxia during the summer, and 3) subsequent DO recovery in fall. The hypolimnetic oxygen demand was determined during initial spring stratification, when DO was observed to be greater than 6 mg/L (Figure 15).

Figure 14 – Hypolimnetic Dissolved Oxygen Data During 2017 – 2020 Stratification

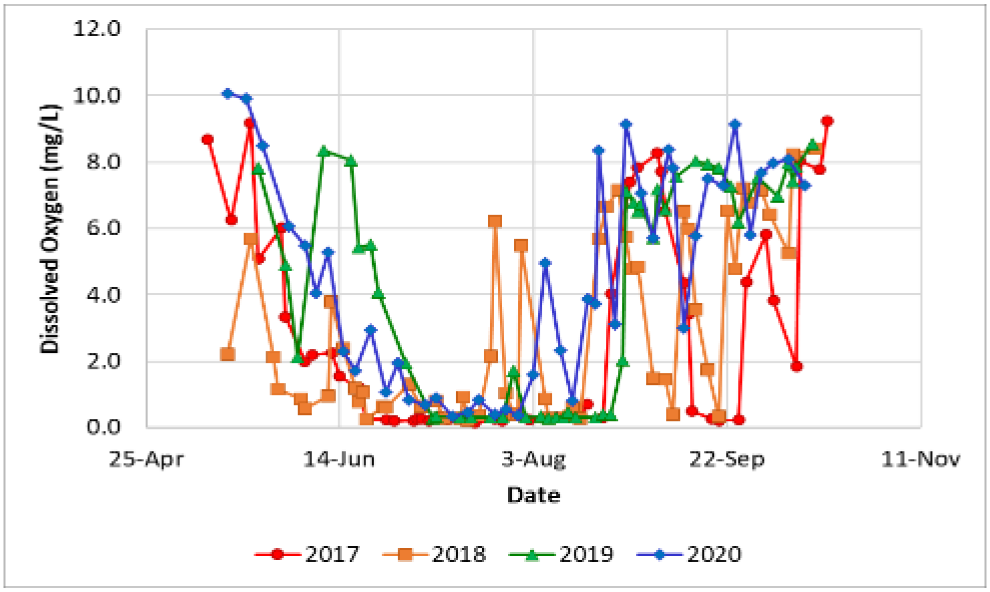
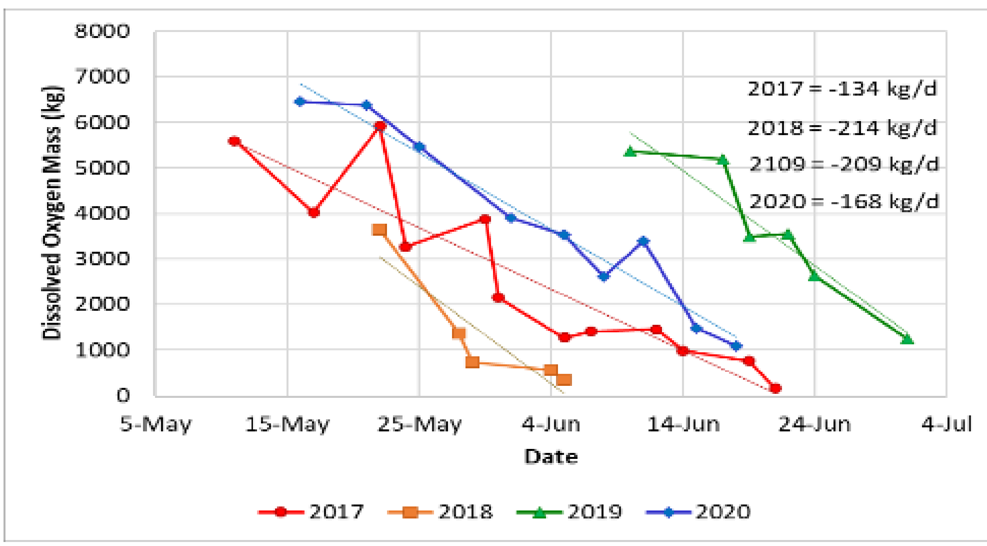


Figure 15 - Oxygen Mass Data Used To Determine Hypolimnion Oxygen Depletion Rates



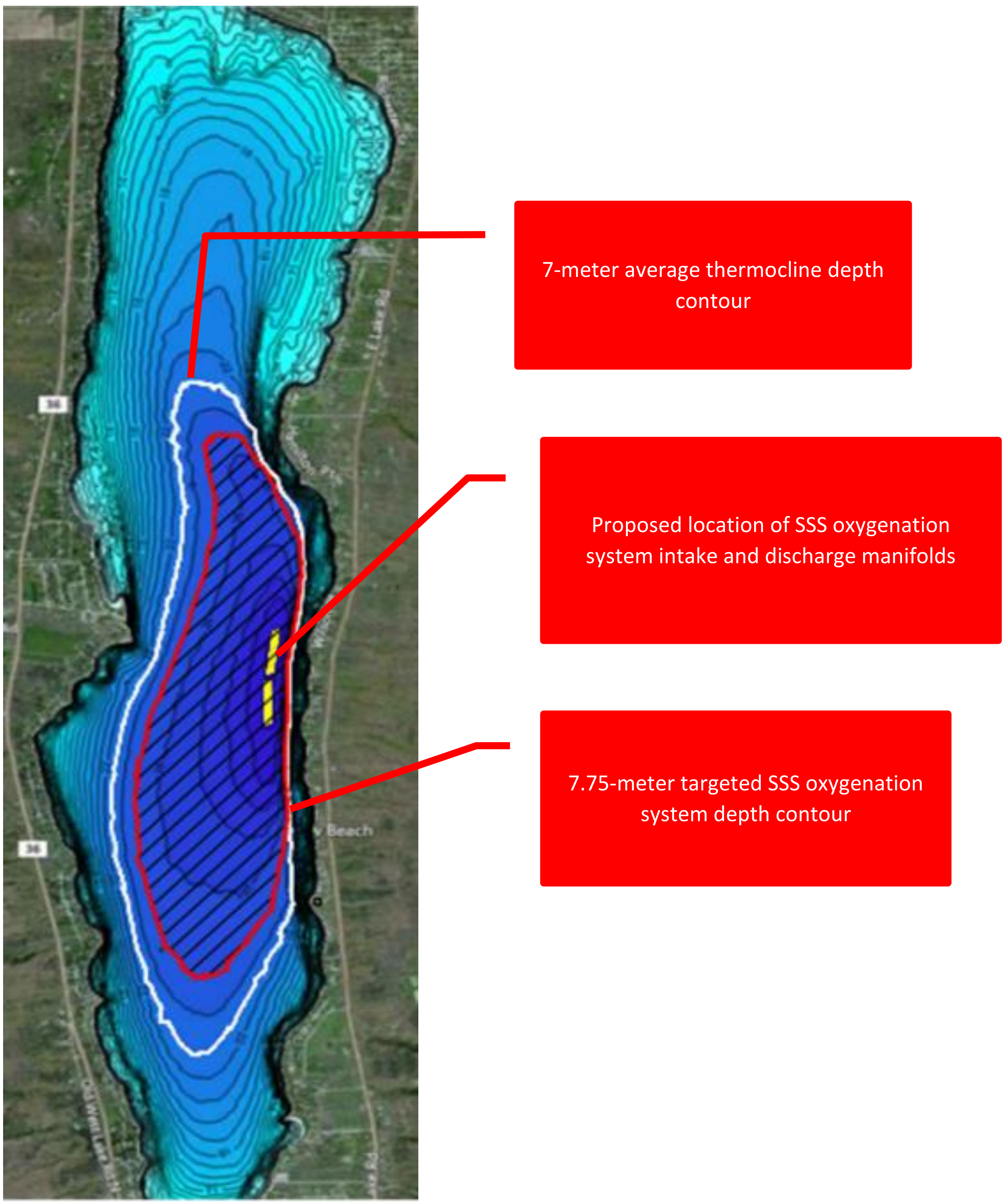
The hypolimnion's DO depletion rate for the water volume below 7.75 m (25 feet) depth was calculated to be 174 kilograms of O_2/day average with a maximum of 214 kg O_2/day (Table 3).

Table 3 - Summary of Hypolimnetic Oxygen Demand for 2017 – 2020 for Water Volume below 7.75 M (25 Feet) Depth.

Year	Date Range	O_2 Deficit in Kg/D
2017	11 May – 21 June	**-134**
2018	22 May – 5 June	**-214**
2019	10 June – 1 July	**-209**
2020	21 May – 29 June	**-138**
Mean		**-174**

Figure 16 is a bathymetric map of Honeoye Lake, with the red line delineating the 7.75-meter (25 foot) contour. The design of the SSS system proposed for Honeoye Lake uses 7.75 meters as the reoxygenation target zone.

Figure 16 - Bathymetric Map of Honeoye Lake Showing the Average Thermocline Boundary Corresponding to the 7 M (23 feet) Contour and the Average Hypolimnion Boundary / Corresponding Target Area of Oxygenation at the 7.75 M (25 feet) Contour



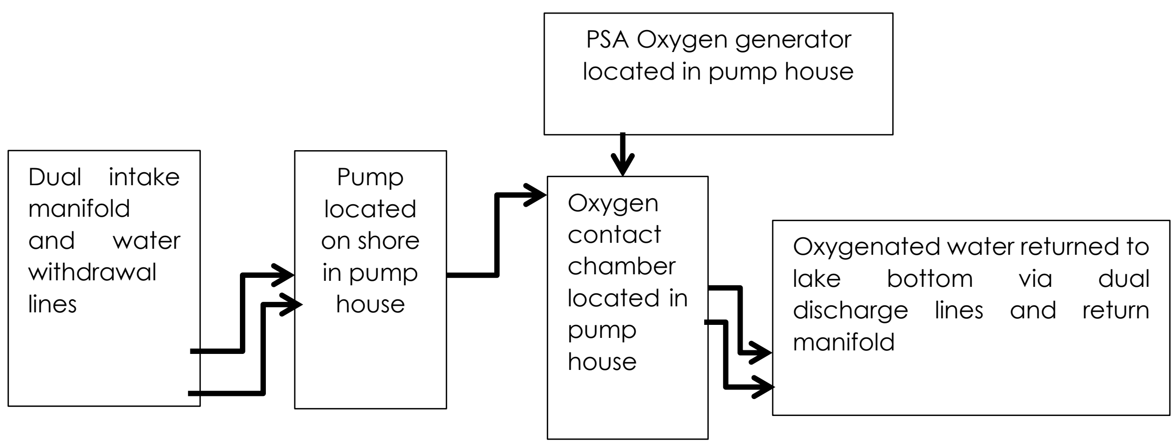
2.5 HONEOYE LAKE SIDE-STREAM SUPER SATURATION (SSS) SYSTEM

Benefits of SSS System for Honeoye Lake - As previously discussed, given the polymictic nature of Honeoye Lake, its pattern of thermal stratification and DO depletion, the SSS system is the best technology to meet the lake's hypolimnetic oxygen demand without disrupting natural thermal stratification. The maximum depth of Honeoye Lake is too shallow, and the lake's thermal profile too erratic for conventional Partial Air Lift hypolimnetic or Layer Air™ aeration. Although aeration and mixing of the hypolimnion using a Full Air-Lift, destratification system is feasible and an acceptable approach to preventing deep-water anoxia and controlling the lake's internal phosphorus load In a polymictic lake, the SSS approach is more dependable, effective, and cost-efficient in this application, as further discussed below.

As previously detailed, an SSS system draws water via an intake manifold positioned in the deepest part of the water column. Oxygen generated using a Pressure Swing Absorption (PSA) unit is mixed with the withdrawn water within oxygen contact chambers located in a pump house on land. This mixing greatly facilitates oxygen dissolution and achieves a greater and more efficient oxygen transfer rate than simple atmospheric dissolution achieved using destratification aeration. Oxygenated water is then pumped back to the bottom of the lake and released via a discharge manifold in the same general area from which it was withdrawn.

Figure 17 is a simplified schematic of a SSS system, illustrating the withdrawal of water from the bottom of the lake, the injection of pure oxygen into the withdrawn lake water, and the return of the oxygenated water to the bottom of lake. The oxygen content in the water returned to the bottom of the lake translates to a 90% oxygen transfer efficiency (OTE).

Figure 17 - Schematic of Side Stream Saturation System



The focused addition of oxygen provides the following advantages over hypolimnetic aeration and/or destratification aeration systems:

- SSS oxygenation targets the problem source, anoxia in the bottom waters and is designed to maintain hypolimnetic DO concentrations greater than or equal to 80% DO saturation at temperature.
- The system can be operated if desired not only to maintain minimum oxic conditions at the bottom of Honeoye Lake but to maintain DO concentrations of 4.0-6.0 mg/L thus improving fish habitat throughout the summer months in the deeper, cooler reaches of lake. Thus, unlike a full lift destratification system, the lake's aeration/oxygenation using the SSS system does not alter the lake's thermal profile. It will be possible to have cool, well oxygenated water at the bottom of the lake throughout the summer.

- SSS oxygenation is neither influenced nor affected by the lake's thermal structure. As the thermocline boundary naturally migrates deeper in the water column, oxygen addition improves.
- Unlike either partial or full lift aeration systems, SSS oxygenation can meet legacy sediment oxygen demand (SOD) and be adjusted to address increasing or decreasing SOD.
- SSS oxygenation can continue into the winter and even during ice cover to further manage deep water anoxia and legacy SOD. This eliminates the potential for winter fish kills and reduces any likelihood of internal phosphorus loading following winter stratification. It should be emphasized that this is an option and is not required to meet the lake's summer DO demands or to control the lake's mid-summer internal phosphorus load.

Based on the recent and most complete four-year dataset analyzed by the Princeton Hydro team, the prescribed 250 kg/day oxygenation rate is sufficient to meet the lake's average oxygen demand (refer to Section 2.5). The prescribed oxygenation rate will also be enough to address situations when the volume of the hypolimnion is greater than the average computed hypolimnetic volume. The prescribed oxygenation rate is also well within the daily oxygen production capacity of the PSA unit specified for Honeoye Lake. Conservatively, oxygenation of the lake bottom could begin in mid-May. This is before the lake's normal pattern of thermal stratification but would ensure that any deep-water oxygen deficit is met early in the season. The system would then be operated until late-September, or that time when the lake is naturally fully mixed, cooling, and unlikely to re-stratify. However, it is possible to truncate the operational period to mid-June through mid-September, the timeframe that coincides with the lake's typical polymictic pattern of stratification and destratification, reducing operating costs. Shortening the system's operational period should only be done after enough DO data (2-3 years) has been compiled under the more conservative operating schedule of mid-May through late-September.

Siting the Land-Based Components of the Honeoye Lake SSS System – The physical location of the land-based components of the SSS system can greatly affect the system's design, capital cost and operational cost. The criteria used to evaluate the feasibility of a given location for the siting of the land-based elements of the system minimize capital, installation, and annual operating costs. They also maximize oxygen supply efficiency and reduce long-term maintenance of the in-lake components. Additional criteria include availability of suitable power, access, aesthetic concerns, and proximity to private residences and, most importantly, likelihood of availability. Criteria include:

- Proximity to the intake and withdrawal manifolds in the deep, central basin of the lake targeted for oxygenation (Figure 16). The lake's deep, central basin is the portion of the lake subject to anoxia. Locating the land-based elements housed close to the deep, central basin decreases the length of water intake and discharge lines and the size of the pumps required to move water through the system. Line length impacts the system's capital equipment and long-term operational and maintenance costs. Keeping the length of the water intake and discharge lines as short as possible also helps decrease the system's possible interference with navigation, angling, and other lake uses.
- Minimal elevation difference between the pump house site and shoreline. A steep grade uphill from the lake requires more power to pump water to the pump house. A flatter site is preferable.
- The site should be located on publicly owned land, or private land where the owner is willing to provide a long-term easement, lease, or option agreement.
- The site should be preferably close to the lake's shoreline and not encumbered by any NYSDEC regulated lands (wetlands, wetland transitional areas, riparian areas, threatened and endangered species habitat, etc.).
- To facilitate construction and installation activities, the site should also be as unencumbered as possible by any steep slopes and require minimal clearing of upland vegetation and/or land grading to create a flat, level base for the pump house.
- The site needs to be either presently serviced by or close to an existing 3-phase, 480-volt power source.

- The site needs to be large enough to erect a suitably sized (20'x20' – 20'x30') structure to house the system's land-based elements; referred to as the "pump house".
- To minimize noise, aesthetic and site use conflicts, the pump house should be adequately distanced from homes and high public-use areas.
- The pump house should be easily accessible to facilitate the periodic inspection and seasonal servicing of the land-based elements of the system.
- The site should have enough existing landscaping or be capable of being further landscaped to additionally mitigate any aesthetic and/or noise impacts.

Working together with the local project committee, Princeton Hydro evaluated potential sites where the pump house could be located. Three potential locations were determined to best meet the noted criteria:

1. Unspecified location along the central eastern shoreline near the lake's deep central basin,
2. Sandy Bottom Park, at the lake's north end, and
3. California Ranch Point, located along the central western shoreline

It would be most desirable to locate the pump house on the central, eastern shoreline of the lake, as close as possible to the deep, central basin of the lake targeted for oxygenation. This would decrease the length of the intake and discharge lines, thus enabling the use of the smallest water pumps. Smaller line runs and smaller water pumps would decrease both capital and operational costs of the system and lessen the amount of maintenance of the in-lake components of the system. During the timeframe of this study, it was not possible to identify a site along the lake's eastern shore that adequately met most of the siting criteria.

Sandy Bottom Park, at the lake's north end meets all the siting criteria with the exception of being close to the lake's deep, central basin. This site was identified in Princeton Hydro's 2020 report as a suitable location for the siting of the land-based elements of the destratification system. However, the report did note the distance of the site from the lake's deep, central basin significantly increased the capital and operational costs of the system and would likely increase maintenance needs due to the length of the numerous air lines running along the lake bottom.

California Ranch Point, located along the central western shoreline, is privately owned. However, it meets all of the other criteria identified above. Therefore, of the three potential investigated locations, the site appearing to best meet the multiple criteria listed above is located at California Ranch Point (Figure 18)[10]. The landowner of this parcel was consulted by members of the local project committee about this study and noted use of the land, including the erection of the pump house and the need for routine access to the site to inspect and maintain the land-based elements of the aeration system. The landowner was gracious enough to grant permission for the inclusion of California Ranch Point as the conceptual site for the land-based facility associated with the proposed aeration system. It must be emphasized that no agreements or commitments have been finalized at this time with the landowner or even the use of California Ranch Point.

This site has access to a 3 Phase, 480-volt power source[11], is relatively flat, already largely cleared of vegetation, and is currently used for boat storage, docking and launching. Also, based on review of available Ontario County GIS data, there is no evidence of wetland or riparian vegetation or sensitive, rare or endangered vegetation

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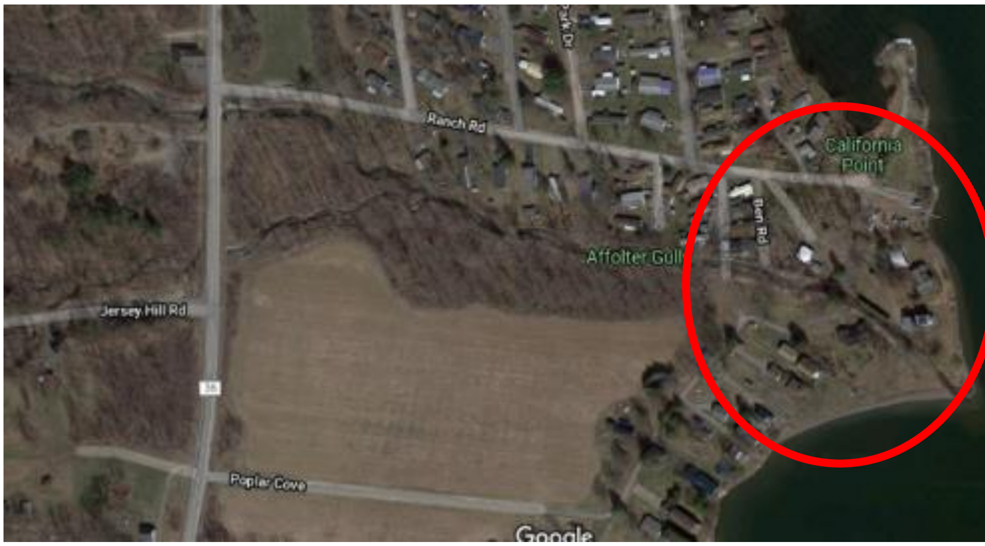
[10] It should be emphasized this is a planning study. Thus, although California Ranch Point is utilized herein for the conceptual siting of the land-based components and to compute line runs, pump sizes and power usage, alternative sites located closer to the deep-water area of the lake may be considered.

[11] It will be necessary to work with National Grid, the County, and the property owner to extend a 3 Phase power line from West Lake Road (Rte. 36) along Ranch Road to the proposed pump house location.

present on the site or along the lake's shoreline adjacent to the site. Additionally, the closest home is over 175 feet from where the pump house would be constructed, and the pump house could be easily insulated and screened with fencing, shrubs, and other vegetation to further minimize aesthetic and noise related concerns. Finally, the site is easily accessed from Ranch Road which intersects with West Lake Road (Route 36), thus enabling easy access to the site for the periodic inspection and maintenance of the land-based elements of the system.

Figure 18 – California Ranch Point (Google Earth 2021)



Recommended Specifications of the Honeoye Lake SSS System - The specific recommended components of the SSS system proposed for Honeoye Lake are illustrated in Figures 19 - 23 and consist of the following:

- A 20 feet x 30 feet, fully insulated and sound deadened structure, set on a concrete slab, and equipped with temperature control / heat dissipation fans and vents (Figure 19).
- For security purposes, the building will be surrounded by a gated fence, screened appropriately with low maintenance vegetation and equipped with an external security system consisting of motion activated LED lighting and motion activated internal and external security cameras. The security system should have remote notification capability via a smartphone application.
- Alarm systems for the building and oxygenation system will be provided. Both should interface with a smart phone. These features are especially important for the oxygenation system. The alarm will sense and alert designated personnel when the system is off-line (e.g., in the event of power failure or equipment failure) or when heat levels rise above a set limit within the pump house.
- One AriSep Model AS-G pressure swing adsorption (PSA) oxygen generator, rated at 320 Standard Cubic Feet per Hour (SCFH). Figure 20 is a photograph of a typical PSA setup using two O_2 contact chambers.
- One 20 HP air compressor with appropriate coalescing filter, air metering equipment, and monitoring gauges. An example of a suitable compressor is the Kaeser SK-20 air center equipped with a 120-gallon compressed air receiver tank. The compressor provides the clean, dry air source needed by the PSA to produce "pure oxygen."
- Four O_2 contact/mixing chambers.
- Two 15 HP water pumps rated at 200 gpm (gallons per minute) and 120 feet of head. The Gould Primeline Pump is an appropriate example water pump for use with this system. The dual pump design provides system redundancy.

It is recommended the proposed system consists of two parallel systems capable of operating independently. The redundant design increases system reliability and ease of maintenance. Each parallel system will consist of an intake and discharge pipe running to/from the pump house to the deep-lake intake and discharge headers.

Each intake and discharge pipe will also have an attached buoyancy line which will facilitate the easy recovery, inspection, and cleaning of the intake and discharge piping and deep-lake intake and discharge headers. The buoyancy line allows the intake and discharge piping to be brought to the surface for inspection, decreasing the need for inspection of the in-lake elements by divers.

The deep-lake water intake lines range between 2,600 and 2,700 feet in length, with the deep-lake oxygenated water return lines reaching an additional 700 to 1,200 feet in length (Figure 21). The total lengths of the intake/discharge lines include the sections of line used to transport water pumped to and from the conceptual California Ranch Point site. Both the deep-water intake and discharge manifolds are approximately 200 to 400 feet in length (Figure 21). The yellow lines shown on Figure 21 are in the deepest part of the Honeoye Lake and represent the anticipated locations of the pre-oxygenated water intake manifold lines and oxygenated water discharge manifold line. The system's two parallel line design allows operations to be scaled back to operating a single line when the lake's oxygen demands are less, such as during early spring and late fall. The flexibility with the system's operation provides the opportunity to reduce early and late season operational costs, an option not available with a conventional destratification aeration system or OI system.

Figure 22 shows a potential location for the pump house at the conceptual California Ranch Point site and its distance to existing homes.

From the pump house to the lake's shoreline, the intake and discharge lines will be set approximately 18" below ground level (or a suitable depth below the frost line, whichever is greater). Each intake and discharge line (6.25" outside diameter) will be run through an 8" inside diameter protective high density, PVC, or corrugated HDPE drainage line. This will protect the lines from physical damage from the pump house to the edge of the lake.
The intake and discharge lines will remain encased within the protective 8" diameter high density, PVC or corrugated HDPE drainage line for a distance approximately 100' from the shoreline out into the lake to water depth approximately 10 feet, thus minimizing the chance for prop-related damage to the lines. This section of the encased and protected lines will not be trenched below the lake bottom, but rather will rest on the lake bottom. Placement of the intake and discharge lines in the protective casing will protect both from nearshore boat damage. The air lines are extremely durable and have proven in other installations to be highly resilient to damage from anchor snags (Gantzer 2022). However, to help minimize possible anchor snags or other potential damage due to boating activity, the locations of air lines, intake and discharge manifolds, and any other subsurface equipment should be geo-referenced using GPS during installation and a map produced.

To inform boaters, anglers, and lake users, it is also recommended signage, based on the GPS created map, be erected at the pump house site, all private marinas, and NYSDEC boat launch. This will help increase public understanding of the locations of the intake and discharge lines and intake and discharge manifolds. A similar illustration can be posted on the HLWTF, Honeoye Valley Association, town, and county websites. Signage and postings will help decrease possible anchor snags and boat related impacts to the in-lake components of the system.

Each system will be positioned on the lake bottom using anchoring ballast, which also provides positioning of the intake and discharge headers slightly elevated (6"-12") above the lake bottom. The ballast pipe is used to reduce the net weight of the system on the bottom to ~ 3 lb./linear foot and provides a means to recover each system for inspection and maintenance.

Sediment resuspension at the intake and discharge headers is anticipated to be minimal as the velocity of water entering and leaving the pipeline is designed to be less than 0.1 – 0.3 feet/second. This should also minimize the impingement and/or entrainment of fish and fish larvae.

To limit zebra mussel fouling of the intake and discharge header, both will be protected by anti-fouling coated screens with 0.032 – 0.062" screen openings. This will adequately pass flow without creating clogging issues. Intake and discharge headers are designed with a safety factor of 10. This allows for 90 percent of the screen opening to be clogged before the design flow velocity is compromised.

As designed, the Honeoye Lake SSS system will reoxygenate 560,000 gallons/day of the lake's hypolimnetic volume. Some questions and concerns have been raised regarding this representing a small fraction of the lake's total hypolimnetic volume and the ability of the system to meet the lake's hypolimnetic oxygen demand. However, the system is designed and sized to address the lake's hypolimnetic oxygen demand. As noted, the SSS system will add 250 kg O_2/day, which is the peak oxygen demand of the lake's hypolimnion (refer to Section 2.4). Because the lake's oxygen consumption rate can be met or even exceeded by calibrating the introduction of oxygen, operation of the SSS system will prevent hypolimnetic anoxia and the internal regeneration of phosphorus from the sediments.

The operation of the SSS system will not alter the lake's thermal properties. The temperature and density of the water withdrawn and returned to the lake will not vary greatly. The oxygen-saturated water returned to the lake bottom via the discharge manifold will diffuse into the lake bottom water across a thermal density gradient below the thermocline.

Figure 19 - Schematic of Equipment in a Typical SSS System Pump house

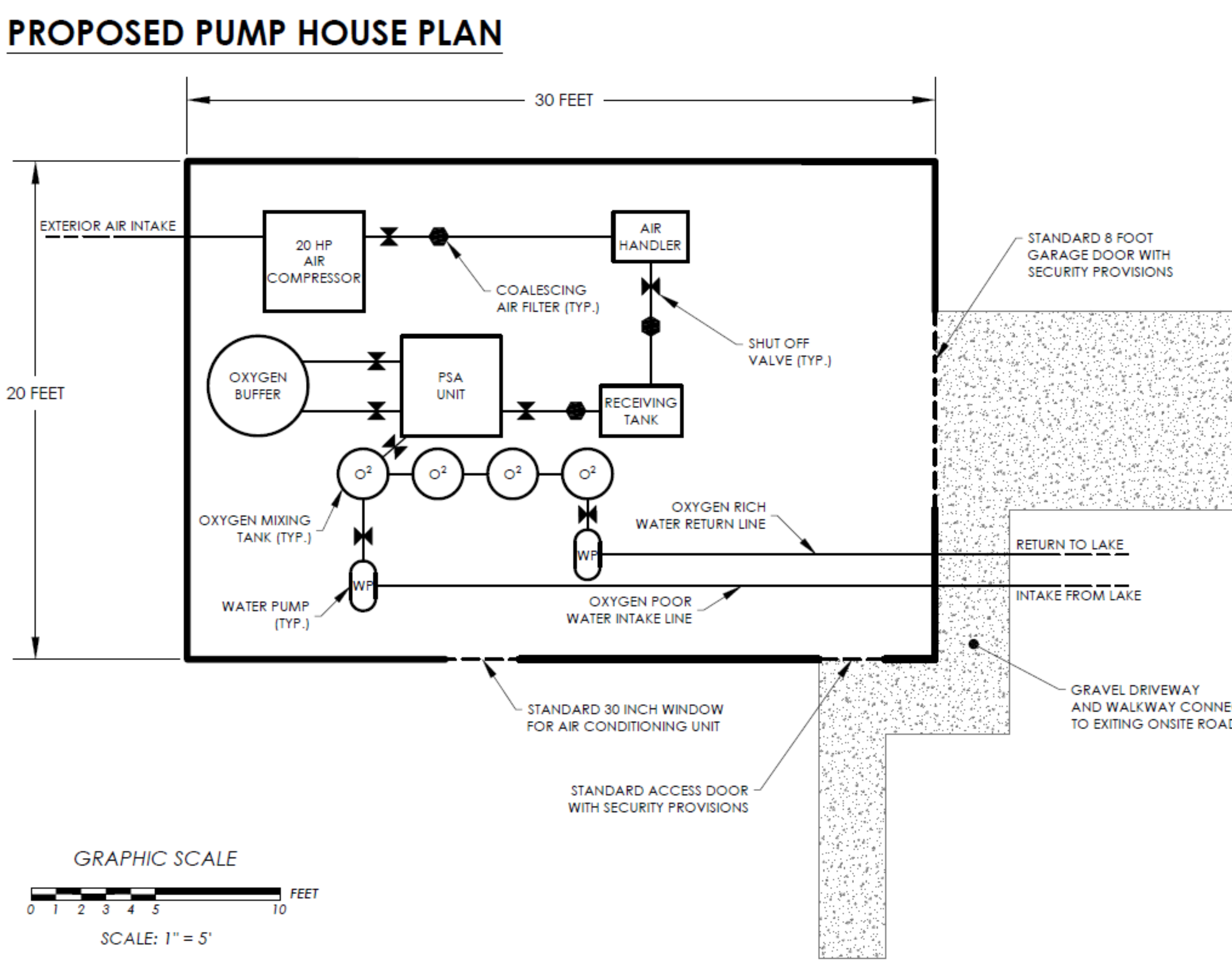


Figure 20 - Illustration of a Typical PSA Setup

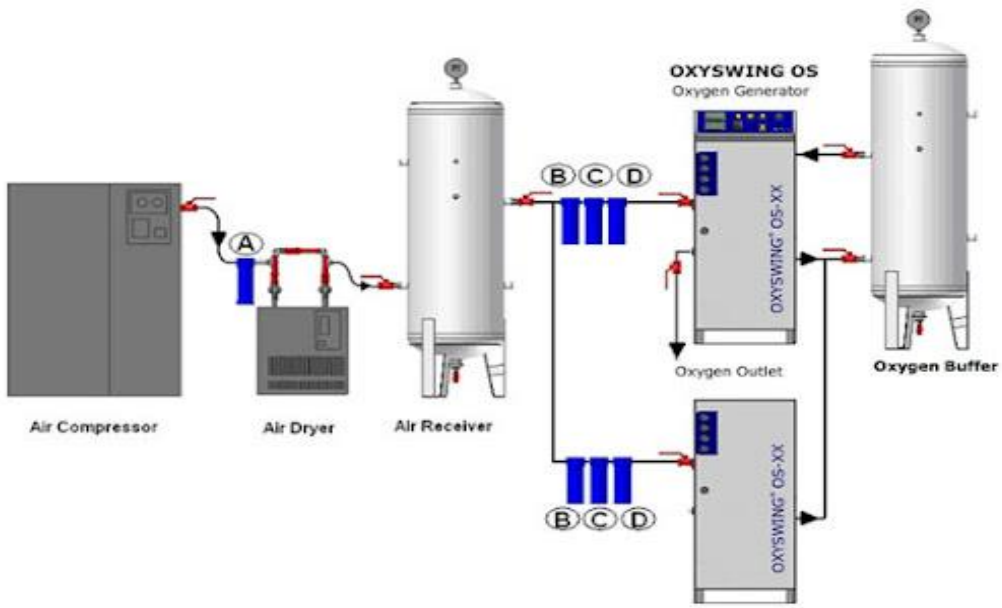


Illustration Courtesy of Jacobs Engineering

Figure 21 - Location of the Intake Manifold, Discharge Manifold and Associated Piping Leading to and from Conceptual Pump House.

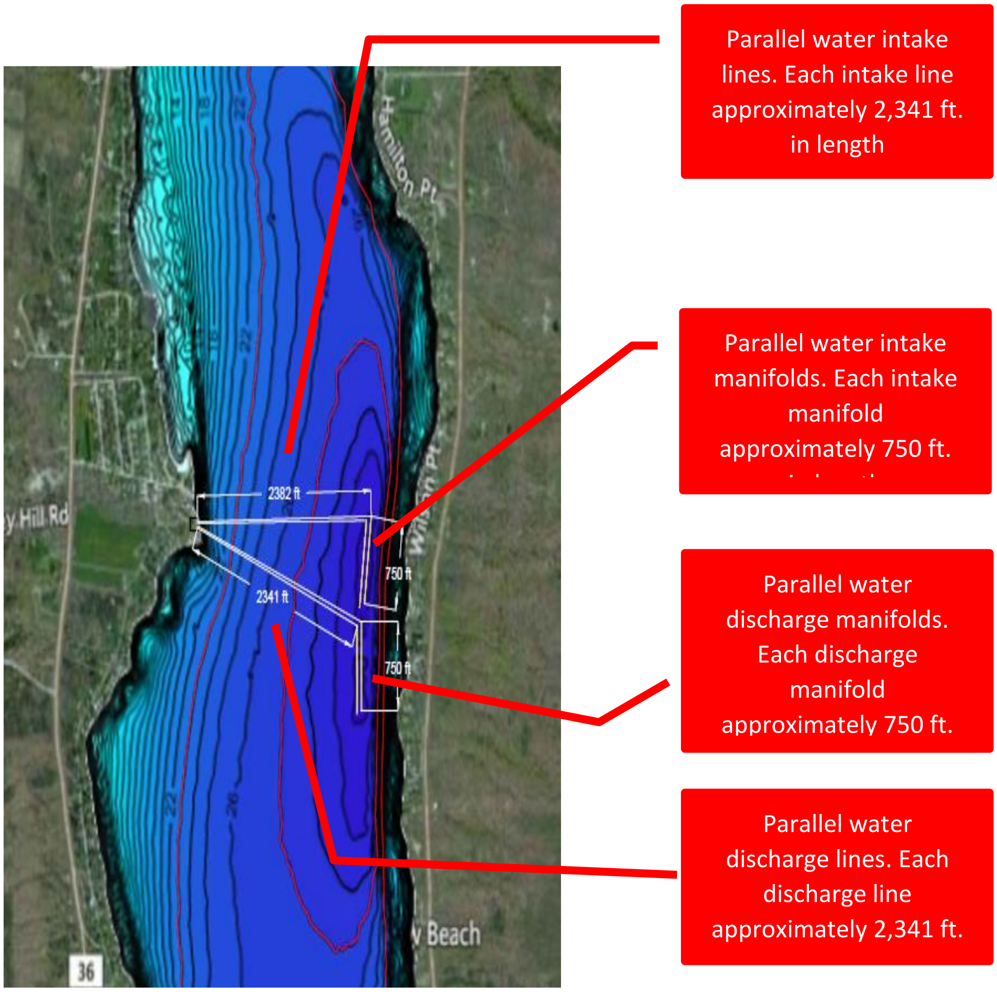


Figure 22 - Potential Pump House Location (Not to Scale) at Conceptual California Ranch Point Site.

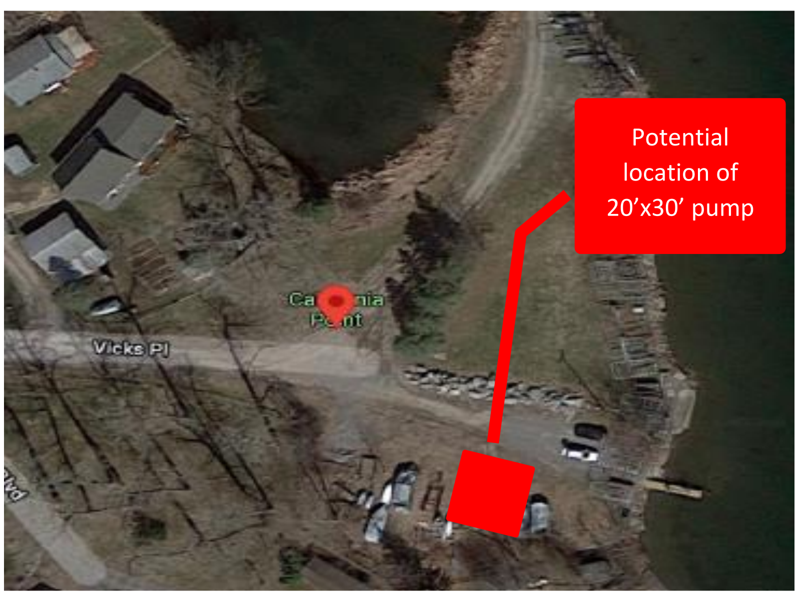
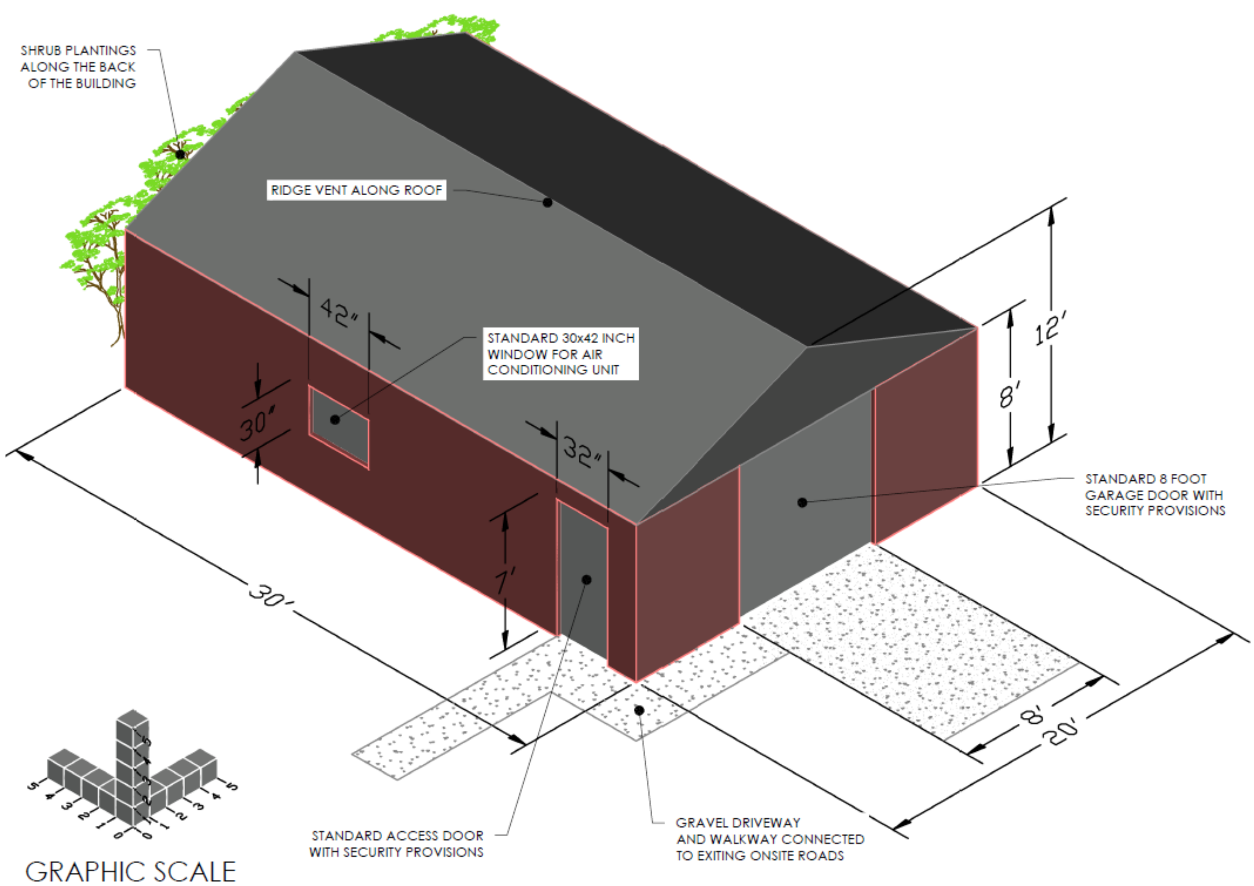


Figure 23 is a conceptual rendering of the pump house. The building will need to be set on a poured in place concrete pad. It should have a large garage door not only to make it more easily accessible for periodic equipment inspection and maintenance, but also to facilitate the initial installation and setup of the land-based elements of the system. Details will be provided at a later date of the building's insulation and sound deadening requirements and heat dissipation equipment and venting. In general, insulation and sound deadening can be accomplished using spray foam. The expected external noise level of the system during operation, as measured beyond 50 feet of the building is 50 dB (less than the sound level of a typical conversation or an air conditioner) as based on the consultant team's experience with other lake aeration systems. Heat management will be accomplished using both passive roof vents as well as thermistor activated powered louvres. The power louvres can be set on timers limiting their operation to daylight hours of the day (7:00 AM – 7:00 PM) further limiting any nighttime noise issues. It is recommended the exterior façade and vegetative buffers and/or landscaping materials be designed in cooperation with the landowner to provide appropriate visual screening and to enhance sound deadening. It is also recommended the building be surrounded by security fencing and equipped with an external security system consisting of motion activated LED lighting and motion activated internal and external security cameras. The security system should have remote notification capability via a smartphone application.

Figure 23 - Simple Rendering of SSS System 20'x30' Pump House



2.6 ESTIMATED CAPITAL AND OPERATIONAL COSTS OF HONEOYE LAKE SSS SYSTEM

A capital costs (equipment and installation) breakdown of the proposed SSS system, capable of generating 250 kg O_2/d, is presented in Table 4.

Table 4 - Itemized Projected Capital and Installation Costs of Honeoye Lake SSS System

Item	**Cost**
PSA unit (1)	$40,000.00
Air compressor (1) including all air filters and air metering equipment	$52,000.00
Water pumps (2)	$32,000.00
Oxygen mixing chambers (4) including all filters	$38,000.00
Water intake and discharge lines	$96,000.00
Intake and discharge manifolds	$63,000.00
Ballast and buoyancy lines	$99,000.00
Freight on above items	$108,000.00
Miscellaneous installation materials and supplies including alarm system	$78,000.00
Pump house (including slab, construction, insulation, sound deadening, fencing, landscaping, security and cooling)	$62,000.00
Installation of 3-Phase Power	$15,000.00
Total Equipment + 20% Contingency/Markup/Inflation	**$819,600.00**
Preparation of NYSDEC permit materials, SEQR materials and permit fees	$80,000.00
Architectural and Engineering: Final Specifications and Bidding Documents	$75,000.00
Installation Labor including general contractor and installation oversight	$220,000.00
Total Projected Cost	**$1,194,600.00**

Table 4 does not include replacement or backup equipment. An equipment parts and replacement budget could be established at the front end of an implementation project to ensure adequate resources for emergency repairs and parts.

Utilities. In keeping with the equipment manufacturers' specifications, to effectively and efficiently power the compressor, water pumps and PSA, the lake's SSS system requires a 3-Phase, 480 Volt power source. The utility cost to run the system is approximately $132 to $166 per day (approximately $19,800 - $24,900 annually, assuming five months of full operation per year) as based on $0.144/Kw-h[12]. This reflects the power needed to operate the PSA unit, the system's water pumps and compressor (total of 50 HP), as well as cooling fans, interior lights, alarm system and ancillary power needs.

System Maintenance. Annual maintenance of the system will consist of the seasonal inspection and maintenance and end of year winterization of the land-based elements. Typically, this is done through a service contract with the equipment supplier or a local firm that specializes in compressor, air handler, and water pump maintenance. The average annual maintenance costs, as based on the Princeton Hydro team's experience with other similar systems, is in the range of $2,000-$3,000/year. At the beginning of the season there will be the need to inspect and clear the intake and discharge pipes, headers, and header screens for zebra mussel fouling and conduct any routine maintenance of the underwater elements of the system. For this servicing, the lines and

[12] National Kw/hr. average as per Bureau of Labor Statistics, September 2021. Operational costs could be significantly decreased by operating the system for shorter period of time, with the operation schedule more closely aligned with the lake's polymictic pattern of stratification/destratification and deep-water anoxia

headers can be raised to the surface of the lake using the attached buoyancy lines. This negates the use and the cost of hiring professional divers for the routine inspection, maintenance, and servicing of the system. Permits or required permissions if navigation will be temporarily impacted during inspection are discussed in Section 5. The projected cost to inspect, service, and conduct routine maintenance of the underwater elements of the system is approximately $7,500 annually assuming it will require three full days of work by a two-person crew plus equipment, materials, and supplies[13]. As such, between $10,000 and $12,000 should be set aside for the routine inspection, servicing, and maintenance of the SSS system. The total estimated operating costs of the Honeoye Lake SSS system is summarized in Table 5.

Table 5 – Itemized Estimated Maximum Annual Operational and Maintenance Costs	
Item	**Cost**
Utility (electrical) costs (maximum)	$24,900.00
Equipment servicing by manufacturer licensed provider (maximum)	$3,000.00
Annual inspection and maintenance of submerged in-lake elements	$7,500.00
Total Estimated Annual Operational and Maintenance Costs	**$35,400.00**

[13] This is a very conservative (high) estimate for the routine maintenance of system's in-lake components. The biggest concern is associated with the potential fouling of the lines and headers by zebra mussel. If fouling is minimal the inspection of the in-lake elements could be conducted bi-annually rather than annually.

SECTION 3: SYSTEM MAINTENANCE PLAN

3.1 ANNUAL OPERATING PLAN

The overriding goal of the Honeoye Lake aeration system is to maintain oxic conditions at a minimum 4 mg/l dissolved oxygen (DO) at the lake bottom for the purpose of controlling and reducing internal phosphorus loading. This is adequate DO to prevent anoxic sediment release of phosphorus and support a mid-summer fishery in the lake's hypolimnion.

On an annual basis it is imperative that the system be ready to go into operation no later than May 1. This is well in advance of the lake's historic pattern of thermal stratification and deep-water anoxia. However, completing a system inspection by the end of April should provide ample opportunity to ensure the system is ready to be put into full operation in May or June.

The following is a basic operating schedule including inspection of the system's land-based and in-lake elements. Please note the annual inspection, maintenance and servicing schedule is generic and may need to be modified to some extent based on the local availability of trained/certified technicians or the equipment manufacturers' specification.

- No later than March conduct all required servicing of the land-based elements of the system by a certified maintenance specialist and conducted for each element in accordance with the manufacturer's maintenance and servicing requirements.
- No later than March inspect the pump house building for any damage and complete necessary repairs. Ensure heat and noise mitigation components of the building are functioning properly.
- The system's design includes buoyancy line that enables each line to be independently floated to the surface for inspection and cleaning. This limits the need for diver-based maintenance of the system[14]. This allows inspection and cleaning be conducted simultaneously without the added cost and safety to perform the work underwater. The pre-operational inspection/maintenance of the in-lake elements of the system should be scheduled for early-April, with permission from Ontario County Office of Sheriff and New York State Office of Parks, Recreation and Historic Preservation (Marine Services Bureau) and prior notice to DEC, marinas, Honeoye Valley Association, lakeshore residents, and other relevant entities. Priority should be given to the inspection of the antifouling screens on the intake and discharge manifolds. The intake and discharge lines should also be inspected along their entire length for any evidence of damage or disconnection from the anchoring ballast or floatation lines. The intake and discharge lines and intake and discharge headers and anti-fouling screens should also be cleared at this time of any zebra mussel build up. Based on information obtained from Dr. Paul Gantzer (2022), full inspection of the air lines should take a 2-person crew no more than a single day to complete; including the time needed to raise and lower the lines. If the lines are fouled with zebra mussels, it could take an additional 1-2 days to unfoul the lines depending on the density of zebra mussels.
- No later than mid-May, turn system fully on and operate accordingly through mid-October[15]. It may be advantageous to further decrease the lake's legacy SOD to continue to partially operate the system later into the fall.
- Throughout the operating period collect weekly water column temperature and dissolved oxygen

[14] The Project Lead may wish to consider, following the first year of system operation, conducting a diver-based inspection of the system to check the integrity of the submerged elements of the system, zebra mussel fouling, etc. Such an inspection would be conducted in late-September/early-October, following the natural autumnal turnover of the lake but before any significant fall/winter cooling of the lake.

[15] This is a conservative period of operation. After the first two years of operation, due to the lake's natural heating and cooling pattern, it may only be necessary to operate the system from May through September.

concentration data (surface to bottom at 1-meter increments)[16]. Use these data, if necessary, to adjust the operation of the PSA and increase/decrease the amount of oxygen mixed with lake water.

- At system shutdown (following lake turnover and surface cooling) in mid-October or earlier, winterize the land-based elements of the system. System winterization should entail clearing all intake and discharge lines of water, and the shutdown, annual inspection and lubrication of the compressors and water pumps and all other requirements prescribed by the manufacturers of the pumps, compressors, PSA, oxygen mixing vessels, air receiving and storage tanks and related system monitoring equipment.

Some questions have been raised about intermittently shutting down the system during the summer following polymixis, the periodic mid-summer turn-over of the lake, as a way of reducing operational costs. This should not be done. First, even when the lake experiences polymixis, the bottom waters may not fully reoxygenate and/or the resulting interim reoxygenation is not enough to meet hypolimnetic SOD. This is reflected in Figures 10-14. The data show that once the hypolimnion becomes anoxic it never fully recovers until late September when Honeoye Lake has cooled and becomes fully destratified, with uniform temperature throughout the water column. As such, the system should be operated continuously during the treatment cycle. Periodically shutting it down impacts the ability to maintain oxic conditions in the hypolimnion and may result in higher operating costs and added stress on the equipment.

3.2 LIFETIME MAINTENANCE PLAN

While a general maintenance plan is provided above, it is recommended that a detailed lifetime maintenance plan be prepared after procurement and installation, consistent with manufacturers' user manuals and specifications and installers' recommendations. Warranties should be included in the bid specifications for equipment procurement.

3.3 INSPECTING FOR ZEBRA MUSSEL FOULING

Because invasive zebra mussels exist in Honeoye Lake, it is recommended that all piping and headers be at least annually cleaned of zebra mussels and any other fouling organisms. The proposed system is designed to be brought to the surface by using compressed air to void the buoyancy lines of water. This results in sufficient buoyancy to float the entire system to the surface of the lake. Once on the surface, all traces of zebra mussels, sediment or other fouling organisms should be removed consistent with any regulatory approved methods. Clearing the lines of mussels and other fouling organisms is needed as the added weight could impact the ability to easily float the lines and headers for regular inspection and maintenance. Once the lines and headers are cleaned, the buoyancy lines can be re-flooded which will allow the lines and headers to slowly sink to the bottom of the lake in their original position. It should be possible after the first or second year of operation to determine the frequency that such line and header maintenance is required. If fouling is minimal, it may only be necessary to raise the lines and conduct ant-fouling maintenance once every two or more years.

[16] More details of a post-installation water quality monitoring plan are provided in Section 4.

SECTION 4: ANALYSIS OF POST-INSTALLATION WATER QUALITY IMPROVEMENTS

Analysis of the effectiveness of the SSS system is an important part of an aeration implementation project. Performance objectives for the Honeoye Lake system include:

1. Prevent the onset and development of anoxic conditions in the lake's hypolimnion.
2. Maintain in the lake's hypolimnion a DO concentration of at least 4 mg/L.
3. Significantly reduce the lake's annual internal phosphorus load from the deep sediments.
4. Although not originally a project goal, with the proposed use of the SSS system, demonstrate the performance objectives 1 - 3 are being met without alteration of the lake's thermal profile.

These performance objectives are in keeping with the NYSDEC's phosphorus TMDL (NYSDEC 2019) and HABs Action Plan (NYSDEC 2018) recommendations for Honeoye Lake, which emphasize the importance of controlling internal phosphorus loading as a key strategy to reduce mid-summer HABs. Honeoye Lake hosts valuable sport fisheries comprised of Black Crappie, Bluegill, Chain Pickerel, Largemouth Bass, Pumpkinseed, Smallmouth Bass, Walleye, and Yellow Perch[17]. Maintaining a minimum of 4 mg/l DO concentration in the hypolimnion will also benefit Honeoye Lake's fisheries as based on conversations with NYSDEC Region 8 staff.

Confirmation that the SSS system is meeting the performance objectives can be accomplished using a combination of modeled data (to compute decrease in internal phosphorus loading) and field data (to measure bottom water DO, differences in epilimnetic and hypolimnetic phosphorus, thermal gradients, lake clarity, phytoplankton composition, and cyanobacteria cell counts).

4.1 MODELED DATA

Modeling the SSS system's ability to decrease the lake's internal phosphorus load can be accomplished using the same approach and methodology used by Princeton Hydro as part of the NYSDEC 2020 study[18]. Essentially, this involved the use of bathymetric data, long-term HLWTF DO/temperature profile data and Nürnberg's (1985) anoxic sediment phosphorus regeneration model to calculate the lake's average annual projected hypolimnetic internal phosphorus load. Princeton Hydro (2014 and 2020) computed an annual internal phosphorus load for the lake ranging between 2,161 kg/year to as much as 7,100 kg/year. In both cases, the internal load is based on a median daily internal TP loading rate of 15 mg/m^2/day (Nürnberg's (1985) and an anoxic hypolimnetic area of 808 acres. The lower range load reflects an <u>anoxic period of 45 days per year</u> whereas the higher range load reflects an <u>anoxic period of 145 days per year</u>. The higher range load of 7,100 kg/year is similar to that computed for Honeoye Lake (7,480 kg/year) by NYSDEC using the CE-QUAL-W2 model (NYSDEC 2019).

The modeled pre-oxygenation internal loading range can be used as a baseline to evaluate the SSS system's effectiveness in controlling and reducing the lake's internal phosphorus load. Operation of the SSS system from mid-May through mid-October captures the maximum 145-day period during which the hypolimnion could experience anoxia and internal phosphorus loading. The same computational approach would be followed as was used by Princeton Hydro (2007, 2014 and 2020), which entails the application of the Nürnberg's median daily internal phosphorus loading rate for 60, 90, 120 and 150-day periods of anoxia and the actual number of days of hypolimnetic anoxia observed following operation of the SSS system. The resulting post-operational loads can then be compared to the pre-operational computed load. If the SSS system maintains hypolimnetic DO concentrations of at least 1 mg/L throughout spring and summer, the model will show a significant decrease in, or total elimination of, the lake's internal phosphorus load, regardless of the amount of time the lake is thermally

[17] https://www.dec.ny.gov/outdoor/25579.html
[18] Princeton Hydro. 2020.

stratified. The predicted post-operational internal phosphorus loading data can then be used with one of the standard trophic state models (e.g., Dillon-Rigler 1975; Carlson 1975, etc.) to predict improvements in lake clarity and chlorophyll *a* concentration, two metrics by which to assess changes in algal productivity and bloom development.

4.2 FIELD DATA

Although the modeled data provide insight, the best way to evaluate the performance of the SSS system is to collect detailed field data. Over the past 20 years, the lake's water quality database has been a valuable tool used by the HLWTF to track the lake's ecology, help guide short and long-term lake management decisions, assess the impact of these decisions on overall lake quality, and provide lake users and the community in general with objective, accurate information regarding the status of the lake and its ecosystem. Within Section 2, the Princeton Hydro team made use of the HLWTF dissolved oxygen and temperature data to estimate the average volume of the lake's anoxic hypolimnion. These data were also used to analyze the lake's average oxygen demand, which was computed to be 240 kg O_2 /day (refer to Section 2.6).

As discussed in Section 4.1, using the Nürnberg modeling approach can be used to theoretically assess whether the SSS system is performing as proposed. However, field data is needed to confirm the modeled data. Specifically, field data are needed to confirm:

- The SSS system is preventing hypolimnetic anoxia,
- Hypolimnetic phosphorus concentrations are low and comparable to surface phosphorus concentrations, and
- The lake's thermal profile has not been altered by the operation of the SSS system.

Lake water quality, dissolved oxygen and thermal profile data are annually monitored by HLWTF through the NYSDEC's Citizen State Lake Assessment Program (CSLAP). <u>The current level of sampling should be more than enough to confirm the above three key operational requirements of the system.</u>

However, there may be interest in conducting a more rigorous monitoring program for the <u>first two years</u> following the installation of the system. The sampling program outlined below is only a suggested expanded sampling program and not a mandatory sampling program. The expanded data collection program outlined herein is beyond the scope and budget of the lake's routine CSLAP monitoring program, and thus its implementation will require an additional source of funding. If such a program were implemented, an additional $35,000 per year in funding would be needed, assuming all of the sampling detailed below was conducted by an outside contractor and not by CSLAP volunteers.

Expanded Field Data Approach: The sampling and monitoring plan presented below focuses on the collection of data related to the lake's thermal, DO, nutrient and phytoplankton (including cyanobacteria) dynamics. These data can be used to compliment the modeled data and assess the post-operational effects of the SSS system on the lake's internal phosphorus load. For the first two (2) years following the installation of the SSS system the key water quality data detailed below should be collected twice a month from April through October through the growing season. This encompasses the important periods related to the formation or decay of thermal stratification and DO/thermal relationships that affect internal phosphorus recycling and phytoplankton/HAB development.

On each sampling date, both *in-situ* and discrete water quality monitoring should be conducted. At a minimum, it is recommended one station be established within the 7.5-meter boundary of the hypolimnion, which is the area targeted for reoxygenation. This deep-water station will be the primary sampling station. In addition to the primary sampling station, sampling should be conducted at two intermediate-depth stations, one located south and one north of the deep-water station (Figure 24). If possible, these sampling stations should coincide locationally with the sampling stations routinely monitored by the HLWTF. At each station dissolved oxygen (DO), temperature, and pH will be measured at 1-meter increments from surface to bottom using a multi-probe water quality meter. In addition, the lake's clarity will be measured at each station and reported as Secchi disk transparency.

Discrete water sampling and analysis will be conducted at each of the three (3) in-situ stations noted above. At each station a discrete water sample will be collected from the lake's epilimnion (1 m), metalimnion (4-6 m depending on the presence and depth of the thermocline), and within the hypolimnion (8 m). These samples will be analyzed for:

- Total Phosphorus (TP),
- Soluble Reactive Phosphorus (SRP),
- Ammonia-N (NH3-N),
- Nitrate-N (NO3-N),
- Total Suspended Solids (TSS),
- Total Iron (Fe), and
- Chlorophyll a (epilimnion only).

Finally, a plankton sample will be collected at the central, deep-water station for the quantitative analysis (cell counts) of the lake's phytoplankton and zooplankton assemblage. These samples can be obtained as a vertical net tow using plankton nets pulled from a starting depth that coincides with the thermocline (or 4 meters whichever is deeper) to the surface.

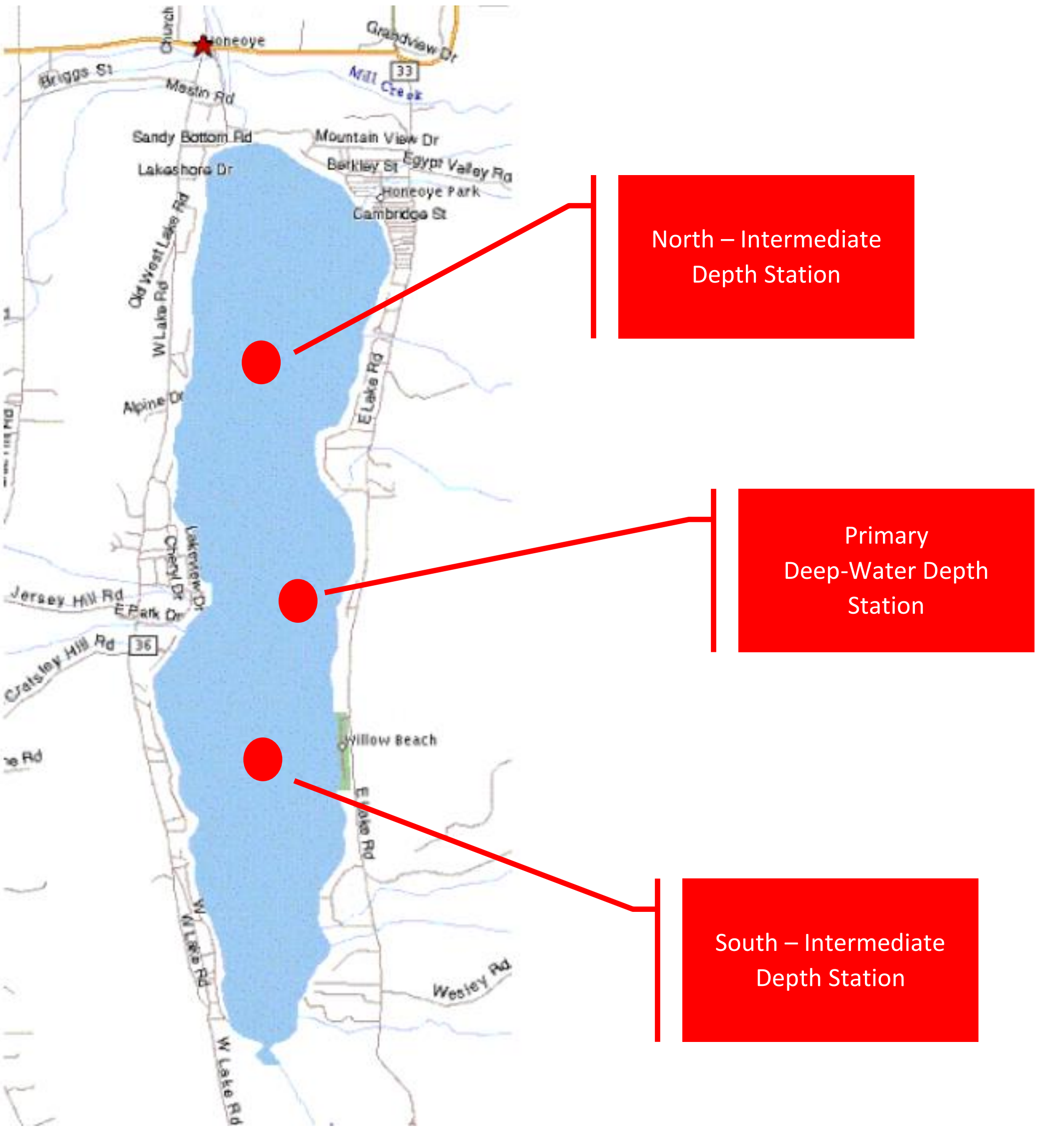
The above in-field data will provide a direct evaluation and assessment of the overall performance of the SSS system providing the data needed to confirm:

- The maintenance of a DO concentration of at least 4 mg/L within the lake's hypolimnion.
- Seasonal changes in the lake's thermal profile and any evidence that the system's operation is altering the lake's thermal properties.
- The system's control of the lake's internal phosphorus load, based largely on the comparison of epilimnetic and hypolimnetic TP and SRP concentrations.
- Changes in lake clarity relative to changes in the lake's chlorophyll *a* concentrations.
- Seasonal changes in the composition of the lake's phytoplankton and zooplankton communities, including the presence and relative dominance of cyanobacteria.
- Any evidence of sediment resuspension, as based on the comparison of hypolimnetic, metalimnetic and epilimnetic TSS concentrations.
- Any evidence of the dissolution of iron from the lake sediments as based on seasonal and spatial changes in the lake's Fe concentrations.
- Production of ammonia due to deep-water, oxygen reduced conditions.
- Availability of nitrate, an easily bio-assimilative form of nitrogen.

The TP and SRP data can also be used to compute mass balance (concentration multiplied by water volume) estimates of both the total amount and bioavailable amount of phosphorus present in the lake over the course of the growing season.

Field data should be collected in accordance with a DEC approved quality assurance plan (QAPP).

Figure 24 – Proposed Sampling Stations, Honeoye Lake Post-SSS Installation Sampling Program



SECTION 5: REGULATORY REVIEW AND APPROVALS

Proposed installation of the aeration system in Honeoye Lake will be subject to regulatory review and approval under multiple jurisdictions, from federal to local. Certain agreements will also need to be established, which are discussed in more detail below. Depending on the final specifications for the project, other agency reviews may be triggered.

5.1 PERMITS AND AGREEMENTS

US Army Corps of Engineers (USACE): Permitting under the Clean Water Act
US Army Corps of Engineers is responsible for a permit program under Section 404 of the Clean Water Act regulating discharge of dredged or fill material into waters of the United States, including wetlands. For the proposed aeration project, trenches will be dredged to bury the water withdrawal and discharge lines in the shallow, nearshore environment to minimize damage to and from boats. As long as the aeration system pump house/equipment is not located in a wetland (triggering additional review), this project would likely fall under USACE's Nationwide Permit Program, a series of general permits for project types having minor effect on waters or wetlands. Nationwide Permit 58 for "Utility Line Activities for Water and Other Substances" would likely apply to the aeration project.

NYS Office of General Services (OGS): Use of Lands Under Water
Honeoye Lake is a public lake. Though most of the perimeter shoreline property is in private ownership, the lakebed (or lands under water) is held in trust for the people of New York State under jurisdiction of the Office of General Services (OGS). Among its functions, OGS Bureau of Land Management reviews applications for activities affecting lands under water pursuant to Public Lands Law. This Bureau also reviews matters affecting navigation pursuant to NYS Navigation Law. Application to OGS Bureau of Land Management will be made to determine whether a license, permit, or easement is required for installation and operation of the aeration system. Permission from the upland property owner where the pump house is to be installed will be required.

NYS ORHP: Floating Object Permit during In-Lake Inspection
An annual floating object permit may be required for inspection of the underwater components, particularly if system intake and discharge lines are floated to the lake surface using the buoyancy lines. A temporary floating object permit may require prior approval from the County's Office of the Sheriff and be subject to review by the Marine Services Bureau of NYS Parks, Recreation and Historic Preservation.

Local Site Plan and Zoning Review
Development of proposed land-based facilities will require approval by the Planning Board of the municipality where the affected parcel is located. Professionally stamped engineering drawings (or plot) are required with an application to the Planning Board. The municipal Planning Board will also review any proposal for subdivision, special use permit, or use variance required to develop and operate the land-based facilities.

The site development application will be referred to Ontario County Planning Board for comment and recommendation if the proposed action is located within 500 feet of a municipal boundary, county or state highway, recreation area, an agricultural district (as defined under Article 25-AA of NYS Agriculture & Markets Law), or under other certain circumstances.

Prior to construction, a building permit must be secured from the local municipality. New construction must be inspected for compliance with applicable building and energy codes prior to issuance of a Certificate of Compliance by the municipality.

Stormwater Management
Construction projects disturbing one (1) acre or more are subject to Federal Clean Water Act stormwater rules, and coverage under the State Pollutant Discharge Elimination System (SPDES) General Permit for Stormwater Discharges from Construction Activity must be obtained. Under the requirements of this permit, a stormwater pollution prevention plan (SWPP) would be required, and the construction project would be subject to inspection by a qualified entity to ensure compliance with pollution prevention measures. The land-based facilities for the SSS system (pump house building and trenching of water intake and discharge lines) should not disturb an acre of land. Nonetheless, the land-based facilities plan should incorporate stormwater Best Management Practices. Ontario County Soil and Water Conservation District can be consulted to provide advice on appropriate measures.

Utility Connection
To bring three-phase electric power to the aeration system pump house, application must be made to National Grid. An easement granted by the property owner for National Grid facilities installed on private property may be required.

Property Agreement
If the pump house is to be installed on private property, a legal agreement (e.g., subdivision and transfer, long term lease, etc.) between the landowner(s) and the project prime will need to be negotiated. Charitable options beneficial to the parties can also be explored.

5.2 NYSDEC AND STATE ENVIRONMENTAL QUALITY REVIEW ACT (SEQR)

The New York State Environmental Quality Review Act (SEQR) is Article 8 of the Environmental Conservation Law. It requires all state and local government agencies to consider environmental impacts alongside social and economic factors when deliberating on actions they have discretion to approve, undertake or fund. SEQR lays out a process to improve decision-making by ensuring 1) agency coordination and communication, 2) determination of a proposed action's "significance" in terms of potential to result in adverse environmental impacts, 3) documentation of potential impacts and options for mitigation for significant actions via completion of an Environmental Impact Statement (EIS), and 4) opportunity for public comment on project documents. Given SEQR's comprehensive and multi-step review process, it is given detailed attention below.

NYSDEC Pre-Application Meeting
The SEQR process is integral to local approval processes outlined above. Local Planning Boards consider SEQR findings in review of development applications. Applications for Department of Environmental Conservation (DEC) permits require submission of an Environmental Assessment Form or EAF, which initiates the SEQR process. Therefore, before initiating any work on local approvals, it is highly recommended that a Pre-Application Permit meeting be scheduled with NYSDEC Region 8 personnel, with staff represented from relevant disciplines, e.g., Permitting, Fisheries, and Wetlands. Through a pre-application meeting, local municipalities, Ontario County, and the HLWTF will be in a better position to determine the types of NYSDEC permits that will need to be obtained for this project and, of equal importance, how to implement the project to minimize impacts.

Based on comments received during a June 2021 Zoom meeting with the project consultants, local project team and NYSDEC, it appears NYSDEC is receptive to the project, including the recommended SSS system, but has concerns related to potential impacts from the placement and anchoring of the water intake and discharge lines and manifolds; turbulence at the intake and discharge headers that could result in sediment disturbance/resuspension; impingement and entrainment of fish at the intake header; and the disturbance of wetlands, riparian and other regulated lands associated with the construction of the pump house and the installation of the air lines at the lake's shoreline. The pre-application meeting will allow specific DEC concerns to be addressed early in the SEQR review process. Such feedback can improve the project environmentally and shorten the application procedure. As such, NYSDEC recommends before beginning the permit process and filing permit applications that the regional NYSDEC permit office be contacted. It is suggested applicants "Keep plans flexible until NYSDEC staff review the proposal and comment on its conformance with permit standards…as minor changes in layout can avoid disagreements and delays and, in some cases, eliminate the need for a permit" (NYSDEC 2020).

Should the project result in the siting of the pump house at the conceptual California Point Ranch site (see Figure 12), this location should eliminate any need for NYSDEC permits associated with disturbance of wetlands or riparian lands, given that the site is already cleared and disturbed immediately to the water's edge and is currently used on a regular basis to launch, moor, and dock boats. Nonetheless, detailed land use and land cover mapping of the site should be conducted in advance of the pre-application meeting and the resulting information available as a series of graphics to present to NYSDEC staff. For cost savings purposes, until so instructed by the NYSDEC, Princeton Hydro suggests waiting to conduct any formal wetland and riparian delineation of the conceptual California Ranch Point site, or any other site deemed equally suitable for the SSS system pump house. To protect the intake and discharge water lines, these lines will need to be trenched between the pump house and the lake. As a result, there will be some disturbance of the lake's shoreline. The remainder of the in-lake elements of the system will be anchored to bottom. While the lines transporting the intake and discharge water to and from the pump house can lie directly in the lake bottom, the intake and discharge manifold lines will be slightly suspended by means of an added buoyancy line above the lake bottom. NYSDEC has permitted other aeration and water intake systems using similarly placed and anchored lines, thus there is some precedent for such an action. Nonetheless, although the Region 8 Fishery representatives that participated in the Zoom meeting held in June 2021 supported in concept the SSS system approach, specific fishery questions about the system may need to be addressed. It will be especially important to have a NYSDEC Fishery representative participate in any pre-application meeting.

Multi-Step State Environmental Quality Review (SEQR) Process

As mentioned above, the installation of the Honeoye Lake aeration system will trigger the SEQR process. Much of the information that follows was obtained from the 2020 (4th Edition) SEQR Handbook published by the NYSDEC Division of Environmental Permitting and DEC webpage https://www.dec.ny.gov/permits/32521.html. However, it also reflects Princeton Hydro's SEQR and environmental permitting history of projects with NYSDEC.

Determine the Project Sponsor and Classify the Action

The first step in the process will be to identify the Project Sponsor who will submit the application for review under SEQR. The next step will be to classify the action, based on definitions described in 6 NYCCR Part 617 (Official Compilation of Codes, Rules and Regulations of the State of New York):

- Type II – a list of actions, described in Section 617.5, that have been determined not to have significant adverse environmental impacts; or
- Type I – a list of actions, described in Section 617.4, that experience has shown are more likely to have significant adverse environmental impact; or
- Unlisted – all actions that are not Type I or Type II. The majority of actions that come under SEQR review fall under this classification.

Type II actions are categorical exclusions from SEQR, and no further environmental review is required. Both Type I and Unlisted Actions require further review under SEQR through preparation of the Environmental Assessment Form (EAF).

Lead Agency, EAF, and Coordinated Review

It will be necessary to identify the Lead Agency that will coordinate the review process of the EAF. The pre-application meeting with DEC will be used as the means to identify the appropriate Lead Agency.

For all projects subject to SEQR (Type I and Unlisted), it is mandatory an EAF be prepared and submitted to the Lead Agency by the Project Sponsor. An EAF workbook is available through NYSDEC (https://www.dec.ny.gov/permits/90125.html). The workbook provides guidance on the content and preparation of the EAF. Preparation of the full, 3-part EAF entails investigation and discussion of a wide array of potential ecological and socio-economic impacts from the project. Where applicable, it should also identify how such impacts can be averted, minimized and/or mitigated. A more succinct form, the short EAF, may be used for some Unlisted Actions.

Declaration of Significance

Following coordinated review, with participation by multiple "involved agencies" with jurisdiction or interest in the project, the Lead Agency will determine whether the project results in significant adverse environmental impact and issue a declaration. If it is determined there will be no significant adverse impacts, the Lead Agency will issue a Negative Declaration and the SEQR process ends. If Ontario County is the Lead Agency, the County Board of Supervisors would act to accept the Negative Declaration following a public hearing. Conversely, if the Lead Agency determines the project could have a significant adverse environmental impact, a Positive Declaration is issued and the SEQR process continues with the preparation of a detailed Environmental Impact Statement (EIS). For Unlisted Actions, a Conditioned Negative Declaration may be issued in certain circumstances.

Draft EIS

Preparation of a Draft EIS first requires a scoping process, usually by the Lead Agency, to focus the issues to be investigated and to provide for public participation. The Draft EIS is reviewed by the Lead Agency. When revisions are complete and the Lead Agency determines the Draft EIS is adequate, a Notice of Completion of the Draft EIS is published. The revised Draft EIS is then made available for 30-day public review and comment. The Lead Agency will decide whether to hold a public hearing on the Draft EIS, which is not mandatory under SEQR. If a hearing is to be held, notice of such shall be as prescribed in 6 NYCCR Part 617, Section 617.12. If a public hearing is required under applicable local or state law, it is not necessary to hold a separate SEQR hearing.

Final EIS and Findings

After addressing and incorporating public comments received, a Final EIS will be prepared and submitted to the Lead Agency. When the Lead Agency is satisfied that the Final EIS is adequate, a Notice of Completion of the Final EIS is published and the Final EIS is made publicly available. A SEQR Findings Statement must be prepared by each involved agency before the Lead Agency renders its Findings, either Positive (the project or action is approvable) or Negative (the project or action is not approvable with an explanation of reasons for denial).

Overall, the SEQR process is likely to take approximately six months to complete following the submittal of the EAF to the Lead Agency with a Positive Declaration. Given the complexity of the SEQR process and the level of detail associated with adequate preparation of the EIS, the cost to prepare documentation and complete the SEQR process could exceed $50,000. Add to this preparation costs of any local, county or NYS DEC or OGS applications for the construction of the pump house or installation of the in-lake elements of the aeration system, and it is possible that the total permitting costs for the project could be close to $80,000. The cost estimate for the SSS system in Section 2.6 includes this estimate for permitting and SEQR review.

5.3 IMPACT ASSESSMENT UNDER SEQR

The SSS System recommended in this report is designed to optimize benefits to water quality and minimize risks and adverse impacts to the Honeoye Lake ecosystem and greater community. Potential impacts to be further evaluated under SEQR are included in Table 6.

Table 6 - Potential impacts for review under SEQR	
Potential Impact	**Comment**
Fish and Wildlife Habitat	Maintenance of DO at lake bottom will enhance cool water fish habitat; slow rate of withdrawal and discharge will minimize artificial water movement that could impact fish and wildlife in the treatment zone.
Zooplankton and Phytoplankton Food Chain Dynamics	Screens on intake and discharge manifolds will limit trapping of organisms. Some plankton will be entrained in the system in the deep waters, but impact on primary food sources is not expected to be significant.
Aquatic Macrophytes	Increasing water clarity could extend the growth of macrophytes into deeper water and the macrophyte growing season.
Wetlands	No known impacts currently.
Endangered or Threatened Species	Requires investigation.
Sedimentation/Sediment Resuspension	The system is designed with low flow rates to minimize sediment disturbance and resuspension at the intake and discharge manifolds. The system should not increase sedimentation to the lake bottom and may, through increased decomposition with the addition of oxygen, eventually cause a net decrease in the organic muck layer in the deep water zone.
Thermal Profile	Unlike the aeration destratification system that circulates water from bottom to top, the SSS system will not disrupt the natural thermal profile.
Shoreline Disturbance/Modification	Installation of the intake and discharge lines will disturb approximately 20 linear feet of shoreline. Boat docking, swimming, and other uses will be impacted in this area. A 20 x 30 pump house will be constructed on slab. Potential for erosion during construction can be minimized through erosion and sediment control practices.
Aesthetics	
Pump House	Design features and vegetative screening can be used to minimize visual impacts.
Noise	System componentry is designed to minimize noise impacts from pumps and compressors. Sound insulation in the building can further minimize noise disturbances.
In-Lake Disturbances	The system is designed to operate in the deep water with no observable impact at the water surface, e.g., bubbling or currents.
Access and Traffic	Impacts can be minimized by locating pump house where access already exists or requires minimal disturbance. Traffic to pump house, except during construction and installation, should be minimal and not cause unreasonable adverse impacts to adjoining properties or increase burden on public roads.
Navigation, Recreation, and Angling	Navigation will be temporarily impacted during installation and annual inspection. Impacts can be minimized by scheduling installation and annual maintenance around the peak lake usage season. Information can be posted at public access points and on websites to inform lake users about the location of SSS system equipment to reduce potential snagging of fishing lines or damage to/from boats propellers where the intake/discharge lines extend from shore.
Mechanical Weed Harvesting	Weed harvesting operations will need to be reduced near shore where intake/discharge lines are located to protect equipment.
Fiscal	Grants can be applied for to reduce the local fiscal impact to an estimated 25% of the project cost. In-kind effort from local agencies and private donations may help further reduce the cost to local governments. New annual operating and maintenance budgets must be established.

SECTION 6: COMMUNITY CONSIDERATIONS

This report details a recommended custom aeration system to maintain oxic conditions and reduce internal phosphorus recycling and associated HABs in Honeoye Lake. On 26 April 2022 a virtual public meeting was conducted during which the proposed lake oxygenation design was introduced and discussed. Appendix A contains questions raised by the public during the meeting and the associated answers to each question. After reviewing the recommended aeration system and associated data and information in this report, deliberation on some practical questions related to roles, responsibilities, and resources will help build community consensus on next steps:

- Is there public support to pursue an implementation grant for an aeration system, likely with a 25% local cost share commitment?
- Who will have primary responsibility for overseeing the aeration system operations and maintenance? Will a separate department with trained staff be created, or can it fit under an existing municipal department? To what extent will operations and maintenance be contracted out?
- Who will respond to alerts in event of malfunctions?
- How will the local share of the capital cost and operations/maintenance be borne and budgeted?
- Who will be responsible for implementation project tasks such as:
    - Grant application(s) and contract(s)
    - Negotiating an option agreement for the pump house site
    - Bid specifications and vendor contracts
    - SEQR process
    - Permitting and Government Approvals
- How will system performance be measured and reported to stakeholders and the community?

There is a long history of cost sharing and cooperation in the Honeoye Lake community, which can assist the community in building a sustainable plan to move forward should it decide to pursue an aeration system to improve the health of Honeoye Lake.

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GLOSSARY OF KEY TERMS

Acidity - The state of being acid, that is, of being capable of transferring a hydrogen ion in solution; solution that has a pH value lower than 7.

Alkalinity - The capacity of water for neutralizing an acid solution. Alkalinity of natural waters is due primarily to the presence of hydroxides, bicarbonates, carbonates and occasionally borates, silicates and phosphates. It is expressed in units of milligrams per liter (mg/l) of $CaCO_3$ (calcium carbonate). Low alkalinity is the main indicator of susceptibility to acid rain. Increasing alkalinity is often related to increased algal productivity. Lakes with watersheds having a sedimentary carbonate rocks geology tend to be high in dissolved carbonates (hard-water lakes), whereas those in a watershed with a granitic or igneous geology tend to be low in dissolved carbonates (soft water lakes).

Amictic – Lakes that never thermally stratify and remain isothermal year-round

Anthropogenic activities – Impacted by, created by, or resulting from human activities.

Aeration - A process which promotes biological degradation of organic matter in water. The process may be passive (as when waste is exposed to air), or active (as when a mixing or bubbling device introduces the air).

Algae - Microscopic plants and other organisms which contain chlorophyll and live floating or suspended in water. Algae may also form dense colonies and mats. Algae also may be attached to structures, rocks, or other submerged surfaces. It serves as food for fish and small aquatic animals. Excess algal growths can impart tastes and odors to potable water. Algae produce oxygen during sunlight hours and use oxygen during the night hours. They can affect water quality adversely by lowering the dissolved oxygen in the water during the night or after die-off. See also phytoplankton.

Alum Treatment - Process of introducing granular or liquid alum (aluminum sulfate) into the lake water, to create a precipitate or floc that is used to strip the water column of fine particles and algae or used to treat the bottom sediment for the purpose of limiting the internal recycling of phosphorus.

Ammonia - A colorless gaseous alkaline compound that is very soluble in water, has a characteristic pungent odor, is lighter than air, and is formed as a result of the decomposition of most nitrogenous organic material. A key nutrient.

Anoxia - The absence of oxygen in the water column, typically used to describe concentrations less than 0.5 mg/L.
Anoxic – Devoid of oxygen or dissolved oxygen. DO concentrations less than 1.0 mg/L are generally treated as anoxic.

Autotroph – Autotrophs are primary producers that sustain their energy from photosynthesis. Phytoplankton and macrophytes are autotrophs.

Bathymetry - (1) The measurement and mapping of water depths and bottom contours.

Best Management Practices - Schedules of activities, prohibitions of practices, maintenance procedures, and other management practices to prevent or reduce the pollution of waters of the United States. BMPs also include but are not limited to treatment requirements, operating procedures, and practices to control plant site runoff, spillage or leaks, sludge or wastewater disposal, or drainage from raw material storage. Practices or structures designed to reduce the quantities of pollutants -- such as sediment, nitrogen, phosphorus, and animal wastes that are washed by rain and snow melt from farms into surface or ground waters.

Chlorophyll *a* - A green pigment found in photosynthetic organisms responsible for the absorption of light and subsequent photosynthesis. May be used as an indicator of algal biomass or to quantify the degree of eutrophication.

Clarity - The transparency of a water column. Commonly measured with a Secchi disk.

Conductivity or Conductance – See Specific Conductivity.

Cyanobacteria – Photosynthetic bacteria with similar characteristics to phytoplankton that can produce toxins under certain environmental conditions. Sometimes referred to as blue-green algae, although they are not taxonomically classified as algae. Blooms of cyanobacteria can be harmful to humans and wildlife and cause impairment of aquatic resources. Cyanobacteria possess certain competitive advantages including the ability to fix atmospheric nitrogen and to utilize organic forms of phosphorus.

Debris - A broad category of large manufactured and naturally occurring objects that are commonly discarded (e.g., construction materials, decommissioned industrial equipment, discarded manufactured objects, tree trunks, boulders).

Detritus - Any loose material produced directly from disintegration processes. Organic detritus consists of material resulting from the decomposing organic materials or from terrestrial sources like leaves.

Diel – Refers to the course of events over a day and includes both diurnal and nocturnal cycles. In limnology diel variations are measured in a variety of parameters.

Dimictic Lake - Lakes that stratify and destratify to a fully mixed state twice per year, generally in the spring after ice out and once again in fall, with the fall mixing event the more ecologically significant of the two.

Dissolved oxygen – The concentration of the gas oxygen (O_2) present in water. Dissolved oxygen (DO) can be an indicator of the ecologic function of the waterbody. Oxygen is more soluble at lower temperatures and less soluble at higher temperatures. Contributors to DO in water include atmospheric diffusion, photosynthetic processes of algae and aquatic vegetation, and tributary streams. Percent saturation refers to maximum concentration of DO per a given temperature due to atmospheric diffusion. Supersaturated conditions occur when excessive photosynthesis contributes more DO to a system than would occur through inorganic processes alone at a given temperature.

Epilimnion- The upper layer of water in a thermally stratified lake or reservoir. This layer consists of the warmest water and has a fairly uniform (constant) temperature. The layer is readily mixed by wind action.

Eutrophication - A process that occurs when a lake or stream becomes over-rich with nutrients; as a consequence it becomes overgrown in algae and other aquatic plants. These autotrophs senesce or die and are decomposed by microbes. This decomposition or respiration by microbes can significantly reduce dissolved oxygen levels to the impairment of other aquatic organisms. Eutrophication can be a natural process or it can be a cultural process accelerated by an increase of nutrient loading to a lake by human activity. Fertilizers, which drain from the fields, and nutrients from animal wastes and sewage are examples of cultural processes and are often the primary causes of the accelerated eutrophication of a waterbody.

Erosion- The wearing down of land surface by wind or water. Erosion occurs naturally but can be caused by farming, residential or industrial development, mining, or timber-cutting.

External Loading - The process by which nutrients, particularly nitrogen and phosphorus, enter a waterbody from the watershed and other external sources, such as runoff, groundwater, or air.

Fecal contamination - The presence in water bodies of living organisms (bacteria and viruses) or agents derived by fecal bacteria that can cause negative human health effects. Fecal contamination may be a result of wildlife, livestock, pet, waterfowl or septic and sewage discharges.

Gas Sparging – the process in which gas (typically compressed air or oxygen) is released directly into the water column with intent to increase oxygen concentrations and improve water quality.

Harmful Algae Blooms (HABs) - any concentration of algae that causes impacts to an aquatic system that can be documented as hazardous to human or ecological health. Algae is a broad term, and many groups can cause HABs. However, cyanobacteria (also called blue-green algae) tend to represent the greatest risk and are sometimes thought of as synonymous with HABs. Toxin-producing cyanobacteria pose human health impacts, which tend to get the most attention, but ecological effects can be quite harmful as well.

Hydrology - The occurrence, circulation, distribution, and properties of the waters of the earth, and their reaction with the environment. For lakes this is usually associated with the quantification of the water flow into and out of the system and the study of pollutant transport that occurs in concert with the inflow.

Hypereutrophic - Pertaining to a lake or other body of water characterized by excessive nutrient concentrations such as nitrogen and phosphorus and resulting high productivity. Such waters are often shallow, with algal blooms and periods of oxygen deficiency. Slightly or moderately eutrophic water can be healthful and support a complex web of plant and animal life. However, such waters are generally undesirable for drinking water and other needs. Degrees of eutrophication typically range from oligotrophy (maximum transparency, minimum chlorophyll-a, minimum phosphorus) through mesotrophy, eutrophy, to hypereutrophy water (minimum transparency, maximum chlorophyll *a*, maximum phosphorus). Also see Trophic State.

Hypolimnion - Bottom waters of a thermally stratified lake. This layer consists of colder, denser water. Temperatures may remain relatively constant year around and it may experience little or no mixing with the upper warmer layers of the water body, although almost all lakes of moderate depth (<100 feet) will periodically mix. The hypolimnion of a eutrophic lake is usually low or lacking in oxygen.

Hypoxia - Low dissolved oxygen conditions in the water column, typically documented as less than 2 mg/L

Hypoxic – low or depressed dissolved oxygen concentrations generally less than 2.0 mg/L, but may be applied to DO concentrations less than 4.0 mg/L.

In-situ water quality parameters - in place; *in-situ* measurements consist of measurements of water quality parameters in the field, rather than in a laboratory.

Internal Loading **-** The movement and recycling of nutrients between the lake sediments and the water column.

Invasive species - A species whose presence in the environment is not native, and causes economic or environmental harm or harm to human health.

Limnology - The study of bodies of fresh water with reference to their plant and animal life, physical properties, geographical features, etc. The study of the physical, chemical, hydrological, and biological aspects of freshwater bodies.

Littoral Zone - That portion of a body of fresh water extending from the shoreline lakeward to the limit of occupancy of rooted plants. Sometimes characterized as twice the Secchi depth or at a depth equal to 1% of incident light penetration at the surface.

Land use/ Land cover - The arrangement of land units into a variety of categories based on the properties of the land or its suitability for a particular purpose. It has become an important tool in rural land-use planning.

Macroinvertebrates – Large aquatic invertebrates. Generally applied to aquatic insects, mollusks, and crustaceans.

Macrophyte – Vascular (higher order) plants that grow in water. Includes different growth forms such as emergents, submerged, rooted floating-leaf, and floating. Also known as submerged aquatic vegetation or aquatic weeds. Includes waterweeds, pondweeds, water lilies, and duckweed amongst others.

Mesotrophic - Reservoirs and lakes which contain moderate quantities of nutrients and are moderately productive in terms of aquatic animal and plant life.

Metalimnetic erosion - The "pulsing" of hypolimnetic of bioavailable, phosphorus rich water into the metalimnion and/or epilimnion without the complete destratification of a lake. This influx of phosphorus rich water can stimulate algae and cyanobacteria blooms.

Microbes – Bacteria, fungus, and other microscopic life forms. Generally responsible for the decomposition of organic materials.

Morphometry or Lake Morphometry – The three-dimensional lake basin shape including depth. This term is generally interchangeable with bathymetry. Lake morphometry is characterized by bathymetry surveys.

Monomictic – Lakes that fully mix in late fall/early winter, then remain isothermal in the absence of winter ice cover until the following spring.

Nitrate – The most common form of nitrogen nutrient in most aquatic ecosystems and the nitrogen species most often utilized by plants and algae. Nitrates are generally found in high supply relative to phosphorus and highly mobile in water.

Nitrogen - An essential nutrient in the food supply of plants and the diets of animals. Animals obtain it in nitrogen-containing compounds, particularly amino acids. Although the atmosphere is nearly 80% gaseous nitrogen, very few organisms have the ability to use it in this form with the exception of cyanobacteria or blue-green algae. The higher plants normally obtain it from the soil after micro-organisms have converted the nitrogen into ammonia or nitrates, which they can then absorb. There are various forms of both oxidized and reduced nitrogen including Ammonia and Nitrates.

Non-point source pollution – Non-point source pollution is the enrichment of pollutants or nutrients through stormwater runoff. Natural or human-induced pollution caused by diffuse, indefinable sources that are not regulated as point sources, resulting in the alteration of the chemical, physical, and biological integrity of the water.

Oligotrophic - Deep lakes that have a low supply of nutrients and thus contain little organic matter. Such lakes are characterized by low productivity, high water transparency and high dissolved oxygen.

pH - A measure of the acidity or basicity of a material, or the concentration of the positive hydrogen ion, liquid or solid. pH is represented on a scale of 0 to 14 with 7 representing a neutral state, 0 representing the most acid and 14, the most basic.

Periphyton abundance - Microscopic underwater plants and animals that are firmly attached to solid surfaces such as rocks, logs, and pilings. In smaller streams this can indicate nutrient and thermal enrichment.

Phosphorus - An element that while essential to life, contributes to the eutrophication of lakes and other bodies of water. There are various species or forms of phosphorus including Total Phosphorus (sum of all species), Organic Phosphorus, and Dissolved Phosphorus amongst others. Soluble reactive phosphorus is a measure of soluble orthophosphates.

Photic Zone – The upper layers of lake in which photosynthesis occurs. Generally, depths less than twice the Secchi depth.

Photosynthesis - The process by which plants and algae transform carbon dioxide and water into carbohydrates and other compounds, using energy from the sun captured by chlorophyll in the plant. The rate of photosynthesis depends on climate, intensity and duration of sunlight, nutrient availability, temperature, and carbon dioxide concentration.

Phytoplankton - Very tiny, often microscopic, plants and other photosynthetic or autotrophic organisms found in fresh and saltwater. Phytoplankton drift near the surface of the water where there is plenty of sunlight for growth. Phytoplankton form the base for most lake food chains.

Phycocyanin – Photosynthetic pigment specific to cyanobacteria.

Point-source pollution - Easily discernible source of water pollution such as wastewater treatment plants and other facilities that directly discharge to waterways.

Pollutant loading - The amount of polluting material that a transporting agent, such as a stream, a glacier, or the wind, is actually carrying at a given time.

Polymictic lakes – Lakes that thermal stratify and destratify multiple times over the course of the spring and summer. The intensity of thermal stratification may be weak due to relatively minor density differences between the surface (epilimnion) and bottom (hypolimnion) layers of the lake, making the water column prone to complete vertical mixing (turn over) due to a high energy event linked to windstorms, waves, storm flows, or a lake's internal seiche.

Relative Thermal Resistance to Mixing - (RTRM; unitless) – Equation used to quantify stratification and water column stability. Provides insight into dispersion of oxygen through a particular density layer. RTRM values greater than 80 indicate high water column stability and lower dispersion between two discrete layers. Values around 30 represent weak dispersion and values below 20 are considered unstratified, with dispersion moving more freely through a defined density layer.

Respiration – The consumption of organic materials by living organisms in a lake. All aquatic life forms, including microbes, algae, zooplankton, and fish respire organic materials. Respiration can lower pH values and for most organisms except certain bacteria requires dissolved oxygen.

Secchi disk transparency - A flat, black and white disc lowered into the water by a rope until it is just barely visible. At this point, the depth of the disc from the water surface is the recorded Secchi disc transparency.

Sedimentation - 1. Process of deposition of waterborne or windborne sediment or other material; also refers to the infilling of bottom substrate in a waterbody by sediment (siltation). 2. When soil particles (sediment) settle to the bottom of a waterway.

Specific conductance - A rapid method of estimating the dissolved-solids content of a water supply. The measurement indicates the capacity of a sample of water to carry an electrical current, which is related to the concentration of ionized substances in the water. Also called conductance.

Stormwater runoff - Stormwater runoff, snow melt runoff, and surface runoff and drainage; rainfall that does not infiltrate the ground or evaporate because of impervious land surfaces but instead flows onto adjacent land or watercourses or is routed into drain and sewer systems.

Stratification - Formation of water layers each with specific physical, chemical, and biological characteristics. As the density of water decreases due to surface heating, a stable situation develops with warmer, less dense water overlaying cooler, denser water. During stratification there is no mixing between layers, establishing chemical as well as thermal gradients. Stratified lakes are often described as having three distinct layers, the Epilimnion comprising the top warm layer, the thermocline (or Metalimnion): the middle layer, which may change depth throughout the day, and the colder Hypolimnion extending to the floor of the lake. Even relatively short periods of thermal stratification can affect many chemical and biological processes in a lake. Probably the most notable effects that can occur when stratification sets in are the loss of oxygen in the hypolimnion and the subsequent accumulation of reduced chemical constituents (e.g., hydrogen sulfide, ammonia, manganese, ferrous iron, and phosphate).

Submerged aquatic macrophyte - Large vegetation that lives at or below the water surface; an important habitat for young fish and other aquatic organisms.

Suspended solids - 1) Solids that either float on the surface or are suspended in water or other liquids, and which are largely removable by laboratory filtering. 2) The quantity of material removed from water in a laboratory test, as prescribed in standard methods for the examination of water and wastewater.

Thermal Stratification – A natural phenomenon in which lakes of sufficient depth are divided into distinct depth zones of varying temperatures. In the summer months the coolest and densest water is located at the lake bottom. In winter months the upper depths of a lake may be warmer than the bottom. The maximum density of freshwater occurs at 39°F. Thermal stratification prevents the mixing of the entire water column.

Thermocline - A distinct transition layer in a waterbody characterized by a steep temperature gradient where the water above the thermocline is a different temperature than the water below the thermocline. When the temperature gradient is extreme, it will prevent mixing of the upper and lower layers. The position of the thermocline in a lake coincides with depth of the metalimnion.

Trophic State – Indicates the level of primary production as measured by photosynthetic activity or other metrics. Various models exist to describe trophic state. Perhaps the most widely used is Carlson's Trophic State Index (TSI) which relies on the use of summer average chlorophyll, Secchi depth, and Total Phosphorus values.

Tributary – A stream or other flowing waterbody discharging to a lake or a larger stream.

Turbidity - A cloudy condition in water due to suspended silt or organic matter often attributable to algae blooms or increased sediment loads.

Water quality - The biological, chemical, and physical conditions of a waterbody. It is a measure of a waterbody's ability to support beneficial uses.

Watershed management - A holistic approach applied within an area defined by hydrological, not political, boundaries, integrating the water quality impacts from both point and nonpoint sources. Watershed management has a premise that many water quality and ecosystem problems are better solved at the watershed scale rather than by examining the individual waterbodies or dischargers. Use, regulation and treatment of water and land resources of a watershed to accomplish stated objectives.

Zooplankton - Microscopic, floating, aquatic animals and protozoans. Zooplankton generally feed upon phytoplankton, organic detritus, microbes, and other zooplankters.

APPENDIX A: PUBLIC OUTREACH AND QUESTIONS AND ANSWERS

A public information session and discussion on the Honeoye Lake Aeration System Planning and Design Project was held on the evening of April 26, 2022 via WebEx virtual format. Dr. Stephen Souza from the aeration project consultant team presented the project background and recommendations. Scott Churm and Dr. Paul Gantzer from the consultant team also participated to answer questions.

A recording of the presentation and discussion is available for viewing on YouTube at:

https://www.youtube.com/watch?v=vZWcKKZgSuA

Written answers to questions and comments submitted to the consultant team during the presentation or by email during a comment period afterward are provided below. The public information session announcement is also included. Each question, exactly as received from the public, is presented first in standard font. The answer to the question is then presented in **bold font**.

1. What happens to the nitrogen that is stripped? **It is released back into the environment.** Is there an environmental impact? **No**

2. "Nominal" intake and outtake. How does that affect the flow of water? Any impact on swimming in the vicinity? **No, the intake and discharge rate of flow is only confined to the near bottom of the lake. Sediment resuspension at the intake and discharge manifolds is anticipated to be minimal as the velocity of water entering and leaving the pipeline is designed to be less than 0.1 feet/second. This should also minimize the impingement and/or entrainment of fish and fish larvae.**

3. Does the thermal profile prevent the distribution of the oxygenated water to the north and south end of the lake? **No, oxygenated bottom waters will move freely below the thermocline and, circulate lakewide upon a mixing event. Lake water (including that at the north and south ends) above the thermocline is not subject to anoxia, with dissolved oxygen provided mainly through interaction with the atmosphere.**

4. Will the oxygenated water help reduce milfoil growth? **No. The primary objective of this project is to control the lake's internal phosphorus load. Rooted aquatic plants like milfoil rely primarily on temperature, sunlight, carbon dioxide, and nutrients in the littoral sediments (the zone extending from the shoreline where rooted aquatic plants grow).**

5. What is the time frame for getting this approved to install it? 1 year out? 2 years out? 5 years out? **Not sure. The timing of the project is dependent on the availability of funding (including grant funds and commitment(s) of local match) and on the required permitting process. It is anticipated, however, if funding was made available in 2023 and permits were issued, the system would be fully operational by 2025.**

6. Great presentation. This definitely holds promise in helping Honeoye Lake's health. A question I have, and I am unsure if it can be answered, does anyone have any information about the results of the aeration project/ study in a lake near Albany**? Not sure which lake this is referencing, but the project team has been supplied with references of other projects using pure oxygen for hypolimnetic aeration. See question 12 below.**

7. It seems that the aeration system is focused on deep water with no oxygen issues. How will this benefit our shallow lake side residents? **The goal of this project is to control and decrease the lake's internal phosphorus load, which is the primary driver of the lake's mid- to late-summer HABs. Decreasing the lake's overall phosphorus load benefits the entire lake. The largest amount of internal phosphorus loading is due to deep water anoxic sediments. Plus, the regeneration of phosphorus from the lake's deep water anoxic sediments occurs during the middle of the summer. Both the magnitude and timing of the internal phosphorus load attributable to deep water anoxic sediments has been shown to stimulate the lake's mid- to late-summer HABs.**

8. Will the costs be defrayed by the boat launch visitors and others who don't have properties on the lake? **Not sure, but it is unlikely boat launch visitors would be charged a fee to defray the cost of this project. The initial capital cost of purchasing and installing the system and the annual maintenance cost would likely have some impact on local municipal budgets, supported by taxpayers in the relevant jurisdiction(s) such as town and county. New York State grant funds up to $1 million have been available in recent years for hypolimnetic aeration projects with proper assessment and documentation.**

9. Would the NYS launch property partly qualify for an area to support the southernmost manifold? **This was evaluated but the lack of a 3-phase power source at this site presently rules out locating the land-based elements of the system at that location.**

10. I have friends on Waneta Lake, it's also a very small lake. I don't have proof, but one resident thinks their lake is treated with some sort of a chemical. In one of the first slides, I think I remember some sort of Aluminous chemical? Is there a chemical that can be used for a quicker fix if the SSS is more than 2 years out? **Currently the NYSDEC limits the treatment of lakes with alum unless conducted under an experimental NYSDEC permit approval. However, using SSS does not preclude future treatment of the lake with alum or another nutrient inactivant. The combination of aeration and alum has been recommended in reports dating back to 2004 as part of the lake's long-term phosphorus management and lake restoration plan.**

11. Does the cost include the property acquisition costs**? No, the cost estimate does not include property acquisition costs**.

12. Can you provide examples of other lakes that successfully used this system? **This information has been provided to the committee. The report includes references of other pure oxygen aeration projects. The committee and/or local officials have the option to meet in person or conduct a virtual meeting with the managers of other lakes and reservoirs to discuss their experience with SSS or similar hypolimnetic oxygenation systems. The following are example hypolimnetic oxygenation projects:**

    a. **Carvins Cove Reservoir, Western Virginia Water Authority, West Virginia**
    b. **Pleasant Lake and Vadnais Lake, St. Paul Regional Water Services, Minnesota**
    c. **Spring Hollow Reservoir, Virginia**
    d. **North Twin Lake, Washington**

e. **Falling Creek Reservoir, Virginia**
f. **Sarah's Pond, Massachusetts**

13. What will be the effect on the weed growth? Increase weeds? **We do not expect a significant change in weed growth, either an increase or a decrease. Rooted aquatic plant communities have sufficient resources for growth (refer to question 4) and hypolimnetic aeration is not expected to impact the availability of those resources in the littoral zone where rooted aquatic plants grow.**

14. Unfortunately, we need to worry about someone damaging this setup if they disagree with this approach. How robust is this setup to vandalism? **That is very unfortunate. The land-based elements will be housed in a locked building equipped with security cameras. The majority of the in-lake elements are in very deep water (>20') and difficult for anyone access. The portion of the lines transitioning from deep to shallow water will be encased in a protective sleeve.**

15. If this project were to move ahead on Honeoye Lake, how soon could we see this solution implemented? **Refer to question 5.**

16. What is the actual likelihood of this project going through, and in what time frame**? The likelihood of the project going through depends on local community support as well as the availability of grant funding for a significant portion of the project cost. Refer to question 5 for potential timeframe.**

17. I assume less nutrients will also work to reduce weeds as well. We will need to continue harvesting? **No, this will not have a significant effect on weed growth. Refer to questions 4 and 13.**

18. Does the system run throughout the year or only in the summer? **The system will likely operate from May through September. It will not be operated during the fall or winter.**

19. What technologies are used at the final output diffusers? **The intake and discharge manifolds are designed by engineers with specific background in lake oxygenation. Details of the system have been provided by Dr. Paul Gantzer, who has designed, installed, and managed a number of pure oxygen lake aeration systems across the U.S. Specifics regarding the intake and discharge velocities and flow rates are provided in the report. Refer to Recommended Specifications of the Honeoye Lake SSS System starting on page 27 in Section 2.**

20. I believe that Princeton Hydro was the same firm that tried to implement an alum solution for Honeoye Lake a while back. In your opinion, how successful was that effort? Perhaps the aforementioned effort vs. tonight's approach? **The alum treatment conducted in 2006 under the direction of Princeton Hydro, and the oversight of NYSDEC, was successful. However, the benefits of the treatment were relatively short-lived; approximately 3-4 years. The reason for this was in part the alum dose rate approved by NYSDEC was much lower than that proposed, even though the proposed rate was demonstrated, via bench testing, to elicit no negative impacts. Additionally, alum treatments have a "lifespan." The continuous**

influx of particulate material with runoff entering the lake adds phosphorus to the lake's sediments that eventually exceeds the binding effects of the alum treatment. Unless the lake's bottom sediments are prevented from becoming anoxic, the additional phosphorus load will require further alum treatments. This is why the long-term management approach for the lake has consistently recommended the combined use of alum and aeration. Refer to the following:

- **Princeton Hydro. 2007. Honeoye Lake Nutrient and Hydrologic Budget, Report to Honeoye Lake Watershed Task Force.**
- **Princeton Hydro. 2020. Feasibility Assessment of Harmful Algal Bloom Management Options for Honeoye Lake and Conesus Lake, New York. Prepared for NYSDEC.**
- **NYSDEC. 2018. Harmful Algal Bloom Action Plan: Honeoye Lake. https://www.dec.ny.gov/docs/water_pdf/honeoyehabplan.pdf**

21. What will power consumption be? **Refer to page 33 of the report. The utility cost (at time of publication) to run the system is approximately $132 to $166 per day (approximately $19,800 - $24,900 annually, assuming five months of full operation per year) as based on $0.144/Kw-h. This reflects the power needed to operate the PSA unit, the system's water pumps and compressor (total of 50 HP), as well as cooling fans, interior lights, alarm system and ancillary power needs.**

22. Will this system have any positive or negative on the weed growth issue in the lake? **Refer to questions 4, 13 and 17.**

23. With the project being implemented in 2 or more years from now is the cost ($1.2 million) projected for that future time or will it be more like $1.5 million by the time of installation. **The project cost could increase over time with inflation.**

24. How can we be sure that anchors won't damage the system? **This question was addressed during the presentation by Dr. Gantzer based on his experience with similar installations. One strategy to further lessen the likelihood of anchor damage is to create and distribute a map showing the locations of the intake/discharge diffusers and intake/discharge lines and identify those locations as "no anchoring" areas.**

25. Will the improved oxygen and therefore less Phosphorus help eliminate the algae in our shallow waterfront swimming areas as well? **The system is designed to mitigate the greatest contributor of available phosphorus fueling algae growth in the summer months, benefitting all areas of the lake as floating algae are known to be pushed by winds and currents, often accumulating along shoreline. However, localized algae blooms that arise in shallow, shoreline areas are not likely to be fully eliminated. Refer to question 7.**

26. What oxygen level do you need to reach to be effective? How hard will it be to reach this level? **1 mg/L DO is required to maintain the phosphorus:iron bond that limits the complete internal release and recycling of sediment bound phosphorus. It should also be noted that phosphorus release is also**

associated with a shift in oxidative reduction potential (ORP), meaning that although DO may be depleted, if NO_3 is present in abundance, phosphorus will remain bound to iron until all of the NO_3 is exhausted. As designed and discussed within the report, the system will maintain a DO concentration of at least 4 mg/L at the bottom of the lake. Equally important, the system's operation is targeted to maintain at least 80% DO saturation at a given temperature (oxygen solubility in water is inversely related to temperature, meaning as water warms DO saturation is achieved a lower DO concentration. Operating the system in this manner will ensure the concentration of DO measured at the sediment water interface is at least 4 mg/l, which is sufficient for keeping phosphorus bound to deep lake bottom sediments. One benefit of the SSS system is that it can be calibrated to achieve a desired DO concentration.

27. Any of the hardware being proposed manufactured outside of the US? **We are not sure if the proposed hardware or components are manufactured outside of the United States. If public funds are used to procure the equipment recommended in this report, a public bidding process would be required and subject to any rules applicable to the source(s) of funds being used. Therefore, it is likely not possible to specify where products for this project are manufactured.**

28. Since the oxygen is essentially trapping phosphates in the sediment, if the system is ever shut down for some reason will it drastically increase the issue? **The oxygen does not trap phosphorus in the sediment. Rather it maintains the chemistry needed to keep phosphorus bound to iron. Should the system shut down in the middle of the summer, or be shut down permanently after years of operation, the rate of phosphorus release from the sediments would be the same as it is now without deep-water oxygenation.**

29. What would the requirements be of the residents on the East side of the lake closest to the discharge/intake pipes? **None, they can use the lake that same as they are using it now.**

30. What is the lifespan of all the equipment once it's installed? **With proper annual inspection and maintenance, the anticipated the lifespan of all the land-side mechanical elements of the system is at least ten years for. The underwater lines and intake and discharge manifolds should not need to be replaced unless physically damaged.**

31. Will zebra mussels affect the system? **This is discussed in the report, refer to Section 3.3. Even if zebra mussels were to grow on the manifolds, the manifolds are designed with a 10:1 factor of safety. This means 90% of the openings can be covered before the design flow velocity is compromised. As noted in the report the underwater elements of the system will need to be inspected annually and maintained as needed. Doing so also reduces any potential zebra mussel fouling impacts.**

32. What organization is responsible for the operation of the system? **The party responsible for operation and maintenance of the system will be considered as local officials weigh whether or not to proceed with the project, and before a grant application is submitted. It could be a public municipal or county entity, including a town or county department. However, it is recommended that maintenance be conducted by qualified contractors.**

33. How will this project affect the number of fish in the lake? Will it increase? **The project is not designed specifically to enhance the lake fisheries. However, by maintaining better DO year-round at the bottom of the lake, the lake could theoretically support larger fisheries.**

34. How close to the east lake shore line will the manifolds be placed? **Approximately 500' from the shoreline at a depth of approximately 9 meters (29.5 feet) below the lake's surface.**

35. Have representatives from Honeoye been to lakes where this system has been installed and spoken to local community members there? **At the time of publication, no. The project team has been supplied with written reports from scientific journals detailing the installation, operation and benefits of similar systems and have been provided with contact information for other waterbodies using similar systems. Refer to question 12.**

36. Who will service the equipment--county employees? **Refer to question 32.**

37. East Lake residents have frequently enjoyed music from the California Ranch - how will any noise levels be mitigated if they can be heard across the lake? **There should be no noise issue. The pump house building will be sound insulated. The system operations at the pump house will generate externally < 60 decibels as measured at 50' from the building, about the same amount of noise as a typical conversation.**

38. I am deeply concerned with disturbance of the quiet nature of the lake and the amount of noise the proposed aeration system would produce. Where will you propose to install the machinery that won't be heard by every one of us shore dwellers? What about nighttime (noise)? Will the pumps be operating during the evening? Will they make a whirring sound or disrupt the peaceful nature of the area? **Refer to question 37.**

39. An increase in bottom dissolved oxygen will increase zebra mussels. Zebra mussels prefer algae other than Microcystis, which may increase. Can you comment? **Zebra mussels are indeed filter feeders, and have been shown to selectively reject Microcystis and other cyanobacteria species as a food source. However, increasing the lake's deep water oxygen levels during the summer is not expected to significantly increase the lake's zebra mussel population. Further, the amount of additional hard surface attachment areas for zebra mussel colonization created by the aeration system hardware is not significant relative to the overall size of Honeoye Lake.**

40. Have any studies been done to ensure the attractiveness of our shores, nesting grounds, fishing, skiing, and swimming areas remain undisturbed? **This will all be covered as part of the SEQR process. Refer to Section 5.3 of the report for a table of potential impacts to be evaluated.**

41. I assume the water being drawn from the lake is being filtered for silt before coming into the system? **There is no need to do so. First, the intake manifolds are anchored in place but elevated approximately 18"-24" above the lake bottom. Second, there are screens on the intake which prevent the entrainment**

and intake of large particulate material. Finally, the pumping rate, as detailed in the report, does not induce sediment resuspension. Collectively this negates the need to filter the water entering the system.

42. Where is there a location on or near the lake to put just a facility? Could such a facility be located 500+' from the lake? **Refer pages 25-27 of the report for a discussion on criteria for siting the land-based facilities. The California Ranch Site was evaluated as the best option at the time of this study, meeting multiple criteria. Siting a facility in an appropriate location on the east side of the lake closer to the manifolds would be optimal, but this area of shoreline has dense residential development. Locating the facility uphill and/or further from the lake presents other impracticalities. For example, moving the facility 500+ feet from the shoreline would:**

   - **Add another 2,000' of intake/discharge line, all of which would be buried and difficult to inspect and maintain,**
   - **Unnecessarily increase the expense excavation, trenching and backfilling,**
   - **Could trigger the need for and cost of larger pumps,**
   - **Result in more land disturbance thus complicating environmental permitting.**

43. When the pump is turned on each season, will it need to be primed to draw water in and, if so, how is that done/what is the water supply? **No, the pumps do not need to be primed.**

44. Will backflushing be used in maintenance of the interior of the pipes? Will chlorination be used? **No. There is no need to backflush or to use chlorine.**

45. The draft report shows about 12,364' of line underwater. How much zebra mussel scraping will be required, and how much time will be required annually? **The plan is to raise the system using the buoyancy lines in the spring of each year to inspect for fouling. It is anticipated two days will be required to raise, inspect, and maintain the lines, including the removal of zebra and/or quagga mussels or other material that may be coating the lines. The entire system can be brought to the surface in less than 30 minutes. It's probably on the order of about ten minutes once air is supplied to the buoyancy line. Once on the surface, inspection can take less than an hour. Cleaning is a separate issue. The 'cleaning procedure' should consist of an engineered semi-circular nozzle assembly that uses high-pressure water via a pressure washer carried on board. This process would require a few hours to clean the piping and the lines would be re-deployed as soon as possible. If it is windy, a bigger issue may be securing the lines while they are on the surface. Line inspection and cleaning at the surface would be coordinated with public agencies having jurisdiction (e.g., Ontario County Office of Sheriff, NYS Office of General Services and/or Parks, Recreation and Historic Preservation.)**

46. Does the design incorporate materials selection to discourage zebra mussel veliger attachment? **Yes, the intake and discharge screens will be coated with NYSDEC approved for drinking water system anti-fouling material.**

47. Have the buoyancy lines been used in lakes with zebra or quagga mussel populations? How do the buoyancy lines work with added weight (from mussels or debris)? **The buoyancy lines have the capacity and ability to raise the system for inspection and maintenance even if fouled with zebra or quagga mussels. The intake and discharge screens will be coated with a NYSDEC approved for drinking water system anti-fouling material. Zebra and/or quagga mussel removal is part of the system's annual maintenance. If we observe after the first full season of operation an excessive amount of fouling, the system could be raised twice annually (in the spring and fall) to remove mussels. There is sufficient buoyancy to accommodate 'some' mussel fouling; however, if the system is neglected for years and the lines get overgrown with mussels, the added weight can be more than the buoyancy can handle and divers would be required to perform inspection and maintenance.**

48. Can you provide a list of lakes where the SSS system has been used**? A list of lakes with similar systems has been provided. Refer to question 12.**

49. Heard this one the most…. Is there an example of a lake like Honeoye that can be shown this process will work? Can we see the data? Similar size? Similar depth, volume, climate, Weir at end, limited outflow, etc. **Refer to question 12.**

50. The premise is that the blooms start in and are fed by the deepest part of the lake – while this area is very, very small. How was this determined? **It is the <u>phosphorus load</u> that originates from deep water sediments that stimulates the mid- and late-summer HABs. This has been documented in numerous studies and reports dating back to 2004 authored by Cornell University, Finger Lakes Community College, NYSDEC and Princeton Hydro. It is also documented in over 20 years of CSLAP data collected by the HLWTF. Refer to the Executive Summary and Section 1.**

51. Observation from many homeowners is that the deep parts are the clearest when blooms start – even on non-windy days. Why? **Cyanobacteria are most obvious in shallower, confined areas where the cells accumulate and clump.**

52. The blooms seem to start when/after the green – cotton candy like structures of algae collect on the weeds close to shore or in shallow areas – and are then disturbed – boats etc. Then sun hits the spread algae and a bloom starts. Thoughts?? **This may add to the problem but is not the direct cause of the HAB.**

53. If the deepest part of the lake is in fact causing this – and it's so small, are there other options?? For example, dredge the deep areas vs. trying this method. Why not attack the source? **The oxygenation of the lake's hypolimnion does attack the source/cause of the lake's mid- and late-summer HABs. Multiple studies conducted by NYSDEC, Cornell, Finger Lakes Community College, and Princeton Hydro, as well as over 20 years of HLWTF CSLAP data, document the liberation and recycling of phosphorus from the lake's deep-water anoxic sediments to be the source/cause most in need of control. Dredging is not a feasible option as it is far too expensive, too difficult to permit, and not a lasting solution.**

54. Do other factors play into the blooms? **Yes, external phosphorus loading is also a contributing factor. This is why the lake's overall management plan includes measures designed to decrease stormwater related**

phosphorus loading. However, the internal load is the primary driver of mid- and late-summer HABs, due to both the magnitude and timing of this source of phosphorus in Honeoye Lake.

55. It was mentioned the location for the pump house would not be feasible at the north end beach – because of three phase power. How is it available on the East side? BTW – I'm an electrical engineer. **The north end location at Sandy Bottom Park was considered due to the existing availability of three-phase power as well as the site being publicly owned. However, the distance of this site is too far away from the lake's deepest area. Siting the land-based elements of the system at this location significantly increases the cost of the project due to added length of the intake/discharge lines. The added distance would also necessitate more maintenance time and higher operational cost due to the use of use of larger water pumps.**

56. What other measures have been considered? Improved outflow? E.g., a weir with gates similar to other nearby lakes? Dredge the outlet? Dredge the deep part, etc. **All feasible lake management options have been previously considered and were discussed in earlier reports. This was an aeration system engineering planning project, and as such was focused on how best to aerate the lake to control its internal phosphorus load. Refer to the following for the review of the other management options both considered and recommended for Honeoye Lake:**
    - **Kishbaugh Scott A. & Hohenstein Betsy R. Hohenstein. 2002. 2000 Interpretive Summary New York Citizens Statewide Lake Assessment Program (CSLAP) Honeoye Lake, NYS Department of Environmental Conservation Division of Water, Lake Services Section.**
    - **Princeton Hydro. 2004. Phase I Lake Restoration Guidance and Prioritization Plan for Honeoye Lake.**
    - **Princeton Hydro. 2007. Honeoye Lake Nutrient and Hydrologic Budget, Report to Honeoye Lake Watershed Task Force.**
    - **Princeton Hydro. 2020. Feasibility Assessment of Harmful Algal Bloom Management Options for Honeoye Lake and Conesus Lake, New York. Prepared for NYSDEC.**
    - **NYSDEC. 2018. Harmful Algal Bloom Action Plan: Honeoye Lake. https://www.dec.ny.gov/docs/water_pdf/honeoyehabplan.pdf**

57. It's understood what has been done to the inlet and alum in the past – is there data showing its worked or getting better? Weed cutter results? It seems to be getting worse, not better. What is the expected improvement – data wise and lake usability wise? **This was an aeration system engineering planning project, and as such was focused on how best to aerate the lake to control its internal phosphorus load. These management options, for the lake, along with other management options, have been reviewed in each of the following reports. Please refer to each of these to the answers to these questions**:
    - **Princeton Hydro. 2020. Feasibility Assessment Of Harmful Algal Bloom Management Options For Honeoye Lake And Conesus Lake, New York. Prepared for NYSDEC.**
    - **NYSDEC. 2018. Harmful Algal Bloom Action Plan: Honeoye Lake. https://www.dec.ny.gov/docs/water_pdf/honeoyehabplan.pdf**
    - **NYSDEC. 2019. Draft Total Maximum Daily Load (TMDL) for Phosphorus, Honeoye Lake, Ontario County, New York. https://www.dec.ny.gov/docs/water_pdf/tmdlhoneoyeaug2019.pdf**

58. Who will be accountable for success (is there success criteria for the subcontractor?? **Please refer to Section 4 of the report for performance objectives for the SSS system and a monitoring plan to measure results.**

Public Information Session Notice

v1.1

Honeoye Lake Aeration System Planning and Design Project

Public Information Meeting – Virtual Format
Tuesday, April 26th, 2022 at 7:00pm - 8:30pm

Learn about a potential aeration strategy to improve the water quality of Honeoye Lake.

A consultant team led by Princeton Hydro, LLC worked over the past year to develop a plan for an aeration system customized for Honeoye Lake. Aeration is a recommended strategy to reduce the availability of phosphorus and control harmful algae blooms (HABs) in Honeoye Lake, according to the New York State Department of Environmental Conservation (NYSDEC) reports: *Total Maximum Daily Load for Total Phosphorus (2019)* and *Harmful Algal Bloom Action Plan Honeoye Lake (2018)*.

Dr. Stephen Souza, CLM and Principal Investigator, will present the aeration project recommendations.

Use the link below to register for the meeting. You will receive an e-mail confirming your registration which will include the Webex meeting link:

https://bit.ly/honeoyeaerationproject

Attend the meeting to learn, ask questions and provide input. Now more than ever you have an opportunity to shape HABs mitigation efforts for Honeoye Lake.

View the draft report here: **2020 Honeoye Lake Aeration System Engineering Planning Project Draft (honeoyelakewatershed.org)**

For a brief overview on how aeration systems can affect HABs, click below:
Aeration Engineering Grant (honeoyelakewatershed.org)

See you soon,
Honeoye Lake Watershed Task Force
Ontario County Planning Department