FEASIBILITY ASSESSMENT OF HARMFUL ALGAL BLOOM MANAGEMENT OPTIONS FOR HONEOYE LAKE AND CONESUS LAKE, NEW YORK

LIVINGSTON AND ONTARIO COUNTIES, NEW YORK

PREPARED FOR:

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1.0 INTRODUCTION

This project was conducted by Princeton Hydro, LLC (Princeton Hydro) under contract with the New York State Department of Environmental Conservation (NYSDEC) as part of Governor Cuomo's state-wide effort to address Harmful Algal Blooms (HABs). The report that follows provides a series of recommendations for Honeoye Lake and Conesus Lake based on our analysis of the feasibility of water column aeration and/or nutrient inactivation techniques to manage nutrient loading, improve the trophic state, and reduce the occurrence of HABs.

Honeoye Lake is the second smallest of the eleven Finger Lakes, having a total surface area of 1,808 acres (Figure 1.1). The lake is relatively shallow. Its maximum depth is 9 meters and its mean depth is 4.9 meters (NYSDEC, 2018d). The lake attains its greatest depths along the east central shoreline (Figure 1.2). Honeoye Lake is classified as a Class AA waterbody. Drinking water, culinary processes, primary and secondary contact recreation, and fishing are listed by NYSDEC (2017) as the best uses for such waterbodies. The Honeoye Lake watershed totals approximately 23,349 acres (Figure 1.3), spanning portions of both Ontario and Livingston Counties and six municipalities (Princeton Hydro, 2014). Watershed land use is dominated by forested land, shrubland, and wetlands, including a 900-acre silver maple–ash swamp forest located along the lake's inlet channel (Figure 1.4). The majority of the developed lands are located immediately adjacent to the lake shore. Of note is that almost a century ago close to 70% of the watershed was open lands (pasture, orchard, and cropland along with pockets of residential development)[1]. Although much of the farmed lands are now wooded, clearing of these lands contributed a legacy sediment and nutrient load to the lake. The lake's hydraulic retention time is approximately 300 days. This is a relatively slow flushing lake, the significance of which will be discussed herein. The lake discharges to the north through a shallow wetland complex and low head weir to Honeoye Creek. The NYSDEC lists Honeoye Lake on its Priority Waterbody List (303d) (NYSDEC, 2018e) due to elevated phosphorus levels, high oxygen demand, and excessive algal and plant growth.

Located in Livingston County, Conesus Lake is the westernmost of the eleven Finger Lakes (Figure 1.5). It has a surface area of 3,420 acres, a maximum depth of 20.1 meters, and a mean depth of 11.6 meters (NYSDEC, 2018a; Livingston County, 2018). The lake consists of three basins: a large, deep southern basin; an intermediate depth, small and narrow central basin; and a large, moderately deep northern basin (Figure 1.6). Conesus Lake is classified by NYSDEC as per the New York Codes, Rules, and Regulations (NYCRR) as a Class AA waterbody. The listed uses for AA waters include drinking water, culinary processes, primary and secondary contact recreation, and fishing (NYSDEC, 2018b). The Conesus Lake watershed (Figure 1.7) encompasses a total area of 44,800 acres consisting of portions of seven different municipalities (EcoLogic, 2003; EcoLogic and Livingston County, 2013). The predominant land use is agriculture (Figure 1.8). A large wetland system lies to the south of the lake and forested land is interspersed throughout the southeast and southcentral portions of the watershed. The majority of developed land occurs immediately adjacent to the lake. The watershed is also characterized by active farmland (38% as per NYSDEC 2019b, Figure 1.8) that serves as both a legacy and continuing source of nutrient and sediment loading to the lake. The lake's reported hydraulic retention time is 1.5 – 3 years. This is a relatively long retention time, meaning that the lake's annualized water exchange (flushing rate) is fairly low. Once again, the significance of this will be discussed within this report. Water is discharged from the lake to Conesus Creek through a short discharge canal controlled by a multiple gate valve-equipped dam located at the northern end of the lake (NYSDEC, 2018b). The NYSDEC lists Conesus Lake on its Priority Waterbody List (303d) (NYSDEC, 2018c) due to elevated phosphorus levels, high oxygen demand, and excessive algal/plant growth.

[1] The land use map provided in this section of the report was developed by NYSDEC and used to compute the pollutant loads contained in the recently published Honeoye Lake TMDL. A comparative, somewhat more detailed map prepared by Gilman and Schultz, 2006 is presented in Appendix II. Overall, the land use types and associated coverages presented in NYSDEC, 2019, Gilman and Schultz, 2006, and Princeton Hydro, 2007 and 2014 are all very similar.

As noted, both Conesus Lake and Honeoye Lake are subject at times to HABs. Data collected over the past 15+ years show that the frequency of occurrence and the severity of the HABs affecting both lakes has increased. Harmful algal blooms are attributable to cyanobacteria, also referred to as blue-green algae. Possessing properties of both bacteria and algae, these prokaryotic photosynthesizing organisms have the ability to produce toxins. Although cyanotoxins are primarily produced to provide cyanobacteria with a competitive advantage over other phytoplankton, at elevated concentrations these organic compounds can affect the health of humans, pets, and livestock that contact or ingest the toxin contaminated water. Cyanobacteria blooms are most apparent when the cells accumulate on the water surface resulting in the discoloration of the water, reduced clarity, and noticeable, unsightly surface scums. However, elevated toxin levels may occur even before such symptoms of a bloom manifest.

Cyanobacteria blooms develop under a variety of conditions, but most commonly occur during the summer when the water is warm and water column mixing and water exchange is minimal. For many of the affected lakes, HABs often occur immediately following water column mixing events that disrupt thermal stratification. In such cases, the severity of the HAB is magnified when the mixing event is preceded by periods of water column anoxia (dissolved oxygen depletion). As will be discussed further, anoxic conditions promote the release of sediment-bound phosphorus which stimulates bloom development. Although HABs are most commonly associated with nutrient rich lakes, as is the case with New York's Finger Lakes, HABs can impact waterbodies characterized by low nutrient (phosphorus and nitrogen) concentrations. Beach closures, restricted recreational use, and the added expense needed to treat HAB-impacted drinking waters can prove costly and negatively affect local economies. As per NYSDEC, since 2013 Conesus Lake has been impacted by 13 confirmed HABs resulting in 46 lost beach days (NYSDEC, 2018a). Since 2012, Honeoye Lake has had 84 confirmed HABs resulting in 104 lost beach days (NYSDEC, 2018d). Fourteen of Honeoye Lake's confirmed HABs had high toxin levels.

Across the globe the occurrence of HABs has seemingly increased over the past few years. Whether a function of accelerated eutrophication due to increased nutrient availability, climate change, or increased public perception and understanding of HABs, the frequency and duration of HABs and their impact on lakes characterized as being low to moderately productive has stimulated an increased need for proactive management of cyanobacteria blooms. Recognizing the importance of protecting the state's water resources, in January 2018 Governor Cuomo announced a $65 million initiative to combat the increasing issue of HABs. Through this initiative NYSDEC identified twelve high-risk waterbodies and for each waterbody developed a HAB Action Plan. Included on this list of twelve high-risk waterbodies are Honeoye Lake and Conesus Lake. Both were selected based on factors known to promote the occurrence of HABs. Each lake's HAB Management Plan (NYSDEC 2018b and 2018d) concludes that excessive phosphorus loading is responsible for the observed HABs, and the prevention and control of future HABs cannot be achieved for either lake without reducing their annual phosphorus loads. The subsequent Total Maximum Daily Load reports prepared for Honeoye Lake and Conesus Lake (NYSDEC 2019b and 2019c) identify internal processes responsible for the majority of each lake's annual phosphorus load and target the reduction of the internal phosphorus load as key to the successful improvement of each lake's water quality and reductions in the occurrence, magnitude, and duration of HABs.

Although both nitrogen and phosphorus are essential to the growth and development of phytoplankton, filamentous algae, and aquatic macrophytes, in most freshwater aquatic ecosystems phosphorus is the limiting nutrient, or the nutrient that is naturally lowest in supply relative to the amount required for plant and algal primary productivity (Schindler, 1977; Schindler, et. al, 2008). As such, a small increase in phosphorus loading has the potential to stimulate a large amount of primary production. Thus, most of the proactive measures taken to control primary production, accelerated eutrophication, and HABs focuses on controlling and reducing phosphorus. Undeniably there is a link between watershed development and HABs. Watershed development leads to an increase in runoff volume and the rate at which that runoff enters lakes and the lake's tributaries. The increased volume of runoff increases the mobilization and transport of nutrients and other non-point source pollutants. The added volume and rate of runoff also leads to the scour and erosion of streams resulting in increased sediment and nutrient loading to the receiving lake system. In addition to external sources of nutrient loading, there are internal sources of nutrient loading. This is especially true with respect to phosphorus. Internal phosphorus loading has been shown in many lakes to be an important stimulant and driver of primary production, especially with respect to the development of phytoplankton blooms (Cooke, et al. 2005). While some internal phosphorus loading can be attributed to the natural die-off of plants, phytoplankton, benthic algae, and other organisms, as well as sediment resuspension, for most lakes characterized by a large internal phosphorus load the primary factors responsible for internal phosphorus loading are thermal stratification and associated water column anoxia (the absence of dissolved oxygen). Although this can occur in both shallow and deep lakes, it is most commonly experienced, and has the greatest negative impact, in moderately deep to deep lakes that become thermally stratified during the summer.

The physical properties of water are such that water reaches its greatest density at 4°C. As water warms its density 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 than the deeper waters (referred to as the hypolimnion). As little as a 1°C temperature difference between any two depths can result in a density difference great enough to inhibit the vertical mixing of the water column. When this occurs, the lake becomes thermally stratified. The depth at which vertical mixing is inhibited is referred to as the thermocline. Once the thermocline becomes established the vertical mixing of the water column is inhibited resulting in the deeper waters of the lake becoming segregated from the surface waters. The thermocline can develop at any water depth; deep or shallow. The depth at which it forms will be dictated by a number of 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 blow across a lake's surface),
- Magnitude and strength of the lake's seiche (an internal wave most commonly produced along the thermocline),
- Other factors that affect light penetration and water column stability.

The maintenance of dissolved oxygen in lake water is largely a function of the consistent vertical mixing of the water column and 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, or the turbulence created at the mouth of a tributary, the majority of re-oxygenation occurs due to the exposure of lake water to the atmosphere. Once stratified, the waters below the thermocline are no longer able to freely mix to the surface, and over time these thermally segregated layers become depleted of oxygen (anoxic) due to community respiration. The rate at which this occurs is variable from lake to lake depending in part on respiration rates, the volume of the segregated layer, the organic composition of the sediments, water temperatures and other factors. When the density differences between the epilimnion and the hypolimnion are great enough, thermal stratification will persist for long-periods of time leading to the majority of the lake water below the thermocline becoming devoid of oxygen. As a result, a large volume of a lake can become oxygen depleted (anoxic) during periods of stratification. This not only results in a large portion of the lake unable to support organisms dependent on oxygen (fish, zooplankton, etc.), but it also alters the chemistry of the lake's sediments.

Under oxic conditions (presence of oxygen) the majority of the phosphorus present in lake sediments is covalently bound to ferric iron ($Fe3+$), forming ferric phosphate and ferric hydroxyl phosphate complexes. These complexes effectively "lock" a large 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 (devoid of oxygen) the ferric iron gains an electron, becoming soluble ferrous iron ($Fe2+$). 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 can buoy back into the photic zone of the epilimnion to photosynthesize and biologically utilize the assimilated phosphorus. This is a metabolic strategy unique to and utilized by a variety of cyanobacteria to effectively capitalize on internally recycled phosphorus and outcompete phytoplankton (Head et al., 1999).

In 2019 NYSDEC published detailed phosphorus total daily maximum load (TMDL) analyses for both Conesus Lake and Honeoye Lake (NYSDEC, 2019b; NYSDEC, 2019c). While multiple factors were shown for both lakes to have a statistically significant effect on the occurrence of HABs, phosphorus availability was deemed to be the most important factor. As such, controlling the amount and availability of phosphorus are the keystone management recommendations presented in each lake's TMDL report (NYSDEC, 2019b; NYSDEC, 2019c) and HAB Action Plan report (NYSDEC, 2018b; NYSDEC, 2018d). For both lakes, the data presented in the TMDL report as well as the HAB Action Plan concluded that internal processes are not only responsible for a significant amount of each lake's phosphorus load, but that the internal phosphorus load is the main driver responsible for the HABs that impact each lake. Specifically, NYSDEC determined that for Conesus Lake internal loading accounts for up to 80% of the annual total phosphorus load, and internal loading accounts for up to 93% of Honeoye Lake's annual total phosphorus load. These findings are consistent with the findings of earlier studies conducted by Finger Lake Community College, Cornell University, SUNY Geneseo, and SUNY Brockport, as well as years of CSLAP lake water quality data collected by local volunteer monitors.

Exacerbating the HAB related impacts attributable to each lake's elevated internal phosphorus loads are three other attributes shared by both lakes: the presence of dreissenid mussels; a relatively long hydraulic retention time; and a relatively long fetch or internal seiche. These ecosystem features have been documented in the scientific literature to facilitate the occurrence of HABs:

- Studies conducted over the past two decades document a statistical relationship in many lakes between the presence of dreissenid mussels and the occurrence of HABs. The link, supported by regression analysis of various data sets appears to be related to both selective grazing by the mussels on "good" phytoplankton and nutrients released by the mussels in their excrement (Nogaro and Steinman, 2013). This biological link was recognized as early as 2001 (Vanderploeg, et al. 2001), but has been repeatedly documented in various lake ecosystems. Both Conesus Lake and Honeoye Lake are impacted by invasive zebra mussels.
- The negative effects on water quality of lakes characterized as slow flushing (having an extended hydraulic retention time) has been recognized for decades and is fundamental to the trophic state models of Vollenweider, Dillon, and Rigler. In slow flushing lakes, phytoplankton (including cyanobacteria) have a greater opportunity to assimilate available dissolved nutrients. Additionally, due to the limited water exchange, phytoplankton have a greater opportunity to accumulate within the water column. Also, sediment retention is greater in slow flushing lakes. Phosphorus adsorbed to sediment particles that settle in the lake represent a "legacy" load that can become subsequently liberated and recycled into the water column during periods of anoxia. The large watershed area and slow flushing rates characteristic of both Honeoye and Conesus Lakes facilitates this type of sediment-phosphorus loading.
- For slow flushing lakes, phosphorus loading during the spring (when tributary inflow is higher) and short-lived but intense mid-summer storm events may exacerbate summer productivity when the phosphorus assimilated by phytoplankton settles with the decomposing cells to the lake bottom and may be retained

within the lake's sediments that could result in the repetitive, subsequent stimulation of summer phytoplankton blooms (Hariston and Gilman, pers. comm, 2019).

- Lakes such as Conesus and Honeoye that are characterized by a long fetch and significant seiche are of greater likelihood to experience metalimnetic erosion. Metalimnetic erosion is essentially the upwelling of phosphorus rich water from the hypolimnion through the metalimnion and into the epilimnion that occurs without a complete breakdown of thermal stratification (Kortmann, et al., 1984).

One of the priority goals stated in both the Honeoye Lake and Conesus Lake HAB Action Plans is to decrease internal phosphorus loading. Although it is important to reduce a lake's external nutrient loading as part of its long-term eutrophication management, for many lakes, the reduction of the internal phosphorus load must be prioritized (Cullen and Fosberg, 1988; Cooke et al. 2005). This is the case for both Conesus Lake and Honeoye Lake. Due to the documented relationship between internal phosphorus loading and HABs, it is important that attention be given to reducing each lake's internal phosphorus load (EcoLogic and Livingston County Planning Department, 2013; NYSDEC, 2018b; NYSDEC, 2018d; Princeton Hydro, 2007; Princeton Hydro, 2005). Two lake management techniques proven to successfully reduce and control internal phosphorus loading are nutrient inactivation and aeration (Pastorak et al. 1981; Welch and Cooke, 1999). This report focuses largely on the feasibility of implementing nutrient inactivation and aeration measures to reduce and control each lake's internal phosphorus load and combat the occurrence of harmful algal blooms. The report also includes a section that discusses management strategies to reduce HAB impacts to Sandy Bottom Park at Honeoye Lake.

Figure 1.1: Aerial view of Honeoye Lake.

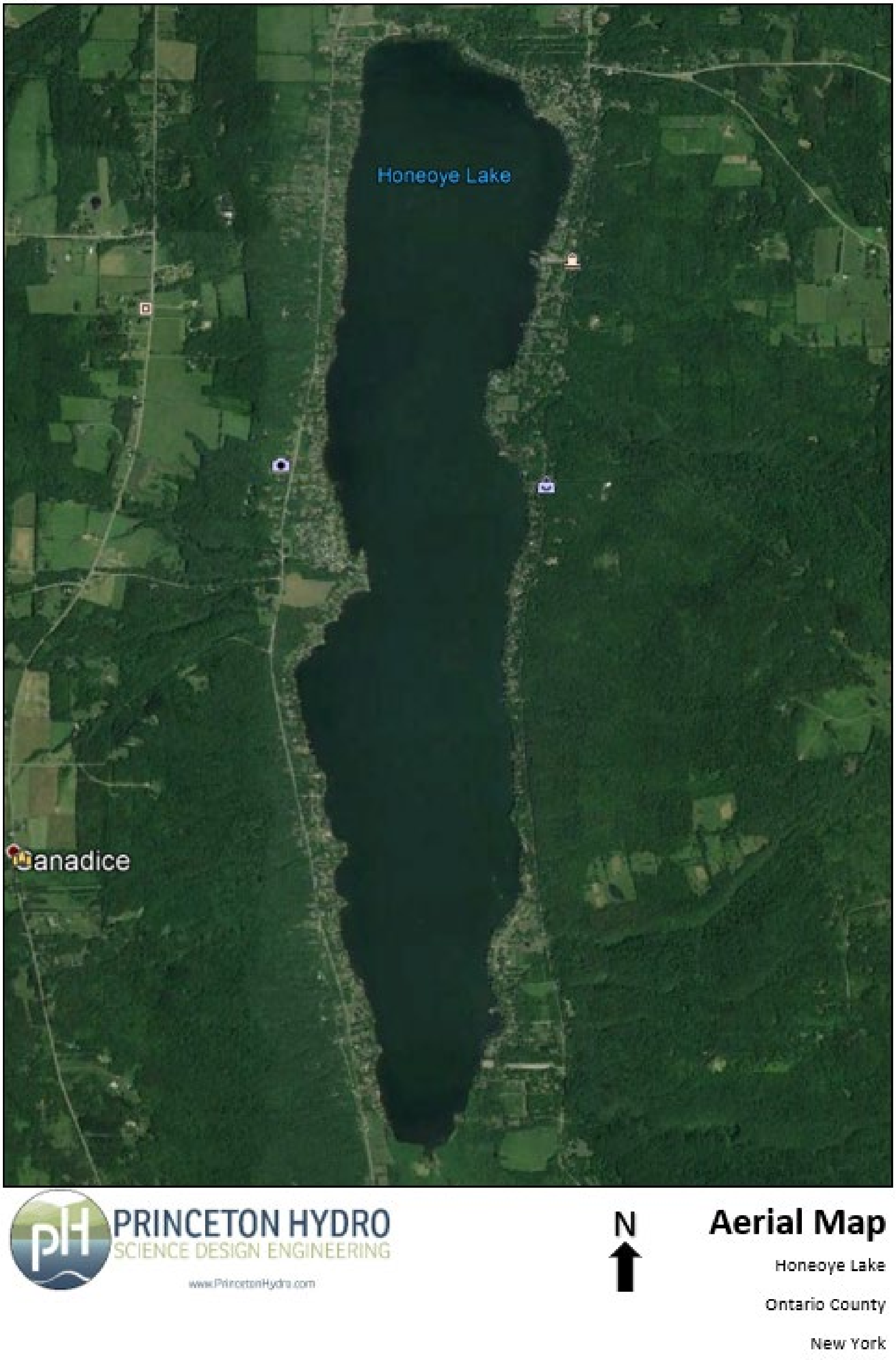


Figure 1.2: Bathymetric Map of Honeoye Lake.

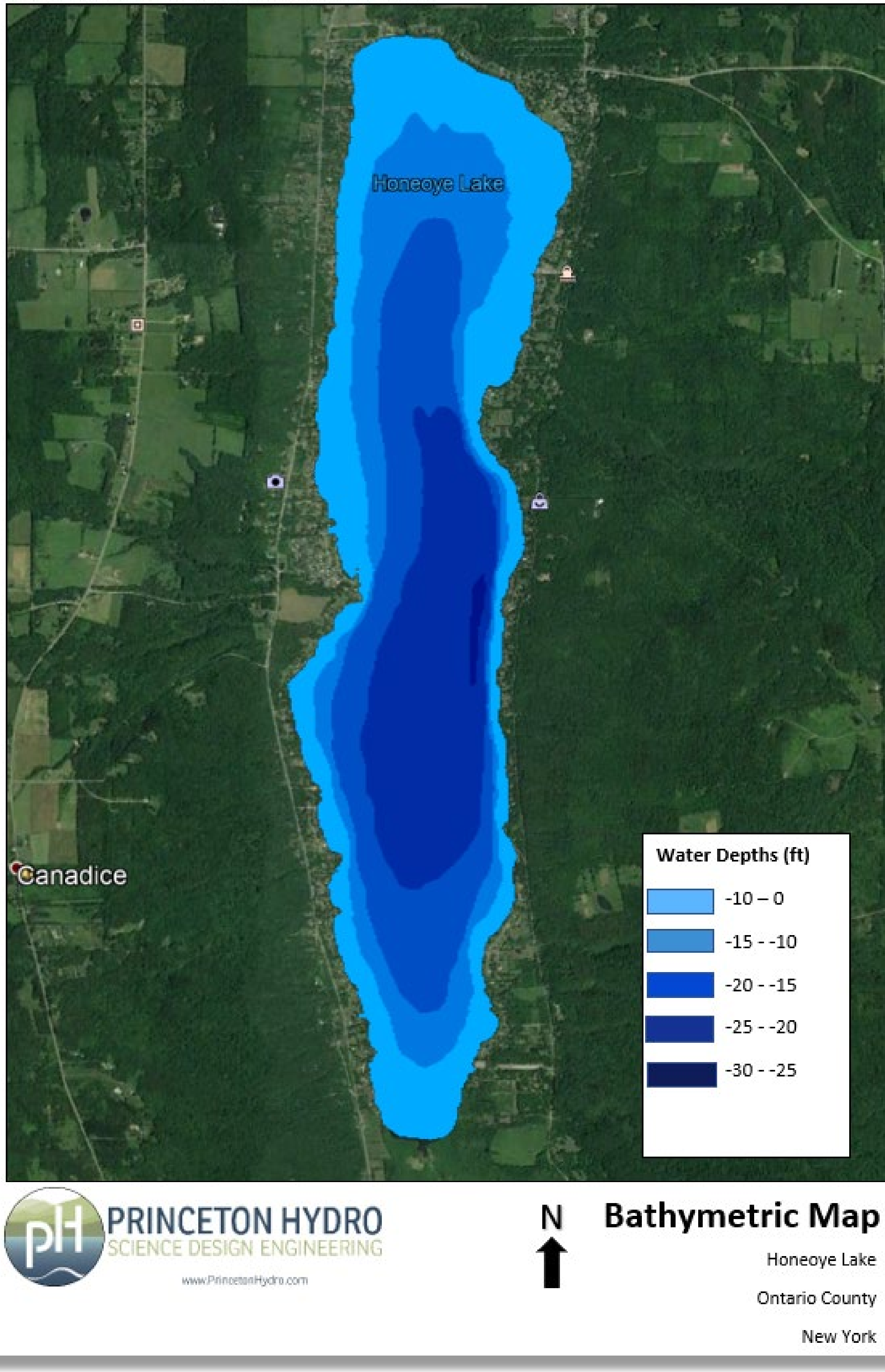
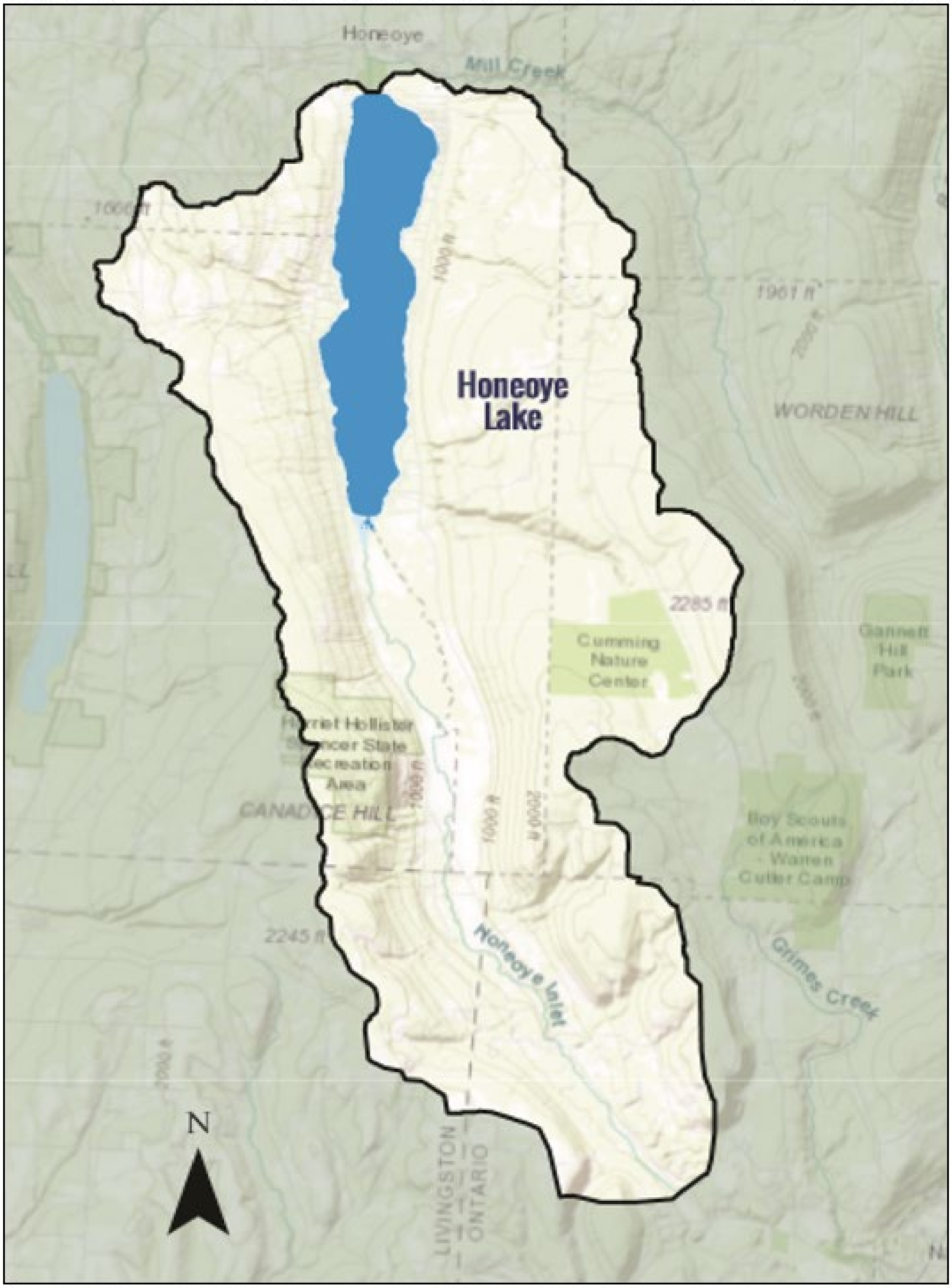


Figure 1.3: Honeoye Lake watershed. Source: NYSDEC HABs Action Plan for Honeoye Lake.



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Watershed Boundary

Honeoye Lake

Ontario County

New York

Figure 1.4: Land use in the Honeoye Lake watershed. Source: NYSDEC TMDL for Honeoye Lake.

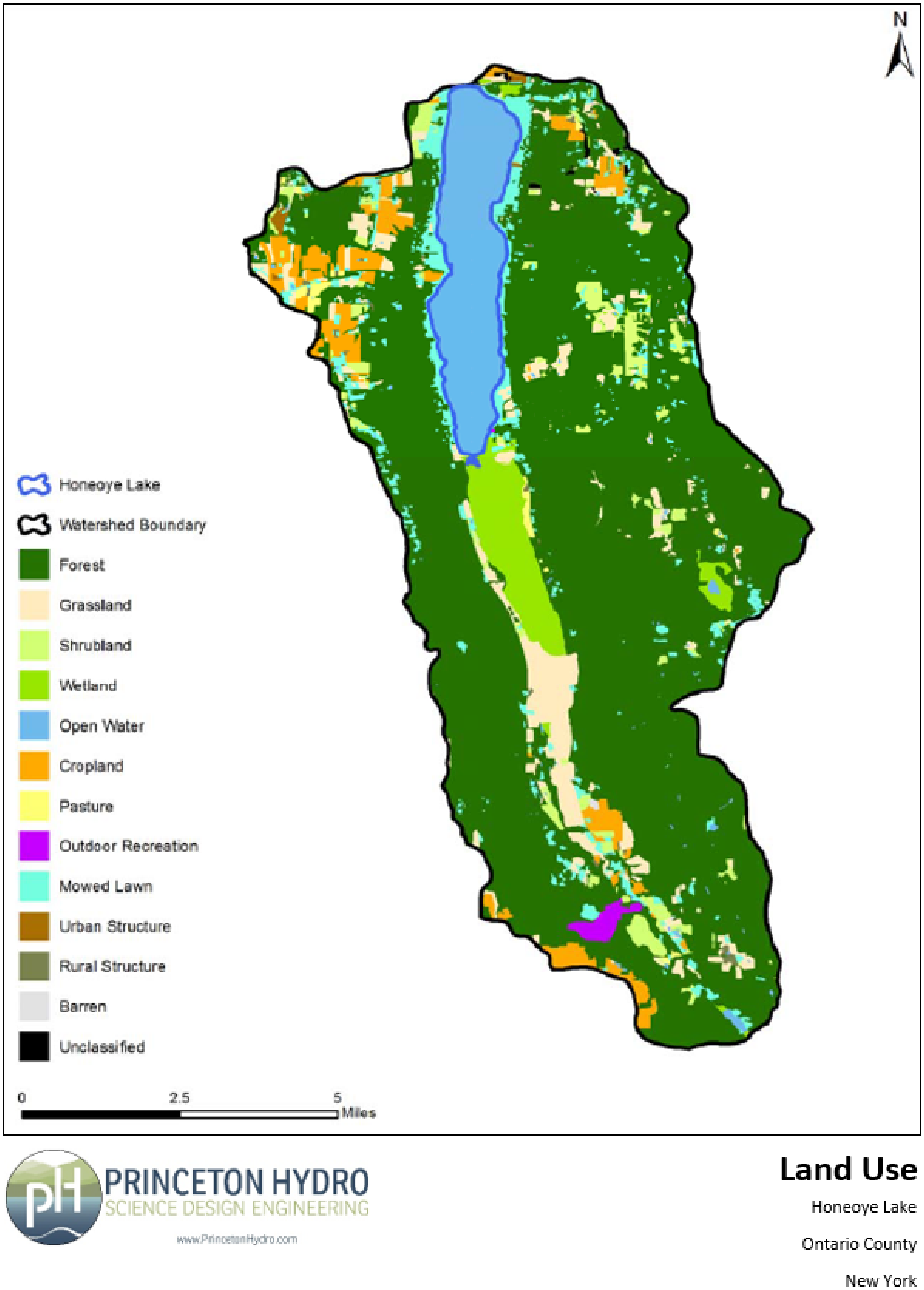


Figure 1.5: Aerial View of Conesus Lake.

Figure 1.6: Bathymetric Map of Conesus Lake

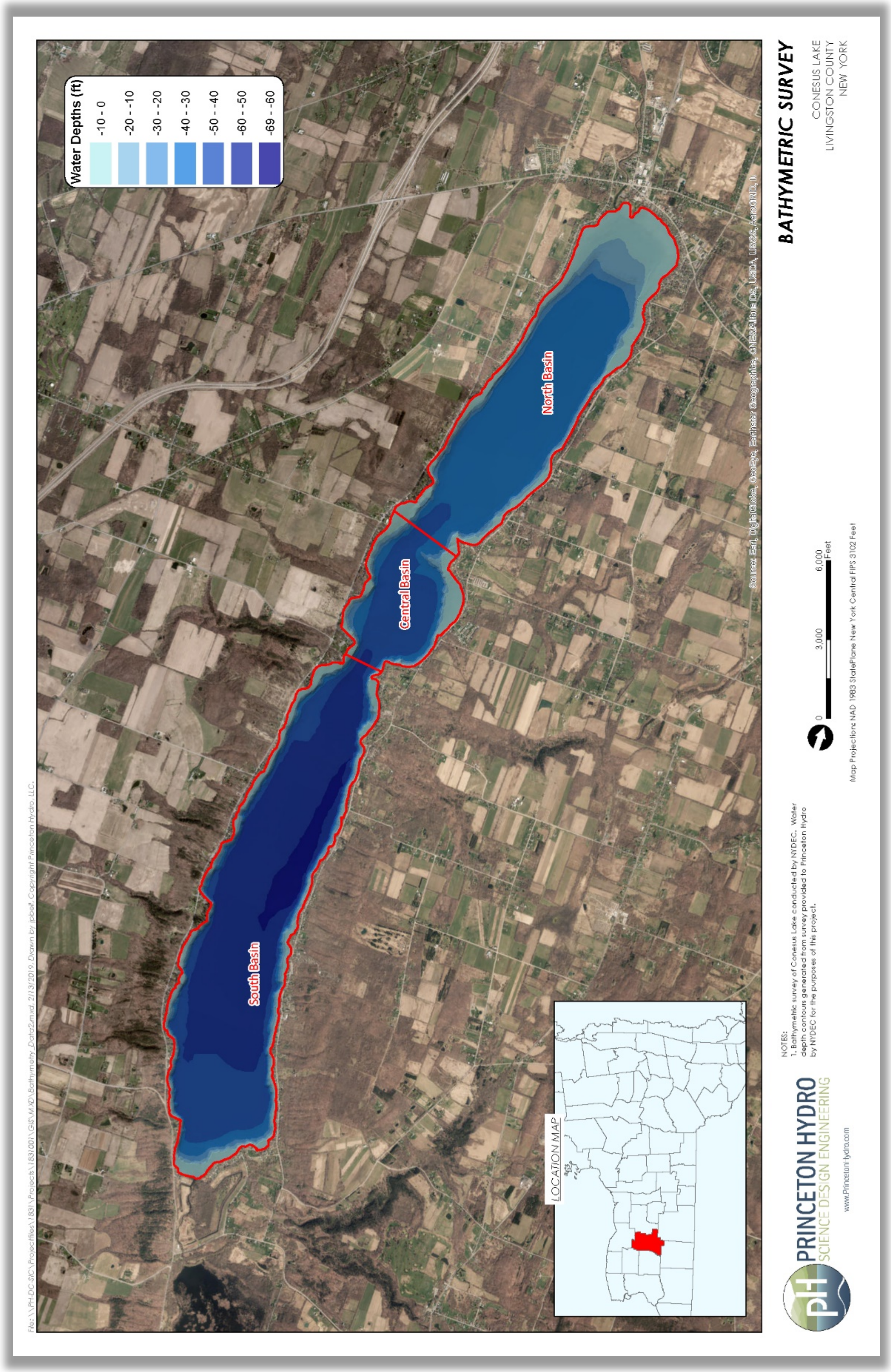
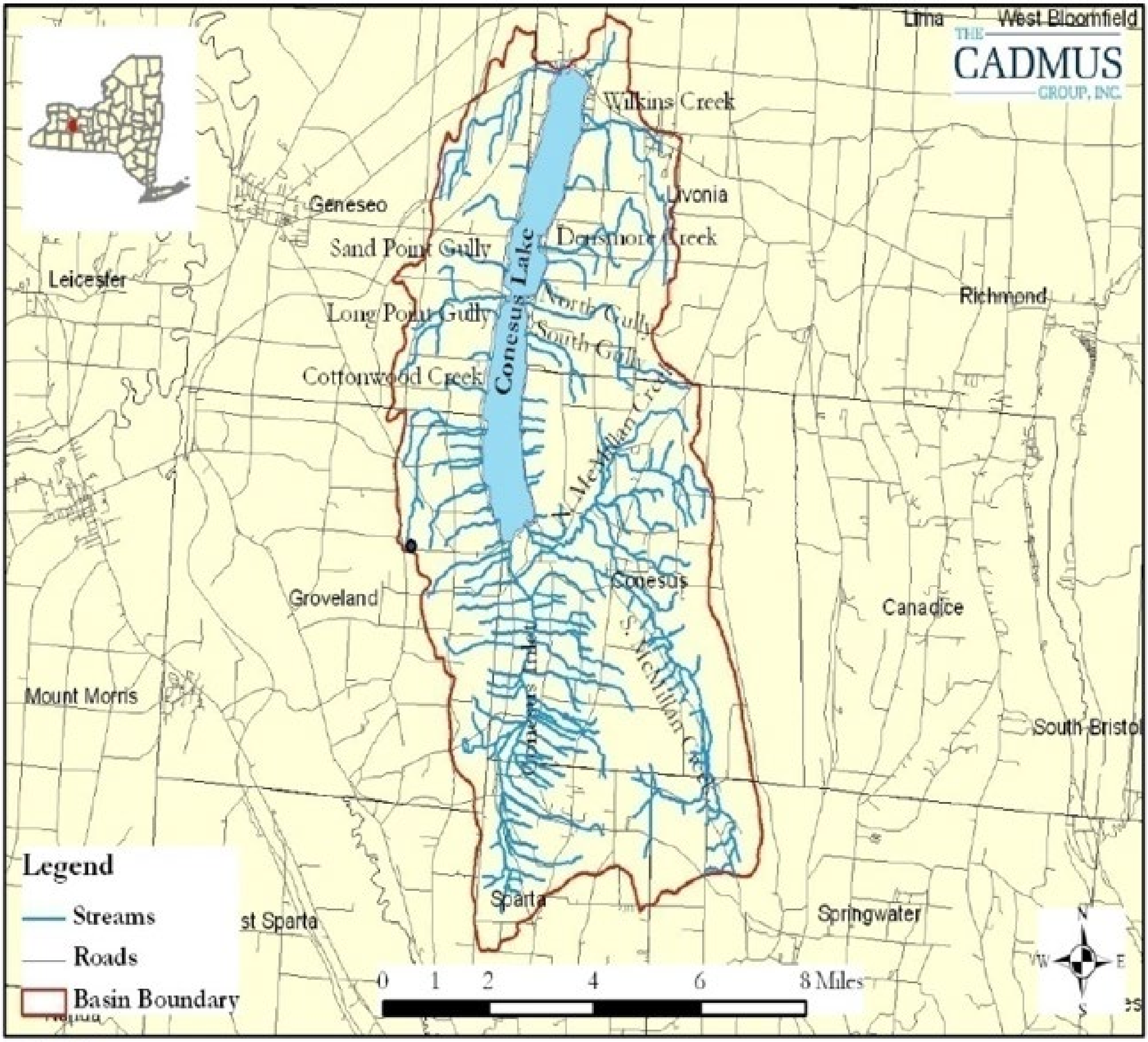


Figure 1.7: Conesus Lake Watershed. Source: NYSDEC TMDL for Conesus Lake.



Watershed Boundary

Conesus Lake

Livingston County

New York

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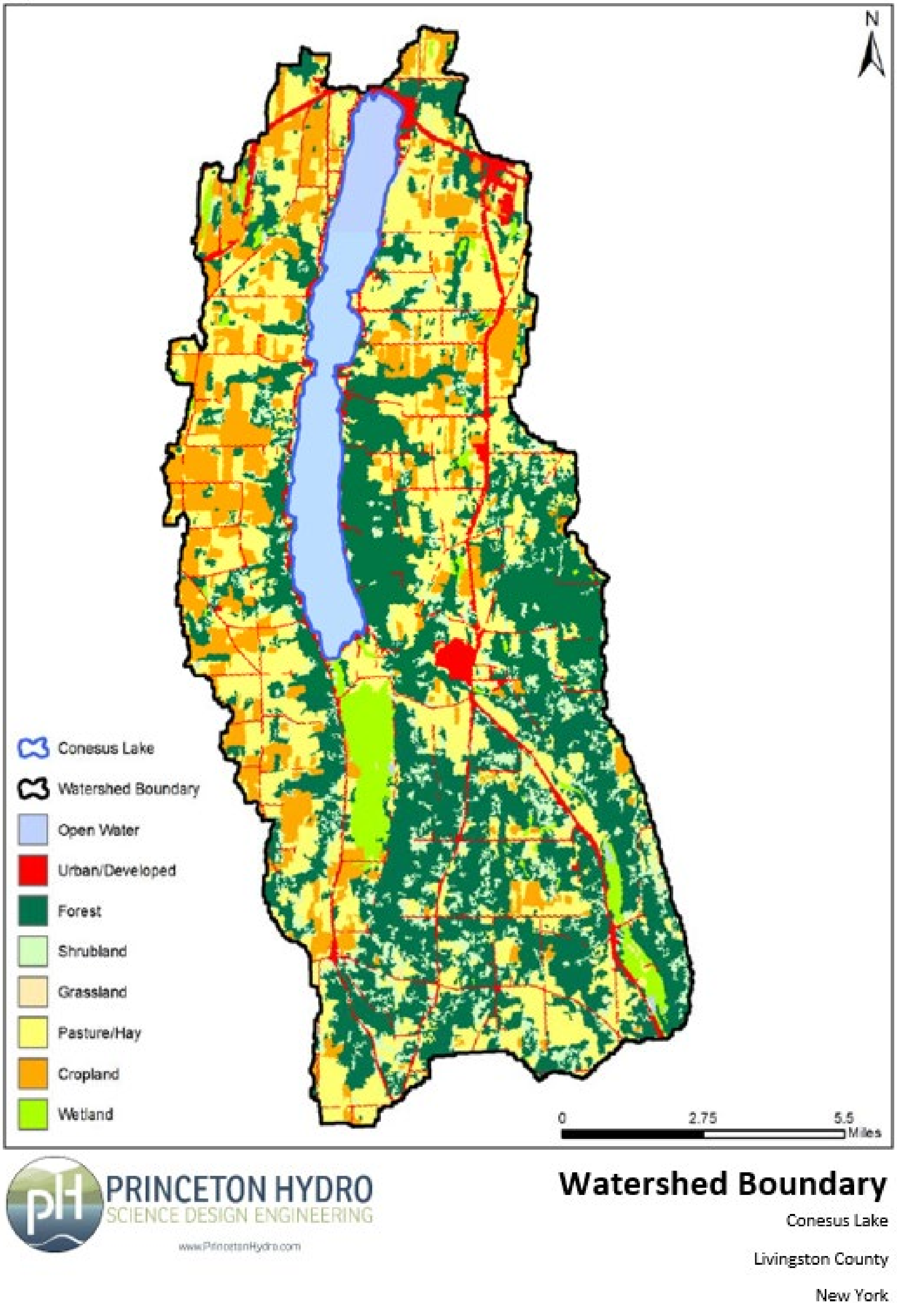
Figure 1.8: Land Use in the Conesus Lake Watershed. Source: NYSDEC TMDL for Conesus Lake.



2.0 REVIEW OF EXISTING INTERNAL PHOSPHORUS LOADING DATA AND RELATED FACTORS AFFECTING THE OCCURRENCE OF HABS IN HONEOYE LAKE AND CONESUS LAKE

HABs may affect lakes on the entire trophic state spectrum, from oligotrophic to eutrophic. Over the past decade both Honeoye Lake and Conesus Lake have been impacted by documented HABs. The Finger Lakes of New York have typically been categorized as moderate productivity (mesotrophic) lakes (NYSDEC, 2019a). Although both Honeoye Lake and Conesus Lake have some of the characteristics associated with lower productivity waterbodies, they display many of the characteristics more reflective of eutrophic lakes. A eutrophic lake by definition is a highly productive lake, characterized by high aquatic plant (weed) and/or phytoplankton growth. Lakes categorized as eutrophic should not necessarily be negatively viewed given that most lakes in New York are eutrophic. Phytoplankton blooms are a common occurrence in eutrophic lakes. The severity, longevity, and even more importantly, the species responsible for these blooms may be tempered and controlled. Thus, efforts implemented in the restoration and management of most eutrophic lakes emphasize reducing the amount of primary productivity. The most commonly employed strategy to address eutrophication and reduce productivity is to reduce the amount and availability of nutrients, especially phosphorus. Nutrient management is also recognized to be the most important action needed to prevent the occurrence of HABs (NYSDEC, 2018f). In the case of both Honeoye Lake and Conesus Lake, NYSDEC has emphasized the importance of reducing the amount and availability of phosphorus as the key to minimizing the frequency and magnitude of cyanobacteria blooms affecting both lakes (NYSDEC, 2018b; NYSDEC 2018d).

In preparing this report, Princeton Hydro made extensive use of recent data and reports published by the NYSDEC. We also reviewed and made use of data reported by local lake stakeholders, county personnel, Finger Lakes Community College, SUNY Geneseo, SUNY Brockport, and Cornell University. Within this sub-section of the report we summarize the data for each lake and discuss the relevance of these data to the feasibility of using a nutrient inactivant and/or aerating the water column to proactively decrease phosphorus loading, phosphorus availability, and the development and persistence of HABs. Our recommendations pertaining to the use of nutrient inactivants and/or aeration are presented in Sections 3 and 4 of this report.

In preparing the recently published TMDL reports for both lakes (NYSDEC 2019b; NYSDEC 2019c), NYSDEC reviewed and used much of the same data used by Princeton Hydro to prepare this report. In preparing the TMDLs for each lake, the NYSDEC made extensive use of the CE-QUAL-W2 model to generate and analyze the internal phosphorus loading data for both lakes. The results of NYSDEC's TMDL modeling efforts were closely reviewed by Princeton Hydro in the preparation of this report. This included Princeton Hydro's independent computation of each lake's internal phosphorus load using Nürnberg's sediment-phosphorus release rate equation (Nürnberg, 1985). This entailed the use of actual measured dissolved oxygen and thermal stratification data collected for each lake over the past 3-5 years. For both lakes, our calculation of internal phosphorus loading under anoxic water column conditions was computed using one of Nürnberg's lower sediment-phosphorus release rates (6.0 mg TP/m^2/d) as well as Nürnberg's median sediment-phosphorus release rate (15.0 mg/ TP/m^2/d). It should be noted that the median release rate of 15.0 mg/ TP/m^2/d reflects sediment core tube analyses, under oxic and anoxic conditions, conducted by multiple researchers and reported in Nürnberg, 1985. We feel that this value is representative of what would be expected under *in-situ* conditions. As discussed below, we found good agreement between the modeled data generated by NYSDEC using CE-QUAL-W2 and the data generated by Princeton Hydro using Nürnberg's median sediment-phosphorus release rate. The use of the sediment core release rate value is consistent with the basic recommendations put forth in multiple studies evaluating the use of the nutrient inactivant alum (aluminum sulfate). As summarized by Pilgrim, et. al (2007), the optimum alum dose computed for whole-lake, nutrient inactivant treatments should be based on the measurement of the amount of "mobile phosphorus" present in the sediments. Mobile phosphorus refers to the phosphorus fraction present in the sediment that is bound to iron. Due to the chemical stoichiometry and relatively "weak nature" of the covalent iron-phosphorus bond, it is this fraction of sediment phosphorus that is initially and rapidly released into the overlying water column during periods of anoxia. Focusing on this fraction provides the most accurate means of assessing the potential internal phosphorus load. As such, sediment core-based release rates should provide the best estimate of the available mobile phosphorus fraction that needs to be targeted by the application of a nutrient inactivant. Although Princeton Hydro has high confidence in the internal phosphorus loading data generated using both CE-QUAL-W2 and Nürnberg's median sediment phosphorus release rate value, in advance of any nutrient inactivation effort it would be prudent to conduct lake-specific sediment core analyses.

The modeled data generated by both NYSDEC and Princeton Hydro support the importance of reducing each lake's internal phosphorus load as a means of preventing and managing HABs. The modeled data, along with the field data collected by the previously noted entities, collectively support the prioritization of management actions aimed at specifically reducing and controlling the internal phosphorus load of each lake.

Our analysis of each lake's internal phosphorus load made extensive use of each lake's empirical data pertaining to the development and persistence of thermal stratification and dissolved oxygen (DO) depletion. The thermal data clearly show that the deep southern basin of Conesus Lake displays the characteristics of a dimictic waterbody in that it experiences one relatively stable stratification period that persists throughout the growing season. However, the central and northern basins of Conesus Lake display a greater amount of thermal instability. This is reflected in data collected over nearly 20 years by SUNY Brockport, SUNY Geneseo, and Livingston County as well as the real-time thermal sensor data recently collected by the Conesus Lake Association's Water Quality Committee (Hanafin, K., pers. comm., 2018). The long-term thermal data collected by the Honeoye Lake Watershed Task Force, Finger Lakes Community College, and Cornell University confirm that Honeoye Lake is a polymictic waterbody that experiences numerous stratification events over the course of the growing season[2].

Each lake's water column stability was also examined by Princeton Hydro by computing changes over time in the relative thermal resistance to mixing (RTRM). These data are presented in Appendix I. RTRM (Kortmann and Henry, 1987) is an expression of the water column's resistance to mixing that is based on the relationship between water temperature and water density. Elevated RTRM values are reflective of a stable water column, or stratum of the water column, and thus indicative of thermal stratification. Low RTRM values are indicative of a water column having relatively uniform water temperatures and water densities. Thus, low RTRM values are characteristic of a non-stratified, easily mixed water column.

2.1 CONESUS LAKE

Once again summarizing, Conesus Lake has a surface area of 3,420 acres and a mean depth of 11.6 meters (NYSDEC, 2018a, Livingston County, 2018). The lake is assessed as an impaired waterbody on the NYSDEC 303d List of Impaired/TMDL Waters due to primary and secondary contact recreation uses that are known to be impaired by nutrients (phosphorus), resulting low dissolved oxygen, and excessive algae. The lake has a history of cyanobacteria blooms. In 2018 the lake was cited on the NYSDEC's HABs Notifications Page eight times between 22 June and 19 October.

As noted above, Nürnberg's sediment-phosphorus release rate equation was used to compute the lake's internal total phosphorus (TP) load. These data were compared to the NYSDEC's CE-QUAL-W2 modeled results. Using CE-QUAL-W2, NYSDEC reports that Conesus Lake's anoxic sediment related internal TP load is 10,641 kg/yr. (NYSDEC, 2019b).

[2] Dr. Nelson Hairston has suggested referring to Honeoye Lake as a continuous bradymictic lake; that is, a lake that slowly mixes due to upwelling events rather than due to the complete destratification of the water column.

Princeton Hydro's calculation of the lake's internal load began with delineating the total area of the lake bottom subject to periodic anoxia. The majority of the phosphorus releases from lake sediments occurs under anoxic conditions. For our analysis we used a DO concentration of < 2.0 mg/L as the threshold for anoxic phosphorus release. This is a very conservative (prone to over-estimation) approach, but because most DO data are collected during the day when photosynthesis is occurring, rather than at night when total community respiration peaks, the 2.0 mg/L threshold enables us to account for potential nocturnal drops in DO and total community respiration. Utilizing this DO benchmark value, the data collected by SUNY Geneseo during the 2017 growing season shows 9.5 meters to be the average depth at which ≤ 2.0 mg/L DO concentrations are measured (Bosch, et al., 2018). Utilizing the lake's bathymetric data (Figure 1.6), approximately 70% or 2,425 acres of the lake bottom should be subject to anoxia, with the resulting anoxic conditions expected to manifest uniformly at a depth > 9.5 meters in all three basins of the lake.

To accurately quantify anoxic loading throughout the growing season, a time period of deep-water anoxia must be established. For our analysis we used the 2017 SUNY Geneseo data. Deep-water anoxia was observed during the 2017 growing season from June 12th to September 14th, a total of 94 days. The total internal phosphorus load for Conesus Lake under anoxic conditions was then calculated using Nürnberg's median sediment-phosphorus release rate coefficient (15.0 mg TP/m^2/d), applied over a lake bottom area of 2,425 acres for a period of 94 days. This yielded an anoxic internal TP load of 14,099 kg TP/year, which reasonably agrees with the CE-QUAL-W2 data. These data also fall within the range (3,618 kg/yr. to 16,082 kg/yr.) of internal phosphorus loading computed by SUNY Geneseo (Bosch 2019). Collectively, the Princeton Hydro, NYSDEC TMDL, and SUNY data conclude that the internal phosphorus load attributable to sediment release under anoxic conditions is not only significant but is the primary phosphorus source driving lake productivity. Controlling this load is therefore important to improving the water quality of Conesus Lake.

2.2 HONEOYE LAKE

As reported by NYSDEC, the CE-QUAL-W2 internal TP load computed for Honeoye Lake is 7,480 kg/yr. (NYSDEC, 2019c). Our independent analysis of Honeoye Lake's internal phosphorus load was conducted using the same approach used for Conesus Lake. This began with delineating the total area of the lake bottom subject to periodic anoxia. As explained above, in order to account for nocturnal respiration our internal phosphorus loading analyses are based on an anoxic DO concentration of < 2.0 mg/L. Again, Princeton Hydro recognizes that this is conservative and could result in an over-estimation of anoxic internal phosphorus loading. However, as noted above, the 2.0 mg/L threshold is justified. Also, due to the polymictic mixing nature of Honeoye Lake, a threshold of 2.0 mg/L helps to account for shifts in stratification patterns and resulting anoxic conditions that occur between sampling events. The 2.0 mg/L DO benchmark was applied to DO and temperature data spanning from 2008 - 2018 collected by Finger Lakes Community College, Cornell University, and the Honeoye Lake Watershed Task Force (HLWTF). These data indicate that as much as 808 acres of lake bottom are subject to anoxia and that anoxic conditions can occur between 90 and 200 days per year. Guidance received from Dr. Nelson Hairston of Cornell University (Hairston, 2018 pers. comm.), suggests that the total bottom area and duration of time that anoxia is experienced may be less than that computed by Princeton Hydro. Data collected by Hairston from 2016 through 2018 do confirm that those areas of the lake 7 meters or deeper routinely become anoxic during the summer. Thus, although the calculated internal TP loads for Honeoye Lake presented herein are conservative, they are reflective of anticipated internal loading values.

In order to best account for the changing stratification patterns that affect Honeoye Lake throughout the growing season and to create the most accurate internal loading model for the lake, the total area of the sediment subject to anoxia was calculated by taking the number of anoxic days at each depth interval throughout the growing season and calculating the internal load for each depth interval. The calculated phosphorus loads for each depth interval were then summed to yield the lake's total annual internal TP load under anoxic sediment conditions. Assuming 808 acres of lake bottom are subject over the summer to anoxia, and anoxic conditions may persist at the sediment water interface between 90 and 200 days per year, the resulting loads generated using Nürnberg's median daily internal TP loading coefficient (15 mg/m^2/day) range from 4,400 kg/yr. to 9,180 kg/yr. This is approximately 60% to 120% of the NYSDEC's CE-QUAL-W2 computed anoxic internal TP load. Thus, using the above data and the data contained in the NYSDEC's TMDL report, internal phosphorus loading from the lake's sediment under anoxic conditions accounts for a significant percentage of the lake's total annual phosphorus load. These data support the conclusion that the lake's internal load is a major trophic state driver. Additionally, when reviewed with respect to the feasibility of managing the lake's other external and internal sources, reduction of the sediment released phosphorus load is the most cost-effective and easiest source to control. Reducing the lake's internal phosphorus load is also consistent with the NYSDEC's Honeoye Lake HAB Action Plan. As such, restoration measures implemented for Honeoye Lake should prioritize the reduction of this source of phosphorus.

Sections 3 and 4 of the report respectively examine the feasibility and application of a nutrient inactivant and the use of lake aeration to control and reduce each lake's internal phosphorus, control eutrophication, and manage HABs. However, it must be noted that the nutrient inactivation (alum) and aeration projects recommended in this report are not intended to control benthic filamentous mat algae (e.g., *Pithophora* and *Spirogyra*) and/or benthic cyanobacteria (e.g., *Gloeotrichia* and *Lyngbya*). These species most commonly colonize shallow, well-oxygenated, nearshore areas and initially obtain the majority of their nutrients from the sediment water interface rather than directly from the water column. The nearshore sediments do not become overlaid by anoxic (dissolved oxygen deficient) waters. Although a recognized source of internal phosphorus loading, nearshore sediments are not targeted for management by either aeration or nutrient inactivation. Thus, although nutrient inactivant treatments and aeration will effectively control and decrease the phosphorus released from the deep-water sediments overlaid by anoxic water, aeration and alum will not likely reduce the development of nearshore benthic algae or cyanobacteria. It should also be recognized that any lake management measure that increases water clarity may result in additional areas of the lakes becoming colonized by aquatic macrophytes (weeds).

3.0 NUTRIENT INACTIVATION TO CONTROL INTERNAL PHOSPHORUS LOADING

The data for both Honeoye Lake and Conesus Lake presented in Section 2 documents the occurrence of harmful algae blooms is driven primarily by the internal phosphorus loading. The majority of the lakes' internal phosphorus loads are generated during periods of thermal stratification following the development of deep-water anoxia. Thus, reducing this source of phosphorus loading should be prioritized for both Honeoye Lake and Conesus Lake.

Honeoye Lake is a polymictic waterbody, meaning that the thermal stratification of the overall water column is weak and inconsistent. As a result, the water column is often unstable, even during the middle of the summer when stratification and RTRM should peak. Data collected and analyzed by CSLAP volunteers, Dr. Bruce Gilman of Finger Lakes Community College, and Dr. Nelson Hairston of Cornell University show that an anoxic hypolimnion may develop at the very bottom of the lake in late-spring. This anoxic layer typically affects only the deepest 1 or 2 meters of the lake. This thermally stratified state commonly persists into early August. The Cornell University data shows that this pattern of stratification occurs during both dry-weather and wet-weather years. Under these conditions, a larger percentage of the water column may become anoxic. Anoxic conditions trigger the rapid release of a large amount of phosphorus from the sediments. The magnitude of the internal load was first modeled by Princeton Hydro (Princeton Hydro, 2007) and since then by others (NYSDEC, 2019c). The modeled data contained in these various reports are also consistent with CSLAP in-field data. Collectively the modeled and field data show that at times the total phosphorus concentrations measured in the deeper reaches of Honeoye Lake may be an order of magnitude greater than the concentrations measured at the lake's surface (NYSDEC, 2017). However, the general instability of the lake's thermocline, combined with the lake's internal seiche and polymictic nature increase the opportunity and likelihood for the phosphorus present in these deeper waters to be transported into the epilimnion. When this occurs productivity spikes, often resulting in a harmful algal bloom. Since 2012, Honeoye Lake has had 84 confirmed HABs (NYSDEC, 2018d) with fourteen of those events exceeding the NYSDEC high toxin threshold for microcystin[3].

Focusing only on the deep southern basin, Conesus Lake would be classified as a dimictic waterbody, meaning that it stratifies and de-stratifies twice annually, once in the spring and once in the fall. For dimictic lakes, thermal stratification tends to be strong and once established the thermocline is consistent and persists through the summer. Water column stability therefore tends to be much greater than that observed for polymictic lakes. For dimictic waterbodies, the upwelling of nutrients from the hypolimnion into the epilimnion is most significant during the fall turnover. However, although the thermal stratification of Conesus Lake's deep southern basin is characteristic of a dimictic waterbody, the transitionary central basin and the shallower northern basin display properties that are more characteristic of a polymictic waterbody. Data from SUNY Geneseo (Bosch, et al., 2015) document the mid-summer upwelling of phosphorus-rich waters within the shallower north basin following intense wind events. Field sampling showed that following intense storms, a 1-2 m deepening of the thermocline occurs, resulting in mixing of the epilimnion and hypolimnion. These mid-summer mixing events lead to measurable increases in the northern basin's phosphorus and chlorophyll *a* concentrations and a greater density of *Anabaena* cells. Although thermal stratification of the lake's southern deep basin is largely indicative of a dimictic lake, the less deep central and the shallower northern basins exhibit less water column stability and water column properties more characteristic of a polymictic lake. Some data also suggest that internal phosphorus loading originating in the lake's deeper southern basin may be transported and upwelled during the summer into the shallower central and northern basins due to wind, wave, and internal seiche mechanisms. Since 2013, Conesus Lake has had 13 confirmed harmful algal blooms (NYSDEC, 2018a). The majority of the beach and high-use recreational areas impacted by these blooms are located in the lake's northern basin.

[3] https://www.dec.ny.gov/docs/water_pdf/habsprogramguide.pdf

3.1 BENEFITS OF NUTRIENT INACTIVATION

Nutrient inactivation is a common in-lake management tool utilized to control phosphorus availability and internal phosphorus loading. Over the past forty years, nutrient inactivation has been successfully implemented in the management and restoration of numerous lakes and reservoirs located in New Jersey, Pennsylvania, New England, and the mid-West (Cooke, et al., 2005). Some of these products have been used for over four decades in the restoration of eutrophic, phosphorus-rich lakes (Cooke, et al., 1977; Cooke, et al., 2005). Numerous studies and supporting data, going back into the 1980s, demonstrate the effectiveness of nutrient inactivant treatments, in many cases accomplished following a single application of a nutrient inactivant (Huser, et al., 2016).

Nutrient inactivant products are used in two, often overlapping, ways:

- To decrease water column dissolved phosphorus concentrations through binding and precipitation,
- To bind phosphorus within sediment interstitial pore water or as that phosphorus is released from the sediment during periods of deep-water anoxia.

The primary objective of any nutrient inactivant project is to decrease the concentration of biologically available phosphorus within a waterbody. There are a number of nutrient inactivant products that can be used to manage phosphorus availability. Examples of the most commonly used products are:

- Aluminum sulfate (alum)
- Sodium aluminate
- Buffered alum (alum + sodium aluminate)
- Polyaluminum chloride (PACl)
- PhosLock (lanthanum)
- Various ferric (iron) products

Of the above, the most commonly used nutrient inactivant is aluminum sulfate (alum). Alum has been used for over 70 years in drinking water treatment plants as a coagulant to strip water of particulate material. Dating back to at least the 1980s, alum has also been widely used in managing and restoring lakes (Cooke, et al., 2005). A primary advantage of alum is that it is produced in bulk and is therefore relatively inexpensive and easy to obtain.

Upon contact with water, alum forms a “fluffy” amorphous aluminum hydroxide precipitate. This precipitate is the result of the liberation of aluminum ions, which are immediately hydrated, and through a progressive series of hydrolysis, form aluminum hydroxide. The resulting colloidal, amorphous floc has high coagulation properties that bind, concentrate, and settle particulate phosphorus and other suspended materials from the water column. The aluminum hydroxide also effectively binds dissolved forms of phosphorus. Because the floc is heavier than water, it settles out of the water column over a 12-24 hour period and becomes integrated into the lake’s soft sediments. The remaining active aluminum hydroxide contained in the floc binds interstitial pore water phosphorus, including that released under periods of anoxia. Any bound phosphorus becomes “inactivated” meaning that it is unavailable for biological uptake by benthic algae and phytoplankton.

The phosphorus bound by the alum is insoluble in water. The major benefit of using alum and the other aluminum and lanthanum-based nutrient inactivants is that the bound phosphate is not redox sensitive and the bound phosphorus will remain biologically unavailable even if the overlying waters become anoxic. This cannot be accomplished using the iron based inactivant products. Welch and Cooke (1999) showed that following a single surface application of alum, the internal loading rate in 7 out of 7 dimictic, eutrophic lakes was reduced on average by 80%, while water column bio-available concentrations of phosphorus remained low for an average of 13 years.

The primary disadvantage of alum is that it will cause the pH of a treated lake to decrease and become more acidic. The extent to which this happens is largely a function of the lake’s buffering capacity, defined by its natural alkalinity. If the pH following an alum treatment drops below 6.0-5.5, the aluminum in the applied alum can enter a dissolved state which may prove toxic to fish and other aquatic life. However, the literature also shows that alum can be safely utilized with no negative consequences to aquatic biota if changes in pH are effectively managed (Welch and Cooke, 1999; Steinman et al. 2004). Essentially this means applying alum only in lakes having adequate buffering capacity as well as applying alum carefully in an amount that does not cause the pH to drop excessively. NYSDEC has historically used a pH threshold of 6.5 as the lower threshold limit for alum treatments.

Data collected over the past 25 years for both Honeoye Lake and Conesus Lake strongly support the use of nutrient inactivation as part of each lake's long-term management strategy. Specifically, this is a function of the magnitude of the computed/measured internal phosphorus loads, the fact that the internal phosphorus loads peak in the summer, and that this source of phosphorus loading contributes to eutrophication. For consistency and specificity, throughout the remainder of this report, nutrient inactivant treatment will be referred to as an alum treatment, recognizing that product selection will ultimately be dictated by bench testing.

3.2 ALUM BENCH TESTING

As previously noted, both Honeoye Lake and Conesus Lake are good candidates for nutrient inactivation using aluminum sulfate (octadecahydrate $Al_2(SO4)_3$ *$18H_2O$). However, before an alum treatment of either lake is implemented, alum bench testing must be conducted. **In fact, the HAB action plans developed for both Honeoye Lake and Conesus Lake identify Bench Testing as a Priority 1 project (NYSDEC 2019b; NYSDEC 2019c).**

Because both lakes have relatively high alkalinity and good buffering capacity, it should be possible to use alum without causing the pH to drop below 6.5. As well as confirm that an alum treatment can be conducted without causing a negative environmental impact, bench testing will also quantify how much alum is needed to effectively bind each lake's internally regenerated phosphorus load. Alum bench testing is a controlled laboratory analysis involving the iterative addition of increasing amounts of alum to lake water samples (Cooke, G.D., et al., 1986). The resulting data is used to establish a number of important end points:

- The Safe Dose – The maximum amount of alum that can be applied before the pH of the lake water sample drops below an environmentally safe pH; in this case 6.5
- The Effective Dose – The minimum amount of alum that is needed to completely bind all of the measurable soluble reactive phosphorus present in the lake water sample, and
- The Treatment Dose – A dose lower than the safe dose but higher than the effective dose that provides a compensatory amount of alum to address environmental factors that may reduce alum efficiency and increase the longevity of the treatment.

The water sample used for alum bench testing must be representative of the entire water column; that is composed of lake water collected from the epilimnion, metalimnion, and hypolimnion. The bench test begins with the analysis of pH, alkalinity, chlorophyll *a*, soluble reactive phosphorus (SRP), total phosphorus (TP), total dissolved phosphorus (TDP), total aluminum (Al), and dissolved Al, and if the lake is characterized by a large amount (> 10 mg/L) of inorganic suspended sediment (turbidity) an analysis of total suspended solids (TSS). The measurement of pH and alkalinity establishes the baseline buffering capacity of the lake and is used to determine if a treatment will depress the pH below NYSDEC's 6.5 pH safety threshold. The measurement of chlorophyll and TSS will help identify the amount of particulate material present in the water column that could negatively affect the overall effectiveness and efficacy of the alum application. As noted, the settling floc will bind suspended material. If at the time of the treatment high concentrations of phytoplankton and suspended sediment are present in the water column this could decrease the amount of aluminum hydroxide actually available to bind dissolved phosphorus. The TP, SRP, and TDP data are used to quantify the pre-treatment concentrations of total phosphorus present in the water column (TP) and the amount of that phosphorus that is biologically available (TDP and SRP). The aluminum analyses provide information pertaining to the pre-treatment amount of total and dissolved aluminum present in the water column.

The alum bench test involves the introduction of specific amounts of the alum to a subsample of lake water. This is done in a stepwise fashion of increasing doses. After each addition of alum, the pH is recorded. Alum is added systematically until the cumulative dose results in the pH falling below 6.5. The process is then repeated using another subsample of lake water again until the pH of the sample falls below 6.5. This is determined to be the maximum Safe Dose. The initial battery of parameters including the phosphorus and aluminum species is then re-analyzed and the resulting data compared to the pre-treatment data. The bench test should demonstrate that there is no significant change in dissolved aluminum concentrations at the observed pH safety threshold of 6.5. No significant dissolution and attendant increase in aluminum toxicity would be expected until an induced pH of 5.5.

Determining the Effective Dose is accomplished during the same testing regime. As noted above this equates to the amount of alum needed to reduce SRP and TDP to non-detectable concentrations. The Effective Dose should be reached well before the Safe Dose alum volume is exceeded. The concentration of total phosphorus should remain approximately the same throughout the analysis because the soluble forms of phosphorus are simply converted by the added alum from a dissolved state into particulate state.

Arriving at the Treatment Dose applicable for either Honeoye Lake or Conesus Lake will require the synthesis of the bench test data and water column *in-situ* (DO, pH, temperature) profile and discrete laboratory (TP, SRP, TDP, total and dissolved Al) data, along with the calculation of various bathymetric statistics (depth, area, and volume of the targeted treatment zone). This includes use of the measured and/or computed internal phosphorus loading data. The lake's internal phosphorus load represents the phosphorus liberated from the sediments during anoxia. This occurs due to the chemical dissolution of iron bound phosphorus and the subsequent release of this phosphorus from the sediment interstitial pore water into the water column. The internal load, based on both computational and field data for both lakes, is significant. According to NYSDEC's recently published TMDL reports, Honeoye Lake's annual internal TP load released from anoxic sediments is approximately 7,500 kg (NYSDEC 2019c). For Conesus Lake, the annual internal TP load released from anoxic sediments is approximately 11,000 kg (NYSDEC 2019b). If the goal of a nutrient inactivant treatment is to provide five years of internal phosphorus load control with a single application of alum, the total internal load being managed amounts to roughly 37,500 kg of phosphorus for Honeoye Lake and 55,000 kg of phosphorus for Conesus Lake. It will be possible using the combination of the bench test data and in-field data to compute each lake's Treatment Dose (expressed as pounds or gallons of alum applied over a given area of the lake). For either lake, the computed Treatment Dose should be great enough to control the five-year load without contravening NYSDEC's Safe Dose value.

With both the Safe Dose and the Treatment Dose established, developing the appropriate dosing calculations is relatively straightforward, consisting primarily of unit conversions. One of the assumptions of the dosing calculation is that adsorption or removal of phosphorus by alum is a one-to-one relationship. That is, 1 kg of active aluminum will bind 1 kg of dissolved phosphorus. But as previously noted, a number of *in-situ* factors can reduce this 1:1 efficiency ratio. This includes water temperature and the amount of organic and inorganic matter suspended in the water column. Therefore, it is highly recommended that the Treatment Dose be further modified by means of an *efficacy factor*. This will help compensate for decreased efficiency and ensure better long-term phosphorus control. Princeton Hydro routinely uses a 50% efficacy factor to arrive at the final Treatment Dose.

The final Treatment Dose for both Honeoye Lake and Conesus Lake should include data pertaining to the:

- Mass and weight of the proposed amount of aluminum that will be applied to each lake,
- The mass, weight, and volume of the alum product, and
- The surficial application rate (Treatment Dose) expressed as gallons of alum per surface acre.

While all these metrics are expressing the same essential concept, they represent the complexity of applying a liquid product at the surface of the lake with the expressed goal of decreasing the water column concentration of bio-available phosphorus as well as binding interstitial pore water phosphorus present in the anoxic sediments at the bottom of the lake. The mass of aluminum is a very useful metric that can be used by the alum applicator, NYSDEC regulators, and those monitoring the lakes. The mass/weight of alum ties these same concepts to the actual product, as distinct from its ingredients, while the volume is used for purchasing and planning the application logistics.

3.3 PROJECTED ALUM TREATMENT DOSE RATES FOR HONEOYE LAKE AND CONESUS LAKE

For both lakes there is an extensive amount of historic data that can be used to estimate the projected alum dose rate (gallons/acre) needed to effectively treat ether lake. This includes the results of alum bench testing conducted in 2002 for Conesus Lake and in 2007 for Honeoye Lake. The alum treatment area projected for Conesus Lake by EcoLogic (2004) was 1,500 acres, but more recently (Bosch, 2019, pers. comm.) concluded that the application of alum should include both the southern and central basins (2,051acres). Although this only accounts for approximately 64% of the total lake area, limiting the alum treatment to only the southern and central basins should not compromise or decrease the effectiveness of the alum treatment. A partial lake treatment would substantially decrease the cost of treating Conesus Lake with alum. However, further analyses, including detailed basin-specific internal load modeling and trophic state analyses would have to be conducted to verify whether limiting the application of alum to the southern and central basins is a technically sound long-term internal phosphorus load management option. For Honeoye Lake, the alum treatment area was originally limited to 850 acres (Princeton Hydro 2007), but it was subsequently expanded to approximately 1,100 acres based on updated bathymetric data. The expanded treatment area encompasses all areas of the lake deeper than 17 feet (5 meters) in depth. It is those portions of the lake greater than 17 feet in depth that annually become anoxic during the summer months.

Although a Conesus Lake alum treatment was never implemented, Honeoye Lake was treated with alum in 2006. The Honeoye Lake dose rate permitted by the NYSDEC (approximately 150 gallons/acre) was less than the originally proposed treatment dose rate (250 gallons/acre). Nonetheless the lake's treatment with alum was considered a success based on comparison of pre- and post-treatment water quality data compiled by the HLWTF (2007), as well as sediment box core samples collected and reported by Rocchio (2011). The latter study showed a significant increase in sediment P concentrations linked to the flocculation and binding of sediment phosphorus by the alum. The additional retention of phosphorus in the sediments was a goal of the alum treatment and internal phosphorus load suppression. Additionally, the 2006 treatment of Honeoye Lake did not cause any documented environmental impacts. Specifically, the lake's pH never dropped below the 6.5 threshold (HLWTF 2007) and there were no changes to the lake's benthic infauna based on the comparison of the pre-alum and post-alum benthic community (Gilman, 2007). The perceived longevity of the Honeoye Lake treatment was 2-3 years (T. Gronwall, 2018 per. comm.).

Bench test data suggest that a Treatment Dose rate for both lakes could be in the range of 300 gallons of alum/acre[4] (Princeton Hydro, 2006). Should the treatment of either lake be permitted by NYSDEC it will be necessary to repeat the bench testing and generate up-to-date Safe, Treatment, and Longevity dose rates for each lake. Additionally, the alum dose rate authorized for application at either lake will also be predicated on NYSDEC technical review of other environmental factors. This report uses an alum treatment dose rate of 300 gallon per acre for both lakes. This appears to be a reasonable dose rate as based on the past bench testing conducted for both lakes. The projected treatment area for Conesus Lake was limited to the southern basin (1,500 acre) and for Honeoye Lake the treatment area was 1,100 acres. Based on a 300 gallon/acre dose rate,

[4] It should be noted that the bench test results reflect a treatment volume of 7 acre-feet or a treatment zone of 1 acre at 7' depth. As noted, alum dosing rates should never exceed the Maximum Safe Dose rate based on NYSDEC's 6.5 pH safety threshold. Alum dose rates should also be determined through laboratory bench test analyses using depth integrated samples.

450,000 gallons would be needed to treat Conesus Lake and 330,000 gallons would be needed to treat Honeoye Lake. The projected amount of time needed to apply this much alum is expected to be 12-24 days for Conesus Lake and 10-20 days for Honeoye Lake.

3.4 ANTICIPATED PROCESS BY WHICH ALUM WILL BE APPLIED TO HONEOYE LAKE AND CONESUS LAKE.

Princeton Hydro, under separate contract with the NYSDEC, developed a monitoring protocol that can be used during an alum treatment to ensure that the treatment does not contravene the 6.5 pH threshold. This begins with conducting daily pre-treatment baseline measurements of the lake's pH by an appropriately trained and equipped sampling crew. These baseline measurements are conducted within that area of the lake designated for treatment on that day. Once the actual application of the alum commences the same sampling crew follows the treatment barge at a distance of 50 to 150 feet and periodically measures water column pH at the lake's surface and at other depths to the bottom of the treatment area. At a minimum, these *in-situ* pH measurements should be performed several times per day. As per the protocol previously developed for NYSDEC by Princeton Hydro, should the pH fall to 6.5, several successive actions are triggered. First, the sampling crew alerts the applicator, and the alum application is temporarily halted until water column pH rises above the 6.5 threshold. At this time, the consultant would also contact NYSDEC to notify the agency of a pH excursion and determine a course of action. The application of the alum would not continue until the pH recovers above 6.5; otherwise, treatment is suspended, and pH is to be reassessed the morning of the next scheduled treatment day. Once the pH rises above 6.5 the application of the alum could resume. Throughout this process, the consultant is to remain in continuous contact with NYSDEC. In addition to the *in-situ* pH readings, DO, temperature, conductivity, and clarity are measured in profile, at an open water, centrally located station in the targeted treatment zone. Discrete water samples may also be collected and analyzed for TP, SRP and TDP. This sampling is done at the beginning of the day, prior to the application of the alum, and then again at the end of the day. These data are used along with the pH data to evaluate water quality changes associated with the application of the alum.

The treatment process may also be affected by environmental conditions that could reduce the efficacy of the application or pose a risk to the applicators and support staff. Applicator safety and product application issues are highly likely to arise when air and water temperatures drop below 4°C. Cold temperatures increase the opportunity for "slip/trip" hazards to the operators. At air temperatures less than 4°C the coagulation and settling of the alum product is likely to occur, requiring the use of heated storage tanks, which adds to the cost of transport, handling, and application. Also, wind and wave issues can affect the stability of the treatment barge and the ability to apply the alum safely and effectively. Thus, if sustained winds exceeding 15 mph are anticipated the application should be rescheduled. Finally, treatments should be avoided during prolonged or intense rain events, as such conditions can impact efficacy by increasing the concentration of water column suspended materials, impact the even distribution of the alum, and create slip hazards for the treatment crew. Thus, if there has been a precipitation event of greater than 0.5 inches in the preceding 72 hours, expected rainfall of more than 1 inch on the day of application, or more than 1 inch of rain expected 48 hours after the application, the applications should be rescheduled.

Given the size and exposure of both lakes, the area of the projected treatment zone, and the total volume of alum needed to correctly treat each lake, the proper and effective application of the alum must be conducted by an applicator with the proven ability to conduct treatments of this magnitude. In order for the alum treatments of both lakes to be completed within a reasonable amount of time, the treatment barge must have enough capacity, and be able to operate safely and quickly enough to apply approximately 20,000 – 50,000 gallons of alum/day. Alum weighs approximately 11 pounds per gallon. A barge capable of storing 1,000 gallons of alum needs to have a gross weight capacity well in excess of 11,000 pounds. To complete the treatments of both lakes within the projected time frame thus necessitates a treatment barge having the capacity to carry a large volume of alum. An example barge image is provided courtesy of HAB Aquatic Solutions, LLC.

3.5 PROJECTED ALUM TREATMENT COSTS FOR HONEOYE LAKE AND CONESUS LAKE

In keeping with this project's scope of work, within this section of the report Princeton Hydro presents the projected cost estimates for the alum treatment of both lakes. The costs presented below are based on an assumed alum treatment dose of 300 gallons/acre. Although the projected costs need to be further refined, they are relatively accurate and consistent with the costs of recently completed nutrient inactivant treatments of other lakes and reservoirs conducted by Princeton Hydro or reported in the literature.

Based on the information developed and discussed above, the <u>preliminary</u> costs associated with the various elements of the alum treatment of each lake is as follows:

- Bench Testing - Honeoye $7,000; Conesus $7,000
- Treatment Monitoring – Honeoye $40,000; Conesus $56,000.
- Preparation of DEIS materials including public hearings - Honeoye $20,000; Conesus $20,000
- Purchase and application of alum-Honeoye Lake $715,000; Conesus Lake $930,000

When totaled, the projected cost to conduct the alum treatment of Honeoye Lake is the range of $782,000 and the projected cost to conduct the alum treatment of Conesus Lake is $1,015,000. These costs estimates are very preliminary and subject to change. Expansion of the Conesus Lake treatment area to include both the Southern and Central basins would substantially increase the cost to treat Conesus Lake.

3.6 TIMING OF AN ALUM TREATMENT FOR HONEOYE LAKE AND CONESUS LAKE

As will be discussed in Section 4 of this report, aeration should be used as the second step of a two-step approach to managing the internal phosphorus loads of Honeoye Lake and Conesus Lake. The first step should be the application of a nutrient inactivant, specifically alum. This two-step approach has proven to be highly effective for the long-term successful management of eutrophic lakes restored by Princeton Hydro. The alum application results in the relatively quick and effective control of any phosphorus already present both in the lake's water column as well as in the sediment's interstitial pore water. This phosphorus is available for biological uptake regardless of aeration, as it is already present in a dissolved, labile state that can be readily assimilated by both benthic and planktonic cyanobacteria as well as filamentous mat algae. The application of alum also addresses any iron-bound phosphorus that would be liberated during periods of anoxia occurring when the aeration system may not be operating (early spring and early fall); thus, continuous year-round internal phosphorus loading control is provided from the outset. Furthermore, for hypolimnetic aerated lakes, the alum application augments the internal phosphorus controls achieved through aeration, in that the alum compensates for any operational or performance issues of the system to fully meet deep-water oxygen demands or the aeration system's ability to unconditionally prevent the occurrence of short-term anoxic or hypoxic events. Such events may occur in mid- and late-summer when the lake's total oxygen demand peaks. For large, deep lakes, such as Conesus, even a short-term anoxic event can result in the large-scale, rapid, internal release of inorganic phosphorus. Given the management goals established for both Honeoye Lake and Conesus Lake, applying a nutrient inactivant in advance of installing and bringing the aeration system on-line helps ensure that the internal phosphorus load of both lakes is controlled as effectively as possible.

3.7 SUPPORTING INFORMATION FOR THE APPLICATION OF ALUM

The process by which to permit the use of alum or other nutrient inactivants is currently being assessed as part of the NYSDEC's HAB Initiative. Decisions about the necessary documentation or possible requirements for future applications will be deferred until NYSDEC's pilot inactivant projects have been completed. However, a large amount of data exists for both Honeoye Lake and Conesus Lake that support the use of alum as part of each lake's long-term phosphorus and HAB management efforts.

Specifically, field data and modeled data generated by the Finger Lake Community College, Cornell University, SUNY Geneseo, and SUNY Brockport, as well as years of CSLAP lake water quality data collected by local volunteer monitors, show Honeoye Lake and Conesus Lake to be good candidate waterbodies for alum treatment. Alum is not an algaecide and does not result in the direct die-off of phytoplankton, algae, or cyanobacteria. Thus, unlike conventional algaecides, because algae are not killed, it does not result in the rapid release of phosphorus and cyanotoxins into the water from the impacted cells. Alum's mode of action is to bind with inorganic phosphorus resulting in less phosphorus being available for photosynthetic assimilation. For both lakes, internal phosphorus loading and the seasonal availability of that phosphorus has been repeatedly demonstrated to be the primary driving factor impacting water quality in both lakes. Furthermore, the data presented in recently published NYSDEC reports (NYSDEC 2019b and 2019c) show that internal phosphorus loading is the most significant source of each lake's total annual phosphorus load. As per NYSDEC, 80% of Conesus Lake's annual total phosphorus load is the result of the internal recycling of phosphorus during periods of anoxia. Likewise, NYSDEC determined that up to 93% of Honeoye Lake's annual total phosphorus load is the result of the internal recycling of phosphorus during periods of anoxia. Therefore, as concluded within the TMDL reports (NYSDEC, 2019b; NYSDEC, 2019c) and HAB Action Plans (NYSDEC, 2018b; NYSDEC, 2018d), controlling the amount and availability of phosphorus is fundamental to improving water quality. Studies conducted nationwide over the past 40+ years have shown that when properly utilized, alum is exceptionally effective in managing internal phosphorus loading.

Data collected since the early 2000s also show that it should be possible to treat either Honeoye Lake or Conesus Lake with alum without causing secondary environmental impacts. For Conesus Lake, previously compiled data show that:

1. Conesus Lake is well-buffered with the lake's alkalinity ranging from 80-130 mg $CaCO_3$/L as measured in all three basins in both the epilimnion and hypolimnion (Makarewicz, et al., 2001).
2. CSLAP data show that the pH of Conesus Lake is typically > 7.
3. Given the lake's buffering capacity, alkalinity, and pH, an alum treatment should not depress the lake's pH below 6.5. As concluded in past studies, these properties of Conesus Lake make it unlikely that during an alum treatment that aluminum will enter a dissolved state (EcoLogic 2004).

4. Past studies concluded that the lake's fish or benthic community would not be harmed by an alum treatment and an alum treatment would not pose a risk of harm to consumers of Conesus Lake waters (EcoLogic 2004).
5. Conesus Lake is a drinking water supply. Both the villages of Geneseo and Avon rely in part on the lake for potable water and the lake provides up to 22% of the drinking water for Livingston County. Precautions will need to be taken to avoid any impacts during the treatment process to any potable water intakes. Such precautions will need to be established in coordination with NYSDEC, NYS Department of Health, and the drinking water treatment plant operator prior to treatment. For example, precautions can be implemented during the treatment process to avoid the application of the product within 100 feet of an intake. Precautions should be taken into consideration as part of the nutrient inactivant permitting process, so as to conduct the treatment on Conesus Lake in a manner that is consistent with State drinking water regulations and ambient water quality regulations.

Likewise, data compiled since the early 2000s show that an alum treatment of Honeoye Lake could be conducted in an environmentally safe manner with little if any impact to the biota and users of Honeoye Lake. Specifically, modeled, laboratory, and field data show that:

1. Honeoye Lake is well-buffered, has mid-summer pH values > 7, and has alkalinity values greater than 60 mg $CaCO_3$/L (Honeoye Lake Watershed Task Force 2007, Gilman 2005, CSLAP database).
2. Given the lake's buffering capacity, alkalinity and pH, an alum treatment should not depress the lake's pH below 6.5. Past studies concluded these properties of the lake make it unlikely aluminum will enter a dissolved state during or immediately following an alum treatment (Princeton Hydro 2005). This was further verified through alum bench scale testing conducted in 2005 (Souza 2005).
3. Based on these data, an alum treatment would not impact the lake's fish or benthic communities.
4. Honeoye Lake is not designated by NYSDEC as a drinking water supply. Thus, in terms of potable water utilization of the lake, an alum treatment will not pose a risk or harm human users of Honeoye Lake because the lake is not used for drinking water.

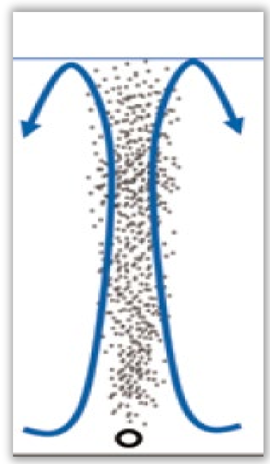
4.0 AERATION AS A MEANS OF CONTROLLING INTERNAL PHOSPHORUS LOADING

4.1 AERATION AS A MANAGEMENT TOOL FOR HONEOYE LAKE AND CONESUS LAKE

Aeration is an in-lake management technique used to convert an anoxic (anaerobic) environment into an oxic (aerobic) environment. Some techniques are designed to manage dissolved oxygen (DO) concentrations throughout the entire water column while others focus on managing DO concentrations within a limited, defined portion of the water column (Pastorak et al. 1981; Cooke et al. 2005). In some applications the water column is maintained in a thermally unstratified state (destratification aeration), whereas in other applications the water column is maintained in a thermally stratified state (hypolimnetic and depth specific/LayerAir™ aeration). Additionally, there are some aeration techniques that involve the direct injection of oxygen (O_2) into either a thermally stratified or unstratified water column.

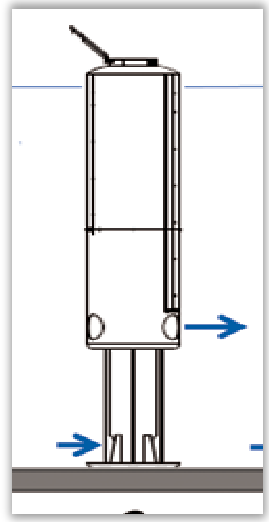
4.1.1 DESTRATIFICATION AERATION

Destratification (complete water column mixing) aeration systems use compressed air to vertically circulate the entire water column thereby preventing thermal stratification from occurring or from persisting. This results in a water column characterized by relatively uniform surface to bottom water temperatures and densities. As a result, the entire water column can be easily circulated from surface to bottom. Lake water reoxygenation occurs due to the constant and consistent vertical mixing of the water column and the exposure of the water to the atmosphere. Although compressed air facilitates water column mixing, it is the exposure of the water to the atmosphere rather any oxygen transfer associated with the compressed air that is responsible for the vast majority of reoxygenation.

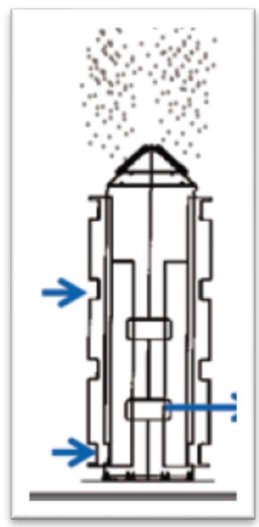


As illustrated by Moore, et al., 2015, destratification systems create a vertical convection current that results in the bottom waters being circulated to the surface of the lake, replicating the natural mixing of a lake during periods of turn over or when the water column is of uniform water temperature and density. This is accomplished by the strategic placement of air diffusers throughout the lake, but especially within the lake's deeper reaches. The air compressors and the negatively buoyant air lines account for majority of the cost associated with destratification aeration systems. The diffusers are relatively inexpensive (approximately $600 per diffuser unit). The compressor(s) must be housed in a suitably sized compressor building. To mitigate the noise and heat resulting from the operation of the compressor(s), the compressor building must be both heat and sound insulated and vented. Destratification systems are operated continuously; typically starting in early- to late-spring (before thermal stratification occurs), throughout the entire summer until early fall (when stratification normally breaks down and the lake would naturally turn over). Operational costs are a function of the size of the required compressor(s). The compressors for a destratification system servicing a relatively large lake typically require 3-Phase, 220-volt or 440-volt power source. The annual maintenance for these systems primarily involves inspection and servicing of the compressor(s).

4.1.2 HYPOLIMNETIC AND DEPTH SPECIFIC AERATION



Conventional, full-lift hypolimnetic aeration systems as well as depth specific/Layer Air™ systems, make use of a "tube within a tube" design (Moore, et al., 2015). These systems also use compressed air to lift deep oxygen-poor water higher in the water column, but with hypolimnetic systems, the deep anoxic water is returned to the bottom of the lake following re-oxygenation. Even though a major transfer of dissolved oxygen results between the warm and cold water, because of the limited duration of time needed to mix the cold, oxygen-poor bottom water with the warm, oxygen-rich surface water, only a nominal increase in water temperature is experienced. Thus, the lake remains thermally stratified. Hypolimnetic systems may be operatated to maintain either high (>4 mg/L) or minimal (1-2 mg/L) DO concentrations at the lake bottom or targetted aeration zone. If the goal is to use the aeration system to control internal phosphorus loading, the targeted DO concentration may only be 1-2 mg/L DO. Conversely, if the goal is to create or maintain cold-water fish habitat as well as control internal phosphorus loading, the targeted DO concentration may be ≥ 4-5 mg/L. As shown in the accompnying illustration, the hypolimnetic unit may be equipped with a hatch, air tube, or vent that allows any hydrogen sulfide present in the anoxic bottom waters to be released into the atmosphere.



Depth specific or Layer Air™ systems also use a "tube within a tube" design approach similar to conventional hypolimnetic systems (Moore, et al., 2015). The difference is that water is drawn into the unit at a specified depth, usually the upper stratum of the hypolimnion or from the metalimnion. Once again compressed air is used to lift oxygen-poor water higher in the water column. The anoxic/oxygen-poor water is then mixed with the more highly oxygenated surface water and then returned to the stratum from which it was drawn. Typically, multiple mixing units are positioned within one or more strata. The designated stratum often provides the cold/cool water needed to provide critical hold-over summer habitat for cold-water fish. Although depth specific/Layer Air™ systems are designed and operated to preserve thermal stratification, they usually are not designed to eliminate bottom water anoxia. Thus, the epilimnetic and metalimnetic strata will be well-oxygenated, but the hypolimnetic strata may remain anoxic. Because deep water anoxia is not abated, hypolimnetic internal phosphorus loading may still occur. But by creating a thermally separated, oxygen-rich mid-water depth zone, it is possible to maintain separation of the phosphorus-rich hypolimnetic water from the photic zone of the epilimnion where photosynthesis occurs. Any phosphorus liberated from the anoxic lake bottom thus remains contained at the bottom of the lake and does not become available for biological uptake.

For depth specific/Layer Air™ and hypolimnetic systems operated in a manner that does not completely prevent anoxia and associated internal phosphorus loading, it will be necessary to manipulate the operation of the system immediately in advance of the lake's natural turnover to prevent the late-season upwelling of phosphorus rich water and avoid an autumnal algae or cyanobacteria bloom. In such cases, the lake's thermal and DO profile will need to be closely monitored. As the water column begins to naturally cool and surface to bottom water temperatures become increasingly uniform, mixing and reoxygenation of the deeper reaches of the lake is intensified resulting in enough deep water DO to create the oxic conditions necessary for the liberated inorganic phosphorus to re-bind with available dissolved iron. Once bound again to iron, the sedimentary recycled phosphorus can no longer be bioassimilated by algae or cyanobacteria.

The power needs, operation, and maintenance of conventional hypolimnetic and depth specific/Layer Air™ systems are very similar. The compressor(s) tend to be relatively large (at least 20 HP) and usually require a 3-Phase, 220-volt or 440-volt power source. The compressors for either type of system must be housed in a large footprint (at least 30' x 30'), properly insulated, and vented compressor building. To decrease the length and cost of the air line runs, the building should be located close to the shore and as close to deepest area of the lake as possible. The majority of the material costs associated with hypolimnetic and depth specific/Layer Air™ systems are related to the length, number, composition, and size of the air lines as well as the size and number of compressor(s). Additionally, the system's cost will be a function of the type and number of mixing units, all supporting system elements (filters, expansion tank, flow meters, etc.), and the construction of the compressor building. The compressors and supporting system elements must be serviced at least annually by manufacturer certified service providers and professional divers may be needed to periodically inspect and service the mixing units and the air lines. Utility costs are a function of the number and size of the compressors but can be expected to be significant ($20,000-$30,000 annually) given that hypolimnetic and depth specific/Layer Air™ systems must be operated continuously from once the lake is thermally stratified in early- to late-spring until early fall after the lake turns over.

4.1.3 DIRECT INJECTION PURE OXYGEN SYSTEMS

Pure oxygen systems (also referred to as direct oxygen or DOX systems) are typically used in large, deep lakes and run-of-river reservoir systems (Mobley, et al. 2019). As with hypolimnetic systems, stratification is maintained but anoxia is overcome. Thus, DOX systems are well suited for managing internal phosphorus loading in deep lakes where stratification must be maintained to support a cold-water fishery. Unlike hypolimnetic systems, DOX systems do not rely on an air lift approach to mix the water column or rely on atmospheric oxygen to reoxygenate the lake. Rather, oxygen (O_2) is directly mixed with lake water.

There are basically two types of direct injection oxygen aeration systems: line aeration systems and Speece cone systems. Although the design and operation of line aeration and Speece cone systems are very different, the underlying approach is similar involving the direct mixing of oxygen gas with lake water. Speece cones utilize a water pump to transfer the oxygen-poor hypolimnetic water into a large, cone-shaped chamber where the water is then mixed with oxygen gas before being released back into the hypolimnion. This form of aeration may also be referred to as slip stream aeration when the Speece cone is located on shore rather than placed directly in the lake. Speece cones are typically very large and their operation requires the use of a fairly large water pump. The purpose of the pump is to extract water from the hypolimnion, pump it into the Speece cone, mix the water with the injected oxygen, and then pump the re-oxygenated water back into the lake's hypolimnion. Oxygen is supplied either by an on-site oxygen generator or oxygen stored in on-site tanks. The oxygen-poor water and oxygen gas are mixed at the top of the conical shaped structure. The shape of the Speece cone maximizes the contact and mixing of the oxygen-poor water with the introduced oxygen gas. The pumping, reoxygenation, and mixing process does not increase the temperature of the hypolimnetic water or result in enough turbulence to cause the lake to thermally destratify.

Line diffuser DOX systems use fine-pore oxygen diffusion lines to introduce O_2 directly into the water. This approach does not rely on any pumps to draw in hypolimnetic water. Rather oxygen gas is released under low pressure into the lake via porous air lines anchored along the bottom but suspended above the sediment. As with Speece cone systems, oxygen may be supplied from large land-based oxygen gas storage tanks or by means of a land-based on-site oxygen generator. At a minimum, the amount and rate of oxygen delivered into the hypolimnion is enough to exceed the lake's computed biological oxygen demand. This will vary seasonally with peak demands occurring in the middle of the summer. When the goal is to sustain cold-water fish habitat, more oxygen may be supplied and higher hypolimnetic DO concentrations maintained (≥ 4-5 mg/L). If the goal is to control internal phosphorus loading, the targeted DO concentration may only be 1-2 mg/L DO. In either case, the rate at which the oxygen gas bubbles are released from the porous air lines is not enough create the turbulence needed to thermally destratify the lake. Thus, anoxia is prevented and internal phosphorus loading is controlled, but the lake remains in a thermally stratified state.

Speece cone and line diffuser aeration systems are operated continuously from late spring/early summer through late summer until the fall turnover. The system is started after thermal stratification and hypolimnetic anoxia occurs and is shut down after the fall turnover, when the lake is thermally destratified and there is no longer the potential for deep water anoxia. Of the two pure oxygen aeration techniques, the DOX line diffuser systems are less expensive and easier to construct, install, and operate than the Speece cone systems.

The power requirements for DOX line diffuser systems can be met using a standard 110 or 220-volt, single phase power source. The amount of land and the size of the building needed for DOX systems will vary depending on whether the system uses oxygen storage tanks or an oxygen generator. For an oxygen tank system, a secure, fence-enclosed concrete pad needs to be constructed along with a structure large enough to house all the supporting metering and gauging equipment. In total this may require as much as 1/8 to 1/4 of an acre of land. Conversely, if the system's oxygen supply is met using an oxygen generator, the building needed to house the system will be much smaller (30' x 30'), similar to that associated with a hypolimnetic or destratification system. In either case the pad/building should be located near the shoreline and as close to the deep-water area of the lake as possible. This will help decrease costs associated with the oxygen supply air lines. Inspection and maintenance of direct oxygen injection systems focus on the routine inspection (at least bi-weekly) of the oxygen reserves in the storage tanks or the operation of the oxygen generator. Annually, divers will need to inspect all in-lake components of the system, in particular the oxygen supply lines. Operational costs are highly variable and dependent on the lake's biological oxygen demands and hypolimnetic DO goals. For systems supplied by land-based oxygen storage tanks, the cost of tanker truck O_2 deliveries must be taken into consideration.

4.2 PROPOSED AERATION SYSTEM FOR HONEOYE LAKE AND CONESUS LAKE

The work scope for this project calls for the identification of the best aeration approach for both Honeoye Lake and Conesus Lake as based on review and analysis of existing data. Recommended aeration system designs, along with some preliminary specifications and cost estimates, are presented in this section of the report for both lakes. It should be noted that for both lakes, further analysis will be needed in order to develop more refined designs and generate more accurate cost estimates. Nonetheless, the aeration approach recommended for Honeoye Lake and Conesus Lake are scientifically well-grounded and based on each lake's physical, hydrologic, chemical, and biological attributes. Although the design and cost of each system needs to be further refined, the information presented herein is consistent with the costs of aeration projects of this scale implemented nationwide at other lakes and reservoirs.

The data referenced and discussed in Section 2 shows that the water column dissolved oxygen concentrations measured in both Honeoye Lake and Conesus Lake at times enter the hypoxic or anoxic range. As previously noted, during periods of anoxia, the sediment chemistry of both lakes is altered, and sediment-bound phosphorus is released into the water column. This can occur at any water depth, but in both lakes is typically observed at water depths greater than 7-8 meters (approximately 26.5 – 30.5 feet) below the surface. These episodes of deep-water anoxia have been linked to internal phosphorus loading events. The water quality and trophic state impacts internal phosphorus loading has had on both Honeoye Lake and Conesus Lake is best reflected in their susceptibility to cyanobacteria blooms. The type of aeration system best suited for each lake is a function of the extent and stability of thermal stratification, the presence/absence of a cold-water fishery, and the lake's morphometry and bathymetry. Also as previously discussed (Section 3.6), aeration would complement the benefits accrued through the alum treatment recommended for both lakes.

4.2.1 HONEOYE LAKE

Historic data collected by NYSDEC, CSLAP volunteers, consultants, and academic institutions demonstrate that Honeoye Lake is best characterized as a polymictic lake, meaning it remains mixed throughout much of the year, but under proper weather conditions will experience short periods of weak thermal stratification. Except for the deepest portions of the lake (8-9 meters), the data show that Honeoye Lake never strongly stratifies and any thermal stratification that may develop over the summer in the lake's shallower reaches dissipates during strong wind events. Honeoye Lake's *in-situ* water temperature and dissolved oxygen data confirms that the water column stays well-mixed throughout the majority of the growing season, but frequent, short bouts of thermal stratification trigger deep water anoxia that in turn results in the internal release of phosphorus from the sediments overlaid by anoxic water. These characteristics make Honeoye Lake a good candidate for a destratification aeration system. There is no concern with raising the temperature of the deeper waters of Honeoye Lake because the water column is often completely mixed and relatively thermally uniform. The proposed destratification system will only sustain this natural process throughout the growing season. Additionally, because the lake does not support a cold-water fishery, there is no biological need to create or maintain a well oxygenated, cold-water hypolimnion.

As early as 2006, Princeton Hydro recommended destratification aeration as part of the lake's long-term internal phosphorus management plan. As part of this project, with assistance provided by Vertex Water Features (Vertex), a preliminary destratification aeration system design was prepared for Honeoye Lake. The preliminary Vertex design requires a total of 250 HP of compressor power to produce enough compressed air to drive a system capable of maintaining the lake in a destratified state. To provide operational redundancy, it is recommended this be accomplished using two rotary screw, air cooled compressors each producing 125HP (562 ACFM @116 PSI). Compressors of this size require a 3-Phase 220-volt power source. The compressors will need to be housed in a fully insulated, sound-deadened, and vented structure with an approximate footprint of 400 – 600 ft^2. A structure of this size will provide enough space to properly house the two compressors, receiving tanks, air filters, and air metering components of the system and provide enough room to attend to and maintain the land-based equipment. Vertex has estimated that a total of 24 diffusers will be needed to achieve the amount of mixing necessary to maintain Honeoye Lake in a destratified state throughout the summer. The 24 diffusers must be clustered in the deepest portion of the lake and in water between approximately 8 meters to 9 meters in total depth (Figure 4.1). Each AirstationXL diffuser consists of four MicronBubble diffuser heads (Figure 4.2). As per the preliminary design, each diffuser is supplied air by a dedicated 1.25" ID, negatively buoyant air line. The air line runs for this system are very long (> 2000 feet). 1.25" PVC barbed fitting and 1.5" stainless steel clamps will be used to connect each 250'section of air line extending from the compressor house to the diffuser head. The air lines are extremely resistant to damage and are warranted for life. The lines are negatively buoyant and will remain on the lake bottom without the need for additional ballast. The fine pore Teflon material on the surface of each diffuser is self-cleaning and very resistant to damage.

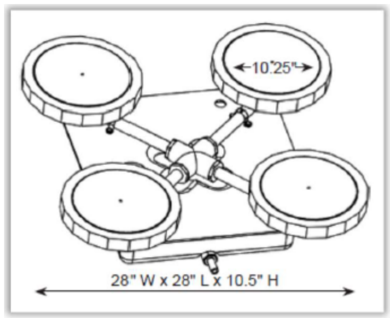


Figure 4.2 – Typical Diffuser Schematic

Three locations were considered for the siting of the compressors used to power the Honeoye Lake system:

- Sandy Bottom Park – located at the far north end of the lake,
- The NYSDEC Boat Launch – located along the south-east shoreline of the lake, and
- California Ranch – located approximately along the mid-point of the lake's western shoreline

Currently, Sandy Bottom Park (Figure 4.3A and 4.3B) appears to be the most feasible location to site the compressor building. This site has enough available open land to construct the compressor house, is presently serviced by 3-Phase power supply, and is easily accessible for the routine inspection and servicing of the compressors and land-based components of the aeration system. However, this location is over 3 miles from the deep area of the lake where the diffusers need to be placed. As result, very long (8,700 ft to 15,300 ft) air line runs must be provided for each diffuser. If the compressors were sited at this location, approximately 300,000 linear feet of air line would have to be run along the bottom of the lake. With the compressors located at Sandy Bottom Park, the use of trunk lines and distribution manifolds would not be feasible due to friction losses and heat gains resulting from such long air line runs. If the compressors were sited at Sandy Bottom Park, the cost of the Honeoye Lake aeration system is projected to be in the range of $1.7 to $1.8 million including installation, with the cost of the air line alone amounting to approximately $1,000,000.

Although much closer to the deepest area of the lake (approximately 1 mile), the NYSDEC Boat Launch site (Figure 4.4) does not have enough available open land to accommodate the construction of the compressor building. Additionally, this site is not serviced by a 3-Phase electrical supply. As such, it does not appear to be a feasible location to site the system's compressors.

Although California Point (Figure 4.5) is private land, it is the closest of the three sites to the deep area of the lake (approximately 2,500 ft). Siting the compressor building closer to deepest area of the lake would result in a significant cost reduction. There is enough open land at California Point to construct the compressor building and although this site is not currently serviced by a 3-Phase power source a proposed pump station that is part of the Canadice public water supply system would bring 3-Phase power relatively close to the California Point site. Overall, excluding the cost of the land needed for the compressor building, locating the compressors at this site should decrease the cost of the aeration system to between $850,000 and $900,000. This is largely due to the much shorter air line runs needed to connect the compressors to each diffuser head. Also, by housing the compressors at this site it may be possible to run 3-4 trunk lines from the compressors to deep-water distribution manifolds from which the individual diffuser air lines would branch. This would further decrease the amount of air line needed for the system, again reducing the system's overall costs. A reduction in the number and total length of air line would also decrease the total amount of compressor horsepower needed to operate the system. Not only would this decrease the capital costs of the system but would decrease annual utility and operating costs.

Because of the uncertainty of where the compressor building can be sited detailed annual operational costs were not computed for the Honeoye destratification system. However, given the projected horsepower of the compressors needed to operate this system, the annual electric utility fees could easily be in the range of $50,000. Annual servicing of the compressors, based on that for other destratification systems servicing relatively large lakes should be in the range of $2,000 for basic compressor, filter, and land-based delivery equipment inspection and maintenance.

Figure 4.1: Aeration System Design for Honeoye Lake (Sandy Bottom Park and California Point Compressor House Options).

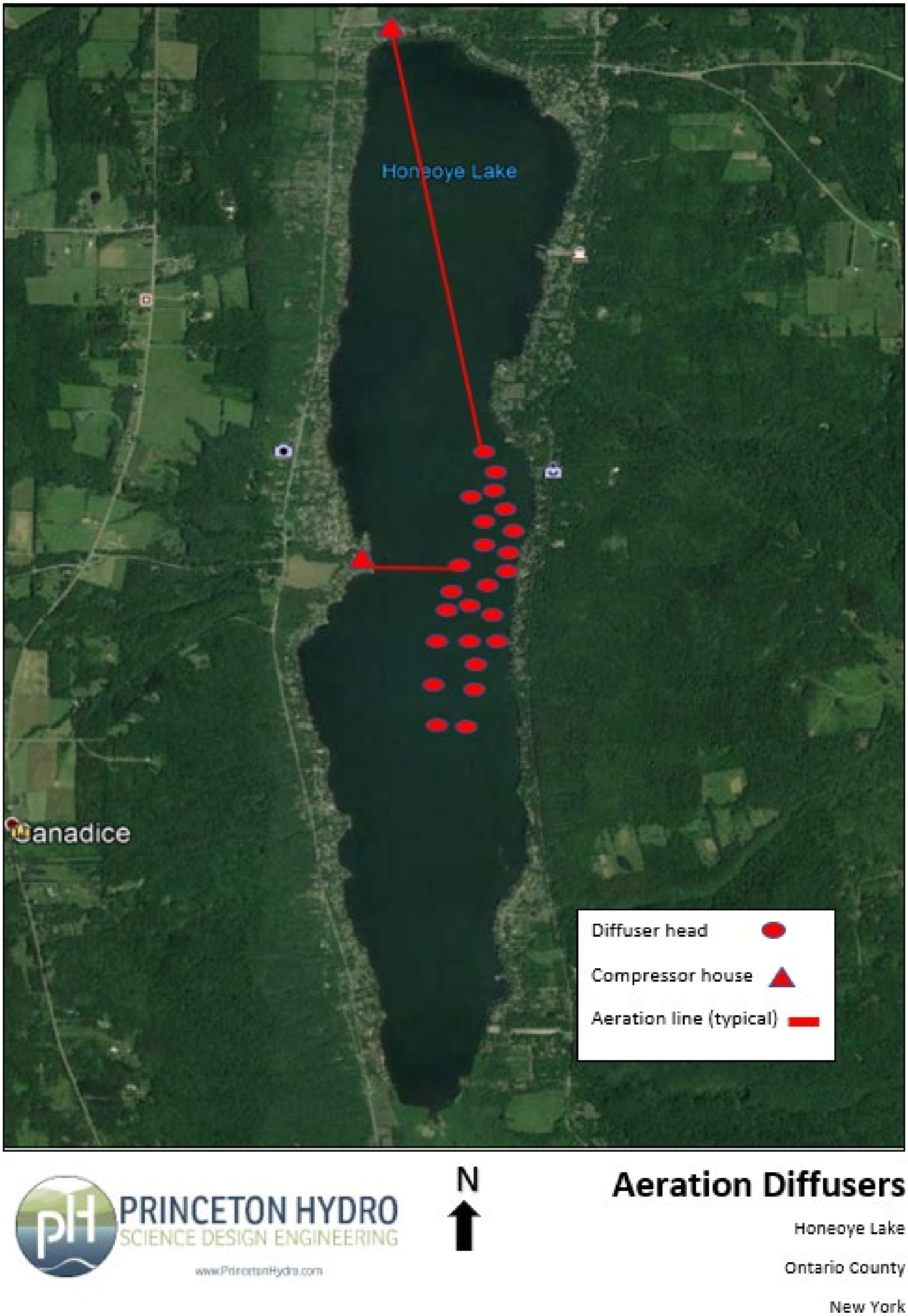


Figure 4.3A: Sandy Bottom Park, Located at the North End of Honeoye Lake.

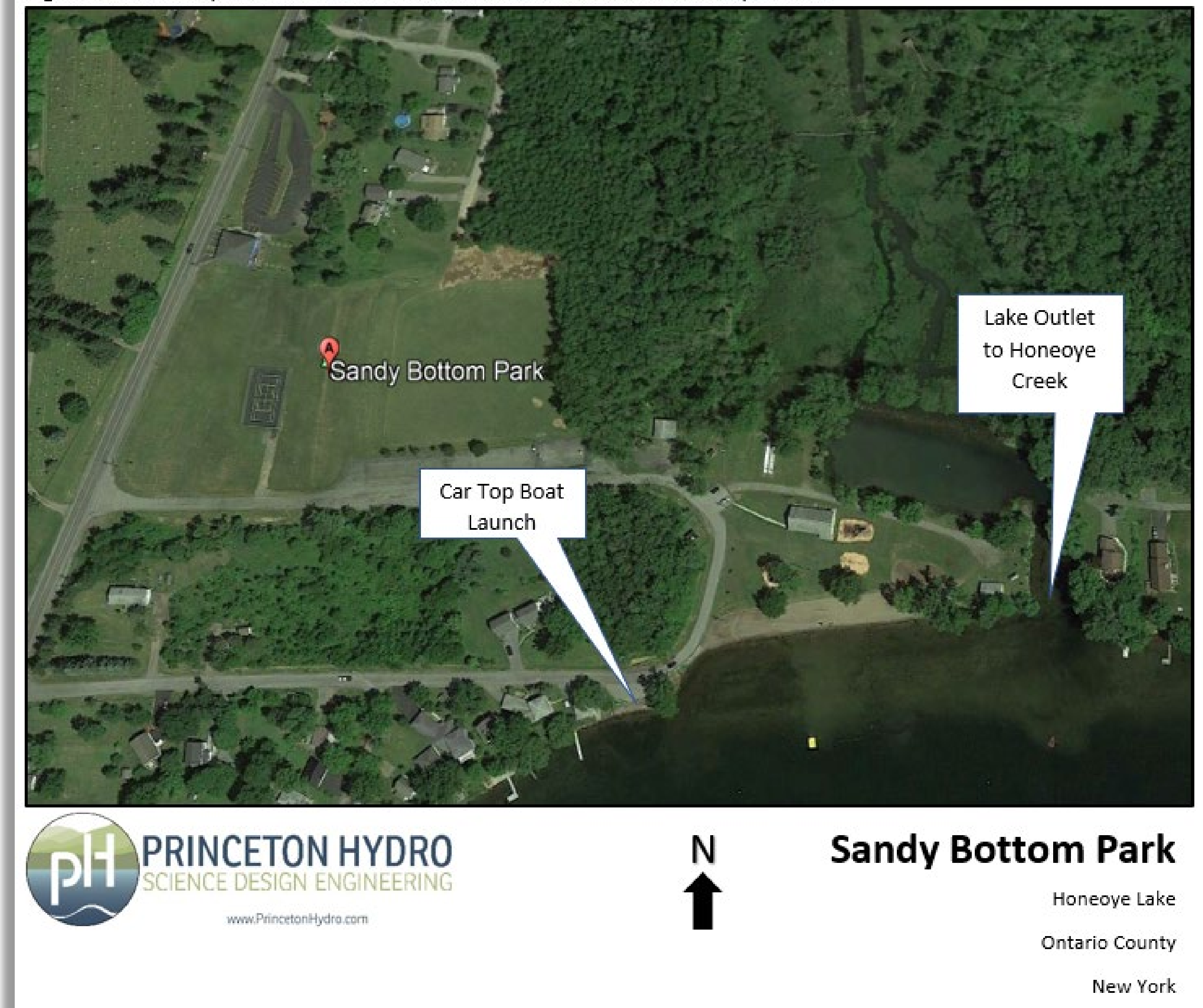


Figure 4.3B: Sandy Bottom Park Beach, Located at the North End of Honeoye Lake.

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SCIENCE DESIGN ENGINEERING
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N

Sandy Bottom Beach

Honeoye Lake

Ontario County

New York

Figure 4.4: NYSDEC Boat Launch, Located on the Southeast Shore of Honeoye Lake.

Figure 4.5: California Point, Located on the West Shore of Honeoye Lake.

4.2.2 CONESUS LAKE

Conesus Lake consists of three interconnected basins. The southern basin is the largest and deepest. The smaller central and northern basins are notably shallower than the southern basin. Data collected by NYSDEC, CSLAP volunteers, consultants, and academic institutions shows that Conesus Lake displays the properties associated with a dimictic lake. This is especially true of the deep, southern basin. Dimictic lakes remain strongly stratified throughout much of the growing season, destratifying twice; once in the spring and once in the fall, with the fall turnover the more significant of the two events. With a maximum depth of 21 m, Conesus Lake has the potential to support a cold-water fishery. Given its size, morphometry, depth, and an existing cold-water fishery, Conesus Lake is a good candidate for hypolimnetic aeration or direct oxygen injection. Either aeration technique would maintain the lake's mid-summer thermal stratification but create the oxygenated conditions within the lake's hypolimnion that would help control the lake's internal phosphorus load and could create/expand cold water fish habitat.

The Conesus Lake HAB Action Plan (NYSDEC 2018b) lists the completion of a detailed hypolimnetic aeration study (including the preparation of engineering plans and specifications) as a Priority 1 project for Conesus Lake. The need for a detailed engineering study is warranted given that the bathymetry and morphometry of Conesus Lake complicates the selection and design of an appropriate aeration system. First, because the lake supports/or has the ability to support a cold-water fishery, NYSDEC has made it clear that the lake cannot be destratified and that a cold-water habitat layer must be created or maintained. Secondly, as noted above, morphometrically Conesus Lake consists of three interconnected basins (Figure 1.6). The largest of the three is the southern basin (1,646 acres), which attains a maximum depth of 20 meters. The northern basin, while encompassing a total of 1,176 acres, only attains a maximum depth of 11 meters. The small, narrow, central basin (405 acres) is a transition area between the north and south basin. It attains a maximum depth of approximately 18 meters. The thermal and dissolved oxygen data collected for both the southern and central basins are characteristic of a dimitic lake. However, the shallower northern basin's thermal and dissolved oxygen data are more characteristic of a polymictic waterbody. The relative volumes of the epilimnion, metalimnion, and hypolimnion of each basin are presented in Table 4.1.

Table 4.1 Conesus Lake Morphometric Data

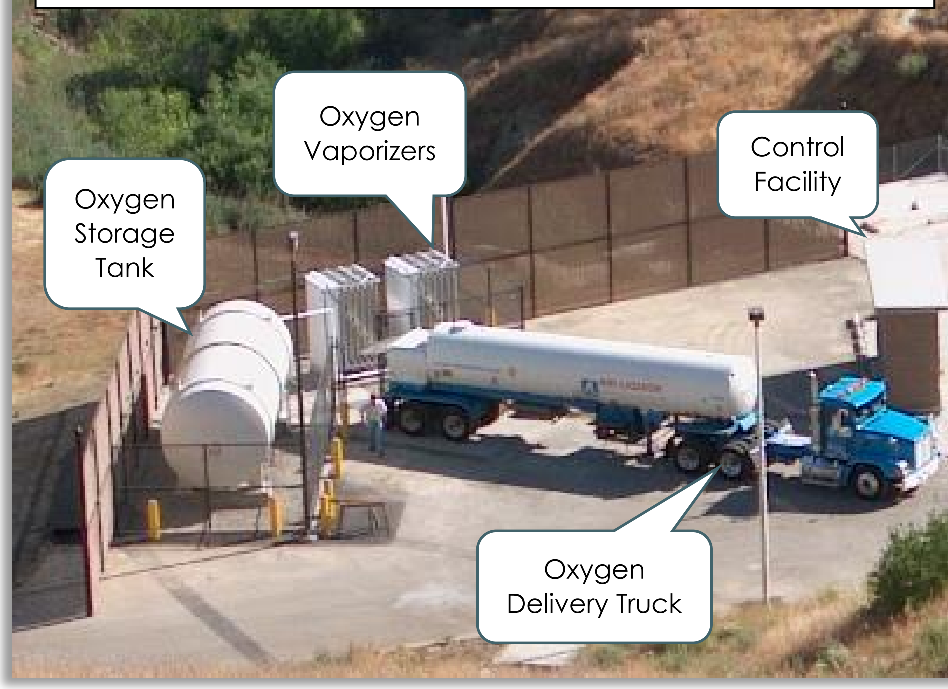
		South	Central	North	Total
Total Area of Basin	Acres	1646.2	405.0	1176.0	3216.8
Area of Hypolimnion	Acres	1413.9	308.6	774.7	2497.3
Hypolimnetic Area as % of Total		86.4%	76.2%	65.9%	77.6%
Total Volume of Basin	Acre-Feet	73937.0	13376.8	31131.4	118445.2
Volume of Hypolimnion	Acre-Feet	39319.6	5431.8	7053.2	51804.6
Hypolimnetic Volume as % of Total		53.2%	40.5%	22.6%	43.7%

Given that this project's underlying goal is to control and limit internal phosphorus loading as a means of minimizing HABs, focus was placed on minimizing the occurrence of anoxia in the lake's southern and central basins. The NYSDEC's Conesus Lake HAB Action Plan (NYSDEC 2018b) also identifies as a Priority 1 project the installation of "up to six water circulation units and associated appurtenances at one or more suitable lake locations, including Camp Stella Maris beach, to minimize potential impacts from HABs". The water circulation units are intended to prevent the accumulation of surface scums in beach and high use direct water contact sites. However, if appropriately sized and distributed, these units could function in concert with the hypolimnetic aeration system to further control the onset, duration, and magnitude of anoxia in the lake's shallower polymictic north basin without resulting in the destratification of the lake.

For the southern and central basins, various types of aeration systems were evaluated that would preserve the lake's thermal stratification while still preventing or mitigating deep water oxygen depletion. Because this project's goal is internal phosphorus load reduction and not fishery management, emphasis was given to aeration systems capable of maintaining at least 2 mg/L DO at the bottom of the lake. However, prior to implementation, NYS Division of Fish and Wildlife will be consulted to ensure the selected system protects aquatic life and does not interfere with the maintenance of a cold-water fishery.

Assistance with the evaluation of aeration options for Conesus Lake was provided by Dr. Ken Wagner and Dr. Chris Holdren, both of whom are past presidents of the North American Lake Management Society and are experienced in the design, installation, and operation of deep lake aeration systems. Of the various available aeration options suitable for use in the management of a thermally stratified lake (conventional hypolimnetic, slip stream, Speece cone, and DOX line aeration), a DOX line aeration system appears the best option for Conesus Lake. The following provides a conceptual overview of such a system[5].

Figure 4.6 – Oxygen Supply Tank (photo courtesy of Mobley



In most cases, the introduction of unconfined, compressed air will result in the destratification of the water column. However as discussed in Section 4.1, the rate at which pure oxygen is introduced via the porous air lines is not enough to create the turbulence needed to thermally destratify the lake. Thus, oxygen is introduced into the hypolimnion, anoxia is prevented, internal phosphorus loading is controlled, but the lake remains in a thermally stratified state. Also as previously discussed, the oxygen for a DOX system may be supplied from large storage tanks (Figure 4.6) or oxygen generators.

In either case the gaseous oxygen moves under its own pressure into the lake, exiting through a porous diffuser line at the intended horizontal and vertical locations within the lake (Figure 4.7). The areal expanse of the hypolimnion will determine the number of porous diffuser lines and the configuration of the lines required for the proper operation of the system and attainment of project goals.

[5] Prepared by K. Wagner 2019, edited and adapted for this report by Princeton Hydro

The limited need for power (mainly for controls and monitoring, which can be handled by solar power if an electric supply is unavailable) and near lack of moving parts makes this an attractive system. Modeling advancements (Wüest et al. 1992, Mobley et al. 2000) have narrowed the range of oxygen that needs to be supplied thus aiding in the efficient positioning of the diffuser line(s).

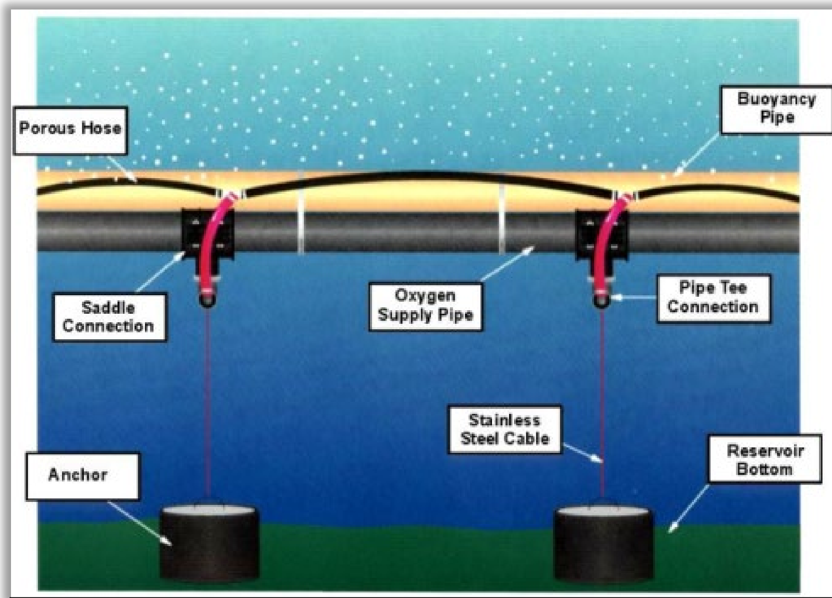


Figure 4.7 – Oxygen Supply Line (courtesy of Mobley

DOX systems are operated in a manner whereby the oxygen is absorbed before the bubbles can cause destratification; there is no bubble once the oxygen has been transferred to water. Bubble size matters, with smaller bubbles providing a greater surface area to volume ratio and being more rapidly eliminated as they rise. Spreading the oxygen throughout the hypolimnion by using longer runs of diffuser hose also limits the potential for thermal destratification. This process has been markedly improved over the last 30 years with the development of suitable equipment and materials (Horne, et al. 2019).

The greatest constraint to successfully using a direct feed oxygen supply aeration system is related to the thickness of the targeted hypolimnion. This requires a system designed with enough vertical run distance to allow for the complete absorption of the introduced oxygen bubbles. Except where the hypolimnion is very thin (<10 feet / 3 m), it is possible to introduce enough oxygen to counter significant biological oxygen demands without causing the thermal destratification of the water column. The hypolimnion of the southern basin of Conesus Lake is greater than 20 feet (6 m) in total depth. As such, it should be possible to introduce enough oxygen into the southern basin without disrupting thermal stratification.

A DOX porous line aeration system for Conesus Lake therefore appears to be the appropriate aeration approach. Such a system can keep the hypolimnion sufficiently oxygenated thus preventing or reducing internal phosphorus loading without causing the lake to become thermally destratified. The low power demands of the system are also attractive given the limited local availability of 3-Phase power, a requirement for the compressors needed to operate a large conventional hypolimnetic aeration system, or to meet the operational needs of Speece cone system.

The specific attributes that need to be considered in designing a DOX porous line aeration system for Conesus Lake can be summarized as follows. As previously noted, the 3,224-acre lake consists of three distinct basins (Table 4.1), with the deepest and largest (by volume and area) being the southern basin. The south basin also has the largest hypolimnetic footprint. The thermocline tends to develop at 7-8 meters in the south and central basins and at a depth of 8-9 meters in the north basin. The RTRM graphs provided in Appendix I illustrate the depth at which stratification occurs in each basin and the magnitude of the thermocline with respect to the energy needed to disrupt it. Data shows that the water column of the shallower northern basin is unstable and subject to turnover as a result of strong mid-summer storm events. A review of the available data suggests that the lake's oxygen demand is between 1.5 and 2.0 g/m^2/day, which is a moderate to high range easily capable of producing hypolimnetic anoxia by early summer. Additional spring DO/temperature profiles when DO concentrations are >2 mg/L are needed to accurately compute and confirm the lake's oxygen demand. The profile data should be collected no more than two weeks apart so as to increase the reliably of the data. Alternatively, laboratory incubation of sediment cores could supply accurate oxygen demand estimates. The estimated oxygen demand based on sediment core data has been shown to be consistent with observed oxygen profiles in the lake. Given the relative ease and cost of collecting DO/temperature profile data as opposed to conducting sediment core incubation analyses, field monitoring is recommended.

The existing data sets show hypolimnetic oxygen demand (HOD) results in low oxygen concentrations in water deeper than the thermocline, with values <2 mg/L observed at depths >7 m in the southern and central basins and >8 m in the northern basin by mid-July. Anoxia at the bottom occurs by early June in the southern basin and by early July in the northern basin, with ongoing mixing in the shallower northern basin preventing earlier anoxia. Conesus Lake's HOD appears to be largely a function of sediment oxygen demand (SOD), as opposed to oxygen demand attributable to water column suspended organic material. The deeper nature of the southern and central basins results in the development of hypolimnetic anoxia sooner in the growing season than observed in the shallower northern basin, which mixes to the bottom later into the spring and periodically during summer.

Depending on a variety of weather-related, morphometric, biological, and hydrologic/hydraulic factors, the area of lake bottom within each basin impacted by depressed oxygen concentrations will vary over time. The maximum area exposed to oxygen concentrations <2 mg/L is 775.7 acres in the northern basin, 308.6 acres in the central basin, and 1413.4 acres in the southern basin (Table 4.1). The overlying volume of water that experiences low oxygen concentrations is estimated at 7,053 ac-ft for the northern basin, 5,431 ac-ft for the central basin, and 39,319 ac-ft in the southern basin. These are the functional target areas and volumes that the Conesus Lake oxygenation system will need to address. The portion of the total area and total volume represented by the hypolimnion increases from the north to the central to the south basin but is large enough in each case to make a difference to basin ecology. This project's goal of improving DO concentrations in the deeper water of each basin is focused on reducing the internal recycling of phosphorus thereby helping to limit and control cyanobacteria blooms. While not the focus of the project, the aeration system would also enhance habitat for cold-water fish.

The difference in the maximum depth of the northern basin as compared to the south and central basins may greatly affect the mechanisms by which phosphorus loading is impacted. The smaller narrow central basin acts as a transition zone between the north and south basins, which functionally can be viewed as separate waterbodies. Indeed, any in-lake remediation management planning must acknowledge the fundamental differences between these basins, especially with respect to hypolimnetic aeration.

Southern Basin – Given the volume of the hypolimnion and the maximum depth (20 m) of the southern basin, this favors an approach that facilitates the re-oxygenation of the basin without causing it to become thermally destratified. Doing so would enable the lake to support cold-water fish throughout the summer while at the same time suppress the recycling of phosphorus from the sediments. It could be possible to achieve this goal using a conventional hypolimnetic aeration system, but this would require multiple units that have very high power demands. A more energy efficient approach would be one using the direct introduction of oxygen by means of a DOX line diffuser, Speece cone, or slip stream aeration system.

Conventional hypolimnetic aeration systems are being used less frequently in lakes of this size due to cost inefficiency and logistical problems associated with anchoring and maintaining the very large, submerged components in place over time. Also, as previously noted, the compressors that power these systems are expensive and have high installation, maintenance, and operational costs. Conventional hypolimnetic aeration has been largely supplanted by DOX, especially where the hypolimnion is thick enough to allow complete absorption of the released oxygen gas bubbles without compromising stratification. Such is the case with the southern basin of Conesus Lake, which has a vertical hypolimnetic depth of as much as 13 m.

Speece cone systems require complicated installation and maintenance procedures especially for lakes with soft bottom sediments. For soft bottom lakes, slip stream systems that utilize a land-based Speece cone are more practical. Slip stream systems can also achieve higher oxygen concentrations in the return water than in-lake Speece cone systems.

Overall, a DOX system is recommended for the southern basin of Conesus Lake. Compared to slip stream systems, more DOX systems have been installed and monitored and DOX systems have a demonstrated greater degree of efficacy. DOX systems are also less expensive to construct and operate than slip stream systems, especially given the minimal power requirements of a DOX system. The biggest issue the DOX system would likely be the siting of oxygen storage tanks and related transfer equipment. As previously noted, as much as 1/4 acre of land may be needed to construct a concrete pad, position the tanks and transfer equipment, and allow easy access for tanker trucks to deliver liquid oxygen. The site could be located on either the east or west shore, but preferably should be near the middle of the lake along the north-south axis.

Central Basin – The central basin is a transition zone between the shallower northern basin and the deep southern basin (Table 4.1). The narrow morphometry of the lake caused by two jutting peninsulas provides greater hydraulic disconnection of the central basin from the southern basin as compared to the northern basin (Figure 1.6). Mid-summer thermal stratification, reflected in the RTRM data (Appendix I), is more pronounced in the central basin than that observed in the northern basin. For the purpose of the Conesus Lake aeration system, it is appropriate to treat the central basin as an extension of the southern basin. Based on the morphometry of the lake, it is reasonable to expect that oxygen injected into the southern basin will likely move laterally into the central basin. To enhance the overall results of the Conesus Lake aeration system a dedicated oxygen distribution line should be extended into the central basin. For planning purposes, including the area and volume of the central basin with the south basin is appropriate.

Northern Basin – The moderate depth (11 m), unstable stratification, and frequent mixing events in the northern basin indicate naturally marginal cold-water fishery habitat quality, which may suggest that maintenance of stratification with respect to cold-water fishery management is of lesser concern here. However, the polymictic nature of this basin makes its role in the internal loading of phosphorus problematic and somewhat more difficult to predict and control than loading associated with the more thermally stable southern and central basins. Basin characteristics and management goals therefore complicate measures to oxygenate the hypolimnion of the northern basin. As noted, destratification seems to occur naturally in this basin, so hypolimnetic oxygenation may not be needed all summer to limit internal phosphorus loading. Similarly, efforts to manage hypolimnetic or metalimnetic cold-water habitat may be interrupted by frequent vertical mixing that contributes to higher temperatures, a level of natural oxygenation, and incur substantial costs. This is important with respect to the difference between oxygenating the hypolimnion to support a cold-water fishery as opposed to preventing internal phosphorus recycling. Again, the focus of this study is the latter, meaning that a target DO concentration of 2 mg/L is adequate. There is also some concern that owing to the relative thickness of the north basin's hypolimnion (<3 m maximum) any oxygenation system could trigger water column destratification.

If the northern basin is to be oxygenated without destratification, DOX will not be applicable due to short vertical run distance for the released bubbles. Conventional hypolimnetic aeration or a Speece cone system could be used, but the very thin hypolimnion represents a challenge for distributing the volume of water necessary to satisfy the oxygen demand without causing some mixing. Additionally, it would be difficult to provide the correct power source needed to meet the demands of either system. A slip stream system, whereby relatively small volumes of water would be pumped from the hypolimnion, super-oxygenated on shore, and then distributed back into the hypolimnion appears feasible. But again, the costs may not justify the results.

An attempt was made to arrive at the capital and operational costs of aerating Conesus Lake, but given the conceptual nature of this project and the limited amount of data that was available for review, the cost estimates provided below should be viewed as very preliminary. Using the best available summary of oxygenation system costs (Wagner, 2015) a probable cost estimate was developed for a DOX system applicable for at least the southern and central basins of Conesus Lake. An appropriate system would need to be sized to manage at least 1,730 acres of hypolimnetic lake bottom area and 45,000 ac-ft of treated hypolimnetic volume. Based on the literature, the capital cost for such a system would be in the range of $2 million, exclusive of any land acquisition costs. The low end of the estimate is about $1.7 million, while the upper end is about $2.2 million. Of the total treated area, the south basin represents about 85% of the total cost. The central basin is much smaller and has less affected volume, only about 15% of the entire system's capital costs are a function of the central basin.

For the north basin, oxygenation could be accomplished using a conventional destratification system. Obviously, this would alter the basin's thermal properties. As such, NYS Division of Fish and Wildlife will be consulted before an aeration system design for the north basin is finalized. However, given the polymictic nature of the north basin, it appears to annually experience multiple episodes of stratification/destratification thus limiting its ability to sustain a cold-water fishery. A conventional destratification diffused aeration system as described above would likely cost between $700,000 and $800,000 to install, based on the area and volume of the north basin's hypolimnion that would need to be managed. If it were mandated that stratification could not be artificially disrupted, the most applicable oxygenation system would be a slip stream system (SSS). It is difficult to generate a cost estimate for such a system from the data available for Conesus Lake. The literature shows that the cost range of such systems is very wide and dependent on a number of factors. Using just the median cost for studied systems, a cost close to $3 million is estimated. As previously noted, the lack of easily accessible 3-Phase power may also limit/affect the design and feasibility of operating either an SSS or conventional destratification system for the lake's north basin.

Estimating operational costs is even more challenging than estimating capital costs of the recommended aeration systems for the individual lake basins or the entire lake. Based on known unit costs for other systems (Wagner, 2015), the DOX system for the south and central basins is likely to cost on the order of $500,000 per year to operate. As the power needs of DOX system are limited, the majority of these costs are associated with the transport and supply of oxygen and the labor to inspect and operate the system. Operational costs can be expected to decline over time as oxygen demand is satisfied. In the most studied example of long term hypolimnetic oxygenation, oxygen need was reduced by 75% over a period of about two decades (Horn, et al., 2019).

If a SSS system was installed in the northern basin, the operational cost is expected to be slightly in excess of $400,000 per year, but given the polymictic nature of the north basin it would not be necessary to operate the system throughout the entire summer. Thus, the annual operational cost could be considerably less. Use of a conventional destratification diffused aeration system in the north basin is not dependent on the lake's oxygen demand. The system would be operated to inhibit the development of stratification. As previously discussed, the majority of the water's re-oxygenation is the result of the constant exposure of the water column to the atmosphere. A destratification system would need to be operated continuously, most likely from late-May through September. At a minimum, the projected operational cost of a conventional destratification system would be in the range of $35,000 to $40,000 per year. Once again, either system would likely require a 3-Phase power source.

5.0 HAB MITIGATION SYSTEM FOR SANDY BOTTOM PARK (HONEOYE LAKE) BATHING BEACH AREA

Part of this project, specific to Honeoye Lake, involved the analysis of HAB mitigation measures that could be implemented in advance of any internal phosphorus load reduction strategies to minimize HAB impacts to the Sandy Bottom Park bathing beach area. Located in the Town of Richmond at the far northern end of Honeoye Lake, Sandy Bottom Park offers a wide range of recreational opportunities including swimming, picnicking, tennis, basketball, and boating. During summer weekends the park and beach are highly used, with much of that use causally linked to water-based activities. The beach front area is roughly 200 feet in length. To the immediate west of the beach is a small car top boat launch.

Unfortunately, the bathing beach has been repeatedly closed over the past three summers due to reported/confirmed cyanobacteria blooms. These blooms also create odor and aesthetic problems that negatively affect the use of the park. The blooms are largely the result of cyanobacteria cells driven by wind, waves, and the lake's internal seiche from the open water areas of the lake. These cells concentrate and accumulate within the bathing area, adjacent to the boat launch, and along the beach front. The location of the beach immediately adjacent to the lake's outlet channel further exacerbates the accumulation of cyanobacteria cells and floating debris consisting of mat algae, aquatic plant fragments, and various floatables.

This section of the report summarizes Princeton Hydro's evaluation of different techniques that could be used to help alleviate the accumulation of cyanobacteria along the beach front and within the park's swimming area. Emphasis was given to relatively low-cost, easy to install, operate, and maintain techniques specifically aimed at preventing or lessening the accumulation of floating material (including cyanobacteria cells) within the beach area. None of these techniques will prevent the development of a cyanobacteria bloom. However, these techniques could be implemented in advance of measures used to minimize or control blooms such as the previously discussed nutrient inactivation and/or aeration measures. Among the techniques evaluated for implementation at Sandy Bottom Park were:

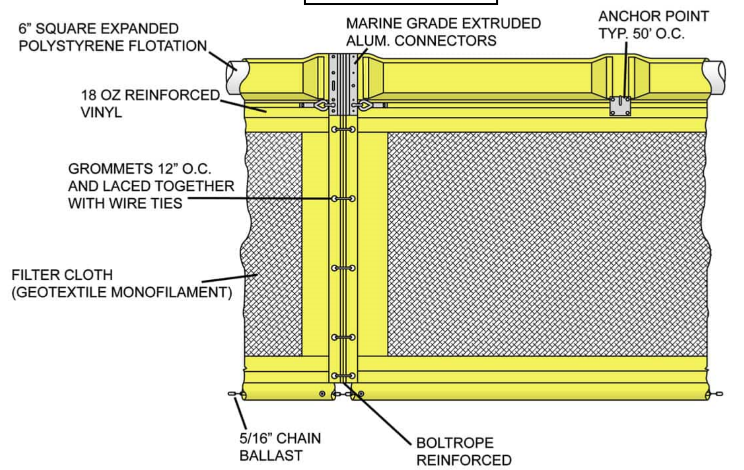
- Sedimentation curtains (deflect flow and divert cyanobacteria cells and floating debris away from the bathing area),
- Water circulation systems (collect and pump water through the bathing area, mix/agitate the water column, and create water currents to push cyanobacteria cells and floating debris out of and/or away from the bathing area),
- Aeration systems (mix the water column and/or create a bubble curtain to deflect cyanobacteria cells and floating debris material away from the beach and bathing area),
- Sonic device (lessen and disrupt the accumulation of cyanobacteria cells), and/or
- Ozone system operated in conjunction with a typical aeration/mixing system (oxidize fine suspended organic material and reduce the nearshore accumulation of cyanobacteria cells).

The use of algaecides, dyes, or other chemical substances deemed to have an algacidal effect were not evaluated as part of this work effort and are not discussed in this report.

Unfortunately, the accumulation of material at this end of the lake and along Sandy Bottom Beach cannot be stopped owing to the lake's prevailing currents and the typical south to north direction of the prevailing winds. Therefore, all of the evaluated and recommended techniques are at best intended to divert material away from the beach area and lessen the amount of material that accumulates within the swimming area and along the shoreline.

Sedimentation Curtain – Of the evaluated options, the sedimentation curtain offers the least expensive and perhaps the most effective, although labor intensive, means by which to decrease the accumulation of cyanobacteria cells and other floating material along the shoreline of Sandy Bottom Park. A typical sedimentation curtain consists of a floatation collar from which a weighted skirt extends to the lake bottom. A Type III curtain should be used. Type III curtains are designed for deployment in high flow areas. Type III curtains come with a standard 8' deep, heavy duty geotextile fabric skirt. The top of the skirt is sewn into a foam floatation collar (8" – 12" in diameter) that is surrounded by a sleeve made of the same material as the skirt. This protects the foam from abrasion and UV light. The bottom of the skirt is weighted down by a heavy (5/16" or greater) galvanized steel chain. Heavy galvanized steel cables are integrated into top of the skirt. The ends of the cables are equipped with high tension grommets from which concrete ballast anchors are affixed. The ballast anchors keep the sedimentation curtain in place. The grommets also allow multiple lengths of the curtain to be attached and configured as needed. The illustration provided below is an example of Type III curtain (Figure 5.1).

Figure 5.1

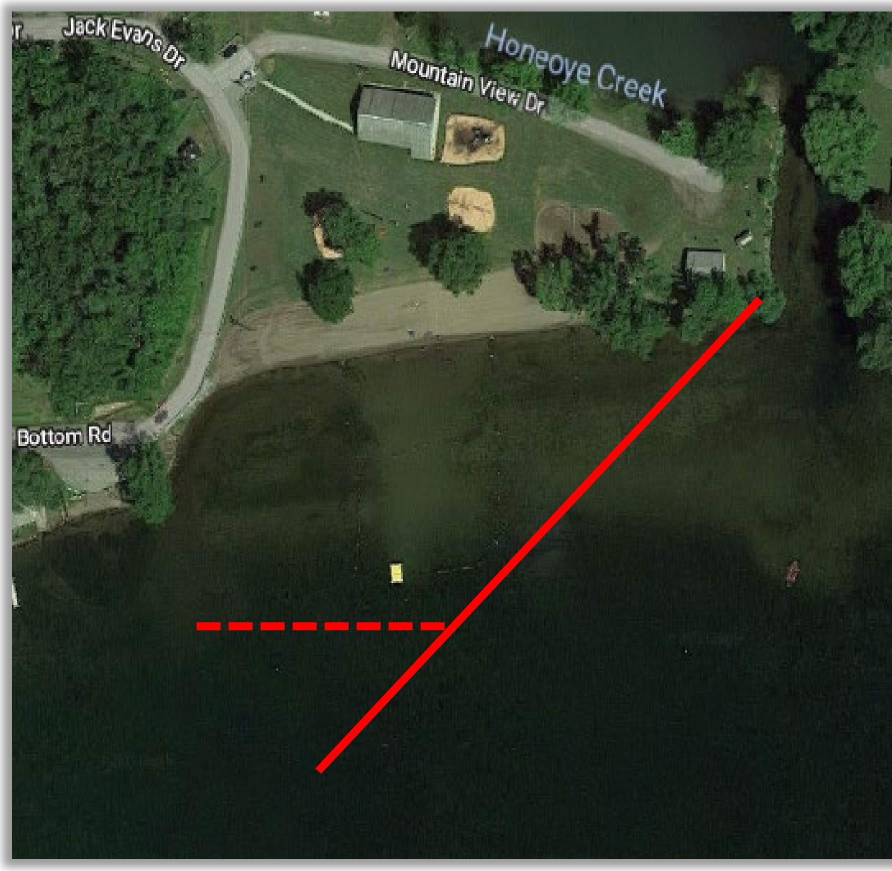


Source:https://www.elastec.com/products/floating-boom-barriers/turbidity-curtains/type-3/siltmax-type-iii/

Sedimentation curtains can be purchased in varying lengths and connected together to create a relatively seamless barrier. The Sandy Bottom Park installation would require a curtain at least 600' in total length. For ease of installation, routine maintenance, and seasonal removal, the sedimentation curtain should consist of interconnected 50' lengths. The sedimentation curtain could be placed and configured as shown in Figure 5.2. As illustrated, by using 50' lengths of curtain it would be possible to deploy the curtain in various configurations that best contain the swimming area and deflect material away from the beach towards the outlet channel. The open water end of the curtain will need to be attached to heavy concrete anchors to keep the curtain in place. At the land end of the curtain, it would need to be connected to a firmly anchored concrete post. Navigational beacons and warning signs would need to be placed along the floatation collar to alert boaters and prevent them from running into the curtain. The curtain would be deployed before the beginning of the swimming season and removed at the close of the season. The in-lake anchoring devices would be left in the water. It should be noted that the placement of the boom, navigational beacons, and warning signs will likely require a NYSDEC permit.

The floating material that accumulates along the curtain (weed fragments, leaves, debris) will need to be periodically removed. This can be accomplished using the weed harvesters that operate on Honeoye Lake, without any modification of the harvester. This would simply involve lowering the bow conveyor 2-3 feet below the water's surface. The material (mostly aquatic weed fragments, leaves, and other floating debris) collected on the conveyor would be transported onto the harvester and then offloaded, as is routinely done with cut weeds, from the machine onto the shore or directly into a dump truck. Material that accumulates at the discharge of the lake into Honeoye Creek could be removed using a backhoe. The removal of accumulated material along the curtain and at the outlet may need to be done weekly making this a fairly labor-intensive option.

Figure 5.2 Sedimentation Curtain Installation Options



The anticipated cost to purchase and install the sedimentation curtain should be in the range of $20,000 (including materials and labor). Although labor intensive, this is the least expensive and the most reliable means by which to reduce the accumulation of cyanobacteria and floating debris along the beach front and within the swimming area.

Water Pumps, Circulators, and Air Curtain – Based on the magnitude of the wind, waves, and current affecting the Sandy Bottom Park beach area, Princeton Hydro concluded that any type of water circulation or bubble curtain option would not be effective in this setting. Additionally, none of these options would likely be capable of keeping weed fragments and larger debris from accumulating along the shoreline. Finally, given the limited expected effectiveness of any of these options, the cost of installation (at least $50,000) and cost of operation are too great to justify their use at this site.

Submerged Aeration System – Installation of the sedimentation curtain will limit water exchange, circulation, and flow within the swimming area. In order to facilitate better water exchange and water column mixing, a small, submerged aeration system could be operated in conjunction with the sedimentation curtain. As per Figure 5.1, an approximately 3-acre area would be enclosed by the curtain. The cost to purchase and install a submerged aeration system capable of circulating the water within the contained area is in the range of $20,000. To minimize interference with swimmers and maximize water column circulation, the diffusers would be placed only in deeper water (> 6-8'). Such a system would only require a GFI 120-volt power source. The compressor (≤ 1HP) would need to be housed as close to the shore as possible. The system could be operated continuously or only during off-hour periods to minimize interference with swimmers. It should be noted that the use of the aeration system is specifically to improve water circulation within the area contained by the sedimentation curtain. Princeton

Hydro does not envision the system playing a major role in minimizing the accumulation of material within the bathing area.

Sonic Device and Ozone Generator – Although both are promising options to actively reduce the accumulation of organic material within the beach and bathing area, neither is recommended for Sandy Bottom Park. First, neither option has been conclusively proven to effectively reduce cyanobacteria blooms. Second, as is the case with the water pump and water circulation options, the magnitude of the wind, waves, and current affecting the beach area is too great and would impede the effectiveness of either a sonic device or an ozone generator. Also, neither would be able to keep weed fragments, large debris, and the cyanobacteria cells entrained on such material from accumulating along the shoreline or within the bathing area. As such, neither a sonic device nor an ozone generator is recommended for Sandy Bottom Park.

6.0 SUMMARY

1. Both Honeoye Lake and Conesus Lake experience the internal regeneration of sedimentary phosphorus during periods of anoxia. This internal phosphorus load constitutes a major amount of both lakes' total annual phosphorus load.
2. Multiple studies, including the lake specific HAB Action Plans and Phosphorus TMDL reports prepared by NYSDEC, conclude that the reduction of the internal phosphorus load is imperative and needs to be a prioritized element of each lake's long-term trophic state management and HAB control efforts.
3. Honeoye Lake is the shallowest of New York's Finger Lakes. It has the water column thermal stability properties characteristic of a polymictic lake. Although the lake's deeper water (8-9 meters) becomes anoxic during the early part of the growing season, the water column's thermal stability, RTRM, and other indicators of stratification are relatively weak. As such, the lake stratifies and destratifies multiple times over the course of the year, especially during the latter part of the growing season (August and September). This results in the mixing of phosphorus-rich hypolimnetic bottom water into the upper epilimnetic stratum of the lake. The added phosphorus stimulates increased phytoplankton productivity, leading to HABs. Adding to the lake's thermal instability is its significant internal seiche. The prevailing southerly winds and the magnitude and amplitude of the seiche aids in the mixing of the water column. Wind, wave, and seiche patterns also cause cyanobacteria cells to accumulate in the northern end of the lake. The resulting concentration of cyanobacteria cells, along with other floating particulate material, impact the use of the lake's primary public recreational area, Sandy Bottom Park.
4. Conesus Lake attains a maximum depth of 20.1 meters (66 feet). Its mean depth is 11.6 meters (38 feet). Approximately 39% of the lake is ≤ 5 meters (16 feet) deep. The lake's thermal and RTRM data show that the deeper southern and central basins of Conesus Lake have the water column stability properties characteristic of a dimictic lake. However, these same data show that the shallower northern basin has water column stability characteristics more consistent with that of a polymictic waterbody. The deeper water of the southern and central basins becomes anoxic during the early part of the growing season. Studies conducted by SUNY Geneseo and SUNY Brockport document that during these periods of anoxia a corresponding significant increase in phosphorus concentration is measured in the hypolimnion of all three basins. Due to the prevailing patterns of mid-summer wind, wave, seiche, and fetch, the phosphorus-rich bottom waters are transported into the shallower depth strata of the lake leading to an increase in epilimnetic phosphorus concentrations great enough to stimulate the development of HABs. These blooms impact the recreational areas located within all three basins, including but not limited to Southern Shores Campground, Long Point Park, Camp Stella Maris, and Vitale Park. The configuration and morphometry of the lake's outlet exacerbates the concentration of cyanobacteria and other floating material at the lake's far north end, further worsening the aesthetic and water quality problems that affect the water-based recreational use of Vitale Park.
5. Both lakes are good candidates for nutrient inactivation. As noted repeatedly in the findings of various studies, each lake's internal phosphorus load is a leading driver of HABs. Given the naturally high buffering capacity of both lakes, it should be possible to use alum to bind and reduce phosphorus liberated from the lakes' sediments during periods of anoxia. In fact, previous bench testing of alum conducted for both lakes shows that large amounts of alum can be introduced without causing the pH of either lake to drop below 6.5. Additionally, Honeoye Lake was previously treated with alum. That treatment resulted in measurable, although relatively short-lived, positive water quality and HABs management results (HLVTF 2007, Gilman 2007). This study concludes that both lakes should be treated with alum and that alum treatment should be the prioritized first step taken in the management of the HABs impacting both Honeoye Lake and Conesus Lake. Based on a projected alum application rate of 300 gallons/acre, the preliminary estimated cost to conduct an alum treatment of Honeoye Lake is in the range of $782,000 and for Conesus Lake it is in the range of $1,015,000. The alum treatment cost could be substantially

reduced if only the southern and central basins were treated, as suggested by Dr. Bosch (Bosch, 2019, pers. comm.). The NYSDEC HAB Action Plan for Honeoye Lake (NYSDEC, 2018d) lists alum bench testing as a Priority 1 Project and recognizes the potential value of nutrient inactivation in the long-term management of the lake's HAB problems. The NYSDEC HAB Action Plan for Conesus Lake (NYSDEC, 2018b) identifies the implementation of a detailed limnological study to assess the feasibility of the use of a nutrient inactivant as a Priority 1 Project. The report goes on to state that if the results of the study are favorable, the nutrient inactivant treatment of the lake should be conducted. Based on our review of the data available for both lakes, and our experience in the management and restoration of lakes using nutrient inactivants, Princeton Hydro highly recommends that both lakes be treated with alum as the first stage to control HABs which impact Honeoye Lake and Conesus Lake. The benefits of conducting an alum treatment in advance of implementing aeration include the following:

- The alum will bond with inorganic phosphorus present in the sediment interstitial pore water. This phosphorus is already labile and will not be controlled by aeration. Binding this source of phosphorus helps decrease nutrient availability, especially at the onset and at the end of the growing season.
- Conducting the alum treatment in advance of aeration binds any bioavailable phosphorus that is already present in the lake, both externally and internally sourced phosphorus.
- Having the lake's potential sediment-related phosphorus inactivated lessens reliance on just aeration to control the internal phosphorus.

The benefits and success of such an approach has been documented for multiple lakes and reservoirs (Osgood 2018, Moore et al. 2012, Moore and Christensen 2009, Lubnow and Souza 2003).

6. Aeration options were evaluated for both lakes. The objective of aeration is to prevent the development of anoxia in a lake's deeper waters. In doing so it will be possible to significantly decrease the regeneration and recycling of phosphorus released from the sediments and thus decrease the lakes' internal phosphorus loads. As such, the NYSDEC has identified aeration as a Priority 1 Project for both lakes (NYSDEC 2018b and NYSDEC 2018d).

   For Honeoye Lake, due to its polymictic nature, the best aeration approach by which to manage stratification and prevent anoxia is to maintain the lake in a destratified state. This is best accomplished using a conventional destratification aeration system. With assistance provided by Vertex Water Features a conceptual design was developed for a Honeoye Lake destratification aeration system.

   The morphometry and thermal dynamics of Conesus Lake are more complicated than Honeoye Lake. While the deep southern and central basins have the thermal properties of a dimictic lake, the thermal dynamics of the shallower northern basin are more consistent with that of a polymictic lake. Nonetheless, the lake's internal phosphorus load is a major driver of the lake's HABs problems. With assistance provided by both Dr. Ken Wagner and Dr. Chris Holdren, aeration options were evaluated for Conesus Lake. As previously discussed, a DOX aeration system, which introduces oxygen gas into the lake's hypolimnion using a porous line diffuser delivery system, is the best aeration option for the southern and central basins. Given the polymictic nature of the northern basin, deep water anoxia could be managed using a conventional destratification system similar in design to that recommended for Honeoye Lake. However, due to concerns raised by NYSDEC regarding maintenance of stratification for the benefit of the lake's cold-water fishery, destratification of the northern basin should not be an option. Because of the shallow nature of the northern basin and its thin hypolimnion, DOX may not be effective and could also disrupt stratification. This leaves slip stream aeration as the most tenable option. This is also a direct oxygen injection technique and it could be implemented without disrupting stratification. It appears though to be far more expensive to install and operate than either a DOX or destratification system.

   In summary, the initial approach to aerating Conesus Lake should begin with the design of a DOX system for the lake's southern and central basins. Given the thin hypolimnion of the shallow northern basin, this system may generate and supply enough oxygen to even manage the oxygen demand of the northern basin though, it is noted, that the even distribution of oxygen throughout the hypolimnion of the lake is challenged by the lake's bathymetry.

7. The prevailing wind, seiche, and fetch of Honeoye Lake result in the accumulation of cyanobacteria and other floating material along the shoreline of Sandy Bottom Park. This has resulted in numerous closures of the park's swimming area, even when cyanobacteria densities and toxin levels are low in the remainder of the lake. Although not an actual cyanobacteria management technique, water quality, aesthetic, and use impacts to Sandy Bottom Beach and the Sandy Bottom Park swimming area could be decreased by actively preventing the concentration of cyanobacteria and other floating material. Of the various options evaluated, it would appear that the least expensive (although somewhat labor intensive) approach is the most feasible. This involves the use of a Type III sedimentation boom in the open water area immediately adjacent to the park, positioned such that accumulated material is deflected away from the shoreline and swim area towards the lake's outlet. Prior to implementation of this strategy, NYSDEC should be consulted on any potential permit requirements and NYS Department of Health will be consulted on design and overall review to ensure compliance with applicable regulations for a regulated bathing beach facility.

8. To best control each lake's internal phosphorus load a two-step approach is recommended whereby the application of alum is conducted as the first stage, followed by the installation and operation of a properly designed aeration system. The alum treatments should use an alum dose rate that would provide at least 5 years of control. It should be noted that controlling the lakes' internal phosphorus loads will not fully restore the waterbody and may not fully prevent the manifestation of HABs. As noted in the TMDL reports prepared by NYSDEC for both lakes, this will require the systematic reduction of the lakes' overall phosphorus loads, which involves reduction of each lake's external as well as internal phosphorus loads.

9. The recommended projects will require varying levels of capital investment associated with upfront design, testing, implementation, and operation and maintenance. To adequately prepare for all facets of these projects, proper consideration and planning is needed for items including, but not limited to, funding, access agreements, ownership, long-term inspection, operation and maintenance, permit materials, public hearings, public notices, regulatory review and approval, bid specifications, advertising and review, contractor oversight, and grant applications for eligible projects.

10. To maximize HAB control and the overall effectiveness of the NYSDEC's HAB management efforts, it is strongly recommended that both alum and aeration be implemented as a two-step program (alum followed by aeration). This is the best means of managing internal phosphorus loading and reducing HABs.

11. As of yet there is no formal nutrient inactivant policy in place in New York. It would be best to conduct an alum treatment as the first-step measure. However, management of the lakes' internal phosphorus loads is critical and should not be delayed. Therefore, the planning, design, and even the installation and operation of the aeration systems for Conesus Lake and Honeoye Lake can proceed in advance of the lakes' alum permitting process and subsequent alum treatment.

12. If the installation of the lakes' aeration system occurs before the alum treatment, it is still highly recommended that the lakes be treated with alum. Use of alum would significantly decrease the lakes' internal phosphorus loads, accelerate overall HAB control, and further complement any water quality improvements gained through aeration.

13. If for any reason a decision is made to implement only one technique at either lake, it is Princeton Hydro's position that it should still be possible to reduce and manage HABs at either lake, but it should be noted that it would likely take longer to realize that goal (Osgood 2018, Moore et al. 2012, and Moore and Christensen 2009). The two-phase approach detailed for both lakes is consistent with the successful HAB management programs implemented at other lakes impacted by significant internal phosphorus loading. This is because aeration prevents the anoxic conditions that promote the accelerated release of inorganic phosphorus from deep-water sediments, while the alum binds phosphates present in the

interstitial pore water as well as deep-water inorganic phosphorus that would be liberated from the sediments during oxic periods (winter, late-fall, and early-spring). The combined positive effects of alum and aeration yields cumulative, long-term, lake management benefits that typically cannot be cost-effectively achieved by relying on only one of the two lake management measures.

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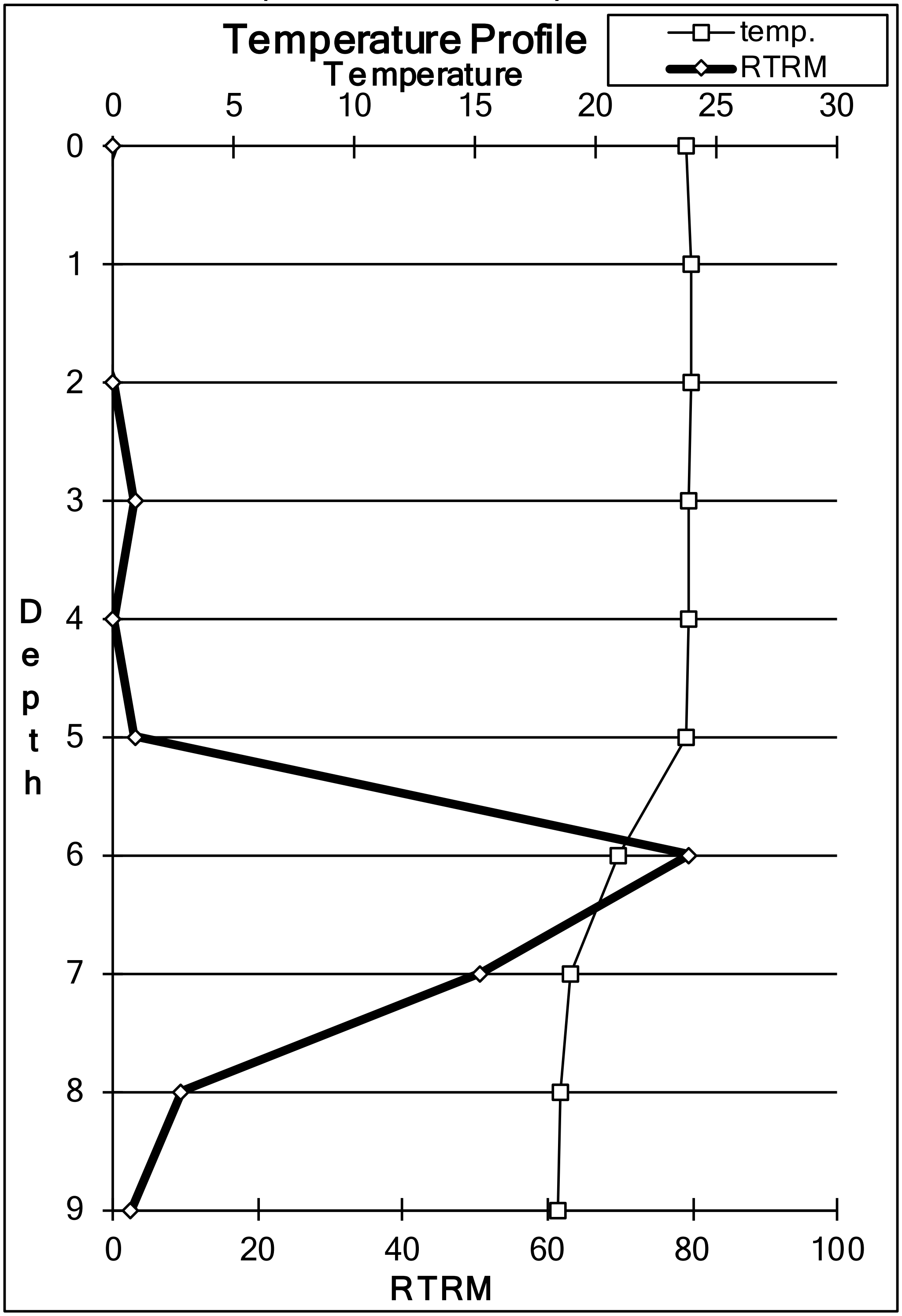
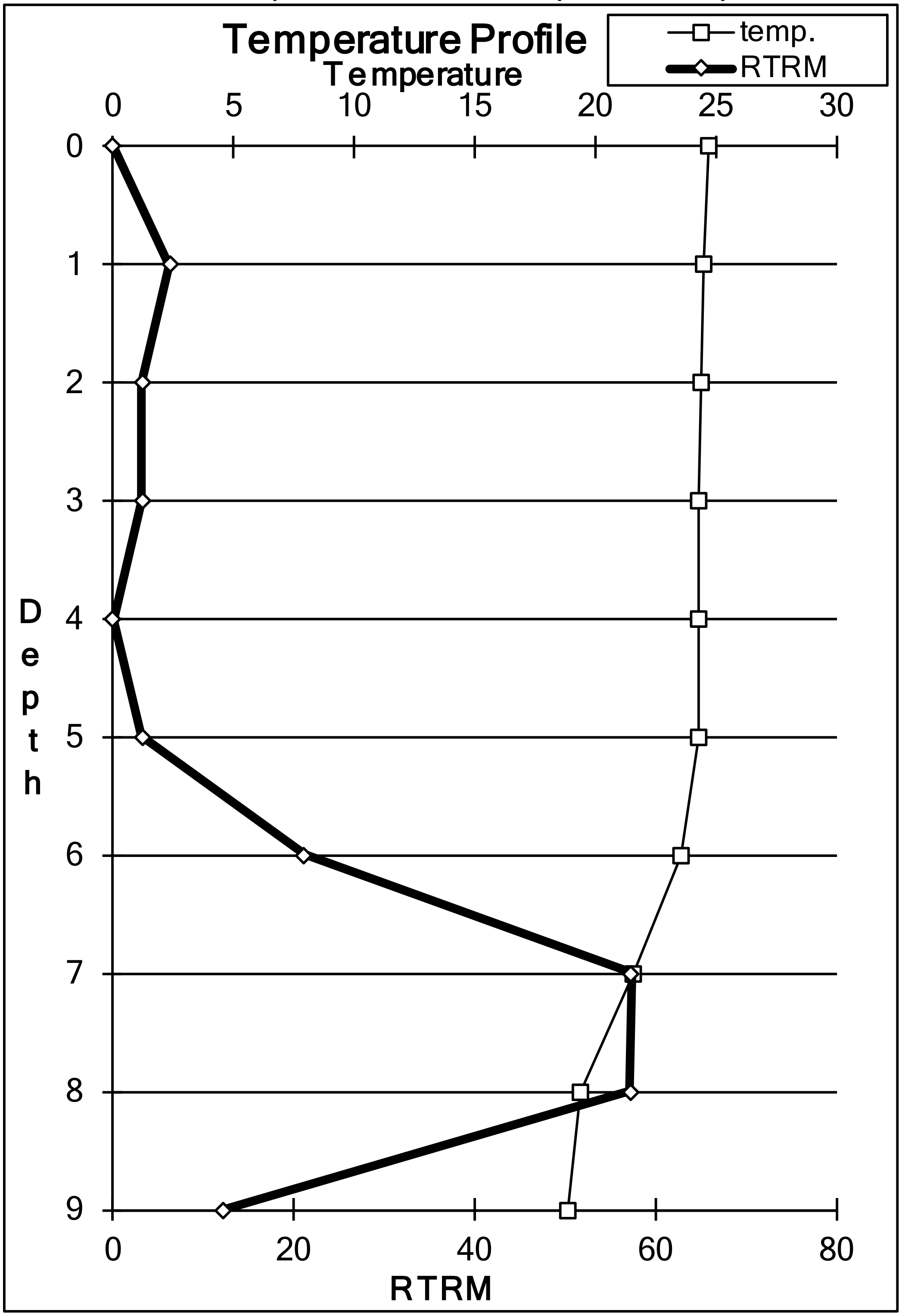
APPENDIX I

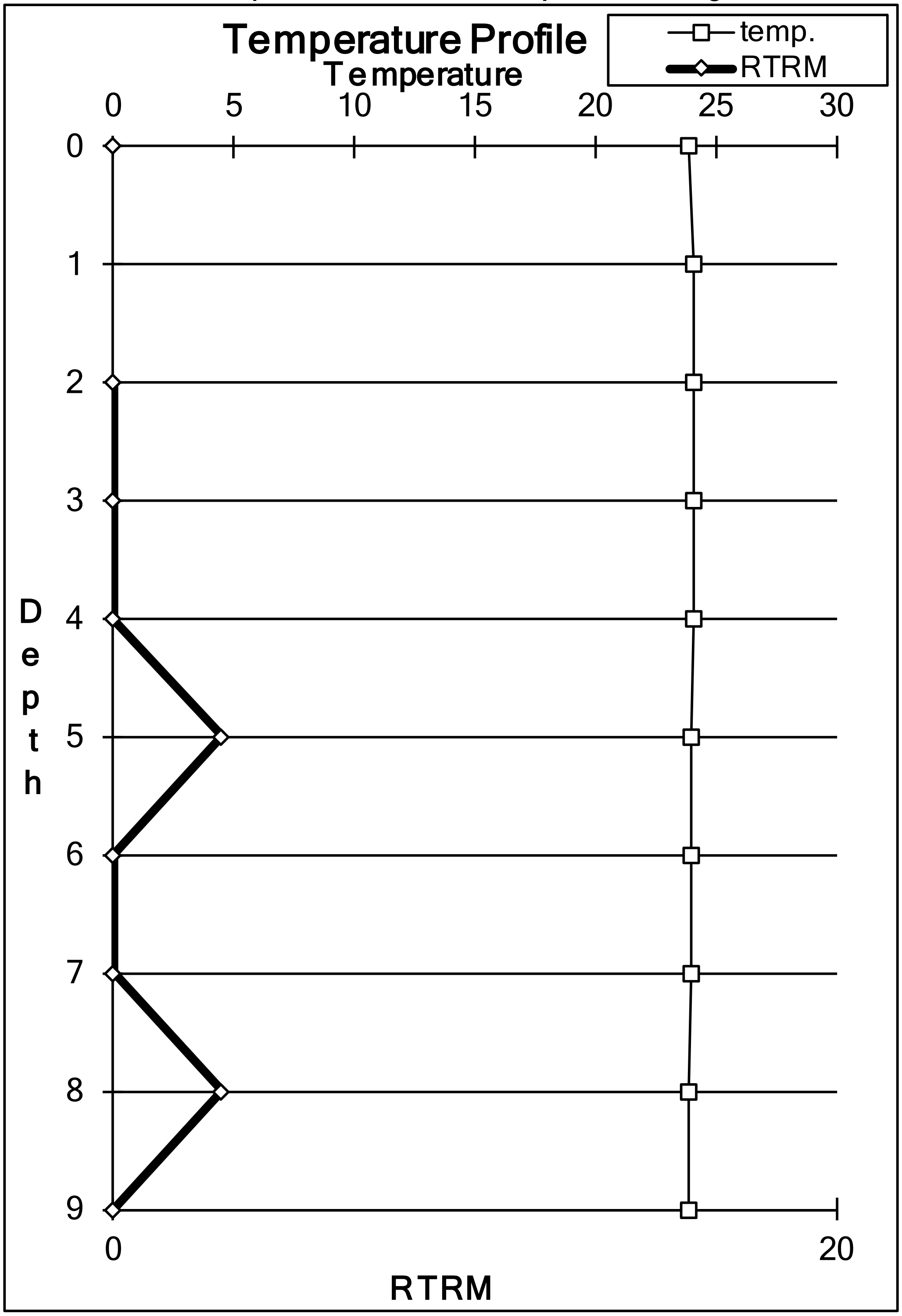
RTRM and Temperature Profile for Honeoye Lake, 27 June 2016



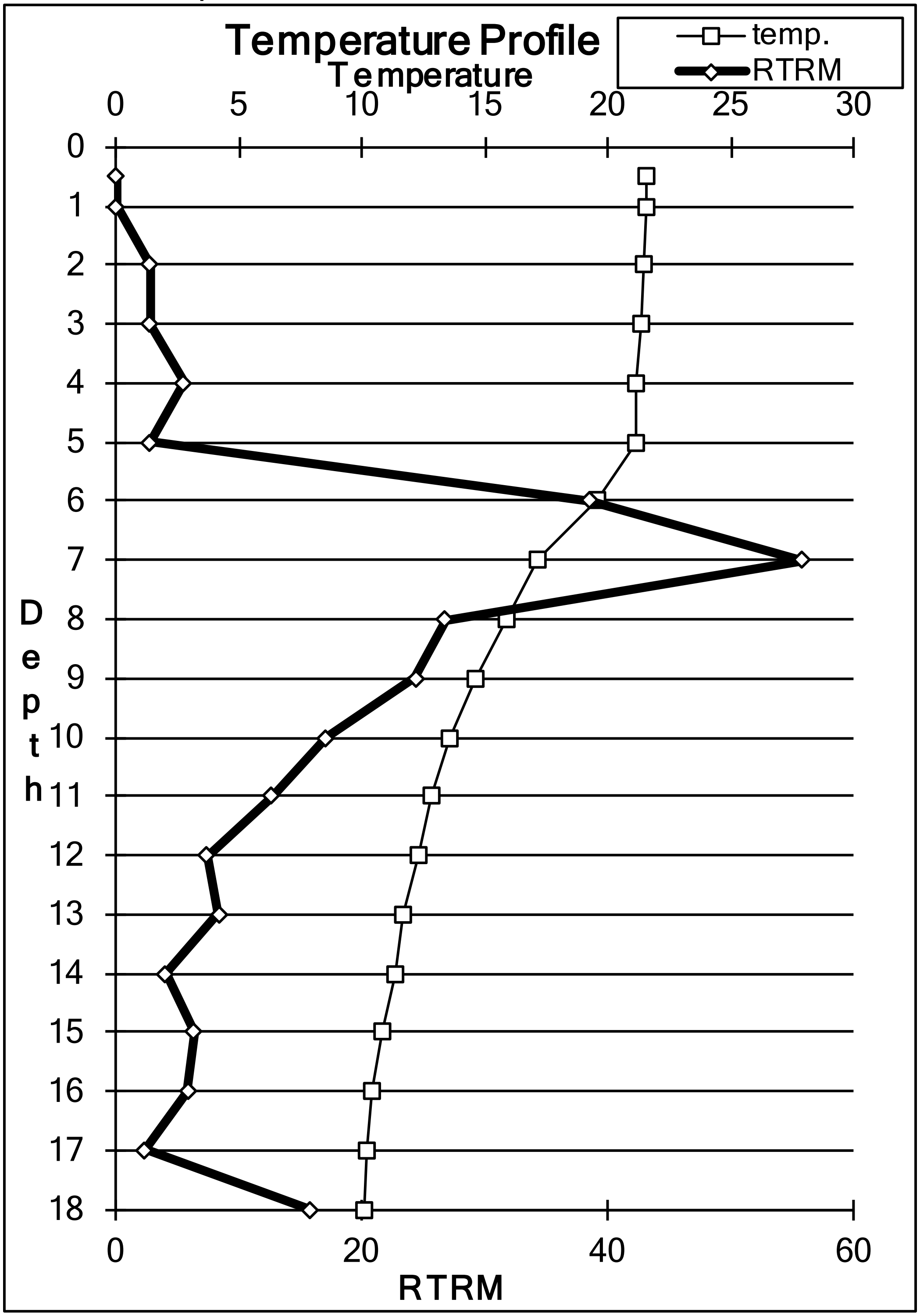
RTRM and Temperature Profile for Honeoye Lake, 11 July 2016



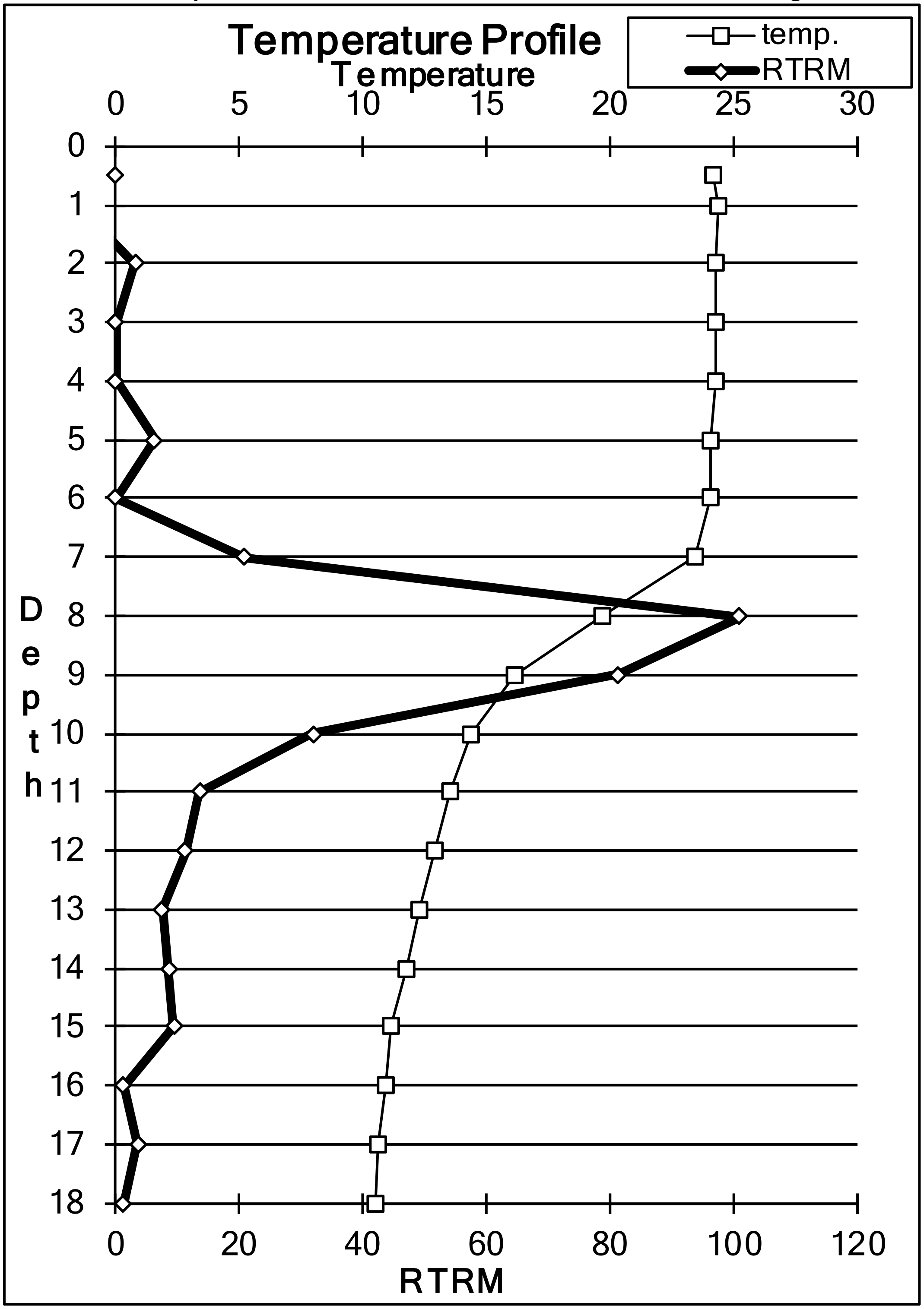
RTRM and Temperature Profile for Honeoye Lake, 22 August 2016



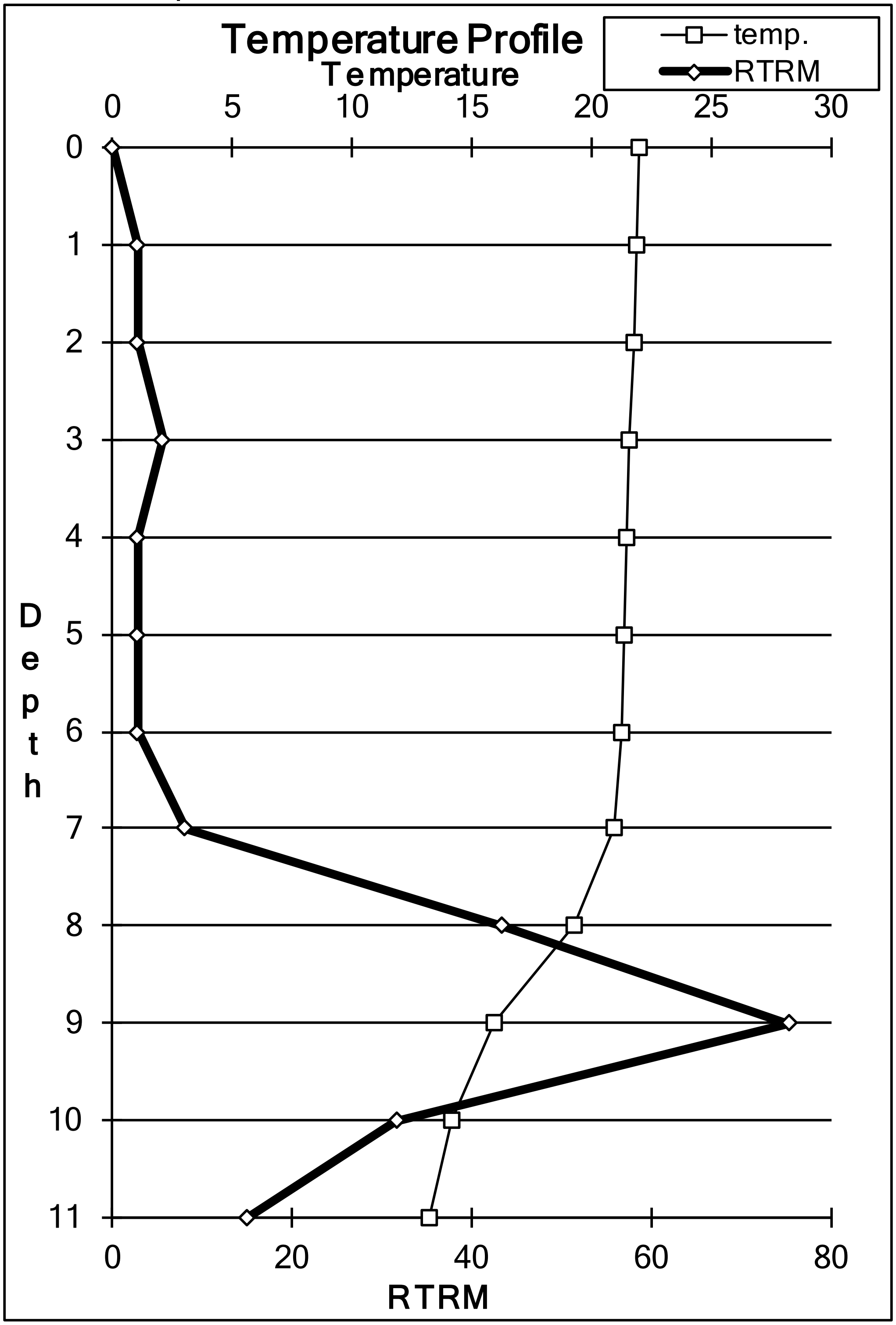
RTRM and Temperature Profile for South Basin of Conesus Lake 28 June 2017



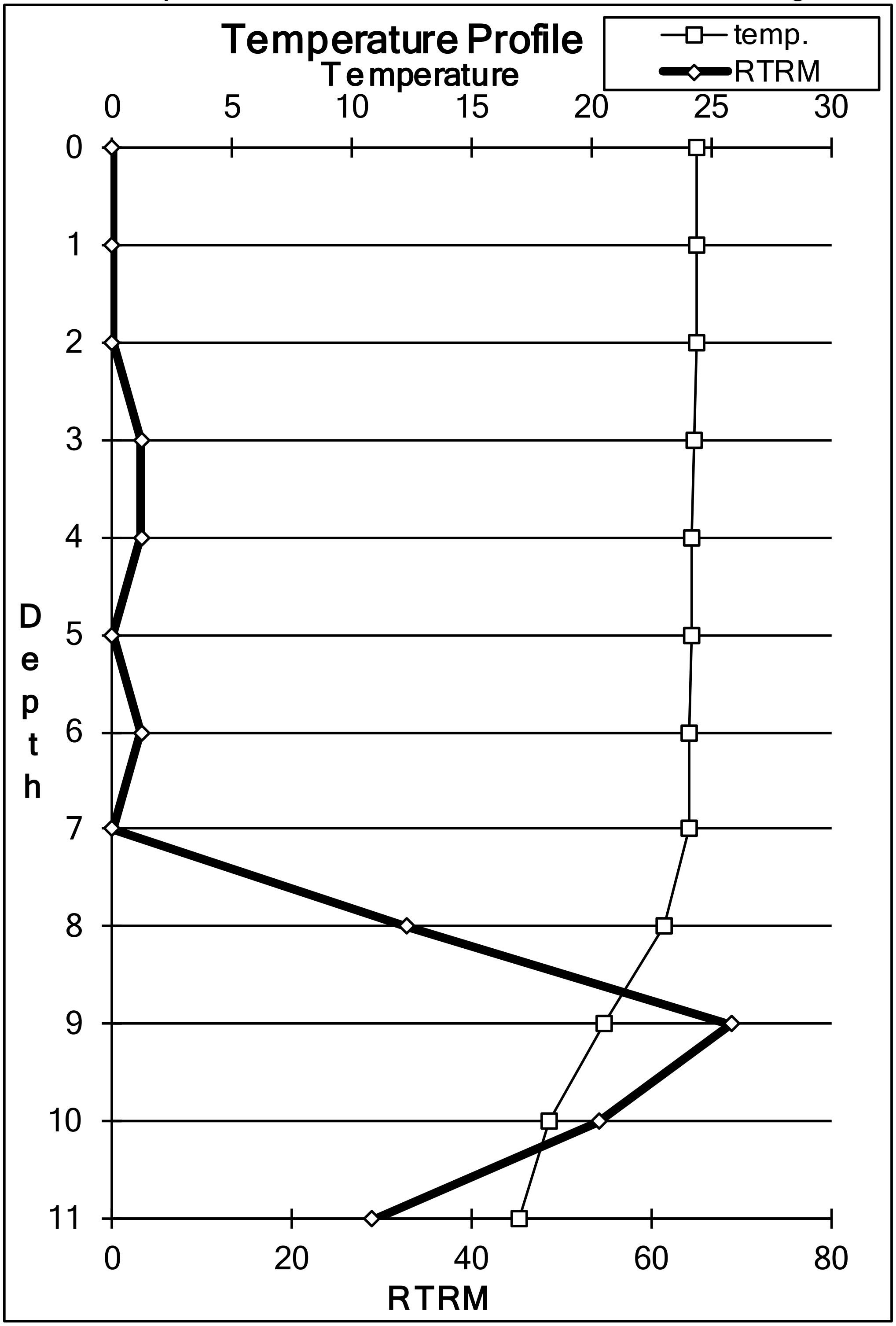
RTRM and Temperature Profile for South Basin of Conesus Lake 22 August 2017



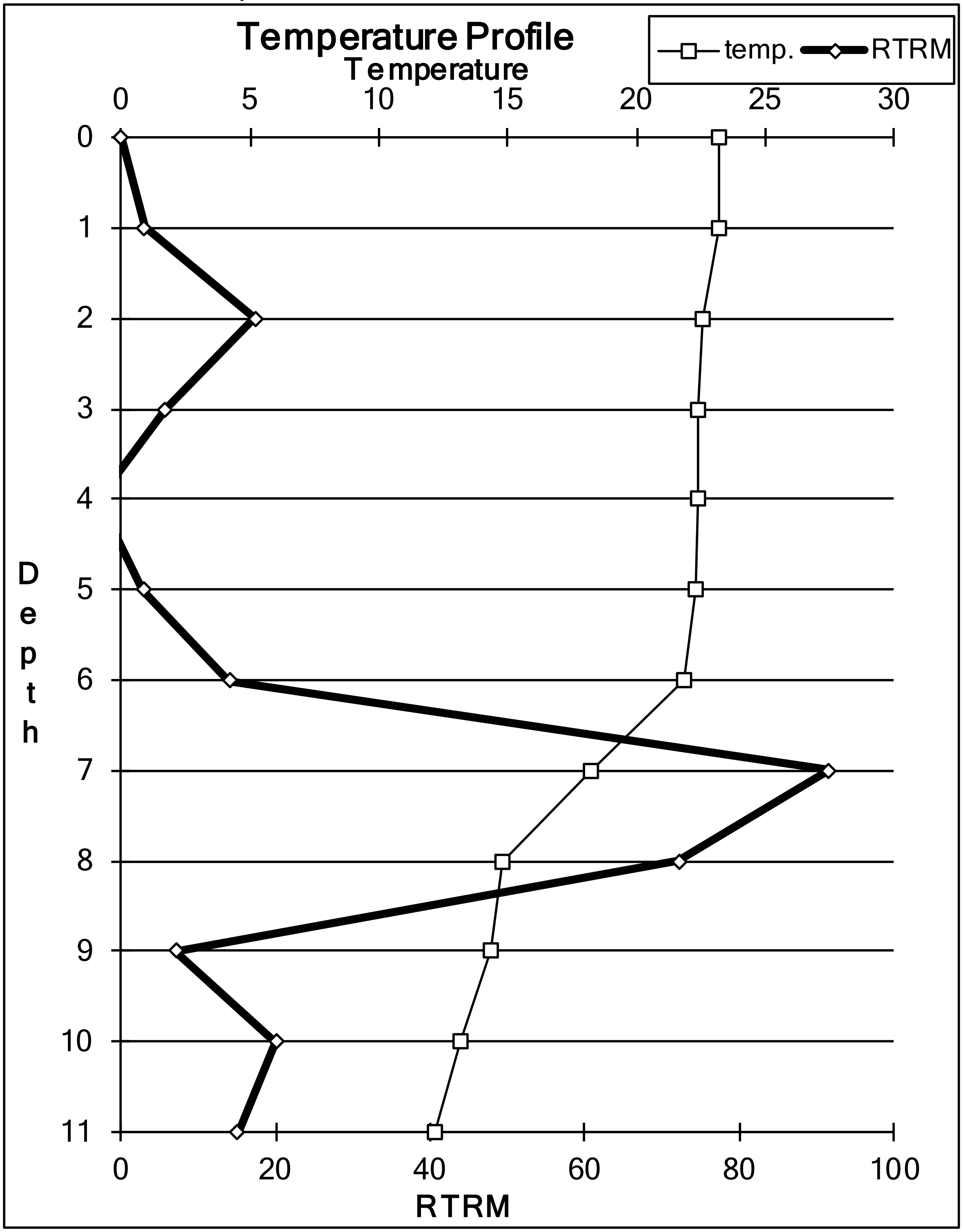
RTRM and Temperature Profile for Central Basin of Conesus Lake 28 June 2017



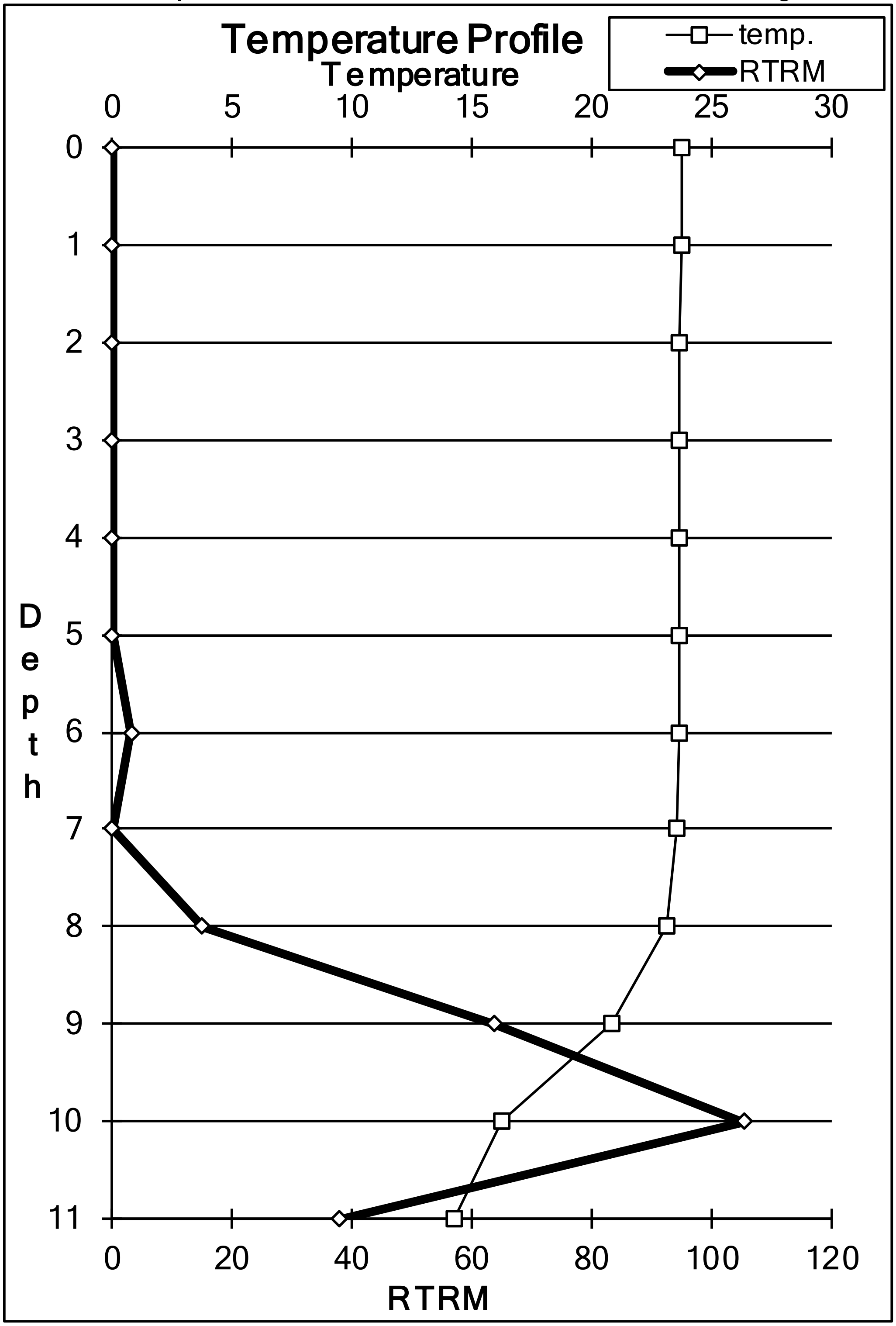
RTRM and Temperature Profile for Central Basin of Conesus Lake 22 August 2017



RTRM and Temperature Profile for North Basin of Conesus Lake 21 June 2017



RTRM and Temperature Profile for North Basin of Conesus Lake 24 August 2017



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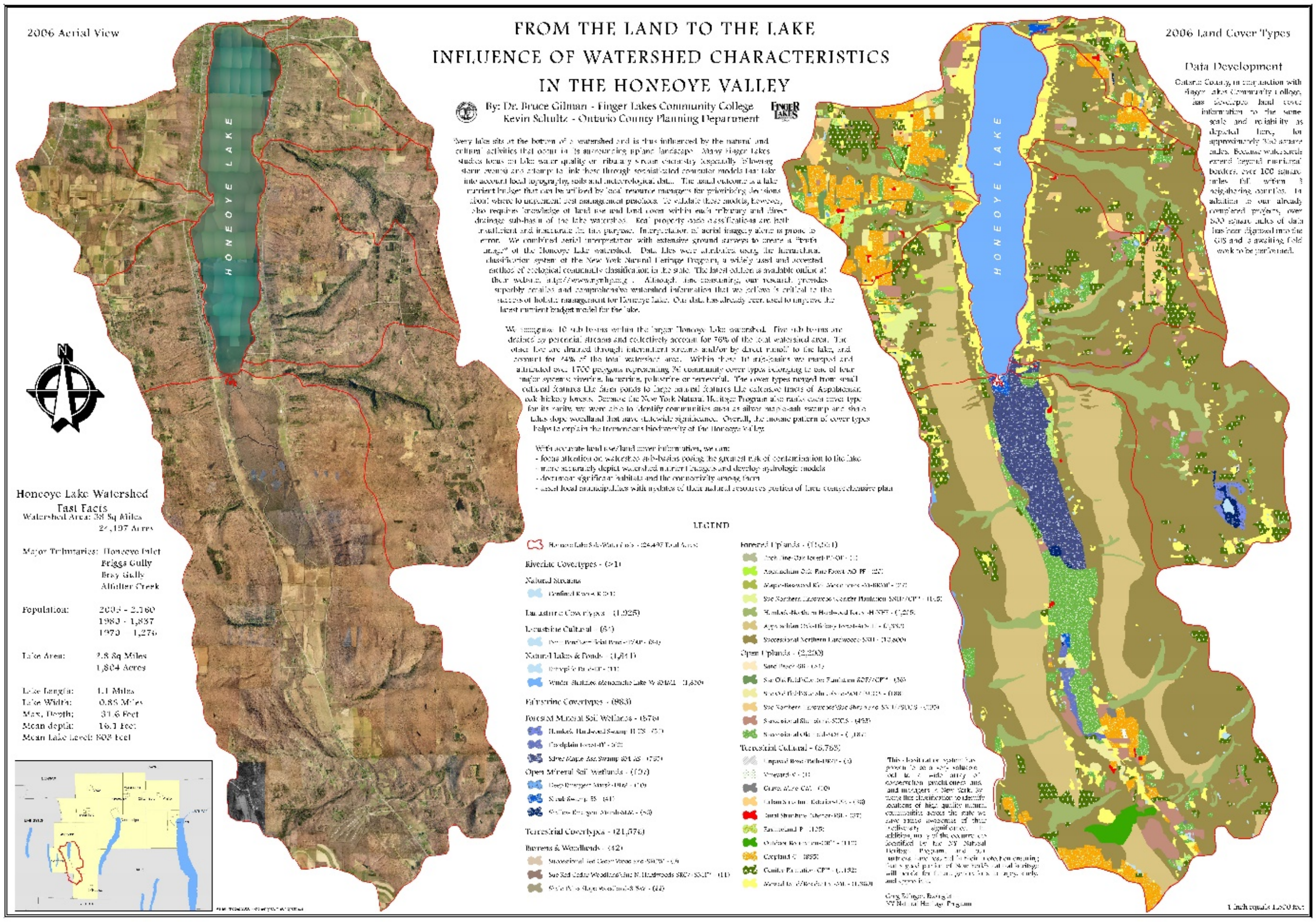
APPENDIX II



Land use in the Honeoye Lake watershed. Source: Gilman and Schultz, 2006

APPENDIX III

Short Environmental Assessment Form
Part 1 - Project Information

Instructions for Completing

Part 1 – Project Information. The applicant or project sponsor is responsible for the completion of Part 1. Responses become part of the application for approval or funding, are subject to public review, and may be subject to further verification. Complete Part 1 based on information currently available. If additional research or investigation would be needed to fully respond to any item, please answer as thoroughly as possible based on current information.

Complete all items in Part 1. You may also provide any additional information which you believe will be needed by or useful to the lead agency; attach additional pages as necessary to supplement any item.

Part 1 – Project and Sponsor Information				
Name of Action or Project:				
Project Location (describe, and attach a location map): Honeoye Lake, New York.				
Brief Description of Proposed Action:				
Name of Applicant or Sponsor:	Telephone: E-Mail:			
Address:				
City/PO: q	State:	Zip Code:		
1. Does the proposed action only involve the legislative adoption of a plan, local law, ordinance, administrative rule, or regulation? If Yes, attach a narrative description of the intent of the proposed action and the environmental resources that may be affected in the municipality and proceed to Part 2. If no, continue to question 2.			NO ☐	YES ☐
2. Does the proposed action require a permit, approval or funding from any other government Agency? If Yes, list agency(s) name and permit or approval:			NO ☐	YES ☐
3. a. Total acreage of the site of the proposed action? __________ acres b. Total acreage to be physically disturbed? __________ acres c. Total acreage (project site and any contiguous properties) owned or controlled by the applicant or project sponsor? __________ acres				
4. Check all land uses that occur on, are adjoining or near the proposed action: 5. ☐ Urban ☐ Rural (non-agriculture) ☐ Industrial ☐ Commercial ☐ Residential (suburban) ☐ Forest ☐ Agriculture ☐ Aquatic ☐ Other(Specify): ☐ Parkland				

	NO	YES	N/A
5. Is the proposed action,			
a. A permitted use under the zoning regulations?	☐	☐	☐
b. Consistent with the adopted comprehensive plan?	☐	☐	☐

	NO	YES
6. Is the proposed action consistent with the predominant character of the existing built or natural landscape?	☐	☐
7. Is the site of the proposed action located in, or does it adjoin, a state listed Critical Environmental Area? If Yes, identify: ______	☑	☐
8. a. Will the proposed action result in a substantial increase in traffic above present levels?	☐	☐
b. Are public transportation services available at or near the site of the proposed action?	☐	☐
c. Are any pedestrian accommodations or bicycle routes available on or near the site of the proposed action?	☐	☐
9. Does the proposed action meet or exceed the state energy code requirements? If the proposed action will exceed requirements, describe design features and technologies: ______	☐	☐
10. Will the proposed action connect to an existing public/private water supply? If No, describe method for providing potable water: ______	☐	☐
11. Will the proposed action connect to existing wastewater utilities? If No, describe method for providing wastewater treatment: ______	☐	☐
12. a. Does the project site contain, or is it substantially contiguous to, a building, archaeological site, or district which is listed on the National or State Register of Historic Places, or that has been determined by the Commissioner of the NYS Office of Parks, Recreation and Historic Preservation to be eligible for listing on the State Register of Historic Places?	☐	☑
b. Is the project site, or any portion of it, located in or adjacent to an area designated as sensitive for archaeological sites on the NY State Historic Preservation Office (SHPO) archaeological site inventory?	☐	☑
13. a. Does any portion of the site of the proposed action, or lands adjoining the proposed action, contain wetlands or other waterbodies regulated by a federal, state or local agency?	☐	☑
b. Would the proposed action physically alter, or encroach into, any existing wetland or waterbody?	☐	☐
If Yes, identify the wetland or waterbody and extent of alterations in square feet or acres: ______		

	NO	YES
14. Identify the typical habitat types that occur on, or are likely to be found on the project site. Check all that apply: ☐ Shoreline ☐ Forest ☐ Agricultural/grasslands ☐ Early mid-successional ☐ Wetland ☐ Urban ☐ Suburban		
15. Does the site of the proposed action contain any species of animal, or associated habitats, listed by the State or Federal government as threatened or endangered? Bald Eagle	☐	☑
16. Is the project site located in the 100-year flood plan?	☐	☐
17. Will the proposed action create storm water discharge, either from point or non-point sources? If Yes,	☐	☐
a. Will storm water discharges flow to adjacent properties?	☐	☐
b. Will storm water discharges be directed to established conveyance systems (runoff and storm drains)? If Yes, briefly describe: ______________________________	☐	☐
18. Does the proposed action include construction or other activities that would result in the impoundment of water or other liquids (e.g., retention pond, waste lagoon, dam)? If Yes, explain the purpose and size of the impoundment: ______________________________	☐	☐
19. Has the site of the proposed action or an adjoining property been the location of an active or closed solid waste management facility? If Yes, describe: ______________________________	☐	☐
20. Has the site of the proposed action or an adjoining property been the subject of remediation (ongoing or completed) for hazardous waste? If Yes, describe: ______________________________	☐	☑

I CERTIFY THAT THE INFORMATION PROVIDED ABOVE IS TRUE AND ACCURATE TO THE BEST OF MY KNOWLEDGE

Applicant/sponsor/name: ______________________________ Date: ______________

Signature: ______________________________ Title: ______________________

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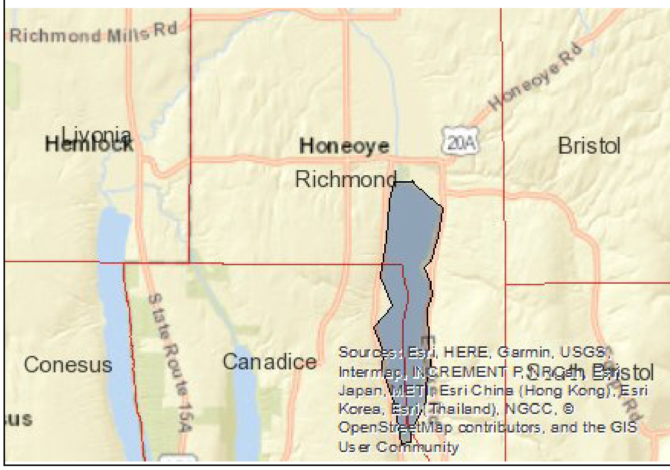
EAF Mapper Summary Report

Tuesday, March 12, 2019 10:12 AM



Disclaimer: The EAF Mapper is a screening tool intended to assist project sponsors and reviewing agencies in preparing an environmental assessment form (EAF). Not all questions asked in the EAF are answered by the EAF Mapper. Additional information on any EAF question can be obtained by consulting the EAF Workbooks. Although the EAF Mapper provides the most up-to-date digital data available to DEC, you may also need to contact local or other data sources in order to obtain data not provided by the Mapper. Digital data is not a substitute for agency determinations.

Part 1 / Question 7 [Critical Environmental Area]	No
Part 1 / Question 12a [National or State Register of Historic Places or State Eligible Sites]	Yes
Part 1 / Question 12b [Archeological Sites]	Yes
Part 1 / Question 13a [Wetlands or Other Regulated Waterbodies]	Yes - Digital mapping information on local and federal wetlands and waterbodies is known to be incomplete. Refer to EAF Workbook.
Part 1 / Question 15 [Threatened or Endangered Animal]	Yes
Part 1 / Question 15 [Threatened or Endangered Animal - Name]	Bald Eagle
Part 1 / Question 16 [100 Year Flood Plain]	Digital mapping data are not available or are incomplete. Refer to EAF Workbook.
Part 1 / Question 20 [Remediation Site]	Yes

Short Environmental Assessment Form - EAF Mapper Summary Report 1

Short Environmental Assessment Form
Part 1 - Project Information

Instructions for Completing

Part 1 – Project Information. The applicant or project sponsor is responsible for the completion of Part 1. Responses become part of the application for approval or funding, are subject to public review, and may be subject to further verification. Complete Part 1 based on information currently available. If additional research or investigation would be needed to fully respond to any item, please answer as thoroughly as possible based on current information.

Complete all items in Part 1. You may also provide any additional information which you believe will be needed by or useful to the lead agency; attach additional pages as necessary to supplement any item.

Part 1 – Project and Sponsor Information				
Name of Action or Project:				
Project Location (describe, and attach a location map):				
Brief Description of Proposed Action:				
Name of Applicant or Sponsor:	Telephone:			
	E-Mail:			
Address:				
City/PO: q	State:	Zip Code:		
1. Does the proposed action only involve the legislative adoption of a plan, local law, ordinance, administrative rule, or regulation? If Yes, attach a narrative description of the intent of the proposed action and the environmental resources that may be affected in the municipality and proceed to Part 2. If no, continue to question 2.			NO ☐	YES ☐
2. Does the proposed action require a permit, approval or funding from any other government Agency? If Yes, list agency(s) name and permit or approval:			NO ☐	YES ☐
3. a. Total acreage of the site of the proposed action? __________ acres b. Total acreage to be physically disturbed? __________ acres c. Total acreage (project site and any contiguous properties) owned or controlled by the applicant or project sponsor? __________ acres				
4. Check all land uses that occur on, are adjoining or near the proposed action: 5. ☐ Urban ☐ Rural (non-agriculture) ☐ Industrial ☐ Commercial ☐ Residential (suburban) ☐ Forest ☐ Agriculture ☐ Aquatic ☐ Other(Specify): ☐ Parkland				

Page 1 of 3

	NO	YES	N/A
5. Is the proposed action,	NO	YES	N/A
a. A permitted use under the zoning regulations?	☐	☐	☐
b. Consistent with the adopted comprehensive plan?	☐	☐	☐
6. Is the proposed action consistent with the predominant character of the existing built or natural landscape?	☐	☐	
7. Is the site of the proposed action located in, or does it adjoin, a state listed Critical Environmental Area? If Yes, identify: ____________________	☑	☐	
8. a. Will the proposed action result in a substantial increase in traffic above present levels?	☐	☐	
b. Are public transportation services available at or near the site of the proposed action?	☐	☐	
c. Are any pedestrian accommodations or bicycle routes available on or near the site of the proposed action?	☐	☐	
9. Does the proposed action meet or exceed the state energy code requirements? If the proposed action will exceed requirements, describe design features and technologies: ____________________ ____________________	☐	☐	
10. Will the proposed action connect to an existing public/private water supply? If No, describe method for providing potable water: ____________________ ____________________	☐	☐	
11. Will the proposed action connect to existing wastewater utilities? If No, describe method for providing wastewater treatment: ____________________ ____________________	☐	☐	
12. a. Does the project site contain, or is it substantially contiguous to, a building, archaeological site, or district which is listed on the National or State Register of Historic Places, or that has been determined by the Commissioner of the NYS Office of Parks, Recreation and Historic Preservation to be eligible for listing on the State Register of Historic Places?	☑	☐	
b. Is the project site, or any portion of it, located in or adjacent to an area designated as sensitive for archaeological sites on the NY State Historic Preservation Office (SHPO) archaeological site inventory?	☐	☑	
13. a. Does any portion of the site of the proposed action, or lands adjoining the proposed action, contain wetlands or other waterbodies regulated by a federal, state or local agency?	☐	☑	
b. Would the proposed action physically alter, or encroach into, any existing wetland or waterbody?	☐	☐	
If Yes, identify the wetland or waterbody and extent of alterations in square feet or acres: ____________________ ____________________ ____________________			

14. Identify the typical habitat types that occur on, or are likely to be found on the project site. Check all that apply:

☐ Shoreline ☐ Forest ☐ Agricultural/grasslands ☐ Early mid-successional
☐ Wetland ☐ Urban ☐ Suburban

	NO	YES
15. Does the site of the proposed action contain any species of animal, or associated habitats, listed by the State or Federal government as threatened or endangered?	☑	☐
16. Is the project site located in the 100-year flood plan?	☐	☐
17. Will the proposed action create storm water discharge, either from point or non-point sources? If Yes,	☐	☐
a. Will storm water discharges flow to adjacent properties?	☐	☐
b. Will storm water discharges be directed to established conveyance systems (runoff and storm drains)? If Yes, briefly describe: ____________	☐	☐
18. Does the proposed action include construction or other activities that would result in the impoundment of water or other liquids (e.g., retention pond, waste lagoon, dam)? If Yes, explain the purpose and size of the impoundment: ____________	☐	☐
19. Has the site of the proposed action or an adjoining property been the location of an active or closed solid waste management facility? If Yes, describe: ____________	☐	☐
20. Has the site of the proposed action or an adjoining property been the subject of remediation (ongoing or completed) for hazardous waste? If Yes, describe: ____________	☑	☐

I CERTIFY THAT THE INFORMATION PROVIDED ABOVE IS TRUE AND ACCURATE TO THE BEST OF MY KNOWLEDGE

Applicant/sponsor/name: ______________________ Date: ____________

Signature: ______________________ Title: ____________

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EAF Mapper Summary Report

Monday, March 18, 2019 8:58 AM

Disclaimer: The EAF Mapper is a screening tool intended to assist project sponsors and reviewing agencies in preparing an environmental assessment form (EAF). Not all questions asked in the EAF are answered by the EAF Mapper. Additional information on any EAF question can be obtained by consulting the EAF Workbooks. Although the EAF Mapper provides the most up-to-date digital data available to DEC, you may also need to contact local or other data sources in order to obtain data not provided by the Mapper. Digital data is not a substitute for agency determinations.

Part 1 / Question 7 [Critical Environmental Area]	No
Part 1 / Question 12a [National or State Register of Historic Places or State Eligible Sites]	No
Part 1 / Question 12b [Archeological Sites]	Yes
Part 1 / Question 13a [Wetlands or Other Regulated Waterbodies]	Yes - Digital mapping information on local and federal wetlands and waterbodies is known to be incomplete. Refer to EAF Workbook.
Part 1 / Question 15 [Threatened or Endangered Animal]	No
Part 1 / Question 16 [100 Year Flood Plain]	Digital mapping data are not available or are incomplete. Refer to EAF Workbook.
Part 1 / Question 20 [Remediation Site]	No

Short Environmental Assessment Form - EAF Mapper Summary Report 1